Double exponential smoothing brown method towards sales forecasting system with a linear and non-stationary data trend

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Abstract. UD Parama Store is a trading company engaged in selling retail goods that sell various types of daily necessities retail. The major problems occurred are the difficulty in predicting the sales due to the maturity level of experience, customer demand changes, and the owner’s limited memory. Therefore, there should be an increase of merchandise stock to prevent any sudden decrease in sales and overcome the stock shortage when there is an increase in sales. In this current research, a sales forecasting web-based system was designed and built to assist the owner in predicting the number of sales in the next period. As a result, decisions can be made in determining the number of goods to be provided. The forecasting method used was double exponential smoothing brown by improving forecasting, averaging (smoothing) the past value of a time coherent data, and decreasing (exponential), which requires one parameter only. It was used to increase and decrease the linear and non-stationary data. The calculation of forecasting accuracy using the MAPE (Mean Absolute Percentage Error) method in forecasting sales of merchandise produces the smallest error rate ranging from 7.99% to 32.42% for 10 different items.

1. Introduction
UD Parama Store is a trading company engaged in selling retail goods that sells various daily necessities at retail. The sold goods are the finished goods purchased from the distributors that can be stored in warehouses or displayed directly in the store’s shelves to be resold and selected directly by consumers. In the procurement of merchandise, the owner will physically calculate the existing goods through the system that he already found, so the owner is able to know the amount of goods that is running low. This process will cause problems in which the slow-moving goods can settle in warehouses and stores due to the excessive purchases and vice versa, but there will be a shortage of goods that move faster. Therefore, the store needs a system that can predict the amount of inventory that owners must purchase to reduce the risk of good deposition, especially goods with linear and non-stationary data trends.

There are several related researches focusing on the forecasting systems. The first is conducted by [1]. This research used single exponential smoothing with golden section optimization to prepare the stock weekly order to the primary production unit of automotive parts. Golden section was used to reduce the alpha area boundary so it will produce an ideal forecast value with the minimum MAPE level. The result revealed that the golden section found the optimal forecasting value with a MAPE level of 43.39%. However, the result of MAPE average value was still too high for forecasting, even though it has been estimated with the golden section. The other research was used double exponential
smoothing to forecast four selected products of British American Tobacco for the next five years [2]. From this research, it was obtained that there was a significant increase from the results in the production output of the selected products using the double exponential smoothing method against the actual production output. The MAPE value from the forecast result is in the range of 1.91883E+01 to 78. The double exponential smoothing method was also used in [3] to predict the hotel room’s reservation rate. The error forecasting results of each alpha score were calculated using the Mean Squared Error method (MSE). The study revealed the forecasting alpha 0.1 with an MSE error value of 19.278478603164 and the best forecasting score of reservation rate for January 2019 was 52,263. The MAPE and MSE score from [2] and [3] were identified as excessive. Single exponential smoothing (SES) and double exponential smoothing (DES) were used in [4] for forecasting product selling. This research compares forecasting using SES and DES. The result showed that MAPE of DES was around 24% and the value was better than SES. The double exponential method was also used in academic forecasting. The acceptance of new students was forecasted using the double exponential smoothing method and returned the MAPE score into 0.25511 [5]. Apart from the single exponential smoothing and dual exponential smoothing methods, there were the other methods, namely the double exponential smoothing brown. The double exponential smoothing from brown was similar to double moving average because both values of single smoothing and double smoothing lag behind from the actual data in every elements trend. The difference between single exponential smoothing and double exponential smoothing can be added to a single smoothing value and adjusted for a trend [6].

In this study, the method used in web-based forecasting system was double exponential smoothing brown which is a procedure that continuously improves forecasting by averaging (smoothing) the past score of time series data in an exponential manner which requires only one parameter. It is also used to increase and decrease linear and non-stationary data, so this method is often called Brown’s one-parameter linear method.

2. Research Method

2.1. Forecasting
Forecasting is the art and science of predicting the future events by involving historical data and projecting it into the future using a systematic approach model. The demand of forecasting must use a particular method. All forecasting methods have the same idea by using past data to predict or project data in the future. Qualitative forecasting can be done by several methods, namely sales forces estimation, executive opinion, market survey, and Delphi method. In quantitative forecasting, the method is classified into two types: causal and time series. Causal method is defined as a method that predicts a value in the future based on a causal relationship of at least two variables. Time series method can be done by naïve forecast, simple moving average, weighted moving average, and exponential smoothing [7].

