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IMPLEMENTATION OF THE BACKPROPAGATION METHOD FOR RECOMMENDING ANNUAL AWARD RECIPIENTS AMONG OUTSTANDING STUDENTS

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ABSTRACT
This study aims to design a recommendation system for selecting outstanding students for annual awards by utilizing the Backpropagation method within an Artificial Neural Network (ANN). Student assessment is based on four main variables: academic grades, attitude scores, extracurricular activity scores, and attendance records. The data were obtained from an elementary school in Pasuruan City through a survey method, and then processed through preprocessing and normalization techniques before being trained with the Backpropagation algorithm. The model was developed using a Sequential architecture with two hidden layers, and its performance was assessed using a confusion matrix and classification report. The test results revealed that the model successfully classified outstanding students with a maximum accuracy of 97%, showing strong performance across precision, recall, and F1 score metrics. This indicates that the Backpropagation method is effective in improving both the objectivity and efficiency of the outstanding student selection process based on historical data.

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I. INTRODUCTION

EDUCATION is one of the most important aspects as it helps balance and enhance the development of both individuals and society [1]. A crucial aspect of education is recognizing students' achievements in both academic and non-academic areas. Such recognition can take the form of awards given by educational institutions to outstanding students in order to motivate them, help them develop their talents and maximize their full potential. Outstanding students are those who demonstrate excellence in either academic or non-academic fields [2].

In the educational context, identifying outstanding students is a significant concern for educators, parents, and educational institutions. Therefore, the selection of outstanding students in schools generally involves various criteria such as academic performance, attitude, social skills, extracurricular achievements, and other personal qualities. However, the selection process in schools often remains subjective and relies on manual decision-making [3]. This can lead to unfairness in the selection of outstanding students.

Technological advancements have had a significant influence every aspect of life, particularly in the area of education. The progress of technology can be utilized in education as a means to produce human resources capable of facing the era of technology and information [4]. Technology can also serve as a solution to assist schools in selecting high-achieving students. Through careful data analysis, schools can identify patterns and trends that may not be visible through traditional assessments. Technological advancements also influence student development. With the use of technology based on artificial intelligence, students may become more motivated to develop their talents. Additionally, students can evaluate their own abilities through an AI-based outstanding student selection system.

In previous studies, the selection of outstanding students mostly relied on the TOPSIS and SAW (Simple Additive Weighting) methods. However, these methods are still static in nature and involve manual weighting. Both approaches have limitations in handling non-linear preferences and uncertainties in determining the ideal solution [5]. The TOPSIS and SAW methods use feature weighting that relies on expert judgment [6], which may lead to a high degree of subjectivity in the data processing outcomes. To address this, the present study proposes

an enhancement by applying the Backpropagation method in the recommendation system for awarding outstanding students. Backpropagation is a component of Artificial Neural Networks (ANN), which operates in a way similar to the human brain [7] in recognizing patterns and trends within complex datasets [8]. It functions by reducing the error value using a gradient descent technique [9]. The iterative process improves prediction accuracy in determining students eligible for awards. By applying this algorithm, the quality of selecting outstanding students can be enhanced compared to previous studies, as Backpropagation is a learning algorithm that can adapt to data without requiring manual weighting like the TOPSIS and SAW methods. As a result, it eliminates subjectivity in the evaluation process.

A previous study that used the TOPSIS method was titled "Decision Support System Using the TOPSIS Method to Determine the Best Student." The results of that study allowed teachers to select the best students based on the highest preference score calculated from five criteria: attendance, personality, achievements, extracurricular activities, and academic grades [9].

Another study titled "Decision Support System for Determining Outstanding Students Using the SAW Method at SDN 02 Ciganjur" utilized purposive sampling as its data collection technique. The researchers chose this method because it offers advantages in terms of ease and efficiency in meeting data requirements [10].

