Optimization of artificial neural networks to improve accuracy of vocational competence selection of vocational school students using nguyen-widrow

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Abstract. The present study used Neural Network Backpropagation combined with Nguyen-Widrow to optimize the disadvantages of ANN causes, which is the difficulty in initializing initial weights. The test was conducted on a dataset of values in semesters 1 and 2. The test results show that the best performance in training model of artificial neural networks with Nguyen-widrow is the smallest average MSE error of 0.002 and the highest average accuracy of 96.38%. Training on artificial neural network model training data with Nguyen-widrow has the smallest MSE error, 0.000996 and the highest accuracy is 97.49% on architecture ANN 9-9-1 with training function parameters: traingdx, epoch: 1000, learning rate: 0.1, and error: 0.001. The best performance was also seen in testing the testing of artificial neural network models with Nguyen-widrow with the smallest average error-MSE of 0.026 and the highest average accuracy of 87.85%. Training data testing on artificial neural network models with Nguyen-widrow has the smallest error-MSE which is 0.004436 and the highest accuracy is 94.50% on architecture ANN 9-9.1 with training function parameters: traingdx, epoch: 1000, learning rate: 0.1, and error: 0.001. The artificial neural network model with Nguyen-widrow has an accuracy difference of 8.53% smaller than the artificial neural network model with an accuracy difference of 9.28%. It can be concluded that the Artificial Neural Network with Nguyen-Widrow can overcome the ANN problem in determining initial weights so that it gives an increase in the accuracy of the prediction of students' competency selection better than the Artificial Neural Network without Nguyen-Widrow.

1. Introduction

The process of determining the competency of expertise that has been used in the WiraHarapan Vocational High School (SMK) is only based on student specialization and interview results. According to students' specialization guidelines based on Government Regulation Number 17 of 2010 concerning Implementation and Management of Education for the selection of specialization in the field of expertise and expertise programs carried out in semester 3, based on report card grades and/or recommendations in SMK/MAK (Madrasah Aliyah Vocational) and/or Outcomes placement test (placement test) by a psychologist. In addition to non-test techniques, it can also use test techniques,
such as psychological tests carried out by testers or specialization tests that can be carried out by BK/Counselor teachers. The specialization guidelines for students based on the 2013 curriculum convey data obtained from test and non-test techniques (documentation, questionnaires, interviews, observations, etc.), which complement each other. Can be interpreted that the more data collected and can be analyzed correctly, the accuracy of determining the interest of students will be higher.

This background becomes the foundation for the application of ANN with Nguyen-Widrow to optimize the prediction of selecting competency expertise. Prediction is basically a guess or prediction about the occurrence of an event or event in the future. So predictions and forecasts are made to support the analysis and decision making process that precedes the control actions of a system [1]. The prediction method is used after seeing the accuracy comparison of the 4 other methods used in the selection of Expertise Competencies. The first method is K-nearest Neighbor, with an accuracy level of 79.68% tested on 160 data which is divided into 64 test data and classified with 96 training data [2]. Lack of K-nearest Neighbor is the value of k bias, complex computation, memory limitations and easily fooled by irrelevant links [3]. The second method is Naive Bayes, which is better than the other methods with a value of 77.51 [4]. The weakness of the Naïve Bayes method is the probability of not being able to measure the magnitude of the accuracy of a prediction [5]. The second method is Decision Tree C4.5 for determining the suitability of the Competency of the Skill, where students get an accuracy of 83.33% [6]. The weakness of Decision tree C4.5 is, if criteria and classes used are in large numbers, they will overlap. Furthermore, Decision tree C4.5 is very dependent on the designation of the Decision Tree because this has an influence on the quality of the decision results obtained [7]. Seeing the results of the accuracy of the 3 methods, the accuracy is still smaller than the journals to predict student achievement with artificial neural networks having 95.6% training error accuracy and 100% testing error [8]. The accuracy comparison is because artificial neural networks have advantages, namely Adaptive Learning where the ability of neural networks is improved through the learning process (learning) [9]. The use of artificial neural network methods using backpropagation algorithms in data processing is still experiencing weakness. The weakness of the neural network method using the backpropagation algorithm is influenced by the initial weight chosen randomly [10]. Initial weight initialization by generating random values from -1 to 1 can cause artificial neural network weakness [11]. As an optimization to overcome the minimum local weaknesses that occur in the initial weighting of artificial neural networks using the Nguyen-widrow method can provide a more convergent value and is used as an initial weighting in the training process in the backpropogation method [12].

