

Holt-Winters Parameter Optimization Using Dichotomous Search Method (Case Study: PT Telkom Indonesia's Closing Stock Price for the Period January 2019-December 2023)

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*Submission date: 25 June 2025, Revision: 06 February 2026, Accepted: 01 August 2026

ABSTRACT

Numerical optimization is the process of finding the optimal parameter values in mathematical problems to minimize the objective function. The selection of optimal parameters is the main key in producing prediction accuracy that is close to the actual value in time series forecasting. Determining the optimal parameters in this method is one of the important challenges that must be solved through the numerical optimization approach. Therefore, the application of numerical optimization algorithms such as the Dichotomous Search method is carried out. The optimal parameters obtained are used in the Holt-Winters model to calculate the level, trend, and seasonal components so as to improve the accuracy of time series forecasting. After constructing the Dichotomous Search method algorithm, the optimal parameters will be determined in the Holt-Winters model, and determine the forecasting results using the optimal parameters on the closing stock price data of PT Telkom Indonesia for the period January 2019-December 2023. The application of the Dichotomous Search method is carried out to find the optimal parameter value at 8 evaluation points iteratively. Based on the analysis results, the Dichotomous Search method produces 12 iterations with a MAPE of 6.48449%, so it has high forecasting accuracy.

KEYWORDS

Holt-Winters, Optimization, Dichotomous Search, Golden Section, MAPE.

1. INTRODUCTION

Numerical optimization is a calculation analysis process that aims to achieve the best conditions on a problem, including in data forecasting. In the context of forecasting, optimal parameter selection can improve the accuracy of the prediction results to be closer to the actual value [1]. One method that is widely applied in time series forecasting is the Holt-Winters method because it is able to capture trend and seasonal patterns in historical data [2].

The selection of the right parameters in the Holt-Winters method is crucial to improve the accuracy of stock price predictions [3]. One of the main challenges in this method is the selection of parameters which has been done by trial and error, which takes a long time. Therefore, more efficient methods are needed to obtain optimal parameters, such as nonlinear optimization algorithms like the Dichotomous Search method [4].

The Dichotomous Search method uses an interval division approach by gradually evaluating the midpoint in the interval $[a, d]$, so it can be applied to various optimization problems, including parameter search in forecasting [5]. The selection of the Dichotomous Search method is justified by its superior computational efficiency in handling one-dimensional optimization

problems. Compared to other algorithms like Golden Section Search or Grid Search, Dichotomous Search has been shown to converge to optimal smoothing parameters with fewer iterations [1]. Given that the parameter space for α, β, γ is bounded between 0 and 1, this method provides a robust and simpler alternative to complex metaheuristic algorithms without sacrificing the accuracy of the Mean Absolute Percentage Error (MAPE) minimization.

Based on this, determining the optimal parameters in the forecasting method can be done using the optimization method. This research aims to optimize the parameters of the Holt-Winters method using the Dichotomous Search method on PT Telkom Indonesia's closing stock price data for the period January 2019 to December 2023. The application of this method is expected to produce stock predictions with a high level of accuracy and contribute to more effective investment decision making.

2. LITERATURE REVIEW

2.1 Nonlinear Optimization

A nonlinear optimization problem is defined as a situation where the objective function $f(x)$ and/or constraints $g(x)$ are nonlinear. Nonlinear optimization is used to handle quite complex problems, namely nonlinear objective functions, with solution regions that have nonlinear constraints. One example of the use of nonlinear optimization is to determine the right parameter values in forecasting, so that the prediction results can be close to the actual data in the future

2.2 Dichotomous Search

Dichotomous Search, the search process is illustrated in **Figure 1** [6]. Dichotomous search is a method to minimize the value of

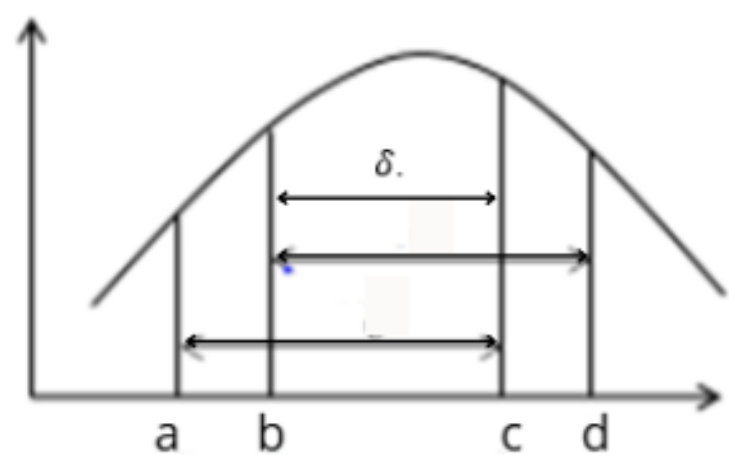


Figure 1. Dichotomous Search

$f(x)$ in the interval $[a,d]$ as follows [1]:

$$c - a = d - b$$

Thus obtained:

$$b = a - c + d \tag{1}$$

$$c = a - b + d \tag{2}$$

And suppose that:

$$\delta = c - b$$

where δ is the difference in length between b and c , thus we obtain:

$$b = c - \delta \tag{3}$$

$$c = b + \delta \tag{4}$$

By solving Equations (1) and (3) we obtain

$$\begin{aligned} 2b &= (a - c + d) + (c - \delta) \\ b &= \left(\frac{a + d - \delta}{2} \right) \end{aligned} \tag{5}$$

By solving Equations (2) and (4) we get

$$\begin{aligned} 2c &= (a - b + d) + (b + \delta) \\ c &= \left(\frac{a + d + \delta}{2} \right) \end{aligned} \tag{6}$$

Furthermore, Equations (5) and (6) will be entered into the functions $f(b)$ and $f(c)$ to obtain MAPE. The results of the two functions will be compared and the following conditions are obtained:

If $f(b) < f(c)$, then the next minimum value is on the interval $[a, c]$.

If $f(b) > f(c)$, then the next minimum value is on the interval $[b, d]$.

If $f(b) = f(c)$, then the next minimum value is in the interval $[b, c]$.

To extend to the multivariable case, some modifications are required, as multivariable functions involve a more complex

Table 1. Criteria for calculating the Error (E) value based on changes in a and d

No.	Case	Formula of E Value
1	$a_{now} = a_{old}$	$E = \left \frac{d_{now} - d_{old}}{d_{now}} \right \times 100\%$
2	$d_{now} = d_{old}$	$E = \left \frac{a_{now} - a_{old}}{a_{now}} \right \times 100\%$
3	$a_{now} = d_{now}$	$E = 0$
4	Otherwise	$E = \left \frac{d_{now} - a_{now}}{d_{now}} \right \times 100\%$

solution space [6]. By using Equations (5) and (6), the following equation is produced [1]:

$$\alpha_1 = \left(\frac{a_1 + d_1 - \delta}{2} \right) \tag{7}$$

$$\alpha_2 = \left(\frac{a_1 + d_1 + \delta}{2} \right) \tag{8}$$

$$\beta_1 = \left(\frac{a_2 + d_2 - \delta}{2} \right) \tag{9}$$

$$\beta_2 = \left(\frac{a_2 + d_2 + \delta}{2} \right) \tag{10}$$

$$\gamma_1 = \left(\frac{a_3 + d_3 - \delta}{2} \right) \tag{11}$$

$$\gamma_2 = \left(\frac{a_3 + d_3 + \delta}{2} \right) \tag{12}$$

2.3 Time Series

Time series data is represented as a series of values that are recorded periodically based on a certain period, such as daily, weekly, monthly, yearly, or other consistent time periods [7]. Time series data can be classified into four categories, namely horizontal data patterns (stable without trends), trend data patterns (long-term increase or decrease), seasonal data patterns (periodic changes at certain intervals) [4].

2.4 Holt-Winters

The Holt-Winters method is a time series forecasting technique that uses three smoothing parameters, α , β , γ valued between 0 and 1 to set the level, trend, and seasonal smoothing rates, so many combinations can be used [1]. Multiplicative seasonal patterns are applied to data that has a trend as well as a seasonal component. The following equation is used [4]:

$$L_t = \alpha \left(\frac{Y_t}{S_{t-s}} \right) + (1 - \alpha) (L_{t-1} + b_{t-1}) \quad (13)$$

$$b_t = \beta (L_t - L_{t-1}) + (1 - \beta) b_{t-1} \quad (14)$$

$$S_t = \gamma \left(\frac{Y_t}{L_t} \right) + (1 - \gamma) S_{t-s} \quad (15)$$

According to [8], the following is the forecasting equation at time t for the multiplicative model:

$$F_t = (L_{t-1} + b_{t-1}) S_{t-s} \quad (16)$$

As for forecasting up to m periods using the following Equation (17):

$$F_{t+m} = (L_{t-1} + (m)b_{t-1}) S_{t+m-s} \quad (17)$$

where:

α, β, γ : forecasting parameters between 0 – 1;

Y_t : actual data at time t ;

S_t : level smoothing at time t ;

b_t : trend smoothing at time t ;

L_t : seasonal smoothing at time t ;

s : seasonal length;

F_t : forecasting period t ;

t : time period;

F_{t+m} : the forecast value for m period ahead;

m : forecasting horizon.

