International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Optimal Number of Hidden Neuron Identification for Sustainable Manufacturing Application

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Abstract*: *There were 50 data sample obtained from industries in Malaysia that practice sustainable manufacturing. Input file is presented in matrix 4x50 and 1x50 matrix as target file. However, there is no suitable number of hidden neuron that can be applied for the neural network model with 4 inputs and 1 output. An experiment has been done to identify the suitable hidden neuron through the observation of values from MSE and Regression. The hidden neuron must be no overfitting. The same goes for output and targets value must have close or linear relationship. The sample of tested hidden neuron is from 5 to 40 hidden neurons. The final answer obtained after look into Mean Square Error (MSE) values, Regression values and plots is hidden neuron 29. Hidden neuron 29 shows positive result in all criteria and should be implemented for this type of neural network model.

***Index Terms*: Hidden Neuron, Mean Square Error, Neural Network, Regression, Sustainable Manufacturing.**

I. INTRODUCTION

Artificial Neural Network (ANN) is one branch out of artificial intelligence. ANN is good and weak in several tasks. The ability to solve missing data, fuzzy or incomplete information based on learning ability exists in ANN algorithm. The weakness of this technique is unable to handle effectively those requires high accuracy and precision[1]. This technique resembles human brain in two aspects. One of the aspects where the acquire knowledge is obtained through the learning process in neural network. The second aspect known as synaptic weights used to store knowledge gain same as in neural network[2]. However, with proper determination of hidden neuron number resulting in better decision made for sustainable manufacturing practice[3]. Figure 1 shows simplified flow of coded information.

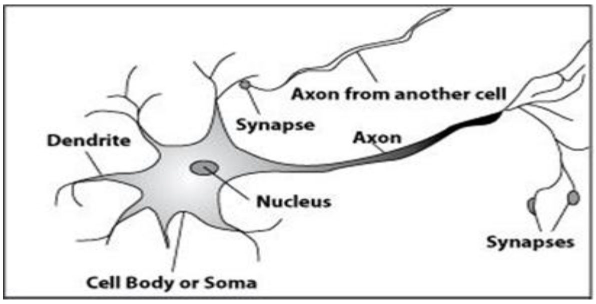

Figure 1: Simplified model of biological neuron[4].

Dendrite is the place where carry in and accept inputs. Further process in Soma and pass to Axon which turns the process inputs into outputs. Axon will later carry away the signal [5]. Number of hidden neuron need to be identified before using NN algorithm. Without suitable number of hidden neuron, the algorithm will not learn in the environment very well[6]. The objective of this paper is to determine the suitable hidden neuron for the data sample of 50 different alternatives. There are four inputs and one output is needed for the process of decision making as illustrated in Figure 2.

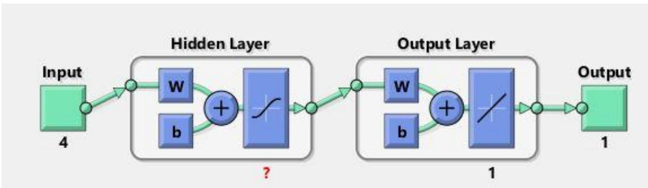

Figure 2: Simplified model of biological neuron from MATLAB

The four input are the criteria and there are 50 options in each criterion according to sustainable parameter. Therefore the model can learn well with right number of iteration and low value of Mean Squared Error (MSE)[7]. MSE is used to identify how near expected output than the desired output[8]. Greater iteration provides higher correlation between coefficient and smaller MSE value for training in this experiment[9]. To prevent over fitting from happening and to improve performance, training was stopped when the MSE value increase and not near zero. This hidden neuron is identified for the application of Levenberg – Marquardt training algorithm[10].

Revised Manuscript Received on 30 July 2019.
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II. METHODOLOGY

This experiment uses data obtained by survey from 50 industries in Malaysia that practice sustainable manufacturing. This experiment conducted by observing the pattern of performance plot, and regression plot. The number of hidden neuron were selected are from 5 to 40 hidden neuron. The hidden neuron which will be tested for the NN algorithm are 4-5-1, 4-10-1, 4-15-1, 4-20-1, 4-25-1, 4-30-1, 4-35-1, 4-40-1. The 50 sample will be divided randomly by 70% training, 15% validation and 15% testing. In the end of this experiment, the best hidden neuron will be determined. The interface of hidden neuron training and the feature to generate the previous mention three types of different plots is shown through MATLAB interface in figure 3. From figure 3, the error histogram is not used because MSE values were referred. As for plot fit link, the feature is unavailable for display due to the input data has more than one element. Proved by MSE value and Regression value to identify either the hidden neuron is suitable to determine the best output. Mean Squared Error is judged according to value. The lower the values, the better selection made to determine hidden neuron[11]. If for an example where the MSE value show zero, this define as there is no error present. For regression values function to determine the correlation between outputs and targets values. If the regression value is given 1 meaning it is a close relationship[12]. Using these parameters, suitable number of hidden neuron will be determined for sustainable manufacturing practice. Further section in the methodology will explain the flow of experiment to be conducted.