The application of this method is done by looking at semester 1 and 2 data on group A and B subjects including; Religion, PPKN, Indonesian Language, Mathematics, Indonesian History, English, Penjaskes and Entrepreneurship to predict competence in appropriate expertise. This study does not consider other factors as a supporter of decision support in choosing competency expertise, for example the factors of skills, talents, interests and other factors. Based on the description above, the authors focus on artificial neural network optimization research for improving the accuracy of the prediction of the competency selection of vocational students' expertise using Nguyen-Widrow.

2. Subject Of The Study
The subject of this study was based on basic education data at WiraHarapan Vocational School with a total of 611 data in 2017. The dataset was in the form of student values in all expertise competencies based on the 2017 value history.

3. Research Method
The method used is experimental research, with the stages of the research that is testing the accuracy of artificial neural network algorithms with Backpropagation models that use parameters in the training and testing process to influence the value, namely; training functions: traindx, epoch: 1000, learning rate: 0.1, and error: 0.001. Comparison of parameters using training functions and hidden layers will provide model information so that the resulting model will affect the accuracy of
predictions [13]. The dataset used is the values of WiraHarapan Vocational School students of all expertise competencies, based on the 2017 value history. Model of Artificial Neural Networks and Artificial Neural Networks with Nguyen-Widrow is tested to compare the results of Error-MSE and the smallest Accuracy seen from hidden layer: 9, 6 and 3 on artificial neural network architecture. The addition of the Nguyen-widrow method aims to look for comparisons as well as to improve the accuracy of research results. So the architecture in the model of artificial neural networks and artificial neural networks with Nguyen-Widrow are: 9-9-1, 9-6-1, and 9-3-1. The combination of architecture and good weight will determine the outcome of a neuron that will be propagated in the neural network until it gives the output of ANN [14]. The determination of the model will be seen from the highest prediction accuracy with the rules of the number of neurons, hidden layers and the training function used. The model with the highest accuracy will be used to predict the competency of students’ expertise so that they will get a model with more accurate prediction results. Prediction results obtained will be validated and measured by comparing the error value of the predicted algorithm. In detail, the method used in this study is illustrated in figure 1.

Figure 1. Research Methodology.
ANN design to predict expertise competencies for vocational students is done by determining the architecture of the artificial neural network model and the artificial neural network with Nguyen-Widrow, which will be used to obtain the model with the highest prediction accuracy, with the following process:

1. **Data Process**
   Data processing is carried out in this study to prepare student grade data so that it can be processed or applied to the ANN model that will be developed, there are several stages that are carried out in the data preprocessing:
   a) **Data Correction**
   Select semester 1 and 2 data on group A and B subjects including; Religion, PPKN, Indonesian, Mathematics, Indonesian History, English, Health and Entrepreneurship. Furthermore, by giving an empty value with an average value.
   b) **Data Normalization**
   Input data processing as training data will also be normalized by the data transformation process, so that normalized data will be stable and can be in accordance with the activation function [15]. The data used will use the sigmoid activation function, so the data will be transformed to a smaller interval that is a value that lies between 0 and 1 with the formula. This transformation process is called data normalization which aims to simplify the calculation process. Normalization is done by using the transformation formula
   \[
   X = \frac{0.8(x - x_{min})}{x_{max} - x_{min}} + 0.1
   \]  
   (1)

1. **Nguyen-Widrow**
   The Nguyen-Widrow algorithm is used to make weighting initialization as a method to increase accuracy in artificial neural network methods. The Nguyen-Widrow algorithm can be shown using the following formula:
   a. Set:
   \[
   N = \text{number of input units}
   \]
   \[
   P = \text{number of hidden units}
   \]
   \[
   \beta = \text{scale factor} = 0.7(p)^{1/n} = 0.7\sqrt[n]{p}
   \]
   b. For each hidden unit \((j = 1, \ldots, P)\), do the stage (c) - (f)
   c. For \((i = 1, \ldots, n)\) (all input units), \(v_{if}(old) = \text{random number between } -0.5 \text{ and } 0.5\)
   d. Calculate values with formulas
   \[
   \|v_f(old)\| = \sqrt{v_{f}^2 + v_{f}^2 + \cdots + v_{f}^2}
   \]  
   (2)
   e. Calculate new weights by formula
   \[
   v_{if} = \frac{\beta v_{if}(old)}{\|v_f\|}
   \]  
   (3)
   f. The bias is used as an initialization:
   \(v_{oif} = \text{random number between } -\beta \text{ and } \beta\)

2. **Training and Test Data**
   The average value in semester 1 will be used as output for later compared with the output from the model of artificial neural networks and artificial neural networks with Nguyen-Widrow produced, so that from the comparison of the reality value and the value of the model results will be obtained its accuracy value. The average value of Semester 2 will be the target for later compared to the outputs
from the model of artificial neural networks and artificial neural networks with Nguyen-Widrow produced, so that from the comparison of the target values and the results of the model results will be obtained the highest accuracy value close to 0.