Initialize the Holt-Winters component to estimate the three smoothing values using the following equation: Level initialization:

$$L_s = \frac{1}{s} \sum_{i=1}^s Y_i \quad (18)$$

Trend initialization:

$$b_s = \frac{1}{s} \sum_{i=1}^s \left(\frac{Y_{i+s} - Y_i}{s} \right) \quad (19)$$

Seasonal initialization:

$$S_1 = \frac{Y_1}{L_s}, S_2 = \frac{Y_2}{L_s}, \dots, S_s = \frac{Y_s}{L_s} \quad (20)$$

2.5 Mean Absolut Percentage Error

MAPE is calculated by dividing the total absolute error for each observation in the time series by the total number of observations in the time series. Mean Absolute Percentage Error (MAPE) which measures the absolute average of percentage error [4]. The MAPE value is calculated using the following equation:

$$MAPE = \frac{1}{N} \sum_{t=1}^N |PE_t| \quad (21)$$

with n being the number of data and PE_t being the percentage error.

$$PE_t = \left(\frac{Y_t - F_t}{Y_t} \right) \times 100\% \quad (22)$$

where:

Y_t : actual data at time t ;

F_t : forecasting for time t .

Table 2. Interpretation of Typical MAPE Values

No.	MAPE (%)	Interpretation
1	< 10	Highly accurate
2	10–20	Good
3	20–50	Reasonable
4	> 50	Inaccurate

2.6 Objective Function in Holt-Winters Optimization

The objective function $f(x_n)$ is formulated based on the Mean Absolute Percentage Error (MAPE) expressed as follows:

$$f(\alpha_j, \beta_j, \gamma_j) = \frac{1}{N} \sum_{t=1}^N \left| \frac{Y_t - F_t}{Y_t} \right| \times 100\% \quad (23)$$

Mathematically, the formulation of this optimization problem is as follows: Minimize

$$f(x_n), \quad x_n = (\alpha_j, \beta_j, \gamma_j)$$

Constraints:

$$0 \leq \alpha_j \leq 1$$

$$0 \leq \beta_j \leq 1$$

$$0 \leq \gamma_j \leq 1$$

where:

N : number of data;

Y_t : actual data at time t ;

F_t : forecasting time t ;

$f(x_n)$: objective function representing forecasting error;

α, β, γ : forecasting parameters between 0-1.

3. METHODOLOGY

3.1 Data sources and analysis procedure

The data used in this study is the closing stock price data of PT Telkom Indonesia for the period January 2019-December 2023. Secondary data, comprising PT Telkom Indonesia's closing stock prices, were sourced directly from [9] for the period of January 2019 to December 2023. The dichotomous search method is originally a single-variable optimization technique using two test points; however, this study implements a modification for three variables (α, β, γ). The eight evaluation points (x_1 to x_8) are distributed using a 2^3 factorial scheme. These points are positioned at each corner of the search space formed by the lower bounds (L) and upper bounds (U) of each parameter interval, ensuring that all extreme combinations of the three parameters are represented in every iteration.

Initialize using Equation (18) for the level component, Equation (19) for the trend component, and Equation (20) for the seasonal component. The following is the search algorithm:

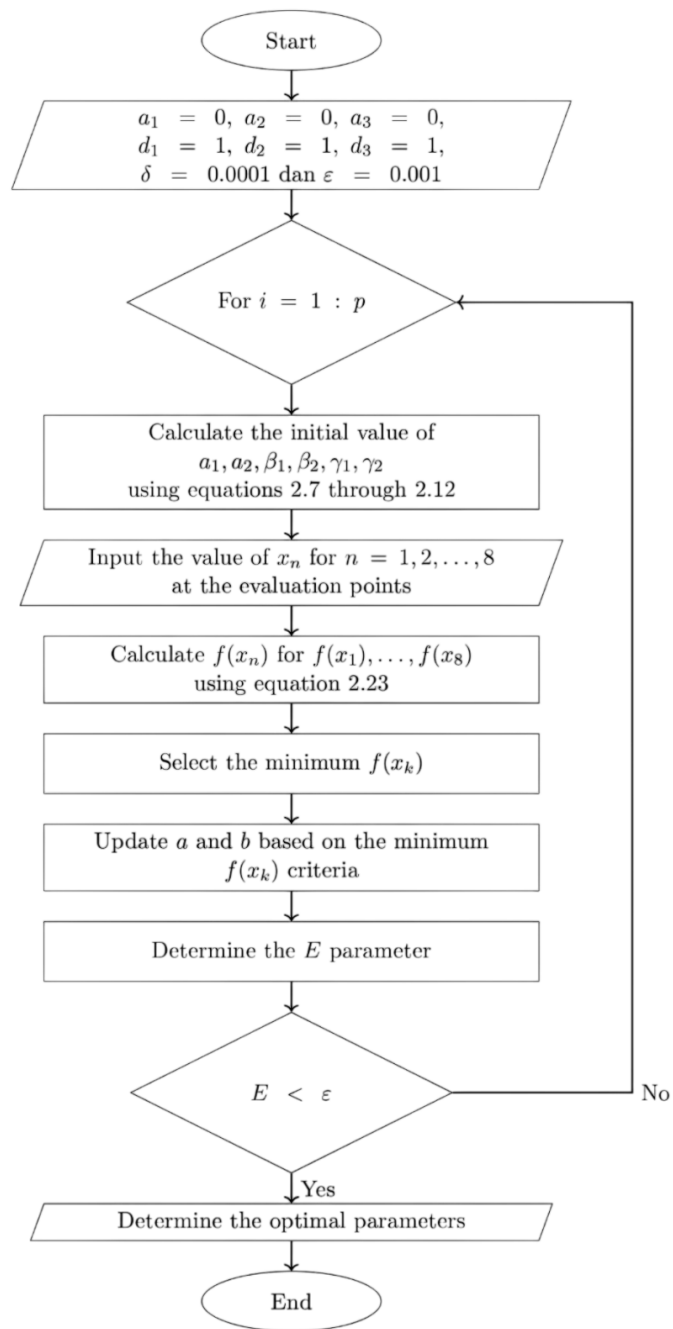


Figure 2. Holt-Winters Parameter Optimization Algorithm Construction

3.2 Multivariable Dichotomous Search Method Algorithm and Forecasting on Holt Winter Method

3.2.1 Multivariable Dichotomous Search Method Algorithm

The initial stage is to determine the initial limits for the lower limit (a) and upper limit (d). In this study, a_1, a_2, a_3 are 0 and d_1, d_2, d_3 are 1 respectively to determine the range of values for the parameters in Holt-Winters. Next, determine the tolerance limit for stopping iteration $\epsilon = 0.001$ and $\delta = 0.0001$. Then the following steps will be continued:

1. Calculate the initial bounds $\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2$ using Equations (7) to (12).
2. Determine the evaluation points $x_n = \alpha_j, \beta_j$, and γ_j with $j = 1, 2$ using the region elimination function approach of

$n = 2^k$ where $k = 3$ so that $n = 1, 2, \dots, 8$.

$$x_1 = (\alpha_1, \beta_1, \gamma_1); x_2 = (\alpha_1, \beta_2, \gamma_1); x_3 = (\alpha_1, \beta_1, \gamma_2); x_4 = (\alpha_1, \beta_2, \gamma_2)$$

$$x_5 = (\alpha_2, \beta_1, \gamma_1); x_6 = (\alpha_2, \beta_2, \gamma_1); x_7 = (\alpha_2, \beta_1, \gamma_2); x_8 = (\alpha_2, \beta_2, \gamma_2)$$

