Jurnal Mantik, 6 (2) (2022) 1603-1611

Published by:Institute of Computer Science (IOCS)

Jurnal Mantik

Journal homepage: www.iocscience.org/ejournal/index.php/mantik/index

Sales Forecasting Applications For Retail Companies Using Double Exponential Smoothing And Golden Section Methods

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ARTICLE INFO

Article history:
Received: Jun 25, 2022
Revised : Jul 15, 2022
Accepted: Aug 06, 2022

Keywords:
Sales Forecasting, Optimization, Exponential Smoothing,Golden Section

ABSTRACT

The availability of goods becomes one of the keys to the success of supermarket business in fulfilling consumer needs. The Forecasting methods can help to predict the sales in the future and it can help to find sales statistics daily, monthly or yearly. The application of exponential smoothing requires the process of determining the smoothing value by performing several tests. The determination of smoothing is a challenge in the forecasting process because it takes several tests of the optimal smoothing value to reduce forecasting errors. This study proposed the application of the golden section in optimizing the determination of the smoothing value. Golden section is an optimization method that provides extreme values of a non-linear function by reducing the range of values that contain extreme values. The results of the Forecasting method were based on the training data in which the trend and the result of the forecasting approached to the training data that used for forecasting. According to the results of the forecasting which conducted based on the training data was MAPE 26.460474 % and MAPE results from comparison of testing data obtained was 21.89696%.

1. Introduction

The transaction activities in supermarket can generate large data sets in the sales database. In order to be able to develop strategies to grow the business, the utilization of databases becomes a demand for companies. One aspect of the supermarket that requires information from the database is inventory. The availability of goods is one of the keys to the success of supermarket business in fulfilling consumer needs. The application of technology in extracting information in the sales database is one of the important things that must be done by the supermarket business management.

Ayunadi Swalayan (Ayunadi Supermarket) is a supermarket located in Denpasar City and has been established for 14 years. In running the business, Ayunadi Swalayan uses a computer-based Point of Sale (POS). In the database, the number of registered items is around 15,000 items with an average number of transactions per day is 1,000 transactions. The inventory management at Ayunadi Swalayan uses the observation method, namely checking the availability of goods in the warehouse and displays. If the goods are not available then the purchasing department will place an order to the distributor. This kind of ordering method frequently has problems with stock emptiness due to the lack of awareness toward other aspects including the history of the transaction numbers in certain period. The transaction history data in POS database is not use properly by the management. The sales database that has been collected for a long time can be used to decide the pattern of the transaction so that it can be used as a basis for estimating the inventory.

According to Heizer and Render, forecasting can be defined as the art and science of predicting the future events. Forecasting requires historical data and projecting it into the future [1]. The Forecasting methods can help to predict the sales in the future and it can help to find sales statistics daily, monthly or yearly. The forecasting of the goods demanded is one of the strategies needed by the retail companies in the current technology era [2]. The forecasting is also needed by the business management in order to support decision

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making. The result of the forecasting can be used to predict the situation in the future. Several researches about forecasting have been conducted by some researchers by utilizing the transaction history in the database system. Moving average dan exponential smoothing are methods that can be used for forecasting. Exponential smoothing showed better performance than the moving average in forecasting the visitors of an hotel [3]. The application of exponential smoothing in predicting the stock of stationery showed an error value below 20%. The results of the forecasting are close with the actual data that used double exponential smoothing process [4]. The double exponential smoothing method showed a better forecasting result in food crop production research [5]. The forecasting research using double exponential smoothing requires smoothing parameters with values between 0 to 1. The Determination of the smoothing parameters value will affect the smoothing error that uses the double exponential smoothing. In the research of the application of exponential smoothing, that has been mentioned, determines the smoothing value by conducting several tests. The determination of smoothing is a challenge in the forecasting process because it takes several tests of the optimal smoothing value to reduce forecasting errors. This study proposed the application of golden section in optimizing the determination of smoothing values. Golden Section can be described as an optimization method that provides extreme values of a non-linear function by reducing the values range that contain extreme values. The golden section optimization method has succeeded in optimizing the sugar extraction values using dilute acid [6]. The iteration process in the golden section can be applied to find the smoothing parameter value with small error values.

