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Implementation of Artificial Neural Networks to Predicte Laptop Sales Using the Backpropagation Algorithm

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Abstrak

Penelitian ini dilakukan untuk memprediksi penjualan laptop di X Computer Elektronik, Kota Medan. Metode yang digunakan oleh peneliti adalah metode Jaringan Saraf Buatan dengan Algoritma Backpropagation. Dalam metode penelitian ini, proses ilmiah untuk memperoleh data yang akan digunakan beserta proses pengolahannya dalam memecahkan suatu masalah akan dijelaskan. Gambaran umum objek penelitian menjelaskan lokasi, waktu penelitian, logo, tujuan, visi dan misi di X Computer Elektronik. Dalam menyelesaikan tesis ini, penulis melakukan penelitian di X Computer Elektronik, yang berlokasi di Jl. Ps. 7 No. 125, Tembung, Kecamatan Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara. Sumber data yang digunakan adalah data penjualan X Computer Elektronik dari Juli hingga Desember 2023, yang dapat dilihat pada [tautan]. Dari uraian yang telah dibahas pada bab sebelumnya, dapat disimpulkan: Model jaringan saraf tiruan dengan metode backpropagation yang dikembangkan untuk memprediksi penjualan laptop menunjukkan kinerja yang konsisten antara fase pelatihan dan pengujian, dengan nilai Mean Absolute Error (MAE) sebesar 4,3400. Struktur optimal model terdiri dari 3 unit input, 4 unit tersembunyi, dan 3 unit output (3-4-3). Kinerja model bervariasi secara signifikan antar merek laptop, dengan MAE individual berkisar antara 0,9462 (terbaik, untuk Acer Aspire 3 Slim) hingga 9,1163 (terburuk, untuk Apple MacBook Air 2020). Hal ini menunjukkan bahwa model memiliki tingkat akurasi yang bervariasi tergantung pada karakteristik penjualan masing-masing merek.

Kata Kunci: Jaringan Saraf Buatan, Penjualan Laptop, Algoritma Backpropagation

Abstract

This study was conducted to predict laptop sales at X Computer Elektronik in Medan. The method used by the researcher was the Artificial Neural Network method with the Backpropagation Algorithm. In this research method, the scientific process for obtaining the data to be used, along with the data processing involved in solving a problem, will be explained. An overview of the research subject describes the location, research period, logo, objectives, vision, and mission of X Computer Elektronik. In completing this thesis, the author conducted research at X Computer Elektronik, located at Jl. Ps. 7 No. 125, Tembung, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra. The data source used was X Computer Elektronik's sales data from July to December 2023, which can be viewed at [link]. From the discussion in the previous chapter, it can be concluded that the artificial neural network model using the backpropagation method, developed to predict laptop sales, demonstrates consistent performance between the training and testing phases, with a Mean Absolute Error (MAE) of 4.3400. The optimal model structure consists of 3 input units, 4 hidden units, and 3 output units (3-4-3). Model performance varies significantly across laptop brands, with individual MAE values ranging from 0.9462 (best, for the Acer Aspire 3 Slim) to 9.1163

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(worst, for the Apple MacBook Air 2020). This indicates that the model's accuracy varies depending on the sales characteristics of each brand

Keywords: *Artificial Neural Networks, Laptop Sales, Backpropagation Algorithm*

INTRODUCTION

Laptops have become a necessity, no longer an exclusive device. Everyone's needs for both work and study are inextricably linked to the need for a computer or laptop. One of the devices most sought after by consumers today is the laptop, partly due to its practicality and portability (Odja et al., 2021).

X Computer Electronics is a growing business in the field of laptop sales. Companies in selling laptops certainly adjust to customer needs, because of the many types of laptops, companies are required to provide various laptop brands such as Acer, HP, Asus, Advan, Lenovo, Apple. However, the company really wants to increase profits every month by looking at the laptop needs desired by customers (H. Aini et al., 2019). Therefore, a method is needed that can predict laptop sales well using previous sales data. Although predictions may not be the same as reality, the use of artificial neural network methods with the Backpropagation Algorithm can at least reduce the level of losses experienced by the company by predicting stock or products that are in high demand by consumers (Atina, 2019). This research is expected to be able to help X Computer Electronics in analyzing and evaluating in making decisions about laptop sales every month or year (Haryanto & Argadila, 2019).

