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Variations in the Number of Layers and the Number of Neurons in Artificial Neural Networks: Case Study of Pattern Recognition

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Abstract. This paper presents the analyst the number of layers and the number of neurons in the hidden layer of the Artificial Neural Network. In this study, case studies were taken in the recognition of alphabet patterns and shape patterns. First, the number of layers is varied to get the best number of layers. Furthermore, the number of neurons is varied to get the best number of neurons. The results showed that the best number of layers was 1-5 layers in the hidden layer, with validation values from the recognition system 96-100%. While the best number of neurons is obtained with 19 neurons, with an average accuracy percentage of 81%.

1. Introduction
Artificial Neural Network (ANN) is a programming algorithm that is applied to the process of computer computing by adapting the structure of human biological neural networks. Artificial neural networks (ANN) are information processing systems that have characteristics similar to biological neural networks. Artificial neural networks resemble the human brain in gaining knowledge that is by learning and storing knowledge gained in the strength of connections between neurons[1], [2]. The accuracy of ANN is influenced by three things, namely: the pattern of relationships between neurons (network architecture), methods for determining weights (learning methods) and activation functions [3].

According to Peterson & Rognvaldsson artificial neural networks have three main layers, namely the input layer, hidden layer and output layer [4]. The input layer is connected to the hidden layer, the hidden layer is connected to the output layer. The final calculation will produce a value at the output layer. In simple terms neural networks have the structure as shown in Figure 1. “W” represents the weights on each path, “x” represents the input layer, “h” represents the hidden layer, and “o” represents the output layer.
The input layer will receive input data from outside of ANN system. All neurons in this input layer are connected to the neurons in the next layer (hidden layer). Hidden layer consists of a number of neurons that receive data from neurons in the input layer. Furthermore, the neurons in this hidden layer will provide the data to the neurons in the output layer [5].

Hidden layer has a function to increase network capabilities to be more full power, so that it will be easier to do their jobs. ANN that does not have hidden layers, has very limited capabilities. Hidden layers can consist of one layer or more. Each layer has a number of neurons. Until now, there were no definitive rules about the number of hidden layers, and the best number of neurons in the hidden layer in ANN. Users still find it difficult to determine the number of hidden layers and the ideal number of neurons in the hidden layer of the ANN system.

In this paper, the author will present the results of the study related to the analysis of the number of hidden layers, and the number of neurons that should be used in designing ANN. In this study, case studies of letter patterns A, B, C, D, and E were used as well as the pattern recognition of shape patterns (triangles, squares, and circles).

2. Research Methods

2.1. Variation the Number of Layers in ANN

This paper presents a study of the analysis of variations in the number of layers and variations in the number of hidden layer neurons in artificial neural networks. The type of ANN that was used in this study is multi-layer perceptron (MLP) with sigmoid activation function. The number of neurons in the input is 35, while the number of neurons in the output layer is 5 for alphabetical pattern recognition, and 4 for shape pattern recognition.

The analysis of the variation in the number of layers is done by taking a case study of alphabetical pattern recognition consisting of letters A to E, with a pattern as shown in Figure 2. The number of hidden layers will vary from amount 1 to 7. First the ANN system is used with 1 layer on the hidden layer. Before being used, ANN needs to be trained first. Some parameters in ANN training include: setting the goal error value is 0.1, the initial value is 0.01, the maximum epoch is 5000, the constant momentum is 0.95, and the minimum gradient is 1e-10. The number of neurons for each layer hidden is 10. After the training phase, and find the best weight results, the system will then be tested. Testing is done using 5 alphabetical A-E patterns, where each alphabet is provided with 6 kinds of variations (by giving noise).
Then this process is repeated (in the same way as above) for the number of hidden layers 2, 3, 4, etc. From testing, this will get 600 results of test data. Next will be analyzed how the system validity is obtained.