2. Method

This article proposed a forecasting application using Double Exponential Smoothing Holt and Golden Section method. The forecasting method using Double Exponential Smoothing based on smoothing parameters alpha (α) and beta (β). The parameter values are determined based on the optimization in the Golden Section method. The parameter of alpha and beta that used were the combination of alpha and beta with the smallest error values during the process of Golden Section. The application was built by using JAVA programming language. The forecasting accuracy in this application is measured using the MAD and MAPE. The forecasting method used in the application is shown in Figure 1.

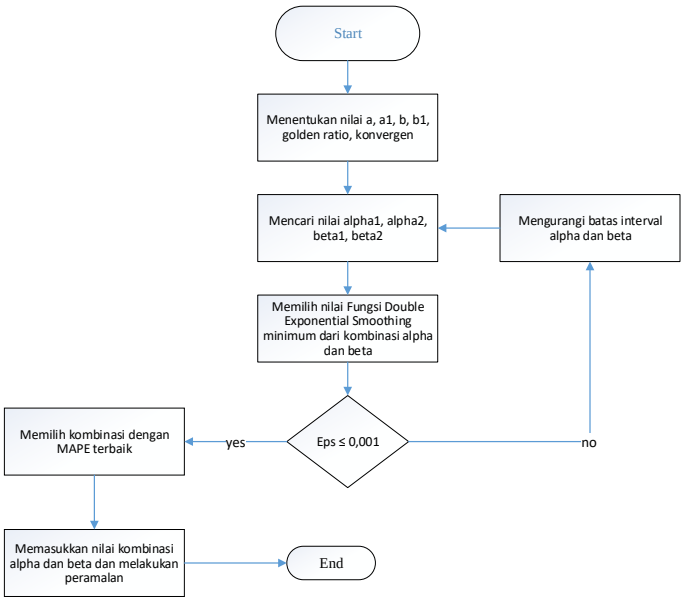

Figure 1. Proposed Method

The first process done in the Figure 1 is the process of determining the a and b value, the a and b value is the value range for the alpha parameters in which the lower limit value or a is 0, and the upper limit value or b is 1. Meanwhile a1 and b1 is the lower limit and upper limit for the beta parameters in which the value of a1 is 0 and b1 is 1. In determining the value of the golden ration, it was obtained a value of 0,618 which is in

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accordance with the theory described in the golden section. The following process is convergence, in which the iteration process or repetition process is determined by convergent with the provisions of convergence = eps ≤ 0,001.

The second process determines the initial value of alpha1, alpha2, beta1, beta2 with the following predetermined formula:

$$Alpha1 = r * a + (1 - r) * b \quad (1)$$
$$Beta1 = r * a2 + (1 - r) * b2 \quad (2)$$
$$Alpha2 = a + b - Alpha1 \quad (3)$$
$$Beta2 = a2 + b2 - beta1 \quad (4)$$

The third process is the process of looking for the minimum function value of the Double Exponential Smoothing with the combination of alpha1, alpha2, beta1, beta2. Then, there is a decision for the iteration that is going to be used with the convergent criteria = eps ≤ 0,001. The results of the eps are obtained by subtracting alpha2 and alpha1. If the criteria are not met, therefore, the following process is the process of reducing the interval limit from alpha1, alpha2, beta1, beta2 by renewing the values of alpha1, alpha2, beta1, beta2 based on the criteria of the golden section, with the condition: if MAPE value is f(alpha1) < f(alpha2) then f(alpha2) = b, if MAPE value is f(alpha2) < f(alpha1) then f(alpha1) = a, if MAPE value is f(beta1) < f(beta2) then f(beta2) = b2, if MAPE value is f(beta2) < f(beta1) then f(beta1) = a2. After that, the process will be continued to the process of determining alpha1, alpha2, beta1, beta2. Moreover, if the criteria for convergence are met, then the best combination of alpha and beta will be chosen based on MAPE. After obtaining the optimum alpha and beta values, immediately insert the alpha and beta value and conduct the Double Exponential Smoothing forecasting process.