Prediction is the activity of forecasting or estimating (Hasan et al., 2019). Companies can use forecasting as a basis for decision-making. While predictions may not be accurate, they can serve as a preparation for future expectations. Therefore, this forecasting activity can guide policies and decisions that provide information and sales forecasts consistent with those predictions (Padilah, 2023). By using and selecting appropriate methods, a company's success in marketing its products will result in profits. Artificial neural networks are data models that are capable and powerful in representing and capturing complex Input and Output relationships, due to their ability to solve several problems, are relatively easy to use, robust to input data, speed for execution, and initialize complex systems (Maulidah, 2020). The backpropagation method is a learning algorithm that minimizes error rates by adjusting its weights based on the difference between the output and the desired target. Backpropagation is one of several artificial neural network methods frequently used by researchers to predict future events with a high success rate (Tambunan et al., 2021). This research is supported by previous research (Mubarokh et al., 2020). in their research, forecasted product sales for electronics and furniture using a backpropagation artificial neural network.

Based on the description above, the author raises a study entitled "Implementation of Artificial Neural Networks for Laptop Sales Prediction Using the Backpropagation Algorithm (Case Study: Laptop Sales at X Computer Elektronik, Medan City)".

METHODS

This research was conducted to predict laptop sales at X Computer Elektronik, Medan City. The method used by the researcher is the Artificial Neural Network method with the Backpropagation Algorithm (Famil Alamdar & Seifi, 2024). In this research method, the scientific process for obtaining data that will be used along with its processing process in solving a problem will be described. An overview of the research object describes the location, time of research, logo, objectives, vision and mission at X Computer Elektronik. In completing this thesis, the author conducted research at X Computer Elektronik, located at Jl. Ps. 7 No. 125, Tembung, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra. The data source used is X Computer Elektronik sales data from July to December 2023, which can be seen in (Srivastava & Books, 2026).

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The research framework is a research framework or research flow carried out by researchers. In this research framework, details or stages of the entire research process will be made, starting from data collection to obtaining conclusions and final results obtained by researchers, thus producing a decision that can be used as input to increase sales at X Computer Elektronik can be seen in Figure 3.4. The data collection method used in this study is by interviewing the cashier (Chopra et al., 2023). Furthermore, after requesting and obtaining permission from X Computer Elektronik, data collection can be carried out. The data collected are product data and laptop sales data at X Computer Elektronik from July to December 2023. The results of this data collection will be used as a knowledge base for conducting research and for data processing.

RESULTS AND DISCUSSION

Backpropagation Neural Network Model

This program uses the Python programming language to implement a simple artificial neural network *to* predict laptop sales. In this study, researchers developed an artificial neural network model *using* the Python programming language to predict laptop sales trends. This program utilizes several libraries, including NumPy for numerical computation, Matplotlib for data visualization, and Graphviz for visual representation of network architecture. The implemented methodologies include (de Castro Moraes et al., 2024):

Data Pre-processing: This program begins by normalizing the sales data using the *min-max scaling method.* The '*normalize*' *function* transforms the data into the range [0,1], which is essential for optimizing the performance of the neural network.

Neural Network Architecture: The developed model is a simple *feedforward network* with three layers: input, hidden, and output. The number of *neurons* in the hidden layer *(hidden_size)* is set as an adjustable parameter.

Activation Function: *sigmoid* function is used as the activation function for all neurons. This choice allows the network to model non-linear relationships in the data.

4. Training Algorithm:

Data

This study uses laptop sales data from various leading brands, including *Lenovo, Asus, Acer, HP,* and *Apple,* covering the period from July 2023 to December 2023. This dataset represents the dynamics of the consumer and business laptop market in Indonesia over the past six months, the data provides information on sales trends and consumer preferences in the rapidly growing technology industry (Chen, 2025).