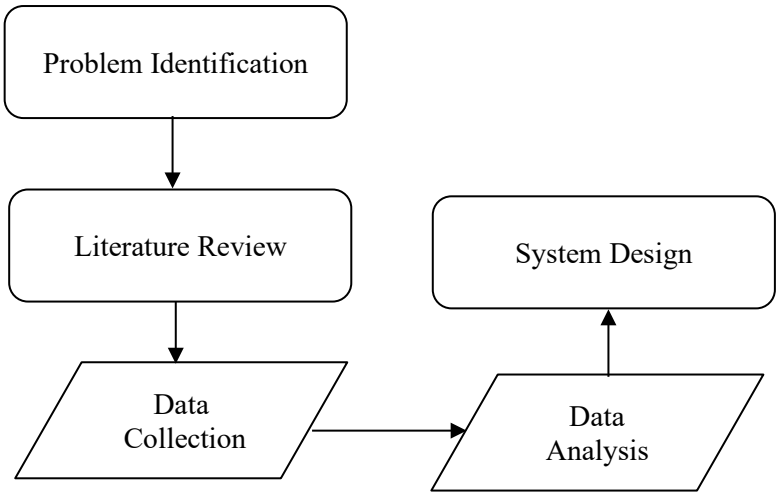
Based on the issues identified in previous studies, the present research aims to identify effective criteria and methods for determining outstanding students by considering various aspects such as academic performance, practical skills, attitude, and active participation in both classroom and extracurricular activities.

II. RESEARCH METHODOLOGY

The research methodology stage is carried out to help readers better understand the flow of the study. In this research, several stages need to be undertaken.

A. Research Flow

This research includes multiple stages for data processing. Figure 1 below provides a general overview of the research process.



Flowchart 1. Research Flow

The initial stage is to identify the existing problem. This research focuses solely on the core issue that forms the basis of the study. Following that, a literature review is conducted using previous research data to demonstrate that the Backpropagation method in artificial neural networks is suitable for solving classification problems based on historical data. The next stage involves data collection. The data obtained consists of raw data provided in Excel files. Undergoes a preliminary analysis to assess its quality before processing. The final phase of this study is system design, which entails developing the complete workflow of the system from beginning to end.

B. Problem Identification

The first stage is to identify the existing problem. This study focuses on the core issue that forms the basis of the research, which involves choosing outstanding students according to established criteria. In the existing selection process, schools still use manual methods and rely solely on report card grades. Since report cards mainly reflect academic performance, a more efficient method is needed to determine outstanding students without

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disadvantaging either the students or the school.

Based on the identified problem, there is a need for a system that can automatically process and analyze student data using an artificial intelligence approach. Through this research, the author hopes to provide a solution to the issue. The role of the school is also crucial in evaluating the success of this study.

C. Literature Review

Based on previous research data, the selection of outstanding students has often utilized methods such as AHP (Analytical Hierarchy Process) and SAW (Simple Additive Weighting). However, the accuracy of these methods has not been particularly high. Therefore, the author selected a more suitable method for this study.

The analysis results indicate that the Backpropagation method within Artificial Neural Networks (ANN) is well-suited for solving classification and prediction problems using a multilayer architecture by optimizing the neural network's weights [11]. The application of ANN is also widely used in Decision Support Systems (DSS), particularly in selection or recommendation processes that involve multiple variables. Previous studies have shown that Backpropagation achieves high accuracy in classification tasks. Hence, the Backpropagation method was chosen for data processing in this research.

D. Data Collection

In this phase, pertinent data for the study is gathered through interviews and field surveys. The steps carried out are as follows:

- Identifying Data Sources

Data was collected directly from one of the elementary schools (SD) in Pasuruan City. The selection of the data source was based on its relevance to the research objectives.

- Data Collection

The data collection technique involved several teachers and the principal of an elementary school (SD) in Pasuruan City. The data were collected in raw form in an Excel format, totaling 325 records. In table I, there are four columns with different assessment criteria in each column. The table includes report card grades for each subject, including Islamic Education or Religion, Civics (PPKN), Indonesian Language, Mathematics, Arts and Crafts, Physical Education, Javanese Language, Environmental Education (PLH), English Language, Total Score, and Average Score. The second column represents student attendance, recording the number of days a student was absent over two semesters, categorized into sick leave, permitted leave, and unexcused absences. The third column contains information about the extracurricular activities participated in by each student. The last column is the attitude score, which includes evaluations of each student's behavior, such as honesty, discipline, responsibility, and politeness. Table I is the table representing the collected data :

TABLE I
DATA MENTAH

No	Nama Siswa	Nilai Rapor		Absensi	Ekstrakulikuler	Sikap	
		……	Rata-rata			……	Rata-rata
1.	Ahmad Yuzarsiv	……	82.00	……	……	……	3
2.	Allea Queensy Kurnia	……	84.59	……	……	……	3
3.	Dania Jannat Aulia	……	83.85	……	……	……	3
4.	Erza Abdul Wahid	……	84.23	……	……	……	3
5.	Hazamul Ghani Ardhani	……	85.25	……	……	……	3
…		……	…	……	……	……	…
325.	Zidqi Mahendra	……	82.04	……	……	……	3

E. Data Analysis

The following stage involves analyzing the data to be processed. The goal of data analysis is to comprehend the data handling process in order to extract valuable information for decision-making or model development. The steps carried out for data analysis are as follows:

1. Data Cleaning

Data cleaning is performed to separate the necessary data from irrelevant or unnecessary data. The data is converted into numerical form to make it easier for the model to process.