2.1 Double Exponential Smoothing

In the DES Holt method, the smoothed trend components are separated by using different parameters, those are alpha (α) and beta (β). In this technique, the trend value can be smoothed using different weights. However, these two parameters need to be optimized so that the searching process for the best parameter becomes more complicated than using only one parameter. Moreover, the seasonal component in this technique is not counted. Below is the process of Holt's Double Exponential Smoothing [7]. The Double Exponential Smoothing method is used when the data shows the existence of trend. The formula of Double Exponential Smoothing are as follows:

$$S_t = \alpha\, X_t + (1 - \alpha)(S_t - 1 + T_t - 1) \quad (5)$$
$$T_t = \beta\, (S_t - S_t - 1) + (1 - \beta)T_t - 1 \quad (6)$$
$$F_{t+m} = S_t + T_t m \quad (7)$$

Description :

S_t = Single smoothing value
X_t = The actual data at time t
T_t = Trend Smoothing
F_{t+m} = Forecasting value
m = Future period
α = Smoothing coefficient (0 < α < 1)
β = Smoothing coefficient for trend (0 < β < 1)

2.2 Golden Selection

The Golden Section method is one of the fastest direct search algorithms to solve single variable optimization problems, in which the searching space is reduced from [a,b] to [0,1] [8]. The algorithms use a principle of iteratively reducing the x boundary area that may produce the optimum objective function (maximum or minimum). In order to obtain a symmetrical point, it is required r value (Golden Ratio) [6]. The optimization of Golden Section to determine the next searching point based on the following criteria: if f(X1)

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< f(X2), then the maximum value will lie between [X1, b]. the maximum value will be used as bara interval in the next iteration, in other side, if f(X1) > f(X2), [a, X2] will be continued to the next iteration. The new interval will be always 0,618 times of the original intervals. That process will be repeated continuously until the distance between X1 and X2 approaches precision [1][9].

2.3 The Forecasting Accuracy

The Forecasting Accuracy can be described as a measurement of forecasting error about the measurement of the level difference between forecasting results and the demand occurs [10]. From several techniques or formulas for the existed forecasting, there are two forecasting accuracy methods used in this article, namely of mean absolute deviation (MAD) and mean absolute percentage error (MAPE).

The forecasting accuracy will be high if MAD and MAPE values are smaller. MAD is the absolute total value of the forecasting error divided by the data. The MAD values are the absolute cumulative error values divided by the period [11]. If formulated, the formula to calculate MAD is as follows:

$$MAD = \frac{\sum|y1-yt\prime|}{n} \quad (8)$$

MAPE is a measurement of accuracy by using absolute percentage error. MAPE shows the average absolute error of the forecasting in a form of a percentage of the actual data [11].

$$MAPE = \frac{\sum\frac{|y1-yt\prime|}{y1}}{n} \; x \; 100\ \% \quad (9)$$

3. Result and Discussion

This research find out the forecasting's application of the sales of items for the retail companies by using the Double Exponential Smoothing and Golden Section methods. The application has two pages, namely the data page of items and the forecasting page of items. The data page of items is the first page of the system shown in the Figure 2. On this page the operator can see a list of the items in the table and select the items by double-clicking on the table.