3. Find the objective function $f(x_n)$ based on the evaluation point x_n , using the parameters of the evaluation point x_n level smoothing calculation using Equation (13), trend using equation (14), seasonality using Equation (15), and forecasting calculation using equation (16).
4. Reduce the interval boundary by determining the new a_1, a_2, a_3 and d_1, d_2, d_3 values in the next iteration based on the value of $f(x_n)$ that satisfies the following rule:
 - (a) If $f(x_1)$ is the minimum value, then:
 a_1, a_2 , and a_3 are a fixed value and new parameters ($d_1 = a_2, d_2 = \beta_2, d_3 = \gamma_2$).
 - (b) If $f(x_2)$ is the minimum value, then:
 a_1, a_3 , and d_2 are a fixed value and new parameters ($a_2 = \beta_1, d_1 = a_2, d_3 = \gamma_2$).
 - (c) If $f(x_3)$ is the minimum value, then:
 a_1, a_2 , and d_3 are a fixed value and new parameters ($a_3 = \gamma_1, d_1 = a_2, d_2 = \beta_2$).
 - (d) If $f(x_4)$ is the minimum value, then:
 a_1, d_2 , and d_3 are a fixed value and new parameters ($a_2 = \beta_1, a_3 = \gamma_1, d_1 = a_2$).
 - (e) If $f(x_5)$ is the minimum value, then:
 new parameter ($a_1 = \alpha_1, d_2 = \beta_2, d_3 = \gamma_2$) and a_2, a_3 , and d_1 are a fixed value.
 - (f) If $f(x_6)$ is the minimum value, then:
 new parameters ($a_1 = \alpha_1, a_2 = \beta_1, d_3 = \gamma_2$) and a_3, d_1 , and d_2 are a fixed value.
 - (g) If $f(x_7)$ is the minimum value, then:
 $(a_1 = \alpha_1, a_3 = \gamma_1, d_2 = \beta_2)$ and a_2, d_1 , and d_3 are a fixed value.
 - (h) If $f(x_8)$ is the minimum value, then:
 new parameters ($a_1 = \alpha_1, a_2 = \beta_1, a_3 = \gamma_1$) and d_1, d_2 , and d_3 are a fixed value.
5. Calculate the tolerance limit for stopping iteration by testing changes in the values of a_1, a_2, a_3 and d_1, d_2, d_3 .
6. Repeat Step 2 until the value of $E_i < \varepsilon$.
7. Determine the optimal parameters.

3.2.2 Forecasting on Holt Winter Method

Once the best method is determined, the optimal parameters obtained from the method are used in the Holt-Winters algorithm to perform stock price forecasting. Forecasting is calculated using Equation (17).

4. RESULT & DISCUSSION

4.1 Holt-Winters Component Initialization

The initial step before determining the optimal parameters is the initialization of the Holt-Winters components. The initialization process for the Holt-Winters model components consists of level, trend, and seasonality. The initialization process is conducted as follows:

1. Level component initialization
 $L_{12} = 3160.003$.
2. Tren component initialization
 $b_{12} = -51.0560$.

3. Seasonal component initialization

$$\begin{aligned} S_1 &= \frac{2998.54}{3160.003} = 0.9489; S_2 = \frac{2967.78}{3160.003} = 0.9392; S_3 = \frac{3044.67}{3160.003} = 0.9635; S_4 = \frac{2913.96}{3160.003} = 0.9221; \\ S_5 &= \frac{2998.54}{3160.003} = 0.9489; S_6 = \frac{3183.06}{3160.003} = 1.0073; S_7 = \frac{3398.41}{3160.003} = 1.0754; S_8 = \frac{3516.95}{3160.003} = 1.1130; \\ S_9 &= \frac{3406.31}{3160.003} = 1.0780; S_{10} = \frac{3248.24}{3160.003} = 1.0279; S_{11} = \frac{3105.98}{3160.003} = 0.9829; S_{12} = \frac{3137.60}{3160.003} = 0.9929. \end{aligned}$$

4.2 Holt-Winters Parameter Search

In this process, a search is conducted using initial values $a_1 = 0$, $a_2 = 0$, $a_3 = 0$, $d_1 = 1$, $d_2 = 1$, $d_3 = 1$, $\delta = 0.0001$, and $\varepsilon = 0.001$, which serve as the basis for the iterative process to determine the optimal parameters for the Holt-Winters model that will produce the minimum possible error. The following are the steps for parameter searching using the Dichotomous Search method:

1. Calculating the parameter points α , β , and γ on the interval $[a, d]$ using Equations (7) to (12).

$$\begin{aligned} \alpha_1 &= \left(\frac{0+1-0.0001}{2} \right) = 0.49995; \alpha_2 = \left(\frac{0+1+0.0001}{2} \right) = 0.50005; \\ \beta_1 &= \left(\frac{0+1-0.0001}{2} \right) = 0.49995; \beta_2 = \left(\frac{0+1+0.0001}{2} \right) = 0.50005; \\ \gamma_1 &= \left(\frac{0+1-0.0001}{2} \right) = 0.49995; \gamma_2 = \left(\frac{0+1+0.0001}{2} \right) = 0.50005. \end{aligned}$$