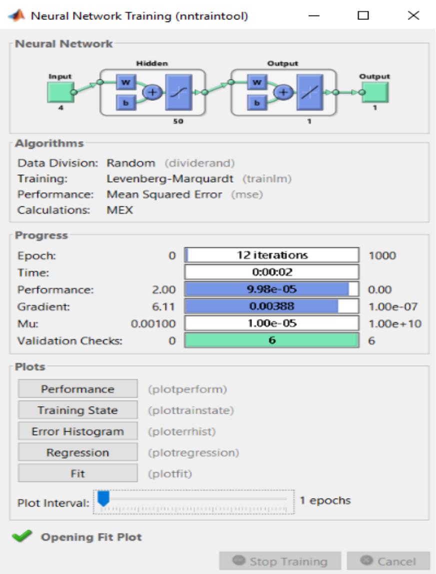

Figure 3: MATLAB interface neural network fitting tool

A. *Plot Methodology*

Input File and Target file is created for experimenting purposes. Each algorithm was trained. Two different plots which are performance and regression plot were generated. The pattern of graph is observed to determine the best hidden neuron. Figure 4 is the flowchart method to determine suitable hidden neuron.

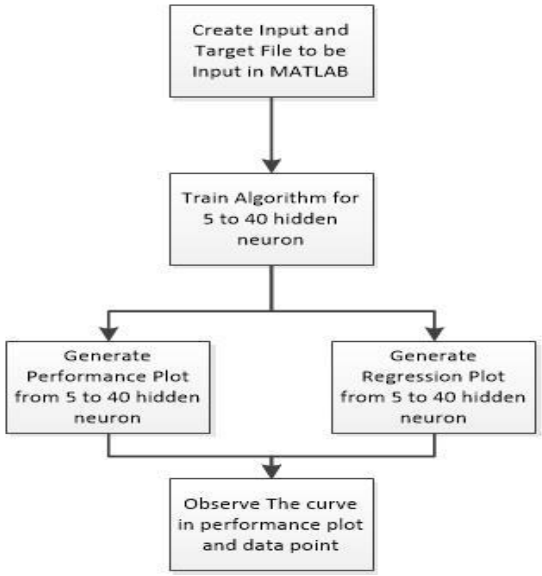

Figure 4: Flowchart of plot observation

The section plot results, displayed three different plots which will be observed in order to select the best hidden neuron. The first plot which is the performance plot is used to determine if there might be overfitting occurred.

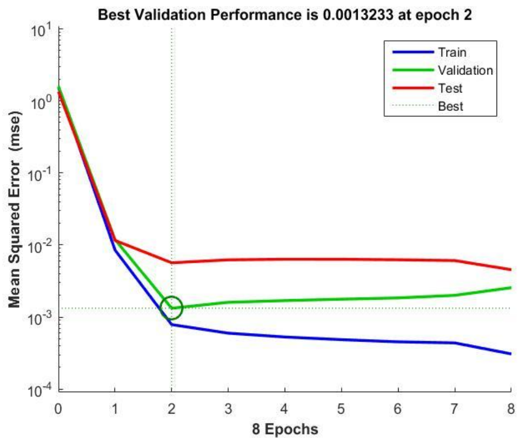

Figure 5: Overfitting example of performance plot

From figure 5, observe that the test curve (red colour) increase significantly from the validation curve (green line). This example shows overfitting happened for this particular feed forward neural network algorithm. The next plot which will be looked into is the regression plot. This plot represent three lines which are training, validate and test data. The dashed line in each plot from the regression figure below shows the best result subtracts outputs which gives targets.

B. *MSE and Regression Methodology*

Further continue with methodology section, this section is where the MSE and Regression value will be taken into consideration. For MSE values, split into three segments as shown in the flowchart from figure 6.

