Covid-19 forecast using Holt-Winters exponential smoothing

by Ismail Djakaria

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Abstract. Covid-19 has spread throughout the world, including in Indonesia and it is known that the virus is reported to be highly contagious. Indonesia is the fourth-largest population for Covid-19 cases in Asia, while in the world the top three for covid-19 cases are United States, Brazil, and India, so it is inevitable, Indonesia will be greatly felt the spread of the pandemic coronavirus, even estimated to be freed from the coronavirus in a shorter period when compared to other countries with less exposure to COVID-19. In this paper, we study the covid-19 prediction model using Holt-Winters exponential smoothing, for a certain period. This study uses the Covid-19 pandemic data area of Gorontalo, Indonesia, from April 10 to October 13, 2020 (especially total cases). It was found that using Holt-Winters exponential smoothing, the best forecasting model is the one with smoothing parameters $\alpha = 0.1$ and $\gamma = \delta = 0.5$ for trend and seasonality respectively, which gives the smallest MAPE value of 6.14.

1. Introduction

The Covid-19, whose spread was declared by WHO to be a pandemic on March 11, 2020, when there was a spike in the number of cases reported by Italy, Iran, South Korea, and Japan [1]. All people's activities are severely restricted by this pandemic, such as economic activities, religious activities, teaching and learning activities, office activities, and others. National celebrations such as the Population Census (SP2020) must be carried out with the Covid-19 protocol.

Indonesia first confirmed two Covid-19 cases on March 2, 2020, and as of October 17, 2020, has reported more than 357,762 cases in total, or 1,327 cases per million of the population. In Gorontalo's situation, the first confirmed one Covid-19 case on April 10, 2020, and until October 17, 2020, has confirmed 2,964 cases in total, or 2,481 cases per million of the population of Gorontalo. Many studies have been carried out to predict the end of Covid-19. Predicting the turning point, duration, and attack rate of COVID-19 outbreaks in major Western countries has been carried out [3]. Meanwhile, [4] predicted the optimal lockdown period with a parametric approach using a three-phase maturation SIRD model for the COVID-19 pandemic. Time series data is a series of data collected based on-time orders at the same intervals. Time series data are widely recorded in various fields such as agriculture, tourism, economy and business, health, and others, including the Covid-19 pandemic. Seasonal patterns can be analyzed by the Holt-Winters exponential smoothing method. The time series method that is often used in forecasting is the Holt-Winters exponential smoothing method. This paper describes the accuracy of the Holt-Winters exponential smoothing time series forecasting model in the Covid-19 pandemic.

The purpose of this study is to find the best forecasting model with the appropriate smoothing parameters. Besides, this study provides predictive or results of forecasting Covid-19 data. It can be shown, either with visual graphs and the result of computation through the existing formula models.

2. Literature review

The Covid-19 pandemic is the most significant global crisis affecting the lives of most of the world's population after the Second World War. Beyond the size and reach of the aftermath of World War, it has affected all the Nations on our planet. The health consequences of a pandemic are devastating. To date, the number of Covid-19 deaths has exceeded 75,000 and is sadly destined to grow exponentially in the future [1][5][6]. Thus, urgent action is needed to prevent the spread of the Covid-19 pandemic to the wider community. Currently, there is no vaccine or specific medication for COVID-19. Though, several ongoing clinical trials are evaluating potential treatments. The recent spread of COVID-19 has revived the attention of the scientific and political community in the mathematical model of an epidemic. Many researchers are making efforts to suggest new, refined models for examining the current situation and predicting possible future scenarios. The SIR model, where SIR refers to Vulnerable, Infected and Removed, was proposed by Griffiths and Higham [2] which is based on a system of initial value problems of ordinary differential equations (ODE).

In this paper, we describe the methods used to predict the Covid-19 pandemic data using the multiplicative Holt-Winters exponential smoothing. This means the paper wants to answer the question that "what is the Covid-19 pandemic data forecasting model using Holt-Winters exponential smoothing?" Holt-Winters exponential smoothing is appropriate if the data is only influenced by trend patterns. However, if the data is not only influenced by trend patterns, but also seasonal patterns, then Holt exponential smoothing is not appropriate for forecasting because it cannot detect any seasonal patterns. Therefore, the Holt-Winters exponential smoothing by adding one parameter to overcome the seasonal patterns in the data. This method, which contains trend and seasonal parameters, is called the Holt-Winters exponential smoothing method. The method used in this study is multiplicative.