This data was obtained through a comprehensive analysis of official sales reports from leading laptop manufacturers in Medan. This data provides an accurate picture of the sales performance of various laptop models across various market segments. The data, presented in graphical form, is shown in

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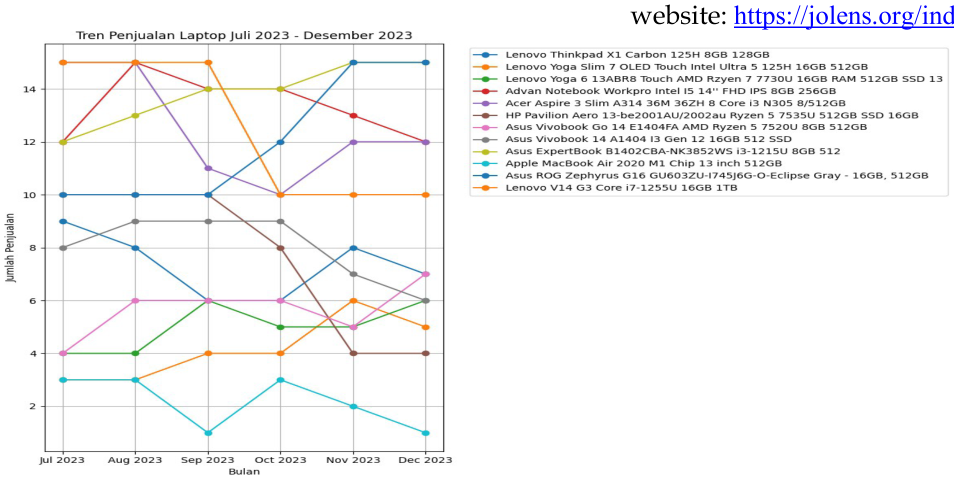

Figure 1. Laptop Sales Trend Graph July 2023 – December 2022

The sales data is supplemented with a sales table in the form of original data as shown in the Laptop Sales Table.

Table 1. Laptop Sales Table

Brand Name	July 2023	Augus t 2023	Septembe r 2023	Octob er 2023	Novemb er 2023	Dec ember 2023
Lenovo Thinkpad X1 C	9	8	6	6	8	7
Lenovo Yoga Slim 7 O	3	3	4	4	6	5
Lenovo Yoga 6 13ABR8	4	4	6	5	5	6
Advan Notebook Workp	12	15	14	14	13	12
Acer Aspire 3 Slim A	15	15	11	10	12	12
HP Pavilion Aero 13-	10	10	10	8	4	4
Asus Vivobook Go 14	4	6	6	6	5	7
Asus Vivobook 14 A14	8	9	9	9	7	6
Asus ExpertBook B140	12	13	14	14	15	15
Apple MacBook Air 20	3	3	1	3	2	1
Asus ROG Zephyrus G1	10	10	10	12	15	15
Lenovo V14 G3 Core i	15	15	15	10	10	10

Data Normalization

The data is normalized using the *min-max method* as in equation 4.1 below so that the data is consistent with the range value [0.1-0.9].

Training and Test Data Sharing

The entire dataset is used for both training and testing. The ratio of the test data to the training data is 100:100 or 1:1. This approach is known as "*in-sample testing*" or "*training on the test set*". This data can be seen from the following lines of code. X_train = normalized_data[:, :3] y_train = normalized_data[:, 3:6] X_test = normalized_data[:, :3] y_test = normalized_data[:, 3:6]. The data in Table 4.3 represents the normalized sales values for the first three months (July, August, September). These values serve as input for the neural network model (Solano Meza et al., 2023).

Table 3. Test Data and Targets

No.	Brand Name	Test Data (Input)	Target (Output)
1	Lenovo Thinkpad X1 Carbon	[0.571429, 0.500000, 0.357143]	[0.357143, 0.500000, 0.428571]

