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Implementation of Artificial Neural Network in Predicting CPO Prices Using Backpropagation

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***Abstract*—**This research examines the development of a forecasting model for Crude Palm Oil (CPO) prices using artificial neural network algorithms, particularly the backpropagation algorithm. CPO, as Indonesia's main export commodity, has significant economic impacts and affects the income of oil palm farmers. Data on CPO prices taken from CIF Rotterdam from January 2019 to December 2023 were used in this study. The research method involved several stages, including data collection, pre-processing, model design, and model implementation using Python programming. The results of training the model using the backpropagation algorithm showed an error value of 0.537829578 after 1000 epochs, while evaluation using Mean Squared Error (MSE) showed an MSE value of 0.022709 during the training process and 0.017604 during the testing process. The model also produced predictions for CPO prices in the next three months: 932.578 for the first month, 949.568 for the second month, and 774.855 for the third month. These findings indicate that the developed model can predict future CPO prices with adequate accuracy, which can assist companies in making better financial decisions and managing risks associated with CPO price fluctuations.

Keywords—Machine Learning; CPO Prices; Artificial Neural Network; Backpropagation; Prediction; Regression; Price Fluctuation.

I. INTRODUCTION

Crude palm oil (CPO) is the main product in the palm oil industry and one of Indonesia's major export commodities originating from the plantation sector because Indonesia has the highest CPO production level in the world [1]. The continuous fluctuation of CPO prices, which tends to experience increases and decreases, impacts the instability of Fresh Fruit Bunches (FFB) prices, the initial product of oil palm that is processed into CPO [2]. Increases and decreases in FFB prices can affect the economy of oil palm farmers, as it can cause discrepancies between their income and FFB production costs [3].

This research uses an artificial neural network approach with the backpropagation algorithm to forecast CPO prices. The learning algorithm known as backpropagation functions to adjust weights based on the difference between the output and the desired target [4][5]. The main goal is to forecast future CPO prices, as accurate predictions can help companies manage risks associated with price fluctuations and make better financial decisions. [6]

Forecasting is a process of estimating future data [7]. Predictions can be made if recognizable patterns exist in the training dataset [8]. This process is based on the information available about the past and present to reduce the error difference between actual events and forecast results [9].

This research aims to develop a CPO price prediction model using the backpropagation algorithm in artificial neural networks. Accurate predictions support strategic decision-making related to sales prices, marketing strategies, and market price targets based on CPO price forecasts [10].

In this study, the researchers also used the regression method. Regression is a statistical analysis technique used to demonstrate the relationship between one variable and another [11]. There are two types of regression methods: Linear Regression and Non-Linear Regression. Linear regression includes models with one independent variable and models with more than one independent variable (multiple linear regression). The linear regression method is a statistical technique used to determine the relationship between one or more independent variables and one dependent variable [12]. On the other hand, non-linear regression includes exponential equation models (ln) and power equation models (log) [13].

An artificial neural network is a network of small processing units modelled after the human nervous system. Artificial neural networks are adaptive systems that can change their structure to solve problems based on external and internal information flowing through the network [14]. The Artificial Neural Network method using the Backpropagation algorithm in Artificial Intelligence can forecast sales by determining the appropriate network architecture so that the prediction results can approximate the actual values [15]. Artificial neural networks can extract relationships between input and output from a process without the need for physical presence.

II. RESEARCH METHODOLOGY

Research methodology is crucial in a study as it is the key to producing quality research. The completion process must be carried out systematically and purposefully from start to finish [16]. The researcher will conduct several stages in this research to design a forecasting model for CPO prices using artificial neural networks. These steps ensure the research's smooth progress and achieve the desired results. Refer to Figure 1.

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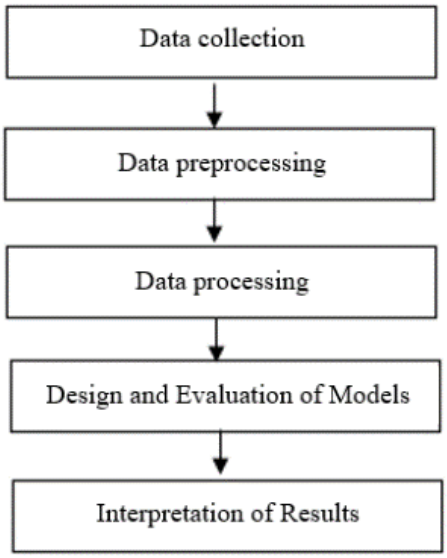

Figure 1. Research Stages

A. Data Collection

Researchers will collect the required data through observation to train and test the artificial neural network model using the backpropagation algorithm. The data collection method is one of the crucial aspects influencing the smoothness and success of research implementation [17].

B. Data Pre-processing

In this process, researchers will conduct data filtering, feature selection, normalization, handling missing values, and data transformation to prepare the data for training the artificial neural network model.