3. Model Design with Artificial Neural Networks (ANN)
The design of artificial neural network models and artificial neural networks with Nguyen-Widrow uses parameters in the training and testing process to influence the values namely; training functions: traingdx, epoch: 1000, learning rate: 0.1, and error: 0.001. Architecture in the model of artificial neural networks and artificial neural networks with Nguyen-Widrow are: 9-9-1, 9-6-1, and 9-3-1.

4. Model Testing
Tests on the ANN and ANN models with Nguyen-Widrow are performed to determine the level of accuracy of the predictions of the ANN and ANN algorithms with Nguyen-Widrow against the actual data.

5. Forecast Model
Artificial Neural Network Model and Nguyen-Widrow artificial neural network were tested with hidden layer: 9, 6 and 3 with predetermined parameters. So that it can compare models from the results of the smallest Error-MSE average results and the average percentage of the highest accuracy to predict the competency skills of SMK WiraHarapan students.

4. Result And Discussion
In this test explains that there is an increase in the accuracy of training data training using artificial neural network models and artificial neural networks with Nguyen-widrow.

| Majors | Hidden Layer | Without Nguyen-Widrow | With Nguyen-Widrow |
|--------|--------------|-----------------------|--------------------|
|        | Error-Mse    | Average Accuracy      | Error-Mse          | Average Accuracy  |
| TKJ    | 9 0.001      | 97.15%                | 0.001              | 97.49%            |
|        | 6 0.001      | 97.44%                | 0.002              | 96.77%            |
|        | 3 0.002      | 96.55%                | 0.003              | 96.58%            |
|        | 9 0.001      | 97.03%                | 0.002              | 96.75%            |
| RPL    | 6 0.003      | 95.93%                | 0.002              | 96.42%            |
|        | 3 0.009      | 91.79%                | 0.002              | 96.11%            |
|        | 9 0.002      | 96.66%                | 0.002              | 96.57%            |
| MM     | 6 0.001      | 97.38%                | 0.002              | 96.49%            |
|        | 3 0.005      | 93.97%                | 0.002              | 96.73%            |
|        | 9 0.002      | 95.95%                | 0.001              | 96.97%            |
| UPW    | 6 0.004      | 95.51%                | 0.003              | 95.33%            |
|        | 3 0.010      | 92.00%                | 0.007              | 93.18%            |
|        | 9 0.001      | 97.51%                | 0.003              | 95.91%            |
| AP     | 6 0.002      | 96.63%                | 0.001              | 97.46%            |
|        | 3 0.003      | 95.94%                | 0.004              | 95.32%            |
|        | 9 0.001      | 97.57%                | 0.002              | 96.57%            |
| JB     | 6 0.002      | 96.95%                | 0.001              | 97.11%            |
|        | 3 0.002      | 96.18%                | 0.001              | 97.12%            |
| TOTAL AVERAGE | 0.003 | 96.01% | 0.002 | 96.38% |
The artificial neural network model with Nguyen-widrow has an average Error-MSE 0.002 smaller than the artificial neural network model that is 0.003. In addition to the smaller error value, the average accuracy of the neural network model with Nguyen-widrow is 96.38% higher than the artificial neural network model with an average accuracy of 96.01%. In the test results get the same comparison as shown in table 2.