2.2. Variation in the Number of Neurons in the Hidden Layer

In the above section, the method for analyzing the best number of layers in the MLP hidden layer is presented. In this session the method will be explained in the analysis of the best number of neurons in the MLP hidden layer. Case studies of the square, triangular, round shape and parallelogram patterns recognition are are used in this study. The ANN used is MLP with one hidden layer with the sigmoid activation function. The number of neurons in the input layer is 35, while the number of neurons in the output layer is 4. Then the ANN training system is done with the setting of the goal error value is 0.1, the initial value is 0.01, the maximum epoch is 5000, the momentum constant is 0.95, and the gradient minimum is 1e-10. The number of neurons in the hidden layer is varied by 25 kinds (1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 50, 75, 100, 250, 500 and 1000).

After training, testing is carried out. Each layer variation, tested 4 patterns (Squares, triangles, rounds, and parallelograms), where each pattern is given 6 variations (by voting), so that the total is 600 times.

3. Result and Discussion

3.1. Variation the Number of Layers in ANN

As explained in the sub discussion of research methods, variations in layers were tested through case studies of Abjad pattern recognition, which in this case represented 5 alphabets A, B, C, D, E which were repeated with the addition of different noise 6 times. Then the layer starts to be varied, starting from 1 layer, 2 layers etc. The test data can be seen in Table 1 and Table 2.

| Abjad | Hidden layer 1 | Hidden layer 2 | Hidden layer 3 | Hidden layer 4 | Hidden layer 5 |
|-------|----------------|----------------|----------------|----------------|----------------|
|       | identified    | recognition value. | identified    | recognition value. | identified    | recognition value. | identified    | recognition value. | identified    | recognition value. |
| A     | 0.9261        | A 0.8764        | A 0.8831      | A 0.9182       | A 0.9106      |
| A'    | 0.9376        | A 0.8764        | A 0.8831      | A 0.9182       | A 0.9016      |
| A''   | 0.9569        | A 0.9250        | A 0.9693      | A 0.8188       | A 0.7654      |
| A'''  | 0.8581        | A 0.8524        | A 0.9164      | A 0.9039       | A 0.9135      |
| A'''' | 0.9308        | A 0.9636        | A 0.9101      | A 0.9138       | A 0.9695      |
| A'''''| 0.9300        | A 0.8399        | A 0.9351      | A 0.8925       | A 0.8416      |
| B     | 0.8363        | B 0.8973        | B 0.9002      | B 0.8910       | B 0.9610      |
| B''   | 0.8255        | B 0.7446        | B 0.9838      | B 0.8730       | B 0.8877      |
| B'''  | 0.9046        | B 0.9313        | B 0.9280      | B 0.8971       | B 0.6979      |
| B'''' | 0.8000        | B 0.8974        | B 0.3870      | B 0.8707       | B 0.9080      |
| B'''''| 0.7851        | B 0.6676        | B 0.9677      | B 0.7750       | B 0.8898      |
recognition accuracy of 100%, when the number of layers in the hidden layer 2, the accuracy is 96%,