2. Normalization

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After the data is separated, a normalization process is carried out to speed up the performance of the Neural Network. The selected features are assigned target labels (classes) in numerical form with the following definitions:
- Outstanding = 1
- Less Outstanding = 0

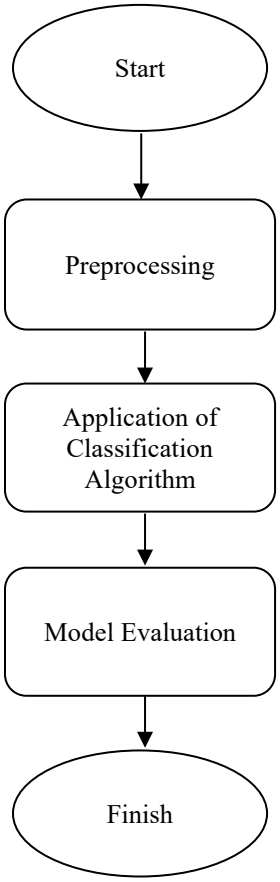
3. Data Splitting (Training and Testing)

The data is split into training and testing sets to prevent overfitting during data processing. The data is split into five categories as follows:

- Split 1: 70% training data and 30% testing data
- Split 2: 75% training data and 25% testing data
- Split 3: 80% training data and 20% testing data
- Split 4: 85% training data and 15% testing data
- Split 5: 90% training data and 10% testing data

The data splitting is carried out using the train_test_split function from the scikit-learn library.

F. System Design



Flowchart 2. System Design

Figure 2 shows the process of data processing, starting from the preprocessing stage to the accuracy calculation.

1. Preprocessing

Due to the large amount of data in the Excel file, data preprocessing is required to extract the necessary information for the classification process [12]. A total of 325 student records were available in the Excel file, from which four key variables were selected: academic grades, attitude scores, extracurricular activity scores, and student attendance. The selected data were then placed into a separate file. Next, the data were converted into numeric format to facilitate easier processing.

After converting all data into numeric form, an additional column was added to assign a class label to each record. This classification helps the model better understand the data during processing. Finally, the data were converted from Excel format to CSV using the Python library Pandas.