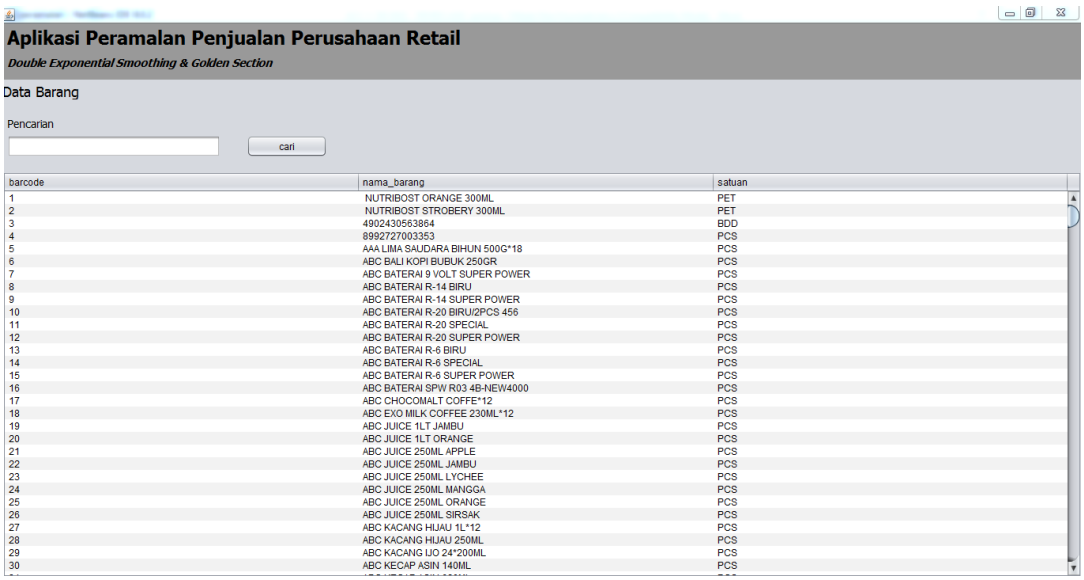

Figure 2. The Data Page of Items

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On the data page of the items there is a feature that can be used to search the items based on the barcode and the item names. Furthermore, it shows the way how to select the items that will be forecasted by double-clicking on the desired item names in the data table of the items. After selecting the desired data, it will immediately be redirected to the forecasting page (Figure 3). On the forecasting page, the operator can see the forecasting results in the table of forecasting results and the forecasting data in the data table as well as the operator can view the results of the Golden Section iteration on the results of the Golden Section. Furthermore, the operator enters the range of the start and the end dates as the forecasting reference. Figure 3 shows a forecasting page that displays the history of the item's sales, the iterations of the optimization of the golden section, and the forecasting results.