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2	Lenovo Yoga Slim 7 OLED	[0.142857, 0.142857, 0.214286]	[0.214286, 0.357143, 0.285714]
3	Lenovo Yoga 6 13ABR8	[0.214286, 0.214286, 0.357143]	[0.285714, 0.285714, 0.357143]
4	Advan Notebook Workpro	[0.785714, 1.000000, 0.928571]	[0.928571, 0.857143, 0.785714]
5	Acer Aspire 3 Slim A	[1,000,000, 1,000,000, 0.714286]	[0.642857, 0.785714, 0.785714]
6	HP Pavilion Aero 13	[0.642857, 0.642857, 0.642857]	[0.500000, 0.214286, 0.214286]
7	Asus Vivobook Go 14	[0.214286, 0.357143, 0.357143]	[0.357143, 0.285714, 0.428571]
8	Asus Vivobook 14 A14	[0.500000, 0.571429, 0.571429]	[0.571429, 0.428571, 0.357143]
9	Asus ExpertBook B140	[0.785714, 0.857143, 0.928571]	[0.928571, 1.000000, 1,000,000]
10	Apple MacBook Air 20	[0.142857, 0.142857, 0.000000]	[0.142857, 0.071429, 0.000000]
11	Asus ROG Zephyrus G1	[0.642857, 0.642857, 0.642857]	[0.785714, 1.000000, 1,000,000]

Network Architecture

The discussion in this section describes a simple *backpropagation network architecture* with one hidden layer. This network was trained using laptop sales data from July to December 2023. The following explains the *backpropagation network architecture* used in this study (Malik et al., 2024).

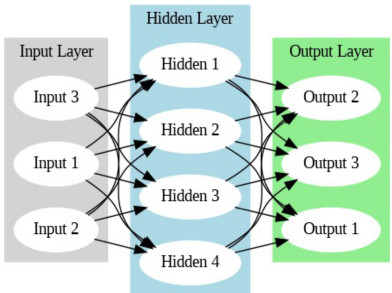

Figure 2. Backpropagation Network Architecture for Sales Prediction

Training was conducted using the previously attached program. The following are the training steps using the *backpropagation neural network algorithm* : Initialize initial weights and parameters

learning rate, target MSE, number of hidden units, and maximum number of iterations are initialized. The weights and biases are randomly assigned, using small random numbers. *The learning rate* used in this training is 0.1 with a maximum number of iterations of 10,000. The activation function used in this study is the sigmoid activation function. The trained architecture is 3-4-3, meaning 3 input neurons, 4 hidden neurons, and 3 output neurons (Dini & Paolini, 2025).

Next, we will explain the manual calculation process for the first iteration of laptop sales prediction. This calculation serves as an illustration to demonstrate and provide an understanding of the prediction calculation process using a Backpropagation Neural Network. This manual calculation will use a learning rate of 0.1 and a number of hidden units of 4 (Dini & Paolini, 2025).

Feedforward

feedforward process is the initial stage in the *backpropagation neural network algorithm,* where information moves forward from the input layer through the hidden layers until it reaches the output layer. In Python, this process can be described as follows (Cardoso et al., 2024).
The input data is passed to the hidden layer.

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At this stage, the normalized input data X_train is used as input to the neural network. X_train has dimensions (number_of_samples, 3), where 3 is the number of input features representing the first three months of sales data.
The input signal value is calculated using the equation:

hidden_layer = sigmoid(np.dot(X_train, hidden_weights))

In this equation, np.dot(X_train, hidden_weights) performs a matrix multiplication between the input data and the hidden layer weights. The result of this multiplication is then passed through a sigmoid activation function. hidden_weights is a weight matrix with dimensions (3, hidden_size), where hidden_size is the number of neurons in the hidden layer (in this case, 4 neurons).
The output value of the hidden layer is calculated using the activation function

sigmoid: sigmoid(x) = 1 / (1 + np.exp(-x))

The sigmoid function maps input values into the range (0, 1), allowing the neural network to model a non-linear relationship between input and output. In the code implementation, the sigmoid function is defined as (Chungyoun et al., 2025):

By running the predict() function, the results of the *feedforward calculations* for each brand are obtained as shown in Table 4.6 Z results for each data.