2. By applying the region elimination method and the values calculated in step a, the evaluation points for x_n are obtained as follows:

$$\begin{aligned} x_1 &= (0.49995; 0.49995; 0.49995); x_2 = (0.49995; 0.50005; 0.49995); \\ x_3 &= (0.49995; 0.49995; 0.50005); x_4 = (0.49995; 0.50005; 0.50005); \\ x_5 &= (0.50005; 0.49995; 0.49995); x_6 = (0.50005; 0.49995; 0.50005); \\ x_7 &= (0.50005; 0.50005; 0.49995); x_8 = (0.50005; 0.50005; 0.50005). \end{aligned}$$

3. Find the value of $f(x_n)$ based on the evaluation point in step b. The smoothing calculation starts from data t_{13} because data $t_1, t_2, \dots, t_{12}$ have been used for initialization, so in the smoothing process $n = 48$. The calculation is performed using the evaluation point x_1 so that $f(x_1) = (0.49995; 0.49995; 0.49995)$ and calculation of smoothing when $t = 13, s = 12$, $Y_{13} = 3.003, 24$:

$$\begin{aligned} L_{13} &= 0.49995 \left(\frac{3003.24}{0.9489} \right) + (1 - 0.49995) (3160.003 + (-51.0560)) = 3136.95. \\ b_{13} &= 0.49995 (3130.34 - 3160.003) + (1 - 0.49995) (-51.0560) = -37.0565. \\ S_{13} &= 0.49995 \left(\frac{3003.24}{3130.34} \right) + (1 - 0.49995) 0.9489 = 0.9531. \\ F_{13} &= (3160.003 + (-51.0560) 0.948 = 2950.09. \end{aligned}$$

The smoothing and forecasting process continues sequentially as above for each subsequent period until $t=60$. After all the calculations of the evaluation point x_1 for smoothing and forecasting until $t=60$ have been completed, the calculation of $f(x_1)$ using Equation (23)) with $n = 48$ can be seen as follows:

$$\begin{aligned} f(x_1) &= \frac{1}{48} \left(\left| \frac{3003.24 - 2950.09}{3003.24} \right| + \left| \frac{2758.24 - 2911.33}{2758.24} \right| + \dots + \left| \frac{3722.55 - 3135.56}{3722.55} \right| \right) \times 100\% \\ &= 8.9942\% \end{aligned}$$

After obtaining the value of $f(x_1)$ in the form of MAPE from the calculation of evaluation point x_1 , the next step is to evaluate the evaluation point at x_n others, namely $x_2, x_3, \dots, x_8$. Based on the calculation process presented, the results of the calculation of the value of $f(x_n)$ at all evaluation points are presented in **Table 3**.

Table 3. MAPE Value in the First Iteration of Dichotomous Search Optimization

X_N	$f(x_n)$
$\alpha_1, \beta_1, \gamma_1$	8.99416%
$\alpha_1, \beta_2, \gamma_1$	8.99437%
$\alpha_1, \beta_1, \gamma_2$	8.99432%
$\alpha_1, \beta_2, \gamma_2$	8.99453%
$\alpha_2, \beta_1, \gamma_1$	8.99334%
$\alpha_2, \beta_1, \gamma_2$	8.99350%
$\alpha_2, \beta_2, \gamma_1$	8.99355%
$\alpha_2, \beta_2, \gamma_2$	8.99371%

- Obtained minimum at point x_5 , then fix the interval based on the criterion x_5 , therefore, the values to be fixed are $a_1 = \alpha_1, a_2, a_3, d_1$ remains $d_2 = \beta_2$ and $d_3 = \gamma_2$. These values will be used in the next iteration if the iteration process has not met the stopping criteria, and the next calculation will be calculated using the formula in step a
- Calculating the tolerance limit for stopping the iteration from the results of obtaining the E_i value. Based on the initial a_1, a_2, a_3 , and d_1, d_2, d_3 values that have been determined for the first iteration, the calculation of the E_i value is carried out using the conditions in **Table 1**. Based on the table, condition 4 is used because the values of a_1, a_2, a_3 , and d_1, d_2, d_3 do not meet, so:

$$E_1 = \left| \frac{1-0}{1} \right| \times 100\% = 100\% = 1$$

From the results of the above calculations, the value of $E_1 = 1$ is obtained, so the iteration process continues until $E_1 < 0.001$. The calculation is done with the help of matlab programming which can be seen in **Table 4**.