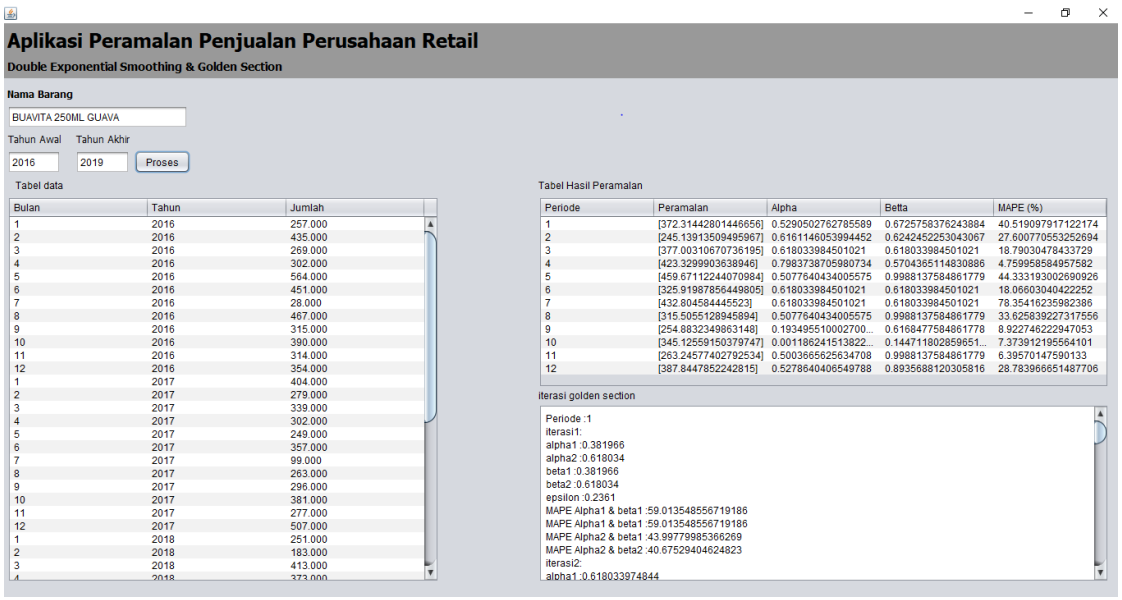

Figure 3. The Forecasting Page

On the forecasting page (Figure 3), there is the name of the items which are immediately filled in according to the name of the items selected on the previous page and there is a starting year and an ending year for the data to be used in the forecasting. After filling in the initial year and the final year, the operator can press the button of process to find out the forecasting results. In the data table will be directly filled with data used for the forecasting. From the example above, the data table will contain the data on sales of the items that have been selected from 2016 to 2019 where it contains the period or month, year, and the number of forecasting. Furthermore, there is a table of forecasting results consist of periods, forecasting results, alpha, beta, and MAPE. The period of this table refers to the month of forecasting year from the first period to the twelfth period. Moreover, there are twelve forecasting results where each period has one forecasting, alpha, beta and MAPE. The Alpha, beta and MAPE are obtained in the iteration process table which is below the forecasting results table. In the golden section iteration table there is an iteration process of twelve periods. The combination for alpha and beta is chosen based on the smallest MAPE in the last iteration.

In accordance with the chart in the proposed method (Figure 1), after the items and the sales history of the items are determined, then the forecasting is done through the initial value of the initiation, golden ratio, convergent conditions, looking for alpha and beta values with the golden section, and forecasting using the double exponential smoothing. The next discussion is about the process of applying the proposed method with a sample of items data and the history of sales. Table 1 shows the data on the sales of items.

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TABLE 1
THE SAMPLE DATA OF THE ITEM'S SALES

Period	2016	2017	2018	2019
1	257	404	251	373
2	435	279	183	341
3	269	339	413	322
4	302	302	373	391
5	564	249	414	452
6	451	357	278	392
7	28	99	305	327
8	467	263	291	350
9	315	296	258	316
10	390	381	346	442
11	314	277	266	278
12	354	507	342	423

The search for trends in this research is the forecasting for each month using the data in the same month with different years. For instance, to find the results of forecasting for the first period or January 2020 using the data sales from January 2016 to 2019. After determining the next data, the process of determining the upper limit, lower limit, Golden Ratio value, and epsilon value is carried out. This epsilon value will be a benchmark for stopping the iteration of the Golden Section process. In this study, the lower limit (a and a1) = 0, the upper limit (b and b1) = 1, Golden Ratio (r) = 0.618034, and epsilon = 0.001.

The iterative process of determining the value of alpha1, alpha2, beta1, beta2 will stop if the epsilon value is less than or equal to 0.001. The results from epsilon are obtained with alpha2 - alpha1 and to update the values of alpha1, alpha2, beta1, and beta2 according to the Golden Section criteria where if the results of alpha1 and beta1 are more optimum than alpha2 and beta2 then the value of b = alpha2 and b1 = beta2, whereas if the value of alpha2 and beta2 are more optimum than alpha1 and beta1, thus the values of a = alpha1 and a1 = beta1. The following results of the Golden Section repetition for twelve periods are shown from Table 2 to Table 3:

TABLE 2
THE FIRST PERIOD OF THE GOLDEN SECTION OPTIMIZATION FORECASTING

Januari									
iteras i	*Alpha1(α1)*	*Alpha2(α2)*	*Beta1(β1)*	*Beta2(β2)*	*Epsilon*	MAPE			
						α1 & β1	α1 & β2	α2 & β1	α2 & β2
1	0.381966	0.618034	0.381966	0.618034	0.2361	59.013549	52.13671	43.9978	40.675294
2	0.618034	0.763932	0.618034	0.76393203	0.1459	40.675294	42.16415	45.8868	48.044126
3	0.527864	0.618034	0.527864	0.61803399	0.0902	44.238625	41.52997	40.7305	40.675294
4	0.618034	0.6737621	0.618034	0.67376208	0.0557	40.675294	41.25135	42.5300	43.177266
5	0.5835921	0.618034	0.5835921	0.61803399	0.0344	40.627352	40.60346	40.7006	40.675294
6	0.5623059	0.5835921	0.618034	0.63932022	0.0213	40.576701	40.56055	40.6034	40.585957
7	0.5491503	0.5623059	0.6393202	0.65247584	0.0132	40.550834	40.54061	40.5606	40.549675
8	0.5410197	0.5491503	0.6524758	0.66060646	0.0081	40.536998	40.53066	40.5406	40.533885
9	0.5359947	0.5410197	0.6606065	0.66563146	0.005	40.529282	40.52539	40.5306	40.526499
10	0.532889	0.5359947	0.6656315	0.66873708	0.0031	40.524834	40.52237	40.5253	40.522801