2.2. Double Exponential Smoothing Brown
The double exponential smoothing method proposed by Brown is a forecasting method which is used when the data shows a linear trend and non-stationary data [8]. The trend in question is an increase or decrease in data that occurs in specific periods or a long-term decline or increase [8]. The non-stationary data in question is a periodic series of data that shows non-stationary properties if the underlying generation process does not have a constant average and has various values [8]. Brown’s premise of linear exponential smoothing is similar to linear moving average since both single and multiple smoothing values lag behind the actual data when there is an element of trend. The single and multiple smooth differences can be added to the single smooth score and adjusted for the trend factor. The double exponential smoothing brown method has one parameter which is between the numbers 0 and 1. This parameter value is used to exponentially decrease the observed value (actual
value) in the older period. The equation used in Brown’s one-parameter linear exponential smoothing implementation is:

1. The equation for single exponential smoothing

\[ S_t^\alpha = \alpha X_t + (1 - \alpha) S_{t-1}^\alpha \]  

Where:
- \( S_t^\alpha \) : t period single smoothing
- \( X_t \) : t period actual value
- \( \alpha \) : smoothing parameter whose magnitude \( 0 < \alpha < 1 \)

2. The equation for double exponential smoothing

\[ S_{t}^{\text{double}} = \alpha S_t^\alpha + (1 - \alpha) S_{t-1}^{\text{double}} \]  

Where:
- \( S_t^{\text{double}} \) : t period double smoothing

3. Determination a

\[ \alpha_t = S_t^\alpha + (S_t^\alpha - S_t^\alpha) = 2S_t^\alpha - S_t^\alpha \]  

4. Determination b

\[ b_t = \frac{\alpha}{1-\alpha} (S_t^\alpha - S_t^\alpha) \]  

5. Forecasting

\[ F_{t+m} = \alpha_t + b_t^m \]  

Where:
- \( F_{t+m} \) : forecasting the future period in the forecast
- \( \alpha_t \) and \( b_t^m \) : smoothing constant

2.3. Forecast Accuracy

In many forecasting situations, accuracy is seen as the criterion for refusing to choose a forecasting method. In many cases, the word precision refers to the virtue of ultimately indicating how far the forecasting model can reproduce the known data. One method for measuring forecasting accuracy is MAPE (Mean Absolute Percentage Error) [8]. MAPE is the absolute average of the percentage error value for each forecast period compared to the actual value of time with the following equation:

1) Percentage error

\[ PE_t = \left( \frac{X_t - F_t}{X_t} \right) \times 100 \]  

Where:
- \( PE_t \) : t period percentage error
- \( X_t \) : Actual value for period t

2) Mean absolute percentage error

\[ \text{MAPE} = \frac{\sum_{i=1}^{n} |PE_t|}{n} \]  

Where:
- \(|PE_t|\) : The absolute value of the percentage error
- \( n \) : Number of forecast periods
3. Design and Implementation

3.1. Data
The data used in this study were monthly sales data of products with a linear and non-stationary trend based on unit root testing with an augmented dickey fuller method in EViews application. The data obtained were five types of products with a sales period starting from January 2018 until December 2019, it can be seen in Table 1 below. Some products’ sales data, such as Bintang Beer Btl 620 ml/12, Sampoerna A Mild 16S, Sampoerna A Mild 12S, Ultra Milk Coklat 250Ml, and Coca Cola Botol 1Lt were used because of the unit root testing. Those data have linear and non-stationary data trend which were suitable to this forecasting method.

Table 1. Monthly Sales Data.