Table 4. Multiplicative Holt–Winters Parameter Optimization Results with Dichotomous Search Method

i	α_1	α_2	β_1	β_2	γ_1	γ_2	MAPE (%)	E
1	0.49995	0.50005	0.49995	0.50005	0.49995	0.50005	8.99334	1.00000
2	0.74993	0.75003	0.24998	0.25007	0.24998	0.25007	7.02735	0.50005
3	0.87491	0.87501	0.12499	0.12509	0.12499	0.12509	6.57227	0.25007
4	0.93741	0.93751	0.06249	0.06259	0.18748	0.18758	6.50815	0.12509
5	0.96865	0.96875	0.09374	0.09384	0.21873	0.21883	6.49259	0.06259
6	0.95303	0.95313	0.07812	0.07822	0.23435	0.23445	6.48892	0.03135
7	0.94522	0.94532	0.08593	0.08603	0.24216	0.24226	6.48681	0.01572
8	0.94131	0.94141	0.08202	0.08212	0.24607	0.24617	6.48561	0.00791
9	0.93936	0.93946	0.08398	0.08408	0.24802	0.24812	6.48506	0.00401
10	0.93838	0.93848	0.08300	0.08310	0.24900	0.24910	6.48474	0.00205
11	0.93789	0.93799	0.08251	0.08261	0.24949	0.24959	6.48460	0.00108
12	0.93765	0.93775	0.08276	0.08286	0.24973	0.24983	6.48452	0.00059

Based on **Table 4**, the optimal parameters are $f(x_1) = \alpha_1, \beta_1, \gamma_1$ with the values $\alpha_1 = 0.93756$, $\beta_1 = 0.08276$, and $\gamma_1 = 0.24973$ so that the level smoothing model is obtained as follows:

$$L_t = 0.93756 \left(\frac{Y_t}{S_{t-s}} \right) + (1 - 0.93756) (L_{t-1} + b_{t-1}) \tag{24}$$

The trend smoothing model is as follows:

$$b_t = 0.08276 (L_t - L_{t-1}) + (1 - 0.08276) b_{t-1} \tag{25}$$

Seasonal smoothing model as follows:

$$S_t = 0.24973 \left(\frac{Y_t}{L_t} \right) + (1 - 0.24973) S_{t-s} \tag{26}$$

The search process converged in 12 iterations, where each iteration aims to narrow the search interval until finding the parameter evaluation point that produces the smallest error rate. The optimal MAPE value is 6.48452%, based on **Table 4** in this model has high forecasting accuracy. From these optimization results, it can be observed that the value of $\alpha = 0.93756$ is quite high, which means that the model considers more recent data compared to historical data. Meanwhile, the low β value of 0.08276 indicates that the trend in the data does not have a dominant influence on the forecasting results. And the γ value of 0.24973 indicates that the seasonal factor still contributes to the model, although it is not very significant.

4.3 Holt-Winters Method Forecasting

Based on the optimized parameters ($\alpha = 0.93756$, $\beta = 0.08276$, and $\gamma = 0.24973$), forecasting was conducted using the defined models (Equations (24) to (26), and (16)). The results are summarized in **Table 5**:

Table 5. Holt–Winters Calculation Results on the Closing Stock Price of PT Telkom Indonesia for the Period January 2019–December 2023

<i>t</i>	<i>Y_t</i>	<i>L_t</i>	<i>b_t</i>	<i>S_t</i>	<i>F_t</i>
13	3003.24	3161.46	-46.7106	0.9492	2950.09
14	2758.24	2948.00	-60.5093	0.9383	2925.28
15	2497.43	2610.48	-83.4315	0.9618	2782.01
16	2766.14	2970.19	-46.7618	0.9244	2330.29
17	2489.53	2642.31	-70.0245	0.9472	2774.05
18	2410.50	2404.23	-83.9307	1.0061	2591.05
19	2533.23	2353.32	-81.1985	1.0757	2495.36
20	2375.42	2142.93	-91.8886	1.1118	2528.77
21	2126.25	1977.41	-97.9822	1.0773	2210.91
22	2176.09	2102.14	-79.5521	1.0297	1931.90
23	2682.73	2685.26	-24.7165	0.9869	1988.01
24	2749.18	2762.05	-16.3168	0.9935	2641.68
25	2583.06	2722.92	-18.2047	0.9490	2606.16
26	2898.68	3065.32	11.6353	0.9401	2537.80
27	2840.54	2961.07	2.0460	0.9612	2959.42
28	2657.81	2880.59	-4.7832	0.9240	2739.18
29	2857.15	3007.56	6.1197	0.9479	2724.03
30	2616.29	2626.17	-25.9470	1.0037	3032.14
31	2826.73	2626.09	-23.8062	1.0759	2797.05
32	2966.32	2663.83	-18.7131	1.1123	2893.33
33	3219.33	2966.96	7.9191	1.0792	2849.53
34	3315.30	3204.29	26.9029	1.0310	3063.33
35	3481.06	3508.65	49.8627	0.9882	3188.99
36	3524.69	3548.37	49.0227	0.9935	3535.45
37	3655.55	3835.97	68.7658	0.9500	3414.04