| Abjad | Hidden layer 6 | Hidden layer 7 | Hidden layer 8 | Hidden layer 9 | Hidden layer 10 |
|-------|----------------|----------------|----------------|--------------|----------------|
|       | identified | recognition value. | identified | recognition value. | identified | recognition value. | identified | recognition value. | identified | recognition value. |
| A     | A          | 0.912            | A             | 0.8593         | A             | 0.8979          | A             | 0.9001         | A             | 0.8951          |
| A'    | D          | A                | E             | 0.9312         | B             | A               | 0.8573         | C             |               |
| A''   | E          | 0.945            | A             | 0.7822         | A             | 0.9441          | A             | 0.9918         | C             | 0.6722         |
| A'''  | A          | 0.911            | A             | 0.8915         | A             | 0.8576          | A             | 0.9662         | A             | 0.8999         |
| A'''' | A          | 0.819            | C             | 0.621          | B             | 0.9379          | B             | 0.9012         | B             | 0.8899         |
| A'''',| D          | 0.939            | B             | 0.9389         | D             | 0.7927          | B             | 0.8497         | B             | 0.9223         |
| A''''',| B           | 0.851            | B             | 0.7727         | D             | 0.8793          | B             | 0.8497         | C             | 0.9503         |
| A'''''| B          | 0.939            | C             | 0.5194         | C             | 0.2485          | C             | 0.8903         | C             | 0.8638         |
| A''''''| B           | 0.851            | D             | 0.8761         | D             | 0.9637          | C             | 0.9271         | D             | 0.9117         |
| B     | D          | 0.984            | A             | 0.8292         | D             | 0.8709          | A             | 0.9129         | D             | 0.9283         |
| B'    | D          | 0.906            | D             | 0.8043         | A             | 0.9003         | D             | 0.9467         | D             | 0.9048         |
| B''   | D          | 0.931            | D             | 0.8556         | D             | 0.7938         | E             | 0.8963         | D             |               |
| B'''' | D          | 0.782            | C             | 0.9687         | C             | 0.9381         | E             |               |               |               |
| B'''''| E          | 0.984            | E             | 0.9351         | E             | 0.9583         | E             | 0.9682         | E             | 0.9395         |
| B''''''| E           | 0.828            | D             | 0.9003         | D             | 0.9493         | E             | 0.9199         | E             | 0.9119         |
| B'''''',| E           | 0.898            | B             | 0.9371         | A             | 0.9318         | E             | 0.9318         | E             | 0.8376         |
| B''''''',| E           | 0.887            | E             | 0.5341         | B             | 0.9539         | D             |               |               |               |

Table 1 and Table 2 show that when the number of layers in hidden layer 1, the system has a pattern recognition accuracy of 100%, when the number of layers in the hidden layer 2, the accuracy is 96%,
when the number of layers in hidden layer 3, the accuracy is 96%, when the number of layers in the hidden layer 4, the accuracy is 100%, when the number of layers in the hidden layer 5, the accuracy is 96%. Accuracy will decrease when the number of layers in the Hidden layer rises above 5. When the number of layers 6, the accuracy is 68%, when the number of layers 7, the accuracy is 64%, When the number of layers is 8, the accuracy is 68%, when the number is 9, the accuracy is 68%, when the number of layers 10, the accuracy is 60%.

It appears that the best hidden layer is achieved when the number of layers ranges from 1-5. Fausset [4] in his book entitled "Fundamental of Neural Network: Architecture Algorithm and Application" said that the number of ideal hidden layers used in backpropagation is 1 hidden layer. However, from the experimental results it is known that the hidden layer still has a high percentage of truth and ideal range between 1-5.

3.2. Variation the Number of Neurons in the Hidden Layer

The ideal number of neurons will be analysed in the hidden layer. From the previous explanation it has been found that the ideal number of layers is between 1-5. Whereas Fausset [4] reinforces that it is best for one layer. Therefore to analyse the number of these neurons, the hidden layer with the number 1 is selected. The number of neurons varied 25 times (1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 50, 75, 100, 250, 500 and 1000). Each layer is tested with 4 types of shapes (square, triangle, round, parallelogram). Each shape is given a variation of noise 6 times. The complete data on the results of testing neuron variations can be seen in Table 3.

The results of testing the effect of the number of neurons in the hidden layer on identifying pattern shapes found that the best results of using the number of neurons is 19 with a validation value of 81%. From the test results it also appears that the worst value is obtained when the use of the number of neurons is 1-3 with the average percentage validation rate of 62%. This indicates that the number of neurons below 4 is not recommended. In other words, it's best to use a minimum number of neurons 4 and above. The best value is obtained when the number of neurons is 19. More than 19, the validation of pattern recognition again decreases. This indicates that the number of neuron in ANN affects the level of accuracy of shape pattern recognition.

Table 3. The results of testing the variation in the number of ANN neurons in shape pattern recognition
4. Conclusion
From the results of the study, it was found that:

(1) the more hidden layers that were used, the more inaccurate results would be obtained. The ideal number of layers that can be used in MLP is less than 5 (<5).

(2) The best number of neurons in the MLP hidden layer is 19 with an accuracy percentage of 81%. The test results also found that the use of the minimum number of neurons was 4. This was proven by the results of the study that for the number of neurons 1, 2 and 3 had the lowest accuracy percentage of 61%, 68% and 57%.

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