Table 4. Z results in each data

The z_in result for each data	
1st data: z_in[0] = -0.4361 z_in[1] = 1.7651 z_in[2] = 0.9533 z_in[3] = -0.6874	7th data: z_in[0] = -0.0231 z_in[1] = 1.0693 z_in[2] = 0.4399 z_in[3] = -0.7049
2nd data: z_in[0] = 0.0397 z_in[1] = 0.6284 z_in[2] = 0.2070 z_in[3] = -0.3048	8th data: z_in[0] = -0.1615 z_in[1] = 1.9837 z_in[2] = 0.8666 z_in[3] = -1.0244
3rd data: z_in[0] = 0.1067 z_in[1] = 0.9934 z_in[2] = 0.2964 z_in[3] = -0.4874	9th data: z_in[0] = -0.1763 z_in[1] = 3.1390 z_in[2] = 1.3087 z_in[3] = -1.5735
4th data: z_in[0] = -0.3061 z_in[1] = 3.2149 z_in[2] = 1.4521 z_in[3] = -1.7910	10th data: z_in[0] = -0.2431 z_in[1] = 0.3239 z_in[2] = 0.2914 z_in[3] = -0.1235
5th data: z_in[0] = -0.7588 z_in[1] = 3.2823 z_in[2] = 1.7585 z_in[3] = -1.4687	11th data: z_in[0] = -0.2454 z_in[1] = 2.3711 z_in[2] = 1.0581 z_in[3] = -1.0995

detailed asan for each step.
Calculate the error value for each output unit:

Calculating the error between the target value (y_train) and the predicted value (output_layer):

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output_error = y_train - output_layer

Then, calculate the output delta by multiplying the error by the derivative of the sigmoid activation function (Luo, 2026):

*output_delta = output_error * sigmoid_derivative(output_layer)*

Calculating the error value for each hidden unit: Backpropagation of the error from the output layer to the hidden layer:

hidden_error = np.dot(output_delta, output_weights.T)

Then calculate the hidden delta:

*hidden_delta = hidden_error * sigmoid_derivative(hidden_layer)*

Updating weights for the output layer:

*output_weights += learning_rate * np.dot(hidden_layer.T, output_delta)*

Updating weights for hidden layers:

*hidden_weights += learning_rate * np.dot(X_train.T, hidden_delta)*

This process is repeated 10,000 times (according to the specified number of *epochs). At each iteration, the network "learns" by adjusting its weights based on the resulting error.* Over time, the MSE is expected to decrease, indicating that the model is getting better at predicting outputs based on the given input (Vishwakarma & Kumari, 2024).

So the calculation results are as follows:

Epoch 1/10000 MSE: 0.187572
Prediction sample (first 3 data):
Data 1: Target = [0.35714286 0.5 0.42857143], Prediction =
[0.27060693 0.07999641 0.33160047]
Data 2: Target = [0.21428571 0.35714286 0.28571429], Prediction =
[0.30959824 0.10025722 0.34219557]
Data 3: Target = [0.28571429 0.28571429 0.35714286], Prediction =
[0.30192619 0.09843159 0.34768486]
Hidden Weights (sample):
[[0.46817166 -0.14828315]
[-0.26466992 -0.24494281]
[-0.49873831 0.5322132]]
Output Weights (sample):
[[0.26792876 -1.89516344 -1.70354392]
[-0.53134826 -0.99202861 0.34006125]]
Epoch 1000/10000 MSE: 0.030210
Prediction sample (first 3 data):
Data 1: Target = [0.35714286 0.5 0.42857143], Prediction =
[0.47953977 0.47658764 0.44834819]
Data 2: Target = [0.21428571 0.35714286 0.28571429], Prediction =
[0.23054284 0.22826953 0.23359996]
Data 3: Target = [0.28571429 0.28571429 0.35714286], Prediction =
[0.3167954 0.31923612 0.3249089]
Hidden Weights (sample):
[[0.31264692 -0.70020568]
[-0.72152654 -1.10934657]
[-1.8733702 -0.77883227]]
Output Weights (sample):
[[-2.91750981 -3.70958404 -4.21707146]
[-2.8610624 -2.26481594 -1.58091714]]
Epoch 2000/10000 MSE: 0.028961

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Prediction sample (first 3 data):
Data 1: Target = [0.35714286 0.5 0.42857143], Prediction = [0.42696839 0.43162541 0.39931521]
Data 2: Target = [0.21428571 0.35714286 0.28571429], Prediction = [0.20680854 0.21601344 0.22315114]
Data 3: Target = [0.28571429 0.28571429 0.35714286], Prediction = [0.3064696 0.31860703 0.32772882]
Hidden Weights (sample): [[0.75572276 -0.36345962]
[-0.46279255 -0.93433168]
[-2.21672948 -1.03850594]]

Testing

In the testing phase, the performance of the artificial neural network model was evaluated using the *Mean Absolute Error* (MAE) metric (Khrais & Shidwan, 2023). MAE was chosen as the primary evaluation metric because it measures the average absolute error between predicted and actual values, providing an intuitive interpretation of how far the model's predictions are from the actual values.

