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Implementation of Grid Search Optimization Algorithm and Adaptive Response Rate Exponential Smoothing In Product Sales Prediction

Franklin Fong[1], Randy Ciptady[2], Anita[3]
[1-3]Fakultas Sains dan Teknologi, Universitas Prima Indonesia

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ABSTRACT

Effective inventory management is one of the keys to a company's success, especially in the retail and distribution sectors that are highly dependent on product availability according to market demand. One common problem faced in inventory management is deadstock, which is a condition where a product is not sold for a long time, causing a buildup of goods and financial losses. This problem is generally caused by inaccuracy in predicting product sales needs. This study aims to overcome this problem by implementing the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm combined with the Grid Search optimization method to improve the accuracy of sales predictions. By utilizing the Sales Data Analysis dataset from Kaggle, the algorithm is implemented in a web-based system using Python and Flask. The results showed that the combination of Grid Search and ARRES was able to significantly increase prediction accuracy, as indicated by a decrease in the MAPE value from 2.845% (ARRES only) to 0.877% (Grid Search + ARRES). This proves that the proposed method can help companies manage stock more efficiently, reduce the risk of deadstock, and increase the effectiveness of product sales planning.

Corresponding Author:

Anita
Fakultas Sains dan Teknologi
Universitas Prima Indonesia
Indonesia
Email: anita@unprimdn.ac.id

1. Introduction

Effective inventory management is one of the important aspects of business, especially for companies engaged in retail and distribution. In maintaining a balance between demand and product availability, companies must be able to estimate stock requirements accurately so that there is no shortage or excess of goods.

One of the main problems often faced by companies in the retail and distribution sector is deadstock, which is a condition where goods are not sold for a long period of time, causing inventory to accumulate. Deadstock not only burdens the company with storage costs, but also has the potential to cause losses if the goods expire or experience a decrease in value.

The solution to overcome the problems described can be done through sales prediction with the application method of the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm, namely a time series modeling method to update predictions based on historical data by giving greater weight to the latest data and less weight to older data which can be used as an effective solution in predicting product sales so that it becomes a solution in preventing deadstock which causes losses in the provision and sale of products in the future. So with this, the title proposed is Implementation of Grid Search Optimization Algorithm and Adaptive Response Rate Exponential in Product Sales Prediction.

2. Research Method

Types of Research

This type of research is quantitative research that focuses on data analysis to identify and solve problems in inventory management. This study uses an experimental approach to test the effectiveness of the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm combined with the Grid Search optimization technique in predicting sales.

Work Procedure

In this research, the work procedures for the research to be carried out can be seen in Figure 2.1.

Figure 2.1. Work Procedure

Dataset

The dataset used in this study was collected and taken from Kaggle, namely Sales Data Analysis, as many as 100 electronic product sales data. The following, Table 2.2. shows the dataset used in this study.

Table 2.2 Research Dataset

No	***Order ID***	***Product***	***Quantity Ordered***	***Price Each***	***Order Date***	***Purchase Address***	***Month***	***Sales***	***City***	***Hour***
0	295665	Macbook Pro Laptop	1	1700	12/30/2019 00:01	136 Church St, New York City, NY 10001	12	1700	New York City	0
1	295666	LG Washing Machine	1	600	12/29/2019 07:03	562 2^{nd} St, New York City, NY 10001	12	600	New York City	7
2	295667	USB-C Charging Cable	1	11.95	12/12/2019 18:21	277 Main St, New York City, NY 10001	12	11.95	New York City	18
3	295668	27in FHD Monitor	1	149.99	12/22/2019 15:13	410 6^{th} St, San Francisco, CA 94016	12	149.99	San Francisco	15
4	295669	USB-C Charging Cable	1	11.95	12/18/2019 12:38	43 Hill St, Atlanta, GA 30301	12	11.95	Atlanta	12
5	295670	AA Batteries (4-pack)	1	3.84	12/31/2019 22:58	200 Jefferson St, New York City, NY 10001	12	3.84	New York	22