2.1. Method of smoothing

In the technique of time series forecasting, it is common for data to show trend patterns, where data show a pattern of an increase or decrease trend. The Holt-Winters exponential smoothing is a method of forecasting using an exponential smoothing approach based on the results of the previous period forecasting. This method adds a parameter that handles seasonal data patterns. The model was chosen based on seasonal patterns [7][8].

The smoothing method is used to forecast the time-series data containing trend patterns, seasonal patterns, or containing both simultaneously. Smoothing is taking the average value over several years to assess the value of a particular year [9]. The smoothing method is categorized into two parts, i.e the smoothing method and the exponential smoothing method [17]. Forecasting data that is influenced by seasonal or trend patterns is conducted using the exponential smoothing method by allocating different weights for past data and these weights have exponential decreasing characteristics [17].

2.2. Method of multiplicative Holt-Winters exponential smoothing

The Holt-Winters forecasting algorithm was developed by Charles Holt and Peter Winters. The algorithm smooth time series data and then uses it for forecasts other aspects in the data they concern [11] and [13]. Exponential smoothing is a method for smoothing a time series data that allocates exponentially decreasing weights and values for past data. There are three types of exponential smoothing. The first type is the single exponential smoothing time series forecasting for univariate data. This type is used when the time series data do not have a systematic structure. The data do not have trends and seasonality [10]. According to Panda M [11], this type of exponential smoothing only uses a single parameter α that lies between 0 and 1 as a smoothing factor. A smaller α value indicates slower learning that takes more past observations to estimate. On the other hand, a larger value indicates faster learning that requires more recent observations to make an estimate.

The next type is the double exponential smoothing where in addition to α, another smoothing parameter γ is used for change in trend. There are two types of trends namely additive trend which provides linear trend analysis and multiplication trend which provides exponential trend analysis. It was observed that during the multi-step forecast in the long term, the trend is not a feasible possibility. Therefore, dampening may be practical by reducing the trend size for the future forecast with a straight line (no trend).

Finally, the third type of exponential smoothing is the triple exponential smoothing method. This method is a smoothing technique used when a series shows seasonal variations, that is, the method allows seasonality. The triple exponential smoothing method depends on three parameters that are α, γ, and δ which values lies between zero and one namely $0 < \alpha, \gamma, \delta < 1$ [12].

The Holt-Winters triple exponential smoothing is the newest exponential smoothing method, named after its founders Charles Holt and Peter Winters, which is useful for finding patterns of changing levels, trends, and seasons over time by using additive or multiplicative seasons. In this paper, Holt-Winters triple exponential smoothing [12] is used for forecasting, with the multiplicative model, i.e

- Exponential smoothing of original data (at the time t), (see also [3][6][13][14][15])

$$L_t = \alpha \frac{Y_t}{S_{t-s}} + (1-\alpha)(L_{t-1} + T_{t-1}) \quad (1)$$

- Trend patterns smoothing (at the time t)

$$T_t = \gamma(L_t - L_{t-1}) + (1-\gamma)T_{t-1}) \quad (2)$$

- Seasonal patterns smoothing (at the time t)

$$S_t = \delta \frac{Y_t}{L_t} + (1-\delta)S_{t-s} \quad (3)$$

So, the p-period forecasting forward is

$$\hat{Y}_{t+p} = (L_t + pT_t)S_{t-s+p} \quad (4)$$

where $(0 < \alpha, \gamma, \delta < 1)$.

2.3. Evaluation of forcasting model

The data pattern to be analyzed in a forecasting method plays a significant role. The best forecasting method selection is based on the prediction error rate, if the method is considered a correct method [16]. It is understandable if a forecasting method cannot accurately predict the future state of the data. Therefore each forecasting method produces errors. The smaller the error rate generated by the forecasting model is, the closer the forecasting result will be to the actual result. To calculate the prediction errors, several statistics are used including mean squared deviation (MSD), mean absolute deviation (MAD), and mean absolute percentage error (MAPE). Forecasting using MSD and MAD as a measuring tool for accuracy can cause problems because this measure does not provide a comparison between different time series and for different time intervals. MSD and MAD are absolute measures that are highly dependent on the scale of the time-series data. Since MSD and MAD involve the square of a series of values, it is not align with our intuitions. Thus, due to the limitations of MSD and MAD as a measuring tool for forecasting accuracy, we used MAPE as an alternative measure of the accuracy in the forecasting.

