Forecasting System Using Single Exponential Smoothing with Golden Section Optimization

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Abstract. Puri Wira Mahkota Ltd is a distributor company in the automotive parts industry. Puri Wira Mahkota has an obstacles in preparing weekly order on stock to the primary production unit. They predicting total sales of product in the coming period just by using an expectation from stock administration staff then it will be compared with sales data in the previous period without any calculations using a definitive formula. Forecasting calculation could support Puri Wira Mahkota to predicting the quantity of product. The purpose of this research is to apply the calculation process that can predict how many the quantity of product should be produced by the primary production unit every month and also to prevent over stock and out of stock. The method used in the forecasting calculation is Single Exponential Smoothing. To optimize Single Exponential Smoothing we used the Golden Section. The principle of the Golden Section is to reduce the alpha area boundary so it will be produce an ideal forecast value with the minimum MAPE (Mean Absolute Percentage Error) level. This research shows the results that the Golden Section finds the optimal forecasting value with a level of MAPE (Mean Absolute Percentage Error) of 43,39%.

1. Introduction

Puri Wira Mahkota Ltd is a distributor company in the automotive parts industry. These companies not only distribute but also produce the products they market. This company needs a system that can help the company's operational activities in forecasting the quantity of products to be ordered by the branch office, and in the future it is expected to help the decision making process according to the conditions and the ongoing market share. Predicting the quantity of products to be ordered in every period is expected can help the management in the process of making decision to determine the quantity of products that should be produced by the primary production unit every month and also to prevent overload stock and out of product in branch warehouse.

The method used in forecasting calculations is Single Exponential Smoothing. Single Exponential Smoothing is an upgrading method of the Single Moving Average where the forecasting method is done by repeating calculations continuously using the latest data. In the calculation of the Single Exponential Smoothing requires parameter values (alpha) between 0 to 1. In order to produce the minimum MAPE (Mean Absolute Percentage Error) value, it must use the appropriate alpha value. The obstacle found in the calculation of the Single Exponential Smoothing is the alpha value which is still determined in a trial-error, so it will take a long time in forecasting calculations process. This study will discuss the calculations that can be used to optimize alpha values in the process of implementing the Single Exponential Smoothing Method. The calculation is the Golden Section. Therefore the title of the study to be reviewed by the author is "Forecasting Systems Using Single Exponential Smoothing With Golden Section Optimization"

There are several previous studies that the authors use as a reference. The first study with the research title "Drug Stock Forecasting System Using the Exponential Smoothing Method" [1] . The study discusses the condition of drug storage in the Pharmacy Installation of the Syarifah Ambami Rato Ebu Bangkalan Regional General Hospital. The hospital must provide enough medicine for the patient. However, these storage activities cannot be carried out for a long time because the drug consists of several chemicals which if the useful period is over, it will be very dangerous to consume. The obstacle discussed in this study is the current system of the Pharmaceutical Installation of the Syarifah Ambami Rato Ebu Bangkalan Regional General Hospital only limited to making a recap of drug sales without data processing so that the pharmaceuticals have difficulty predicting the stock of drugs that will appear in the coming period. The lack of forecasting of drug stocks in the Pharmacy Installation of this Hospital, resulting in the distribution of drugs to patients is often delayed. So that patients still have to get out of the hospital environment to buy medicine at the nearest pharmacy.

Another related research is the research entitled "Inventory Forecasting System with Weight Moving Average Method in The Kids 24 Store" [2] . The study discusses the activity of calculating the quantity of product that must be purchased by The Kids 24 Store in the coming period based on sales data of the previous period. As for the obstacles discussed in this study, in the sale of The Kids 24 Store products still use the recording in the cash book every day by the finance department, the product that have been sold will be recorded in the ledger. Then the shopkeeper at the end of each month will count directly the quantity of product left in the store and then report to the owner. With the operational system as described above the manager is often confused in determining the number of products that must be ordered or purchased in the next period. Resulting in an impact, the store manager only guesses about what kind of products and how many will be purchased from these products without a definite calculation process and without calculating the real demand of consumers in the future.