									City	
6	295671	USB-C Charging Cable	1	11.95	12/16/2019 15:10	928 12th St, Portland, OR 97035	12	11.95	Portland	15
7	295672	USB-C Charging Cable	2	11.95	12/13/2019 09:29	813 Hickory St, Dallas, TX 75001	12	23.9	Dallas	9
8	295673	Bose SoundSport Headphones	1	99.99	12/15/2019 23:26	718 Wilson St, Dallas, TX 75001	12	99.99	Dallas	23
9	295674	AAA Batteries (4-pack)	4	2.99	12/28/2019 11:51	77 7th St, Dallas, TX 75001	12	11.96	Dallas	11
10	295675	USB-C Charging Cable	2	11.95	12/13/2019 13:52	594 1st St, San Francisco, CA 94016	12	23.9	San Francisco	13
..	..	..	..	..	..	..	..	..	..	..
13621	222909	AAA Batteries (4-pack)	1	2.99	6/25/2019 14.33	209 11th St, Atlanta, GA 30301	6	2.99	Atlanta	14

Explanation of Grid Search and ARRES Optimization Algorithms

Grid Search

Grid Search is a technique in machine learning that is used to find the optimal combination of parameters in a model with the aim of identifying the best parameter settings that produce the best model performance on a particular dataset.

ARRES

The Adaptive Response Rate Exponential Smoothing (ARRES) method is an Exponential Smoothing method that uses an adaptive response rate to determine the response to changes in data patterns dynamically. This method is suitable for time series data that has non-stationary characteristics or often experiences pattern changes.

Implementation of ARRES Algorithm and Grid Search

Grid Search Optimization Algorithm

The Grid Search optimization algorithm is a systematic search method to find the optimal combination of parameters in a model. In Grid Search, the range of values for each parameter is determined first, then a comprehensive search is performed. Optimization is performed using the Grid Search algorithm to determine the most optimal alpha value for the model. The parameters used are alpha values with a range of 0.01 to 0.99, with an addition of 0.01 for each grid. In addition, a parameter is also used in the form of the initial month of the prediction, namely from January to December, with an addition of 1 month for each grid. The use of the initial month as an important parameter because it affects the model in studying data and producing more accurate predictions.

Adaptive Response Rate Exponential Smoothing (ARRES) algorithm

Adaptive Respose Rate Exponential smoothing (ARRES) method is a forecasting method that is almost the same as the Single Exponential Smoothing (SES) forecasting method. In its application, the calculation in ARRES does not need to determine the best alpha value, because the alpha value always changes each period adjusted to changes in data patterns. The formula for ARRES is as follows:

$$F_t = \alpha_{t-1} * A_{t-1} + (1 - \alpha_{t-1}) * F_{t-1} \quad (1)$$

Where:

F_t = The predicted or smoothed value for period t.

A_{t-1} = Actual value or observation data in the previous period (t−1)

F_{t-1} = Smoothed predicted values in the previous period (t−1).

α_{t-1}= Adaptive smoothing factor parameters determined in the prevoius period (t−1).

Prediction Model Evaluation

Mean Absolute Percentage Error is a method of calculating errors whose value is obtained by finding the percentage of error from each prediction period and then dividing it by the amount of data in the time period used. The following is the equation for MAPE.

$$MAPE = \left(\frac{100}{N}\right) \sum A_t - \frac{F_t}{A_t} \quad (2)$$

Where:
N = Number of prediction period involved
F_t= Forecast prediction in period-t
A_t= Actual data at period-t

The MAPE value obtained from the calculation results can be analyzed whether a prediction has good performance. The following explains the performance of the MAPE value as shown in Table 2.3. below.

Table 2.3 MAPE Value Performance

MAPE Values	Prediction Accuracy
MAPE < 10%	High
10% < MAPE < 20%	Goog
20% < MAPE < 50%	Reasonable
MAPE > 50%	Low

3. Result and Discussion

The results obtained from this study were processed using Google Colab, utilizing the Python programming language as the primary tool for data analysis and model implementation. The main objective of this research was to address the issue of deadstock, which often arises due to inaccuracies in forecasting product sales demand. Deadstock not only leads to financial losses for businesses but also results in inefficient inventory management and increased storage costs. Therefore, accurate sales prediction plays a crucial role in optimizing stock levels, minimizing waste, and improving overall operational efficiency.

To achieve this objective, the study employed and analyzed the performance of two forecasting techniques: the Grid Search optimization algorithm and Adaptive Response Rate Exponential Smoothing (ARRES). Grid Search was utilized to fine-tune the model's parameters by exhaustively searching through a predefined set of hyperparameters to find the best combination that yields the highest accuracy. On the other hand, ARRES is an advanced smoothing technique designed to dynamically adjust the response rate based on recent trends and patterns in sales data, thereby enhancing the accuracy of forecasts in volatile or seasonally affected markets.