3. Methodology

The steps for the forecasting method described above will be clearly stated in this section.

3.1. Data collection technique

The research stages used in this study are as follows.

- Conduct to plot Covid-19 pandemic actual data collection

This study uses the Covid-19 pandemic data area of Gorontalo, Indonesia, between April 10 – October 13, 2020 (especially total cases) [18].

- Plotting Covid-19 pandemic time series data using Holt-Winters exponential smoothing.
- Select the smoothing parameter by trial and error which makes the accuracy of the predictions the better.

3.2. Data analysis technique

The analysis of the Covid-19 pandemic data was carried out with the help of *MINITAB* 17 *Statistical Software* and *Microsoft Excel*.

4. Result and discussion

Plotting of Covid-19 pandemic time series actual cases data, area of Gorontalo, April 10 – October 13, 2020 (especially total cases), Figure 1. This data plot shows that the data is influenced by both trend and increasing patterns. Holt-Winters exponential smoothing method, as stated above, uses three parameters, i.e the level parameter (α), the trend parameter (γ), and the seasonal parameter (δ). Therefore, several forecasting models will be obtained with different parameters. Decide on the best model for predicting the Covid-19 pandemic data using this method can use the MAPE value. The model taken is a model that has the smallest MAPE value. The following are some models for predicting the Covid-19 pandemic data using the multiplicative Holt-Winters exponential smoothing method, by forecasting three times trial and error, respectively, for the first experiment, $\alpha = \gamma = \delta = 0.2$, the MAPE accuracy is 6.48, see Figure 2, the second experiment, $\alpha = 0.1$, $\gamma = 0.2$, $\delta = 0.5$, MAPE is obtained equal to 6.56, like Figure 3, and the third experiment, $\alpha = 0.2$, $\gamma = \delta = 0.5$, with a MAPE value of 6.14 (Figure 4), as below:

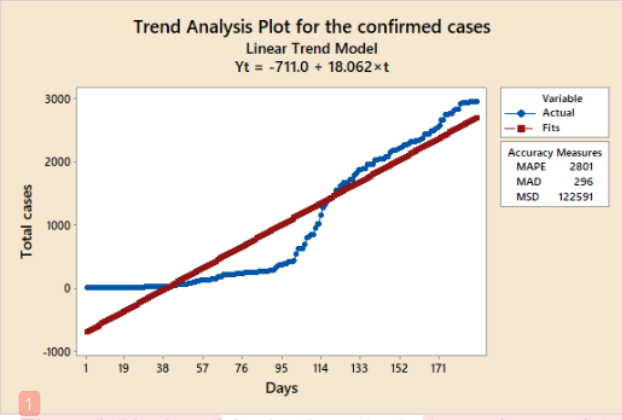

Figure 1. Plotting of Covid-19 pandemic time series actual data.

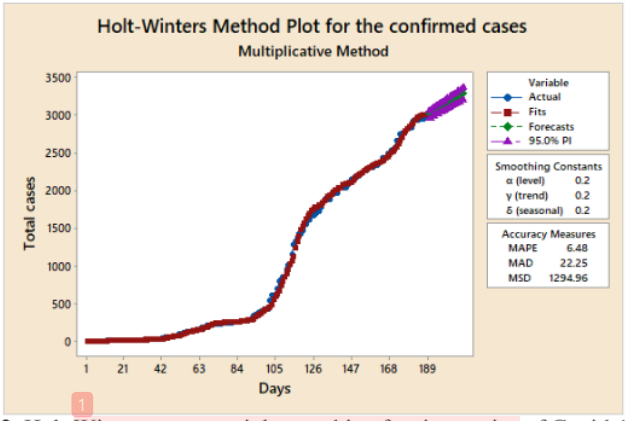

Figure 2. Holt-Winters exponential smoothing for time series of Covid-19 pandemic data. using $\alpha = \gamma = \delta = 0.2$.