**Table 2.** Error-MSE and accuracy in testing data testing.

| MAJORS | HIDDEN LAYER | WITHOUT NGUYEN-WIDROW | WITHOUT NGUYEN-WIDROW | WITH NGUYEN-WIDROW | WITH NGUYEN-WIDROW |
|--------|--------------|-----------------------|-----------------------|-------------------|-------------------|
|        | Error-MSE    | Average Accuracy      | Error-MSE             | Average Accuracy  |                   |
| TKJ    | 9             | 0.09                  | 92.63%                | 0.073             | 74.42%            |
|        | 6             | 0.298                 | 85.30%                | 0.088             | 74.83%            |
|        | 3             | 0.043                 | 81.25%                | 0.012             | 90.49%            |
|        | 9             | 0.067                 | 77.77%                | 0.097             | 69.89%            |
| RPL    | 6             | 0.086                 | 73.21%                | 0.013             | 90.73%            |
|        | 3             | 0.240                 | 60.96%                | 0.027             | 85.81%            |
|        | 9             | 0.004                 | 94.65%                | 0.006             | 94.30%            |
| MM     | 6             | 0.010                 | 91.83%                | 0.014             | 89.56%            |
|        | 3             | 0.037                 | 82.00%                | 0.015             | 89.20%            |
|        | 9             | 0.033                 | 84.01%                | 0.029             | 85.41%            |
| UPW    | 6             | 0.015                 | 90.05%                | 0.015             | 90.01%            |
|        | 3             | 0.047                 | 81.93%                | 0.041             | 83.02%            |
|        | 9             | 0.006                 | 93.96%                | 0.004             | 94.50%            |
| AP     | 6             | 0.005                 | 94.41%                | 0.005             | 94.40%            |
|        | 3             | 0.002                 | 96.04%                | 0.006             | 93.61%            |
|        | 9             | 0.003                 | 95.65%                | 0.005             | 94.12%            |
| JB     | 6             | 0.013                 | 90.26%                | 0.006             | 93.52%            |
|        | 3             | 0.006                 | 95.14%                | 0.006             | 93.45%            |
| TOTAL AVERAGE | 0.051       | 86.73%                | 0.026                 | 87.85%            |

The artificial neural network model with Nguyen-widrow has an average Error-MSE of 0.026 smaller than the artificial neural network model of 0.051. In addition to the smaller error value, the average accuracy of the neural network model with Nguyen-widrow is 87.85% higher than the artificial neural network model with an average accuracy of 86.73%. Thus the Nguyen-Widrow method has contributed to improving the accuracy previously obtained by the ANN method.

In the training of artificial neural network model training data with Nguyen-widrow, there is the smallest MSE error, 0.000996 and the highest accuracy is 97.49% on the architecture of ANN 9-9-1 with training function parameters: traingdx, epoch: 1000, learning rate: 0.1, and error : 0.001. Comparison of the average total Error-MSE and accuracy in training data training can be represented as in figure 2.
Figure 2. Comparison of average error-MSE and accuracy in training data training.

The best performance was also seen in testing the testing model of artificial neural networks with Nguyen-widrow with the smallest average error-MSE of 0.026 and the highest average accuracy of 87.85% shown in table 3.

Table 3. Average Total Error-MSE and accuracy in testing data testing.

| DATA TESTING      | Error-MSE | Average Accuracy |
|-------------------|-----------|------------------|
| WITHOUT NGUYEN-WIDROW | 0.051     | 86.73%           |
| NGUYEN-WIDROW     | 0.026     | 87.85%           |

Training of artificial neural network model training data with Nguyen-widrow has the smallest MSE error, the value of 0.004436 and the highest accuracy of 94.50% on the architecture of ANN 9-9.1 with training function parameters: traingdx, epoch: 1000, learning rate: 0.1, and error: 0.001 . Comparison of the average total Error-MSE and accuracy in training data testing can be represented as in figure 3.

Figure 3. Comparison of average Error-MSE and accuracy in data testing training.

The difference in accuracy can also be seen from the difference between training data and testing of artificial neural networks and with artificial neural networks with Nguyen-widrow. The artificial neural network model with Nguyen-widrow has an accuracy difference of 8.53% smaller than the artificial neural network model with an accuracy difference of 9.28%.
5. Closing

Based on the test results and analysis of the results from Matlab, it can be concluded that:

1. The results of experiments on training data with artificial neural network models, obtained different values of accuracy in each of the expertise competencies of SMK WiraHarapan. Competence of TKJ expertise with the highest accuracy of 97.44% and error-MSE as low as 0.001 on architecture ANN 9-6-1. RPL expertise competency with the highest accuracy is 97.03% and error-MSE is as low as 0.001 on the architecture of ANN 9-9-1. MM competence with the highest accuracy is 97.38% and error-MSE is as low as 0.001 on architecture ANN 9-6-1. UPW expertise competence with the highest accuracy of 95.95% and error-MSE 0.002 on ANN 9-9-1 architecture. AP expertise competence with the highest accuracy is 97.51% and error-MSE is as low as 0.001 on the architecture of ANN 9-9-1. JB's competence with the highest accuracy is 97.57% and error-MSE is as low as 0.001 on the architecture of ANN 9-9-1. The results of this accuracy and error-MSE use parameters; training function: traingdx, epoch: 1000, learning rate: 0.1, and error: 0.001 in the process of training data training to influence grades.