Through the experiments conducted, the effectiveness of each method was evaluated based on several performance metrics, including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE). The results demonstrated that the integration of these techniques can significantly improve prediction accuracy compared to traditional forecasting methods. This highlights the importance of adopting data-driven approaches in modern inventory management systems. Furthermore, this study provides valuable insights into how predictive analytics and machine learning techniques can be practically applied to solve real-world business problems, particularly in the retail and e-commerce sectors, where anticipating customer demand is essential for maintaining competitiveness and profitability.

Data Collection Results

In the study, the collected data was taken from Kaggle, namely Sales Data Analysis as many as 13,621 data. Each data is grouped per product item so that it can be processed in the next stage. There are 19 product items tested in this study, namely 20in Monitor, 27in 4K Gaming Monitor, 27in FHD Monitor, 34in

Ultrawide Monitor, AA Batteries (4-pack), AAA Batteries (4-pack), Apple Airpods Headphones, Bose SoundSport Headphones, Flatscreen TV, Google Phone, LG Dryer, LG Washing Machine, Lightning Charging Cable, Macbook Pro Laptop, ThinkPad Laptop, USB-C Charging Cable, Vareebadd Phone, Wired Headphones, and iPhone. The collection of daily transaction data is grouped into monthly transaction data so that 12 months of transaction data are obtained and are transaction data in 2019. All data is appropriate so that there is no need to do the data preprocessing stage.

Result of Implementation of Grid Search and ARRES Optimization Algorithms

In this study, the implementation of the Grid Search and ARRES optimization algorithms was written directly through Google Colab. Training data was taken from sales data from February to October 2019 and testing data was taken from sales data from November to December 2019.

Result of Implementation of Grid Search and ARRES Optimization Algorithms

Evaluate the prediction results using the Mean Absolute Percentage Error (MAPE) method from each prediction period. The following are the evaluation results:

1. *20in Monitor* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	420	414	424
2019-12	569	553	568

2. *27in 4K Gaming Monitor* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	420	414	424
2019-12	569	553	568

3. *27in FHD Monitor* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	719	743	740
2019-12	962	940	960

4. *34in Ultrawide Monitor* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	551	560	552
2019-12	849	820	846

5. *AA Batteries (4-pack)* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	2.625	2.726	2.698

2019-12	3.724	3.624	3.714

6. *AAA Batteries (4-pack)* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	3.025	3.135	3.110
2019-12	4.241	4.130	4.230

7. *Apple Airpods Headphones* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	1.513	1.567	1.560
2019-12	2.076	2.025	2.071

8. *Bose SoundSport Headphones* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	1.252	1.287	1.254
2019-12	1.824	1.770	1.818

9. *Flatscreen TV* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	460	477	467
2019-12	666	647	644

10. *Google Phone* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	493	501	494
2019-12	715	694	713

11. *LG Dryer* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	56	53	53
2019-12	86	83	86

12. *LG Washing* product selling

Periode	Produksi Aktual	Produksi Prediksi (ARRES)	Produksi Prediksi (*Grid Search* + ARRES)
2019-11	53	54	53
2019-12	80	77	80

13. *Lighting Charging* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	2.210	2.296	2.238
2019-12	3.087	3.008	3.079

14. *Macbook Pro Laptop* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	440	446	441
2019-12	643	623	641

15. *ThinkPad Laptop* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	374	381	375
2019-12	539	523	537

16. *USB-C Charging Cable* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	2.256	2.312	2.260
2019-12	3.250	3.156	3.240

17. *Vareebadd Phone* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	177	184	179
2019-12	284	274	283

18. *Wired Headphones* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	1.934	1.984	1.937
2019-12	2.749	2.673	2.741

19. *Iphone* product selling

Period	Actual Production	Predicted Production (ARRES)	Predicted Production (*Grid Search* + ARRES)
2019-11	665	682	683
2019-12	906	884	894

3.2. Discussions

The conclusion of the MAPE test results is shown in Table 3.1 and Figure 3.1.