Overall Training MAE: 4.3400 Overall Testing MAE: 4.3400 Overall Normalized MAE: 0.310000 Overall Denormalized MAE: 4.3400

The results of testing an artificial neural network model for predicting laptop sales showed varying performance. The overall performance results are as follows: MAE Training and Testing: The MAE values for the training and testing data are identical, at 4.3400. This indicates consistent model performance between the training and testing phases, indicating no significant overfitting (Iman, 2026). Normalized MAE: The value 0.310000 indicates the average absolute error on a scale of 0-1. It provides perspective on the magnitude of the error relative to the range of the data. Denormalized MAE: A value of 4.3400 represents the mean absolute error in the original sales scale. This means that, on average, the model's predictions are off by about 4-5 sales units from the original value (Gozali et al., 2026).

Discussion

The results of testing an artificial neural network model for predicting laptop sales show several important findings that need further discussion:

Overall Model Performance

The model demonstrated consistency between training and testing performance, with an MAE of 4.3400 for both. This indicates the model has good generalization ability and shows no significant signs of overfitting. However, this MAE also indicates there is room for improvement in prediction accuracy (Ramos et al., 2023).

The normalized MAE of 0.310000 provides perspective that the average prediction error is approximately 31% of the normalized data range. This indicates that the model still has a significant error rate and may require further refinement (Cavalcante et al., 2023).

Performance Variability Across Brands

Individual MAE analysis for each brand revealed substantial variation in prediction accuracy: a. Top Performer: Acer Aspire 3 Slim with an MAE of 0.9462 indicates that the model is highly accurate in predicting sales for this brand. This may be due to the more stable or predictable sales patterns for this product. b. Worst Performance: Apple MacBook Air 2020 with MAE 9.1163 demonstrates the model's difficulty in accurately predicting sales. This could be due to unique factors influencing Apple product sales, such as strong brand loyalty, varying product release cycles, or frequently changing market dynamics. c. Over and Underestimation Trends: The model's tendency to overestimate some brands (such as the Lenovo Yoga Slim 7) and underestimate others (such as the Asus ExpertBook) suggests that the model may not fully capture the market dynamics specific to each brand.

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Data Implications and Representation: a. Market Complexity: The variation in performance across brands demonstrates the complexity of the laptop market, where each brand may be influenced by unique factors such as marketing strategies, customer loyalty, or the latest technology trends (Endahti & Faturahman, 2025) c. The Need for a More Specific Approach: Significant differences in predictive accuracy across brands suggest that a "one-size-fits-all" approach may not be optimal. More specific models for each brand or market segment may be needed to improve overall predictive accuracy c. Data Limitations: These results may also reflect limitations in the dataset, such as the lack of additional explanatory variables that may be relevant (e.g., marketing data, product reviews, or macroeconomic indicators).

CONCLUSION

From the description that has been discussed in chapter previously, then can concluded : Network model nerve imitation with backpropagation method developed For predict laptop sales show consistent performance between training and testing phase, with The Mean Absolute Error (MAE) value is 4.3400. The optimal structure of the model consists of from 3 input units, 4 hidden units, and 3 output units (3-4-3). Model performance varies significant between laptop brands, with individual MAEs ranging between 0.9462 (best, for the Acer Aspire 3 Slim) to 9.1163 worst, for the Apple MacBook Air 2020). This show that the model has level varying accuracy depending on the characteristics sales of each brand. In a way Overall, the model shows a normalized MAE of 0.310000, which indicates that the average error prediction is about 31% of normalized data range. Although the model shows good potential, still There is room For improvement accuracy prediction.

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