C. Data Processing

The raw data will be transformed or processed into more relevant forms during data processing. This processing will generate information that can be used for decision-making and analysis, helping to determine the data to be utilized in the research as the data to be processed [18].

D. Design and Evaluation of Model

It is forecasting CPO prices using the artificial neural network method. Artificial neural networks are a method that operates based on the neural networks in humans [8]. The architecture of the artificial neural network in this research uses 12 neurons in the input layer, 6 neurons in the hidden layer, and 1 neuron in the output layer. It can be seen in Figure 2.

The learning algorithm, called Backpropagation, reduces the error rate by adjusting weights based on the difference between the output and the desired target. Backpropagation also teaches how to minimize the error rate. This method is a form of supervised learning. In this research, the artificial neural network model uses ReLU activation functions for both the input and hidden layers.

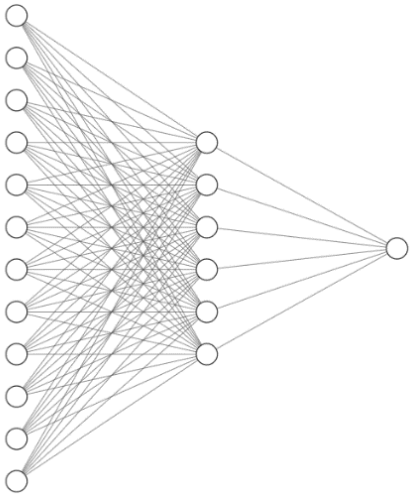

Figure 2. Artificial Neural Network Architecture

Rectified Linear Unit (ReLU) is an activation function with simple computation [19]. ReLU is an activation function used primarily in artificial neural networks, especially hidden layers. It transforms the input value into the output value simply yet effectively. The ReLU function is defined as follows: (2).

$$f(x) = max(0, x) \quad (2)$$

E. Interpretation of Result

The interpretation of results is analyzing and explaining the meaning of the data or results obtained from a study. The purpose of interpreting results is to provide a deeper understanding of the data obtained.

III. Result and Discussion

A. Data Collection

In this study, a backpropagation artificial neural network model will be constructed to forecast CPO prices based on previously collected data. The data obtained from CIF Rotterdam from January to December 2019 to 2023 consists of 60 data points. This dataset contains the list of monthly CPO prices, which will be used as research data in Table I.

TABLE I
DATA LIST OF CPO PRICES

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2019	537	596	552	530	525	505	505	570	567	660	705	855
2020	890	775	637	625	550	600	692	717	740	775	900	1,045
2021	1,060	1,110	1,155	1,115	1,280	1,130	1,060	1,197	1,250	1,320	1,425	1,300
2022	1,390	1,420	1,975	1,700	1,775	1,795	1,480	1,125	1,165	935	1,160	1,120
2023	1,075	1,000	1,000	1,060	990	872	990	965	1,000	910	890	965

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B. Data Pre-processing

In the data obtained from CIF Rotterdam, which is still in raw form and contains a small number of data rows, a change in the data rows is performed by grouping the data into two categories: input and target data. In the input data, the prices of CPO from January to December are included, while the target data utilizes the data from the 13th month. The target data consists of the data from January 2020 to December 12 as input data and the price of CPO in the next month as the target data. For example, in the first row of the dataset, the target is in January 2020, with input data from January 2019. The results of the data manipulation performed by the author can be seen in Table II.

The obtained data will then undergo the data pre-processing stage. The purpose of this stage is to prepare and clean the data before performing the data forecasting process. Next, the data will undergo transformation and normalization to make it suitable for use in an artificial neural network [20]. The data transformation process conducted in this research involves converting character data into numerical form. Table I shows that the collected data will be normalized using the min-max method with Equation (1), as shown in Table III. Where the *x* variable is the data attribute, the *min(x)* and *max(x)* variables are the minimum and maximum values of *x*, and x' is the old value of each entry in the data.

$$x_{norm} = \frac{x' - \min(x)}{\max(x) - \min(x)} \quad (1)$$

The previously designed model is then implemented using the Python programming language. The initial step involves using 39 training data samples for the training process, consisting of 12 neurons in the input layer, 6 in the hidden layer, and 1 in the output layer.