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							40.5206	40.5223	40.52083
11	0.5309697	0.532889	0.6687371	0.67065646	0.0019	40.522209	9	77	6
							40.5196	40.5206	40.51974
12	0.5297834	0.5309697	0.6706565	0.6718427	0.0012	40.520634	95	9	2
							40.5190	40.5196	40.51911
13	0.5290503	0.5297834	0.6718427	0.67257584	0.0007	40.519679	98	95	1

From the results of the Golden section process in the first period, it was obtained thirteen repetitions to get an epsilon value of less than 0.001 with the smallest MAPE results shown in the results of the thirteenth repetition with a combination of alpha1 & beta2 with a MAPE value of 40,519098% with an alpha value of 0.5290503 and a beta value of 0.67257584. After getting the results of the first period, the results of second period can be seen in Table 3 below:

TABLE 3
THE SECOND PERIOD OF THE GOLDEN SECTION OPTIMIZATION FORECASTING

Januari									
iteras i	*Alpha1(*α1 *)*	*Alpha2(α2)*	*Beta1(β1)*	*Beta2(β2)*	*Epsilo n*	MAPE			
						α1 & β1	α1 & β2	α2 & β1	α2 & β2
	0.381966	0.618034	0.381966	0.618034	0.2361	48.46006	41.15554	34.83446	27.67398
1						4	8	7	1
	0.618034	0.763932	0.618034	0.7639320	0.1459	27.67398	30.10737	31.92422	34.46641
2				3		2	8	4	7
	0.527864	0.618034	0.527864	0.6180339	0.0902	34.26116	31.58062	30.17542	27.67398
3				9		7	4	5	1
	0.618034	0.6737621	0.618034	0.6737620	0.0557	27.67398	28.53340	29.44214	30.45013
4				8		1	1	9	7
	0.5835921	0.618034	0.583592	0.6180339	0.0344	29.95962	29.00360	28.59640	27.67398
5			1	9		8	5	8	1
	0.618034	0.6393202	0.618034	0.6393202	0.0213	27.67398	27.93217	28.30644	28.68441
6				2		1	4		4
	0.6048784	0.618034	0.604878	0.6180339	0.0132	28.51203	28.15917	28.02155	27.67398
7			4	9		5	7	5	1
	0.618034	0.6261646	0.618034	0.6261646	0.0081	27.67398	27.70275	27.84944	27.99222
8						1	6	2	6
	0.613009	0.618034	0.613009	0.6180339	0.005	27.98892	27.85605	27.80605	27.67398
9				8		1	9	1	1
	0.618034	0.6211396	0.618034	0.6211396	0.0031	27.67398	27.64644	27.70392	27.72601
10				1		1	4	3	
	0.6161146	0.618034	0.621139	0.6230589	0.0019	27.66167	27.61153	27.64644	27.64862
11			6	8		1	3	4	3
	0.6149284	0.6161146	0.623059	0.6242452	0.0012	27.65432	27.62335	27.61153	27.60077
12				3		7	7	3	1
	0.6161146	0.6168477	0.624245	0.6249783	0.0007	27.60077	27.61312	27.62673	27.63949
13			2	6		1	9		4

From the results of the Golden section process in second period, it was obtained thirteen repetitions to get an epsilon value of less than 0.001 with the smallest MAPE results shown in the results of the thirteenth repetition with a combination of alpha1 & beta1 with a MAPE value of 27.600771% with an alpha value of 0.6161146 and a beta value of 0.6242452. The next step is comparing the forecasting results with the data test in order to obtain the MAPE from the data test. In addition to looking for MAPE from the data test, this section will compare the trend graphs from the data test, forecasting results, and training data for the last twelve months. The following is a comparison of forecasting results with the data test, as shown in Table 4 below:

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TABLE 4
THE RESULT OF FORECASTING