Research with the title "Forecasting System Using Single Exponential Smoothing With Golden Section Optimization" has similarities with previous research, in the process of determining product to be ordered in the next period is still being carried out without a definite calculation system. This causes a mismatch between the quantity of product that have been ordered or produced with actual consumer demand. The difference between this research with previous research is in terms of the methods that used in the forecasting calculations and in terms of the method that used to optimize parameter value in forecasting calculations. In this study, for the process of forecasting calculations the method that uses is Single Exponential Smoothing Method which will then be optimized using the Golden Section.

2. Research Methodology

2.1. Forecasting

Forecasting is an activity to help achieve an optimal decision, requires an appropriate, systematic and accountable way. One of the tools needed by management and an integral part of the decision making process. Forecasting methods are used to measure or estimate the situation in the future. Forecasting is not only done to determine the quantity of products that need to be made or the capacity of services that need to be provided, but also is needed for various other fields (such as in procurement, sales, personnel, resources, including for forecasting technology, economics, or socio-cultural changes). In the structure of company, one section always has a relationship with each other section, so that a good or bad forecast will affect the company as a whole [3]. Forecasting is an important data, because of the existence of data forecasting that can help in determining decisions to take forward. Forecasting will provide information about anything that will happen in the future. The old data will be used as reference data in predicting the future data [4].

Forecasting is an art and science in predicting future events. Forecasting will involve taking historical data (such as last years sales) and projecting them into the future with a mathematical model [5].

Forecasting (forecast) is a statement about the value that will come from variables such as demand. This means that forecasting are predictions about the future [6].

2.2. Single Exponential Smoothing

Exponential Smoothing Forecasting is one of the categories of time series methods that use past weighting of data to forecast. The magnitude of the weight changes exponentially depending on historical data. Forecasting with the Single Exponential Smoothing Method is done by entering the current demand forecast with actual demand data into the Exponential Smoothing formula [5].

To calculate single exponential smoothing, the equation can be used (1):

$$F_{t+1} = \alpha A_t + (1 - \alpha)F_{t-1} \qquad (1)$$

Where:

F_{t+1} = forecasting value in the coming period
α = parameter value between 0 to 1 ($0 < \alpha < 1$)
A_t = actual data
F_{t-1} = forecasting value in the previous period

2.3. Golden Section

In this study the parameter values are determined using the Golden Section calculation. Golden Section Optimization is a clasical solution to the single peak optimizing problem. A search interval [a, b] of length L is divided by two points X_1 and X_2, which must satisfy equation (2):

$$ax_2 = x_1 b = \lambda L \qquad (2)$$

Where the value of λ is equal to 0.618. After comparing the corresponding function values $f(X_1)$ and $f(X_2)$, Golden Section Optimization selects the next search space according to the following rules. If $f(X_1) < f(X_2)$, the maximum must lie in the range of [X_1, b], which is taken as a new interval for the next iteration. On the other hand, if $f(X_1) > f(X_2)$, [a, X_2] is taken in the next iteration. The new interval is always 0.618 times the original interval. The process is repeated continuously until the distance between X_1 and X_2 is less than a certain chosen precision [7]. The steps taken to explain the Golden Section function interventions carried out in stages as follows:
Optimization of the Golden Section in the Single Exponential Smoothing (SES) Model