2. Application of Classification Algorithm

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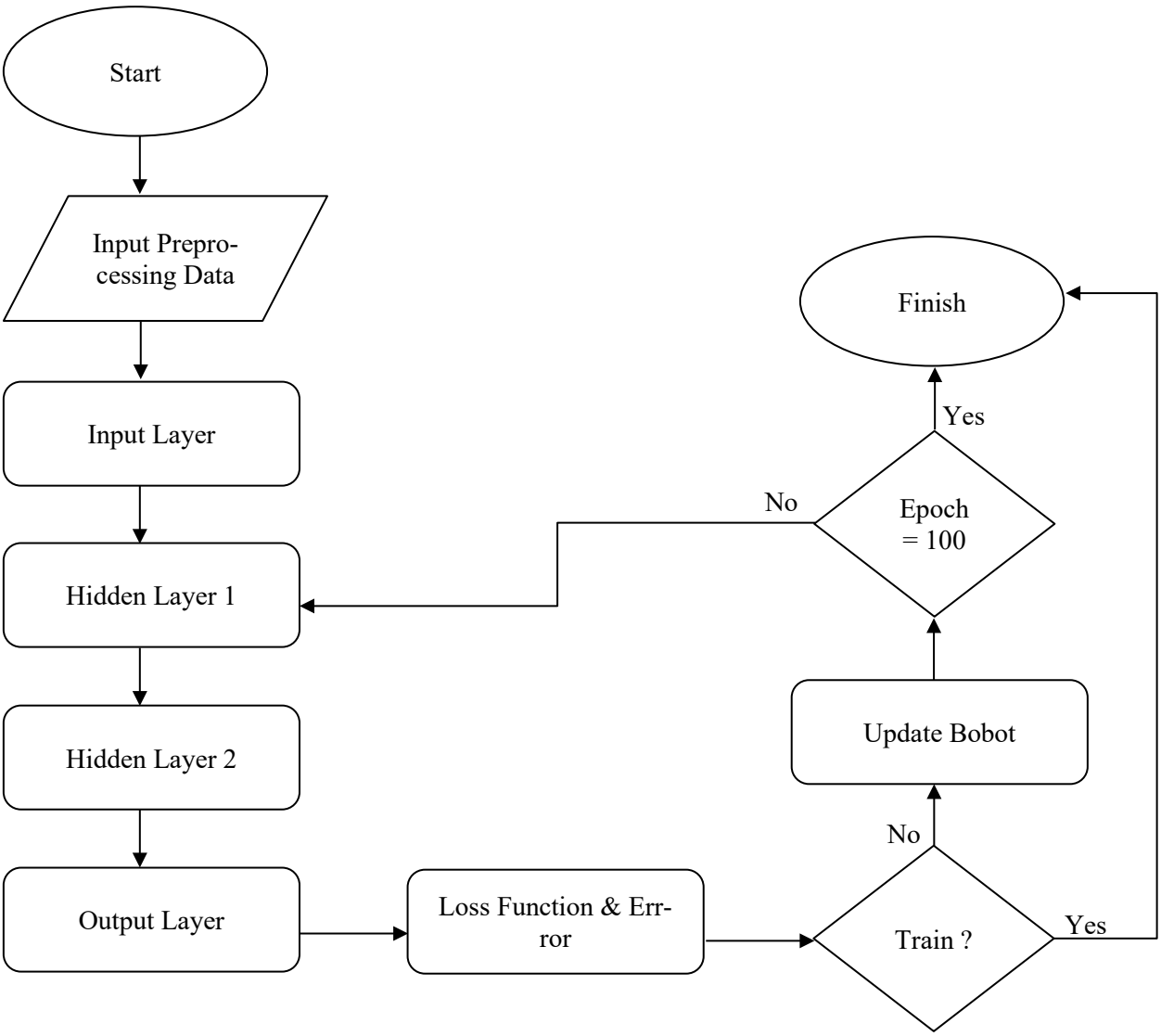
Classification is the process of logically grouping objects or items [13], used to predict the class of unknown objects [14]. Data classification is a crucial tool in various fields, particularly in the realm of computing. Machine learning is often associated with data classification, as systems are trained to recognize patterns in the data [15].

The next step in this study is to perform classification using the Backpropagation method. This step involves building and training an Artificial Neural Network (ANN) model using Backpropagation. One of the advantages of neural networks is their ability to recognize activities based on past experiences or historical data previously learned by the model [16]. The determination of outstanding students can be carried out by utilizing neural networks through the Backpropagation method [17], based on variables such as academic grades, attitude scores, extracurricular activities, and attendance records. This research involves several stages in data processing. Below is the flowchart representing the Backpropagation process:



Flowchart 3. Backpropagation Flow

a. *Input Data Preprocessing*
The first step involves importing the dataset into Google Colaboratory for processing. The data, stored in a CSV file, has already been filtered to exclude irrelevant entries. Data preprocessing is performed using the Pandas library.

b. *Input Layer*
In the neural network stage, a Sequential model is used, as it is suitable for datasets with a unidirectional flow, as in this study. The input layer consists of 295 neurons and uses the ReLU (Rectified Linear Unit) activation function.

$$f(x) = \begin{cases} 0{,}01x, if \ x < 0 \\ 1, if \ x \geq 0 \end{cases} \quad (1)$$

c. *Hidden Layer 1*

After the input layer, a dropout of 0.3 was added, meaning 30% of the neurons are randomly dropped during training. This is intended to reduce overfitting in the neurons during training. Next is the first hidden layer, comprising 128 neurons and employing the ReLU (Rectified Linear Unit) activation function, as illustrated in Equation 1. This layer aims to detect fundamental patterns within the data and identify both linear and non-linear combinations of features.

$$f(x) = \begin{cases} 0{,}01x, if \ x < 0 \\ 1, if \ x \geq 0 \end{cases} \quad (2)$$

d. *Hidden Layer 2*

The second hidden layer contains 64 neurons and also employs the ReLU activation function, ike the one used in the input layer shown in Equation 1. This additional layer serves to deepen the network's understanding of non-linear relationships. The second hidden layer also functions as a filter for the initial feature extraction results.