2. The results of experiments on training data model of artificial neural networks with Nguyen-widrow, obtained different values of accuracy in each of the expertise competencies of SMK WiraHarapan. Competence of TKJ expertise with the highest accuracy of 97.49% and error-MSE as low as 0.001 on the architecture of ANN 9-9-1. RPL expertise competency with the highest accuracy is 96.75% and error-MSE is as low as 0.002 on the architecture of ANN 9-9-1. MM expertise competence with the highest accuracy is 96.73% and error-MSE is as low as 0.002 on architecture ANN 9-3-1. UPW expertise competency with the highest accuracy is 96.97% and error-MSE is as low as 0.001 on the architecture of ANN 9-9-1. AP expertise competence with the highest accuracy is 97.46% and error-MSE is as low as 0.001 on architecture ANN 9-6-1. JB's competence with the highest accuracy is 97.12% and error-MSE is as low as 0.001 on architecture ANN 9-3-1.

3. The results of experiments on testing data with neural network models obtained different accuracy values in each of the expertise skills of SMK WiraHarapan. Competence of TKJ expertise with the highest accuracy of 92.63% and error-MSE as low as 0.009 on the architecture of ANN 9-9-1. RPL expertise with the highest accuracy is 77.77% and error-MSE is as low as 0.067 on the architecture of ANN 9-9-1. MM competence with the highest accuracy is 94.65% and error-MSE is as low as 0.004 on the architecture of ANN 9-9-1. UPW expertise competencies with the highest accuracy is 90.05% and error-MSE is as low as 0.015 on architecture ANN 9-6-1. AP expertise competencies with the highest accuracy is 96.04% and error-MSE is as low as 0.002 on architecture ANN 9-3-1. JB's competence with the highest accuracy is 95.65% and error-MSE is as low as 0.003 on the architecture of ANN 9-9-1.

4. The results of experiments on the testing of neural network models with Nguyen-widrow, obtained different values of accuracy in each of the expertise competencies of WiraHarapan Vocational School. TKJ competence with the highest accuracy is 90.49% and error-MSE is as low as 0.012 on architecture ANN 9-3-1. RPL expertise with the highest accuracy is 90.73% and error-MSE is as low as 0.013 on architecture ANN 9-6-1. MM competence with the highest accuracy is 94.30% and error-MSE is as low as 0.006 on ANN 9-9-1 architecture. UPW expertise competencies with the highest accuracy is 90.01% and error-MSE is as low as 0.015 on architecture ANN 9-6-1. AP expertise competencies with the highest accuracy is 94.50% and error-MSE is as low as 0.004 on the 9-9-1 ANN architecture. JB's competence with the highest accuracy is 94.12% and error-MSE is as low as 0.005 on ANN 9-9-1 architecture.

5. The results of experiments on training and testing data with artificial neural network models and artificial neural networks with Nguyen-widrow obtained 9-9-1 architecture which has the best accuracy performance. Can be seen from the 24 highest accuracy and lowest error-MSE, architecture 9-9-1 appears 14 times, 9-6-1 appears = 6 times, and 9-3-1 appears 4 times.

6. The amount of data has an influence on the results of experiments on training and testing data with artificial neural network models and artificial neural networks with Nguyen-widrow. Comparison
of the average accuracy of training data is 0.10% and testing is 6.48% lower on TKJ expertise competencies when using artificial neural networks with Nguyen-widrow. This is due to the fact that data on TKJ's expertise competencies is less than other expertise competencies.

7. Based on the comparison of Error-MSE values and the average accuracy between artificial neural network models and artificial neural networks with Nguyen-widrow, training and network testing using artificial neural network models with Nguyen-widrow can be an option to improve the accuracy of prediction of the competency selection of participant expertise students.

The results of this study need to get more developments to get better and perfect results. Development that can be given, among others, by: 1) Implement new parameters to be able to improve the accuracy of prediction of the competency selection of WiraHarapan Vocational School students' competency. So that it can contribute to the world of education and science until it finally benefits society; 2) Implementing architectures that vary from the application of hidden layers so as to provide the smallest accuracy and error-MSE increase for research using artificial neural networks. 3) Adding methods or changing methods so that performance is seen from the accuracy and error-MSE will be better for speeding up the weighting process or determining the bias value.

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