No	Product Names	MAPE ARRES	MAPE *Grid Search* + ARRES
1	*20in Monitor*	2,078	0,568
2	*27in 4K Gaming Monitor*	2,602	0,292
3	*27in FHD Monitor*	2,825	1,586
4	*34in Ultrawide Monitor*	2,547	0,281
5	*AA Batteries (4-pack)*	3,256	1,530
6	*AAA Batteries (4-pack)*	3,115	1,543
7	*Apple Airpods Headphones*	3,010	1,673
8	*Bose SoundSport Headphones*	2,855	0,239
9	*Flatscreen TV*	3,300	0,942
10	*Google Phone*	2,309	0,258
11	*LG Dryer*	4,590	2,959
12	*LG Washing Machine*	2,272	0,242
13	*Lightning Charging Cable*	3,224	0,766
14	*Macbook Pro Laptop*	2,240	0,251
15	*ThinkPad Laptop*	2,362	0,266
16	*USB-C Charging Cable*	2,681	0,241
17	*Vareebadd Phone*	3,610	0,81
18	*Wired Headphones*	2,687	0,233
19	*iPhone*	2,497	1,976
Averages		2,845	0,877

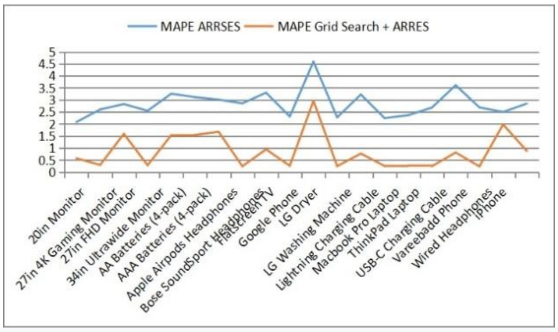

Figure 3.1 Graph of MAPE Test Results for All Product Sales

In this study, an analysis was conducted on the results of product sales prediction using the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm and the Grid Search optimization algorithm combined with ARRES. The evaluation results show that the use of Grid Search optimization can improve prediction accuracy compared to using ARRES alone. This is indicated by the lower Mean Absolute Percentage Error (MAPE) value in the Grid Search + ARRES method compared to ARRES alone in most of the products tested.

One of the main factors that affect prediction accuracy is the stability of sales data patterns. Products with sales patterns that tend to be stable, such as electronic products with consistent demand every month, show lower MAPE values. For example, in the 27in 4K Gaming Monitor product, the MAPE value generated by the Grid Search + ARRES method is 0.292%, much smaller than ARRES which has a MAPE of 2.602%. This shows that parameter optimization using Grid Search is able to adjust the forecast parameter values better, resulting in more accurate predictions.

On the other hand, some products with fluctuating sales patterns, such as LG Dryer and LG Washing Machine, tend to have higher MAPE values compared to other products. This can be caused by greater demand variability, for example the influence of external factors such as seasons, promotions, or consumer behavior that cannot be fully predicted by the forecasting model used. However, the Grid Search + ARRES method still shows an increase in accuracy compared to ARRES alone, such as in the LG Dryer product, where MAPE decreased from 4.590% to 2.959%.

Based on the test results on all products, the average MAPE value produced by the ARRES method is 2.845%, while with Grid Search optimization, the average MAPE value decreases to 0.877%. Thus, in general the Grid Search + ARRES method is in the high category because it has a MAPE below 10%, which shows that this model is very accurate in predicting product sales. From the MAPE results table, most products experienced an increase in accuracy after using Grid Search optimization, especially products with stable sales trends.

From the results obtained, it can be concluded that the Grid Search + ARRES method has advantages in increasing the accuracy of sales predictions compared to ARRES without optimization. This improvement is especially seen in products with more stable demand patterns. However, for products with high fluctuations, this model still has limitations in capturing sudden changes in demand patterns. Therefore, for future improvements, the use of more adaptive forecasting techniques can be considered, such as a combination of machine learning-based models or deep learning methods to capture more complex data patterns.

4. Conclusion

a. The use of the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm combined with Grid Search optimization can improve the accuracy of product sales predictions. With higher prediction accuracy (lower MAPE), companies can be more precise in planning inventory, so that the risk of deadstock due to excess stock can be minimized. In addition, more optimal stock management also helps reduce stockout events, which can improve customer satisfaction and business efficiency.

b. The results of the study show that the Grid Search + ARRES method has a higher level of accuracy than ARRES without optimization. This is evident from the decrease in the average MAPE from 2.845% (ARRES) to 0.877% (Grid Search + ARRES), which is included in the high accuracy category (MAPE < 10%). Products with stable demand patterns show a more significant increase in prediction accuracy compared to products with fluctuating sales patterns.

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