1. Optimization of the Golden Section in the Single Exponential Smoothing (SES) Model. Determine the lower limit (a), the upper limit (b) and the tolerance value of cessation of iteration (eps). For the Exponential Smoothing Method the lower limit is 0 and the upper limit is 1.
2. Calculates the value of Golden Ratio (R).
3. Determine the initial value for the parameter, $r_1 = \frac{-b+\sqrt{5}}{2} = 0{,}618$ and $r_2 = \frac{-b-\sqrt{5}}{2} = -1{,}618$
   Because the parameter value is $0 < \alpha < 1$, then (r) value use 0,618. Determine the initial values for the parameters alpha1 = $r \times a + (1 - r) \times b$ and alpha2 = $(1 - r) \times a + r \times b$.
4. Find the maximum value *f(x)* between combinations x_i = alpha1, alpha2.
5. Reduce the interval based on the Golden Section criteria.
6. Repeat steps "e)" until |alpha 2 – alpha 1| ≤ eps.
7. Determine the minimum value between a combination of calculations a,b, alpha1 and alpha2. Alpha produced is optimal.

3. Design and Implementation

3.1. Data

The data that used in this research is monthly product sales data from the stock administration staff of Puri Wira Mahkota Ltd Denpasar Branch. The data obtained were 81 (eighty one) data of products with sales period starting from January 2016 until June 2019.

3.2. General Overview

The system development will be adjusted to the data contained in Puri Wira Mahkota Ltd Denpasar branch. The process will be start from the stock administration staff who will recapitalize the data of products and track list of sales in the previous period. Then after the recapitalize process is done it will be produce the data of product selling detail. In the next process, the data of product selling detail will be use to carry out the process of calculating forecast parameter values using the Golden Section. After Golden Section calculation is done, it will get the results of the forecast parameter values which are then used to do the Single Exponential Smoothing calculations. After calculating Single Exponential Smoothing will get forecasting results which in the next steps will be continued with MAPE (Mean Absolute Percentage Error) calculation. Forecasting results and MAPE (Mean Absolute Percentage Error) values will be used to reduce the interval boundary according to the Golden Section criteria. If the iteration has received a convergent value, the process will continue to save the data store of forecasting which is later can be checked by the area manager in the form of forecasting reports. However, if the iteration has not found a convergent point, the process will return to the Golden Section calculation and continue to the next process until it finds the point of iteration (convergent). The implementation of the explanation above can be seen in the Figure 1:

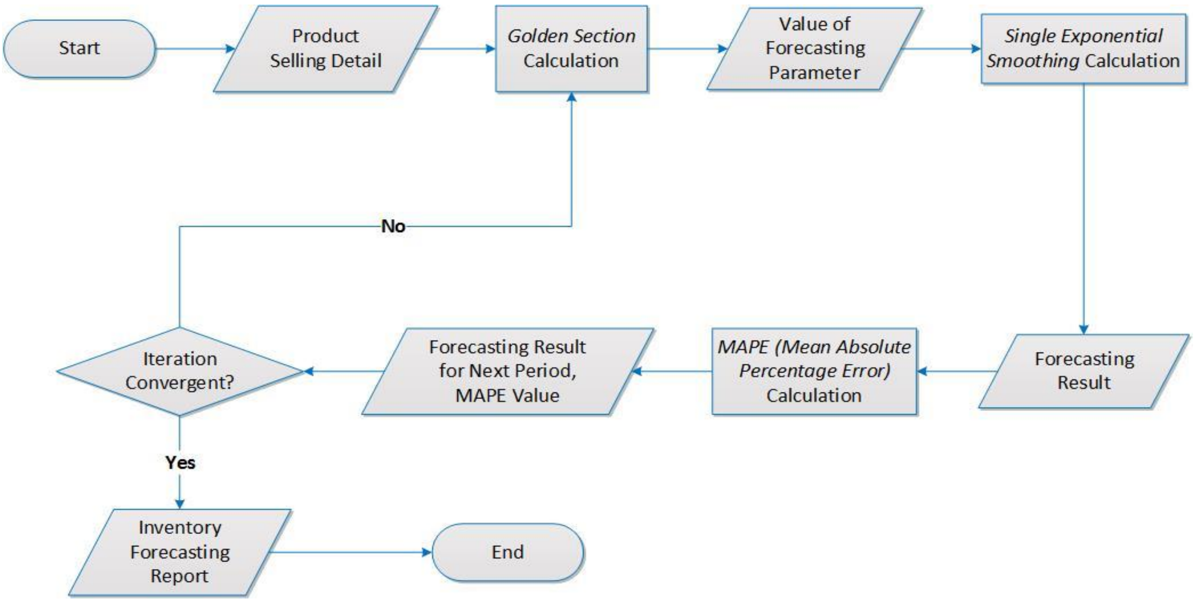

Figure 1. General Overview of Forecasting Calculation

3.3. Implementation

Implementation of Single Exponential Smoothing calculations for Vario Headlamps products without Golden Section optimization.

1. The calculation of Single Exponential Smoothing will be applied using actual sales data and forecast data in the previous period, October 2016 and November 2016. For October 2016 actual sales data is 555 (five hundred fifty five) and forecast value is 234,51 (two hundred thirty four point fifty one). Data from October 2016 will used to calculate forecast value in November 2016. After the calculation is done, for November 2016 actual sales data is 407 (four hundred and seven) and get the forecast value 266,56 (two hundred sixty six point fifty six). Has the same process with the previous period, data from November 2016 will be used to calculate forecast value in December 2016. For the equation of Single Exponential Smoothing calculation (3):

$$
\begin{aligned}
F_{t+1} &= \alpha A_t + (1-\alpha)F_t \\
F_{t+1} &= (0{,}1 \times 407) + (1-0{,}1) \times 266{,}56 \\
F_{t+1} &= 40{,}7 + (0{,}9 \times 266{,}56) \\
F_{t+1} &= 40{,}7 + 239{,}90 \\
F_{t+1} &= 280{,}60
\end{aligned}
\quad (3)
$$

2. Mean Absolute Percentage Error (MAPE) is calculated using the absolute error in each period divided by the observed values that are evident for that period. Then, averaging those fixed percentages. This approach is useful when the size or size of a prediction variable is significant in evaluating the accuracy of a prediction [8]. Calculate the accuracy of the forecast with an alpha value of 0.1 using the MAPE (Mean Absolute Percentager Error) calculation. For the equation can be seen as follows:
   Example of calculating the forecast error value in December 2016 (4):

$$
\begin{aligned}
Error\ Value &= Actual\ Data - Forecast\ Value \\
et &= A_t - F_t \\
et &= 457 - 280{,}60 = 176{,}40
\end{aligned}
\quad (4)
$$

Example of calculating the percentage of forecast errors in December 2016 (5):

$$Percentage\ Error\ = \frac{Error\ Value}{Actual\ Data} \times 100$$

$$e/y\ = (et/A_t) \times 100 \qquad (5)$$
$$e/y\ = (176{,}40/457) \times 100$$
$$e/y\ = 38{,}60\%$$

Example of calculating MAPE (Mean Absolute Percentage Error) of forecast (6):

$$MAPE = \frac{\sum \frac{[Actual - forecast] * 100}{Actual}}{n}$$
$$MAPE = (1050{,}29/42) \times 100\% \qquad (6)$$
$$MAPE = 25{,}01\%$$

Implementation of Single Exponential Smoothing calculations for Vario Headlamps products using Golden Section optimization.

Determine the lower limit of iteration (7):

$$alpha1 = r \times a + (1 - r) \times b$$
$$alpha1 = 0{,}618 \times 0 + (1 - 0{,}618) \times 1 \qquad (7)$$
$$alpha1 = 0{,}382$$

Determine the upper limit of iteration (8):

$$alpha2 = (1 - r) \times a + r \times b$$
$$alpha2 = (1 - 0{,}618) \times 0 + 0{,}618 \times 1 \qquad (8)$$
$$alpha2 = 0{,}618$$

The example of iteration limit calculation is implemented to find the optimum alpha value by reducing the interval limit according to the Golden Section criteria. If the alpha value has been found then it will be implemented in Single Exponential Smoothing calculation to find the forecast value, andd the next step to determine the accuracy of the forecast, so it will produce an ideal MAPE value with a minimum error rate.