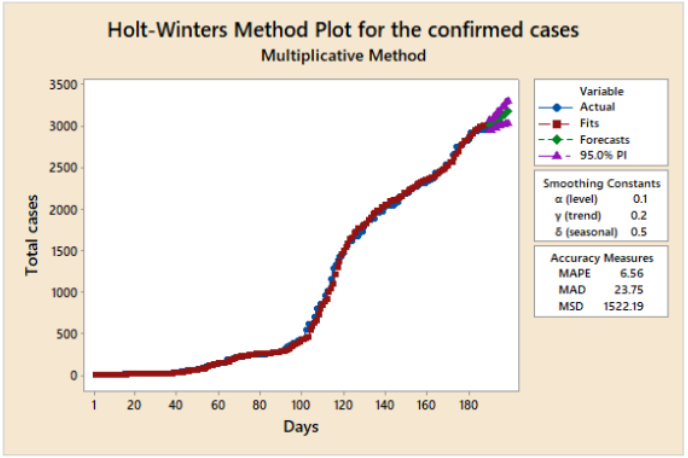

Figure 3. Holt-Winters exponential smoothing for time series of Covid-19 pandemic data using $\alpha = 0.1, \gamma = 0.2, \delta = 0.5$.

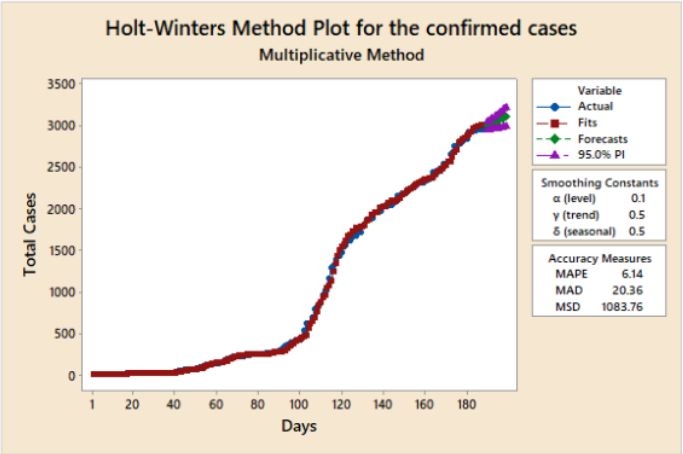

Figure 4. Holt-Winters exponential smoothing for time series of Covid-19 pandemic data using $\alpha = 0.1, \gamma = \delta = 0.5$.

Based on the time series data forecasting plot above (Figure 4), the forecasting model is obtained using the Holt-Winters exponential smoothing method, according to Equations (1), (2), (3), and (4), respectively, which gives the smallest MAPE value (6.14) as follows.

- Exponential smoothing of original data (at the time t),

$$L_t = 0.1\frac{Y_t}{S_{t-12}} + 0.9(L_{t-1} + T_{t-1}) \tag{5}$$

- Smoothing trend patterns (at the time t)

$$T_t = 0.5(L_t - L_{t-1}) + 0.5T_{t-1}) \tag{6}$$

- Smoothing seasonal patterns (at the time t)

$$S_t = 0.5\frac{Y_t}{L_t} + 0.5S_{t-14} \tag{7}$$

So, the p-period forecasting forward is

$$\begin{aligned}\hat{Y}_{t+p} &= (L_t + pT_t)S_{t-s+p} \\ &= \left[\left(0.1\frac{Y_t}{S_{t-14}} + 0.9(L_{t-1} + T_{t-1})\right) + p\left(0.2(L_t - L_{t-1}) + 0.8T_{t-1}\right)\right] \\ &\times \left[0.5\frac{Y_{t-s+p}}{L_{t-s+p}} + 0.5S_{t-14+p}\right]\end{aligned} \tag{8}$$

5. Conclusion

According to the analysis and discussion of Covid-19 pandemic data forecasting area of Gorontalo from April 10, 2020 to October 13, 2020 (especially total cases), it can be concluded that:

1. The forecasting model using Holt-Winters exponential smoothing is best with smoothing parameters for level $\alpha = 0.1$, trend, and seasonality ($\gamma = \delta = 0.5$), respectively.
2. The trend of confirmed cases of Covid-19 pandemic prediction, in Gorontalo Province, using the Holt-Winters exponential smoothing forecasting data model won't be over any time soon. Except

that, there is government intervention such as procuring vaccines to give up the spread of Covid-19. This can be seen in the visualization of Figure 4, where the model does not show a decreasing trend.

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