e. Output Layer

The output layer contains only one neuron, as the binary classification involves just two classes: 0 and 1. This final layer uses the sigmoid activation function, which transforms the output into a probability between 0 and 1. The sigmoid activation function is shown in Equation [20]:

$$Y_{out} = f(x_i) = \frac{e^{xi}}{\sum_{j=1}^{J} e^{xj}} \quad (3)$$

f. Loss Function

The binary crossentropy loss function quantifies the difference between the predicted output and the actual label. This metric is minimized during the model training process. Binary crossentropy is appropriate for binary classification tasks where the target variable (y) has only two classes: 0 and 1. The training process also uses Adam (Adaptive Moment Estimation) as the optimizer in deep learning. The formula for binary crossentropy loss is as follows [18]:

$$L = -(y_i \ \log(\hat{y}_i) + (1 - y_i) \log(1 - \hat{y}_i)) \quad (4)$$

Explanation :

y = expected result

$\hat{y}$ = result from the model

Additionally, the model uses accuracy as a metric to monitor its performance during training. The formula for accuracy is [19] :

$$Accuracy = \frac{jumlah \ prediksi \ benar}{jumlah \ keseluruhan \ data} \quad (5)$$

g. Weight Update

The final stage is to adjust the weights and biases. Weight updates are essential to correct errors identified during backpropagation. The formula for updating weights is as follows:

$$W_{ij}(baru) = W_{ij}\,(lama) + \Delta W_{ij} \quad (6)$$

In this study, 100 epochs are used to process the data. If the process converges without overfitting, training will stop and be considered complete. However, if errors occur during data processing, the training will be repeated starting from the first hidden layer until the errors are minimized or eliminated.

3. Accuracy Calculation

Calculating accuracy is necessary to determine how well the model performs in classification tasks [20]. In this study, accuracy is measured using a confusion matrix. The confusion matrix functions as a means to evaluate performance of classification algorithms and to understand how accurately the method classifies input data or objects [8]. Simply put, a confusion matrix shows how well a model predicts. It consists of four important components, True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN). However, accuracy alone is not always the best metric. Therefore, other metrics such as precision, recall, and F1-score should also be considered to provide a more comprehensive evaluation [19].

$$Precision_i = \frac{TP^i}{FP^i + TP^i} \quad (7)$$

$$Recall_i = \frac{TP^i}{FN^i + TP^i} \quad (8)$$

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$$Accuracy_i = \frac{\sum_i TP^i}{\sum_l^L \sum_k^L E_{lk}} \quad (9)$$

$$F - Measure = \frac{2 \times Precision \times Recall}{Precission + Recall} \quad (10)$$

Explanation :
TP_i = true Positive value for class i
FP_i = false Positive value for class i
FN_i = false Negative value for class i
E_{lk} = total number of data

III. RESULTS AND DISCUSSION

The result of this research is a recommendation system designed to identify high achieving students using the Backpropagation algorithm within an artificial neural network.

A. Equations

The raw data from the school needs to be preprocessed to separate the relevant data from the unnecessary. In this study, four variables were selected to serve as criteria for assessing outstanding students: report card grades, attendance records, number of extracurricular activities, and attitude scores. These criteria were determined based on agreements with the teachers and the principal of the elementary school.

TABEL II
HASIL DATA PREPROCESSING

No	Nama Siswa	Nilai Rapor	Sakit	Ijin	Alpa	Jumlah Ekskul	Nilai Sikap	Class
1	Ahmad Yuzarsiv	82.00	7	0	0	1	3	0
2	Allea Queensy Kurnia	84.59	7	3	3	2	3	1
3	Dania Jannat Aulia	83.85	4	2	0	3	3	1
4	Erza Abdul Wahid	84.23	7	1	0	1	3	0
5	Hazamul Ghani Ardhani	85.25	2	2	0	2	3	1
…	…….	…	…	…	…	…	…	…
325	Zidqi Mahendra	82.04	5	3	0	1	3	0

Table III presents the results of the data preprocessing. In the report card grades table, several assessments for each subject are available; however, only the average score for each subject is used, in accordance with the school's criteria. Additionally, a new column named class was added as the target label, with a range of 0 to 1. A value of 0 indicates a student who is less outstanding, while 1 indicates an outstanding student.

B. Classification Using Backpropagation

Based on the data processing results, various values for accuracy, precision, recall, and F1-score were obtained from different data split configurations. The table below presents the accuracy outcomes:

TABEL III
HASIL AKURASI

Split Data	Akurasi	Precission	Recall	F-1 Score
70:30	95%	0.99	0.96	0.96
75:25	96%	0.98	0.97	0.98
80:20	95%	0.98	0.96	0.97
85:15	96%	0.97	0.97	0.97
90:10	97%	1.00	1.00	0.98

From Table III, it is evident that the highest accuracy was attained with a 90% training and 10% testing data split, reaching an accuracy of 97%. This is likely due to the fact that a greater amount of training data tends to produce a more effective model. The performance of each model also suggests that the volume of training data plays a significant role in influencing accuracy.