Results of the Golden Section iteration calculation use the sample Vario Headlamps product:

Optimization of the Single Exponential Smoothing parameter on the Vario Headlamps product is obtained at the 4th iteration with alpha2 - alpha1 = 0.0000 $\leq \varepsilon$, meaning that the iteration stops at that point. Furthermore, the alpha1 and alpha2 values were convergent at 0.6180 and the f(alpha1) and f(alpha2) convergent values were obtained for a Mean Absolute Percentage Error value of 24.1319%. If it is displayed in table form, then as can be seen in Table 1.

Table 1. Forecasting Iteration of Vario Headlamps Product

Iteration	Alpha1	Alpha2	MAPE 1	MAPE 2	Alpha 2 – Alpha 1
1	0,3820	0,6180	24,4499	24,1317	0,2360
2	0,6181	0,7639	24,1320	24,8674	0,1458
3	0,5279	0,6180	24,0264	24,1318	0,0901
4	0,6181	0,6180	24,1320	24,1319	0,0000

4. Result and Analysis

After the Golden Section calculation is implemented in the inventory forecasting system, iterative summaries and convergent MAPE values are obtained for each product. Based on the optimum alpha value, then proceed with the forecasting process of goods inventory using Single Exponential Smoothing, and get an average result of Mean Absolute Percentage Error for the all product of 43.39%. As can be seen in Table 2.

Table 2. All Product Convergent Result

PRODUCT NAME	ITERATION CONVERGENT	MAPE CONVERGENT
LEGSHIELD LUAR SUPRA X 125 07 HITAM	19	49,3194
LEGSHIELD LUAR GRAND	3	42,0739
LEGSHIELD LUAR JUPITER MX HITAM	3	48,2700
LEGSHIELD TENGAH ATAS SUPRA X 125 07	7	54,4435
LEGSHIELD DALAM SUPRA HITAM	3	36,6072
COVER BODY SUPRA HITAM + COVER STOP	3	40,4834
COVER BODY VEGA R HITAM + COVER STOP	3	54,8891
FRONT FENDER SCOOPY FI HITAM	3	38,9640
FRONT FENDER BEAT FI HITAM	3	54,4224
FRONT FENDER BEAT FI PUTIH	3	50,5681
FRONT FENDER BEAT HITAM	3	45,8184
FRONT FENDER A SUPRA X 125 07 HITAM	3	44,5157
FRONT FENDER VARIO HITAM	3	31,3497
FRONT FENDER VARIO PUTIH	3	44,4836
FRONT FENDER A SUPRA FIT NEW HITAM	3	53,7495
FRONT FENDER SUPRA X HITAM	3	34,9918
FRONT FENDER A GRAND HITAM	3	50,9872
FRONT FENDER A SMASH HITAM	3	51,2546
FRONT FENDER JUPITER MX HITAM	3	49,8996
FRONT FENDER JUPITER Z HITAM	3	41,2328
PANEL BEAT FI HITAM	3	46,3879
PANEL BEAT FI PUTIH	3	42,7729
PANEL BEAT HITAM	3	47,6756
PANEL VARIO HITAM	3	30,4406
PANEL VARIO PUTIH	3	26,9666
PANEL SUPRA X HITAM	3	48,2736
FRONT HANDLE COVER ABSOLUTE REVO HITAM	3	45,5257
FRONT HANDLE COVER SUPRA X 125 07 HITAM	3	42,1601
FRONT HANDLE COVER VARIO HITAM	3	49,5842
FRONT HANDLE COVER SUPRA X 125 HITAM CAKRAM	3	49,8949
FRONT HANDLE COVER SUPRA FIT HITAM CAKRAM	4	51,5459
FRONT HANDLE COVER GRAND HITAM	3	48,9082
FRONT HANDLE COVER JUPITER Z 06 HITAM	3	50,7211
FRONT HANDLE COVER JUPITER MX HITAM (KOPLING)	3	48,3468
REAR HANDLE COVER VARIO	3	33,8835
REAR HANDLE COVER SUPRA X 125	3	49,2241
REAR HANDLE COVER SUPRA FIT	3	46,5796
REAR HANDLE COVER SUPRA X	3	30,5728
BOX SAMPING SUPRA X HITAM	7	55,3718
LAMPU DEPAN VARIO TECHNO 125	3	34,1278
LAMPU DEPAN BEAT FI	3	34,2005
LAMPU DEPAN BEAT	3	30,9301
LAMPU DEPAN SUPRA X 125 07	3	36,4982
LAMPU DEPAN VARIO	4	24,1320
LAMPU DEPAN SUPRA X 125	3	47,8484
LAMPU DEPAN SUPRA FIT NEW	3	34,0315
LAMPU DEPAN KARISMA	3	51,2604
LAMPU DEPAN SUPRA FIT	3	45,8401
LAMPU DEPAN SUPRA X	3	28,8088
LAMPU DEPAN SUPRA	3	46,0945
LAMPU DEPAN MIO M3	3	42,5587
LAMPU DEPAN JUPITER MX 11	3	46,9593
LAMPU DEPAN VEGA ZR	3	37,6352
LAMPU DEPAN MIO 08	3	46,0674
LAMPU DEPAN JUPITER Z 06	3	35,7506
LAMPU DEPAN JUPITER MX	7	31,4294