| Period   | Product Name |
|----------|--------------|
|          | Bintang Beer Btl 620 MI/12 | Sampoerna A Mild 16S | Sampoerna A Mild 12S | Coca Cola Botol 1Lt | Ultra Milk Coklat 250MI |
| Jan 2018 | 558.00       | 338.00        | 133.00        | 21.00           | 89.00            |
| Feb 2018 | 471.00       | 254.00        | 148.00        | 19.00           | 60.00            |
| Mar 2018 | 473.00       | 299.00        | 153.00        | 30.00           | 103.00           |
| Apr 2018 | 652.00       | 318.00        | 163.00        | 27.00           | 103.00           |
| May 2018 | 841.00       | 318.00        | 189.00        | 24.00           | 100.00           |
| Jun 2018 | 620.00       | 383.00        | 211.00        | 31.00           | 96.00            |
| Jul 2018 | 695.00       | 321.00        | 200.00        | 30.00           | 113.00           |
| Aug 2018 | 770.00       | 412.00        | 177.00        | 38.00           | 111.00           |
| Sep 2018 | 699.00       | 402.00        | 206.00        | 36.00           | 123.00           |
| Oct 2018 | 630.00       | 371.00        | 210.00        | 48.00           | 109.00           |
| Nov 2018 | 686.00       | 359.00        | 195.00        | 46.00           | 85.00            |
| Dec 2018 | 1,414.00     | 390.00        | 200.00        | 72.00           | 173.00           |
| Jan 2019 | 912.00       | 306.00        | 177.00        | 46.00           | 109.00           |
| Feb 2019 | 691.00       | 295.00        | 143.00        | 48.00           | 108.00           |
| Mar 2019 | 525.00       | 334.00        | 127.00        | 62.00           | 41.00            |
| Apr 2019 | 614.00       | 323.00        | 129.00        | 49.00           | 88.00            |
| May 2019 | 701.00       | 294.00        | 116.00        | 51.00           | 108.00           |
| Jun 2019 | 749.00       | 324.00        | 155.00        | 35.00           | 62.00            |
| Jul 2019 | 1,172.00     | 295.00        | 144.00        | 33.00           | 100.00           |
| Aug 2019 | 1,248.00     | 376.00        | 155.00        | 48.00           | 102.00           |
| Sep 2019 | 1,002.00     | 320.00        | 140.00        | 47.00           | 80.00            |
| Oct 2019 | 896.00       | 321.00        | 126.00        | 60.00           | 71.00            |
| Nov 2019 | 1,884.00     | 358.00        | 137.00        | 50.00           | 78.00            |
| Dec 2019 | 1,896.00     | 384.00        | 151.00        | 36.00           | 82.00            |

3.2. System Overview
The system built is a system that can perform sales forecasting calculations in the next period. The flow of an overview of the system being built. The further details are presented in figure 1:
1. The forecast period to be calculated is included first
2. Sales data in the previous period and alpha values will be searched in the database
3. Double exponential smoothing brown method is used to calculate the forecasting for the next period
4. The forecast results will be stored back in the database
In the use of the forecasting system’s case diagram for merchandise sales at UD Parama Store shown in Figure 2. There is one actor who is the user. The user can manage the user data, manage item category data, manage goods data, manage sales data, determine forecast weights, calculate forecasts, print forecasting reports, and manage the user data.

Figure 1. System Overview.

3.3. Implementation

The example of forecasting calculations was carried out by using one product which was Sampoerna A Mild 16S sales data. The training forecasting was done from the alpha value’s range of 0.1 to 0.9 to determine the value used in actual forecasting calculations. The actual α value for the forecasting system was obtained from the smallest MAPE value. In this example calculation, the value used was 0.20. The following section is the forecast calculation for December 2019 using the double exponential smoothing brown method as follows:

a. Single Exponential Smoothing

\[ S_{t} = \alpha X_{t} + (1 - \alpha) S_{t-1} \]

\[ S_{22} = 0.20 \times 358.00 + (1 - 0.20) \times 327.85 \]

\[ S_{23} = 71.60 + 0.80 \times 327.85 \]
b. Double Exponential Smoothing

\[ S''_{t+1} = \alpha S''_t + (1-\alpha) S''_{t-1} \]

\[ S''_{23} = 0.20 \times 333.88 + (1 - 0.20) \times 332.31 \]

\[ S''_{21} = 66.78 + 0.80 \times 332.31 \]

\[ S''_{23} = 66.78 + 265.85 \]

\[ S''_{28} = 332.63 \]

c. Determination a

\[ \sigma_2 = S''_t - S''_t \]

\[ \sigma_{23} = 2(333.88) - 332.63 \]

\[ \sigma_{28} = 667.76 - 332.63 \]

\[ \sigma_{28} = 335.13 \]

d. Determination b

\[ b_t = \frac{\alpha}{1-\alpha} (S''_t - S''_{t-1}) \]

\[ b_{28} = \frac{0.2}{1-0.2} (333.88 - 332.63) \]

\[ b_{28} = 0.25 \times 1.25 \]

\[ b_{23} = 0.31 \]

e. Forecast where m = 1 (the next period is December 2019)

\[ F_{t+m} = \sigma_t + b_t \times m \]

\[ F_{24} = 335.13 + (0.31) \times 1 \]

\[ F_{24} = 335.44 \]

The calculation of the forecasting accuracy in each period using PE (Percentage Error) dan APE (Absolute Percentage Error):

\[ PE_t = \left( \frac{X_t - F_t}{X_t} \right) \times 100 \]

\[ PE_{24} = \left( \frac{384.00 - 335.44}{384.00} \right) \times 100 \]

\[ PE_{24} = 12.65\% \]

\[ | PE_t | = 12.65\% \]

The Calculation of the overall forecasting accuracy using the method of MAPE (Mean Absolute Percentage Error):

\[ MAPE = \frac{\sum_{t=1}^{n} | PE_t |}{n} \]

\[ MAPE = \frac{118.02}{12} = 9.84\% \]
4. Result and Analysis

4.1. Result

The forecasting detail page shown in Figure 3, which displays the detailed results of the forecasting process with various weights. This display also includes a description of the products suggested by the system. The intended result was the result with the smallest error value in the forecast calculation process. On this page, the user as the owner could use forecasting data as a foundation for consideration in decision making to determine the number of items need to be provided based on the total estimated sales in the upcoming period.