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The outcomes of precision, recall, and F1-score demonstrate a balanced classification between class 0 and class 1, where class 0 represents underperforming students and class 1 represents high-achieving students. In the 90:10 data split, a very high accuracy was observed, with only 1 misclassification out of 33 data points. The training process also produced accuracy and loss graphs that reflect the model's effectiveness throughout the training and validation phases.

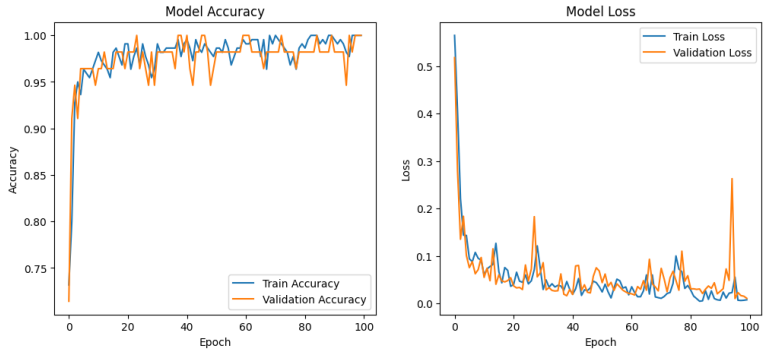

Figure 4. Accuracy and Loss Graph

Figure 4 shows that the initial increase in accuracy occurred from epoch 0 to epoch 10. From epoch 10 to epoch 90, the accuracy fluctuated but remained consistently above 95% for both training and validation. The final improvement in accuracy occurred between epochs 98 and 100, reaching values close to 100% for both training and validation. Meanwhile the loss graph indicates a significant drop in loss from epoch 0 to epoch 10. After that, the loss remained low and stable which suggests that the model did not experience overfitting.

C. Confusion Matrix

From the various accuracy results obtained, the highest accuracy of 97% was chosen to provide a more in-depth explanation regarding the model's performance using the confusion matrix. The following is table IV, which presents the results of the classification report:

TABEL IV
HASIL CONFUSION MATRIX

Class	Precission	Recall	F1-Score	Support
0	0.96	1.00	0.89	24
1	1.00	0.89	0.94	9
Accuracy			0.97	33

The elevated precision, recall, and F1-score values in table IV indicate that the model is capable of performing classification effectively, especially for the majority class (class 0). Although the recall for class 1 is slightly lower, the precision is perfect, meaning the model rarely makes false positive predictions.

TABEL V
HASIL CONFUSION MATRIX

Keterangan	Support
True Positive (TP)	8
True Negative (TN)	24
False Positive (FP)	0
False Negative (FP)	1

Table V shows the results of 8 True Positive (TP) cases in predicting class 1. True Negative (TN) correctly predicted class 0 in 24 cases. The False Positive (FP) value, which predicts class 1 when the actual class is 0, occurred in 0 cases. Lastly, the False Negative (FN) value, which predicts class 0 when the actual class is 1, occurred in 1 case. This indicates that the model is highly accurate and performs as expected, with only one misclassification out of 33 data samples.

The data processing results indicate that the model is highly effective in interpreting the data, achieving near-perfect accuracy on each data split. Compared to previous studies, the data processing in this research does not rely on weighting each feature, which in earlier methods was still dependent on expert judgment. This reliance introduced a high degree of subjectivity. The model developed in this study can be applied to other schools, provided that the features used are the same as those in this research. If the features used in other schools differ, retraining of the model will be necessary to achieve the desired results.

IV. CONCLUSION

The findings from the research and analysis indicate that the implementation of the backpropagation method is suitable for the classification of outstanding student selection. The Artificial Neural Network (ANN) is able to recognize patterns very well among report card grades, attendance scores, extracurricular activity scores, and attitude scores. Among the accuracy results, the maximum accuracy attained was 97% with a data split of 90% for training and 10% for testing. Additionally, the preprocessing process is crucial in enhancing the performance of the neural network model. This is evidenced by the success of the developed system, which can reduce subjectivity in the outstanding student selection process, increase efficiency in the selection procedure, and produce consistent and objective recommendation results.

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