Periode	Peramalan 2020	Aktual 2020	Error	MAD	MAPE
1	372.31443	381	8.685572	8.685572	2.279677
2	245.13914	272	26.86086	26.86086	9.875318
3	377.00311	577	199.9968	199.9968	34.66150
4	423.32999	566	142.6700	142.6700	25.20671
5	459.67112	506	46.32887	46.32887	9.155904
6	325.91988	283	-42.9198	42.91987	15.16603
7	432.80458	271	-161.804	161.8045	59.70648
8	315.50551	283	-32.5055	32.50551	11.48604
9	254.88323	310	55.11676	55.11676	17.77960
10	345.12559	306	-39.1255	39.12559	12.78614
11	263.24577	347	83.75422	83.75422	24.13666
12	387.84479	276	-111.844	111.8447	40.52347
		Rata-rata			21.89696

From the comparison table of forecasting results with the data test, the smallest MAPE results in January with MAPE of 2.279677%, and the largest MAPE in July with MAPE of 59.70648% and the average MAPE for twelve months is 21.89696%. From the comparison results of the forecasting results of 2020 with the data test of 2020, a comparison chart is obtained as shown in Figure 4:

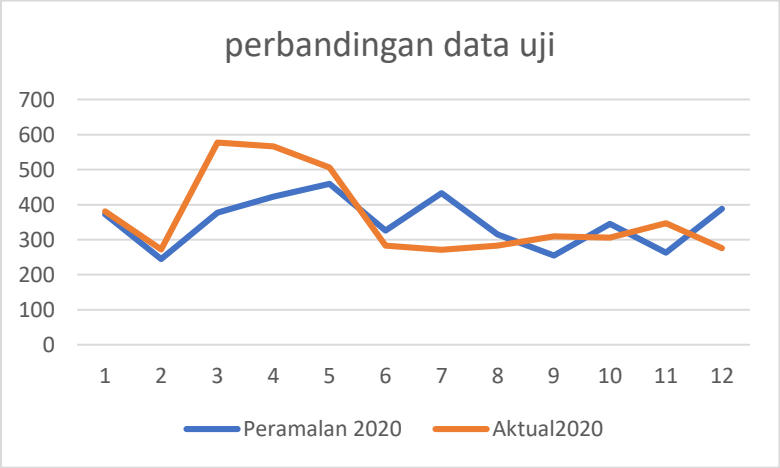

Figure 4. The Comparison Chart of The Result of Forecasting and The Actual Data

In the comparison chart of the data test refers to the forecasting column and the actual of the data test table of 2020, a comparison chart is obtained where the blue line shows the forecasting results of 2020 and the red line shows the actual data of 2020. From the observations, it can be concluded that in the first period to the second period the graph shows the same downward movement. Meanwhile, from the second to the third period, the graph shows an upward movement even though the difference is quite large. Then in third period to the fifth period there is a difference where the forecasting results show an upward movement while the actual data results show a decrease. From the fifth to the sixth period shows the equation of the movement of the graph again where the movement shows a downward movement. From the actual data results from the sixth to the tenth period, it shows a slight upward movement, while the forecasting results from the sixth to the tenth period have an up and down movement whereas in the sixth to seventh period it shows an upward movement, while from seventh to ninth period it shows a downward movement and rose again in the tenth period. In the tenth to eleventh period, it shows an upward movement in the actual data and a downward movement in the forecasting

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results. In the last period, the forecasting results moved up and the actual data of 2020 moved down. It can be concluded that the comparison between the forecasting results of 2020 and the actual data of 2020 from the view of trends there is an equation from the first period to the sixth period.

4. Conclusion

Based on the results of the design and implementation of the Sales Application with the Double Exponential Smoothing Method and the Golden Section Parameter Optimization at Ayunadi Supermarkets, it can be concluded that the forecasting results are based on training data where the trend and forecasting results approach to the training data used for the forecasting. From the results of the forecasting based on the training data obtained MAPE 26.460474 % and MAPE results from the comparison of the data test obtained 21.89696%. This research was supported and financed by the Research and Community Service Institute of STMIK STIKOM Indonesia with contract number 47/09/LPPM/PPDS/VII/2019

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