t	Y_t	L_t	b_t	S_t	F_t
38	3786.42	4019.91	78.2963	0.9406	3670.93
39	3995.81	4153.53	82.8737	0.9614	3939.10
40	4030.71	4354.45	92.6420	0.9244	3914.37
41	3760.25	3996.85	55.3847	0.9461	4215.46
42	3489.79	3512.99	10.7623	1.0011	4067.05
43	3825.44	3553.67	13.2382	1.0760	3791.11
44	4123.87	3698.83	24.1548	1.1129	3967.36
45	4033.44	3736.47	25.2701	1.0793	4017.93
46	3970.13	3845.34	32.1882	1.0313	3878.20
47	3653.61	3708.37	18.1905	0.9875	3831.91
48	3391.34	3433.17	-6.0875	0.9921	3702.22
49	3481.78	3650.12	12.3686	0.9510	3255.78
50	3508.91	3726.37	17.6547	0.9408	3444.82
51	3671.69	3814.46	23.4836	0.9617	3599.46
52	3843.52	4137.87	48.3023	0.9255	3547.81
53	3653.61	3881.86	23.1209	0.9449	3960.70
54	3617.43	3631.68	0.5047	0.9998	3909.26
55	3505.79	3281.46	-28.5177	1.0741	3909.31
56	3515.22	3164.43	-35.8423	1.1124	3620.29
57	3534.07	3265.34	-24.5253	1.0800	3376.63
58	3722.55	3586.44	4.0746	1.0330	3342.36
59	3543.49	3588.53	3.9103	0.9875	3545.58
60	3722.55	3742.37	16.3169	0.9927	3563.91

By applying Equation (17) with the optimized Holt-Winters parameters, the forecasting results for periods $t = 61$, to $t = 65$ (January 2024 – May 2024) are presented in **Table 6**:

Table 6. Forecasting the Closing Stock Price for the Period January 2024–May 2024

No.	Year	Month	Price Forecasting
1	2024	January	3574.44
2		February	3551.67
3		March	3646.05
4		April	3524.03
5		May	3613.28

Table 6 shows a relatively stable trend with not too sharp fluctuations. This stable value may reflect relatively calm market conditions or a balance between supply and demand factors in the data. A consistent relationship between the predicted values and historical trends indicates that the parameters used adequately represent the characteristics of the data.

Based on **Figure 3** the horizontal axis represents the time span, while the vertical axis shows the closing stock price. The forecasting results shown with the red line are quite close to the actual data (blue line) indicating that the model has a high level of accuracy in capturing historical trend patterns. As a continuation of forecasting the actual data, stock price forecasting for the next five months from January 2024 to May 2024 was also conducted. The results are shown in **Figure 3** with a circular red line, indicating relatively stable price movements in the short term without significant changes. However, this prediction is based on historical patterns and does not take into account external factors that may affect the stock price in the future.



Figure 3. Forecasting chart of PT Telkom Indonesia's closing stock price for the period January 2019 – May 2024

5. CONCLUSION

Based on the results and discussion, it can be concluded that the optimization using the the Dichotomous Search method to solve this problem was completed in 12 iterations with a MAPE of 6.48449%. The results show that the Dichotomous Search method has a higher forecasting accuracy for the closing stock prices of PT Telkom Indonesia for the period January 2019 – December 2024. Furthermore, the results of stock price forecasting using the Holt-Winters method based on the optimal parameters from the Dichotomous Search method indicate that the Holt-Winters model can represent the historical trend patterns of the data, as the forecast line consistently aligns with the actual data. The high value of $\alpha(0.9376)$ suggests that current stock prices are heavily influenced by recent market shocks, necessitating an adaptive forecasting model.

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