LAMPU DEPAN F1Z-R	6	57,6826
MIKA LAMPU VARIO 110 FI	3	28,3293
MIKA LAMPU VARIO TECHNO 125	3	22,0457
MIKA LAMPU BEAT FI	4	51,2673
MIKA LAMPU VARIO	3	28,7579
MIKA LAMPU MIO SOUL GT	5	48,5018
MIKA LAMPU MIO 08	3	45,3529
MIKA LAMPU MIO SOUL	5	53,3563
MIKA LAMPU JUPITER Z 06 + INNER	3	50,1900
MIKA LAMPU MIO	4	59,5105
MIKA SPEEDOMETER BEAT FI	5	46,5758
MIKA SPEEDOMETER BEAT	3	45,9651
MIKA SPEEDOMETER VARIO	3	46,0542
MIKA SPEEDOMETER SUPRA X 125 + INNER	3	52,5856
MIKA SPEEDOMETER SUPRA	3	31,7265
MIKA SPEEDOMETER GRAND	5	46,2670
MIKA SEN Fr VARIO (P)	3	50,1744
MIKA SEN Rr + STOP VARIO (P/M) KO	3	34,5615
FRONT WINKER ASSY VARIO	4	32,8902
FRONT WINKER ASSY GRAND (C/P)	3	54,1146
Fr / Rr WINKER ASSY V-IXION	3	26,2413
STOP LAMP ASSY VARIO	3	42,4764
STANDARD SAMPING SUPRA	3	50,8912
HANDFAT BEAT / BEAT 10 / VARIO TECHNO / VARIO / SPACY	3	42,3613
PIPA GAS SUPRA / SUPRA X / SUPRA FIT / SUPRA V / SUPRA XX	3	49,5755

5. Conclusion
According to the result and analysis above, can be concluded that After calculating the Golden Section, an optimum parameter value is obtained which will then be implemented in the Single Exponential Smoothing calculation to find the ideal MAPE. The average MAPE obtained using 81 product data and sales data from January 2016 until June 2019 was 43.39%. With the details of the smallest MAPE value is 22.04% and the largest MAPE value is 59.51%.

6. Future Research
In this research, the Mean Absolute Percentage Error rate was 43.39%. For the future research will be conducted research on the use of methods other than Single Exponential Smoothing so that the rate of Mean Absolute Percentage Error obtained is lower than the research that has been done.

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