Figure 3. Forecasting Details Page.

Forecasting analysis page is a display that shows the comparison between sales and forecasting results for the sales period, which uses primary data in determining forecasting. This comparison is used to determine the value of the forecast calculation error. Comparisons are displayed in graphical form and comparison table form, as seen in Figure 4 below.

Figure 4. Forecasting Analysis Page.
4.2. Analysis
The implementation of forecasting in the resulting system was carried out using monthly sales data of five products that met the trend of linear and non-stationary data. Each monthly sales data of the five products was used in forecasting calculation with the range of alpha value of 0.1 to 0.9. The result of forecasting can be seen in Table 2.

| Item Product               | Best Alpha Value | MAPE (%) |
|----------------------------|------------------|----------|
| Bintang Beer Btl 620 ml/12 | 0.1              | 23.04    |
| 16S                        | 0.2              | 9.84     |
| Sampoerna A Mild 12S       | 0.6              | 12.19    |
| Ultra Milk Coklat 250Ml    | 0.2              | 32.42    |
| Coca Cola Botol 1Lt        | 0.1              | 18.07    |

Based on the results shown in table 2, it can be seen that the average MAPE value is 19.11%. This result is much lower when compared to the average MAPE score on [1], [2], [4], and [5]. These results indicate that trend analysis to determine the suitability of trend data used in forecasting influenced the forecasting results. The research in [1], [2], [4], and [5] did not state about it. The best alpha value for each item product can be used in next period forecasting calculation. The smallest MAPE value is 9.84% for Sampoerna A Mild 16S, while the most enormous MAPE value is 32.42% for Ultra Milk Coklat 250Ml. Those results indicate that the higher the fluctuation in the sales value (see Table 1), the higher the resulting MAPE value.

5. Conclusion
From the test results of the sales forecasting system, conclusions can be drawn from the research carried out as follows. The sales forecasting system with the double exponential smoothing brown method had been successfully implemented by displaying the results in the form of forecasting data with the lowest error value or error in the next period with a linear tendency and non-stationary data, and the level of forecasting system accuracy with the double exponential smoothing brown method resulted in the average rate of 19.11% which were calculated using the Mean Absolute Percentage Error (MAPE) method.

6. Future Research
For the future research that will conduct the related research, the study can be modified by using the other methods to investigate the problem, such as neural network method so that the forecasting is able to handle the data with high fluctuations and does not depend on data trends.

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References
[1] Widitriani N P S, Parwita W G S, and Meinarni N P S 2020 Forecasting system using single exponential smoothing with golden section optimization J Phys Conf Ser Epub ahead of print DOI: 10.1088/1742-6596/1516/1/012008
[2] Chukwulozie O P et al 2017 The analysis of cigarate production using double exponential smoothing model Acad J Sci. 07
[3] Ramadiani et al 2019 Forecasting the Hotel Room Reservation Rate in East Kalimantan Using
Double Exponential Smoothing *Fourth Int Conf Informatics Comput* Epub ahead of print
DOI: 10.1109/ICIC47613.2019.8985916

[4] Sidqi F and Sumitra I D 2019 Forecasting product selling using single exponential smoothing and double exponential smoothing methods *IOP Conf Ser Mater Sci Eng* 1–6

[5] Silitonga P D, Himawan H, and Damanik R 2020 Forecasting acceptance of new students using double exponential smoothing method. *J Crit Rev*. 7 300–5

[6] Pujiati E, Yuniarti D, and Goejantoro R 2016 Peramalan dengan menggunakan metode double exponential smoothing dari brown (Studi Kasus: Indeks Harga Konsumen (IHK) Kota Samarinda) *J EKSPONENSIAL*. 7 33–40

[7] Heizer J and Render B 2014 *Principles of Operations Management 9th Edition* (Pearson Education)

[8] Makridakis S, Wheelwright S, and McGee V 1999 *Metode dan Aplikasi Peramalan* jilid 1 (Binapura Aksara)