TABLE II
DATA MANIPULATION

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	Y
1	537,05	597,05	552,05	530	525	505	505	570	567,05	660	705	885	890
2	597,05	552,05	530	525	505	505	570	567,05	660	705	855	890	775
3	552,05	530	525	505	505	570	567,05	660	705	855	890	775	637,05
…	…	…	…	…	…	…	…	…	…	…	…	…	…
46	935	1160	1120	1075	1000	1000	1060	990	872,05	990	965	1000	910
47	1160	1120	1075	1000	1000	1060	990	872,05	990	965	1000	910	890
48	1120	1075	1000	1000	1060	990	872,05	990	965	1000	910	890	965

TABLE III
DATA NORMALIZATION

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	y
1	0,0221	0,0629	0,0323	0,0170	0,0136	0	0	0,0140	0,0122	0,0771	0,1087	0,2140	0,2140
2	0,0629	0,0323	0,0170	0,0136	0	0	0,0442	0,0122	0,0771	0,1087	0,2140	0,2385	0,2385
3	0,0323	0,0170	0,0236	0	0	0,0442	0,0425	0,0771	0,1087	0,2140	0,2385	0,1578	0,1578
…	…	…	…	…	…	…	…	…	…	…	…	…	…
46	0,2925	0,4455	0,4183	0,3877	0,3367	0,3367	0,3775	0,3087	0,2263	0,3087	0,2912	0,3157	0,3157
47	0,4455	0,4183	0,3877	0,3367	0,3367	0,3775	0,3299	0,2263	0,3087	0,2912	0,3157	0,2526	0,2526
48	0,4183	0,3877	0,3367	0,3775	0,3299	0,0025	0,3087	0,2912	0,3157	0,2526	0,2385	0,2385	0,2385

C. Design and Evaluation of Model

In Figure 3, the backpropagation neural network algorithm reduces error after undergoing 1000 training epochs. Notably, there is a steep decline in error from the first epoch to the 100th epoch. However, from epoch 200 to epoch 1000, the error reduction rate slows down.

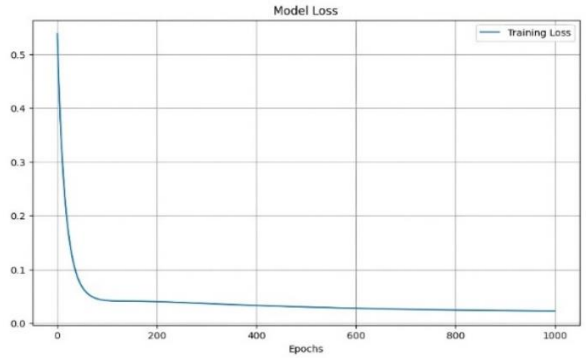

Figure 3. Graph of The Neural Network Model Training Results

Then, after applying the backpropagation model, the error value obtained for forecasting CPO prices is 0.537829578 after 1000 epochs, as seen in Table IV—the number of epochs and their corresponding error values during the training process.

TABLE IV
TRAINING DATA RESULT

Epoch	Error
1	0.537829578
100	0.042199768
200	0.040129788
300	0.036524642
400	0.033010095
500	0.030128015
600	0.027759328
700	0.025867706
800	0.024504764
900	0.023510445
1000	0.022720611

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After completing the training process, the next step is to compare the test data with the actual data using linear regression. Figure 4 shows the comparison results between the test data and the actual data.

Figure 4. Comparison Graph of Predicted Data with Actual Data

In Figure 4, the regression graph is generated as a visualization comparing actual and predicted data. The graph displays a blue line representing the actual data, while the red line represents the predicted data. The comparison of values between predicted and actual data is crucial, as a smaller difference between predicted and actual values indicates better model performance. This study aims to minimize the difference between predicted and actual values as much as possible.

D. Interpretation of Result

The interpretation of results will explain the accuracy level in predicting CPO prices. Further evaluation can be conducted using Mean Squared Error (MSE) to gain a more detailed insight into how well the model performs predictions. MSE is defined by Equation (2).

$$MSE = \frac{\sum(y_i - \hat{y}_i)^2}{n} \quad (2)$$

The regression model evaluation results in Table V indicate an MSE value of 0.022709 during the training process and 0.017604 during the testing process.

TABLE V
FORECASTING CPO PRICES FOR THE NEXT MONTH

Future Period	1	2	3
Forecasting	923.578	949.568	774.855

IV. CONCLUSION

This study aims to develop a forecasting model for Crude Palm Oil (CPO) prices using artificial neural network algorithms, specifically the backpropagation algorithm. Data on CPO prices from CIF Rotterdam from January 2019 to December 2023 were utilized in this research. The methodological steps of the study included data collection, data pre-processing, model design, and model implementation using the Python programming language.

The research results indicate that after training the model using Backpropagation, an error value of 0.537829578 was obtained after 1000 epochs. Evaluation of the model using Mean Squared Error (MSE) showed an MSE value of 0.022709 during the training process and 0.017604 during the testing process. The model also produced CPO price predictions for the next three months: 932.578 for the first month, 949.568 for the second month, and 774.855 for the third month.

Thus, the developed model can be used to predict future CPO prices with adequate accuracy, which can assist companies in making better financial decisions and managing risks associated with CPO price fluctuations. Accurate price predictions can also benefit oil palm farmers by giving them better information for planning their production and sales, which can help improve farmers' economic stability and welfare.

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