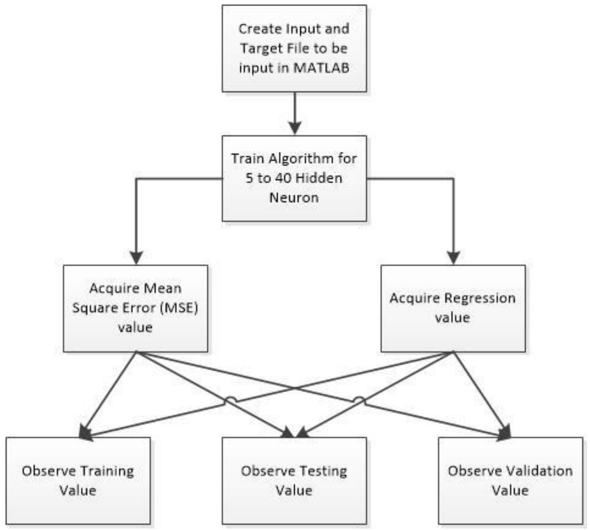

Figure 6: Flowchart of MSE and regresion values

The same input file and target file is used for MSE and Regression experiment. The same neural network from 5 to 40 is trained. For every sample of hidden neuron were run, the value for MSE and regression for 3 activity are recorded. The three values are, testing, training and validation recorded for hidden.

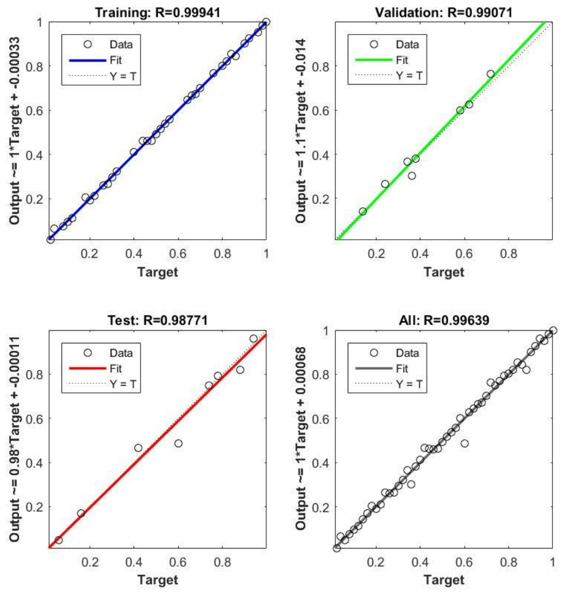

Figure 7: Data scattered on regression plot

Shown in Figure 7 that the training, validation and testing shows near value 1 which means there is linear relationship between output and target. If regression plot show value towards zero proved that there is no close relationship between both output and target. The data scatters are align well with the line. Overall can be seen in all plot that the value is 0.99639 near to 1 show the data align well to the line. The value which will be look into in MSE is the training, testing and validation values as shown in Figure 8. Figure 8 is an interface from MATLAB software. Convenient way rather than generate plot is to cross check with the reading produce in Train Network Interface. This MSE value must near to zero which indicates zero error occur in the feed forward neural network algorithm. As for regression value is the same as MSE consist of 3 values but this values must near to 1. This is to prove that the model have linear relationship between the output and targets value.

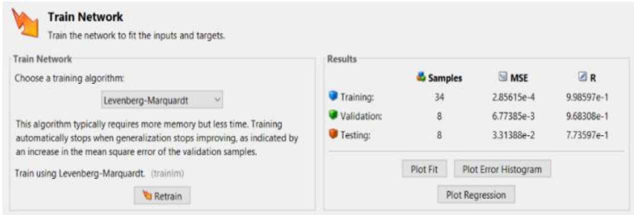

Figure 8: MATLAB interface of MSE and regression values

III. RESULT

This section discuss the result obtained based on the parameter stated previously. Comparisons that were carried out are the reading of MSE and Regression. The samples that are look into are training, testing and validation.

A. *MSE and Regression (Training)*

The input and target file are uploaded into MATLAB and the hidden neuron from 5 up to 40 is tested. The reading generated is note down in Table 1. For MSE, the desired value must be approaching zero or zero and regression value must approach to one. Observe from Table 1, the lowest value approach zero is in hidden neuron 29 (0.000104797) and 30 (0.00010144). However hidden neuron 30 is selected.

Table 1: Training value for MSE and regression

Hidden Neuron (Training)	Mean Square Error (MSE)	Regression (R)
5	1.42711e-3	9.91188e-1
10	5.77859e-3	9.81953e-1
15	7.24824e-4	9.9564e-1
20	6.37606e-4	9.96491e-1
25	1.68019e-3	9.95725e-1
29	1.04797e-4	9.99414e-1
30	1.01440e-4	9.99408e-1
35	1.10912e-4	9.99339e-1
40	4.13904e-4	9.97585e-1

Figure 8 shows the bar chart of hidden neuron versus the training values. Approximately the hidden neurons of 29 and 30 are about the same height approaching zero. However, hidden neuron 29 in figure 9 shows regression value approaching one. If were to compare with others, hidden neuron 29 have the highest height in bar chart. From MSE and regression for training activity, the selected hidden neuron can be either 29 or 30.

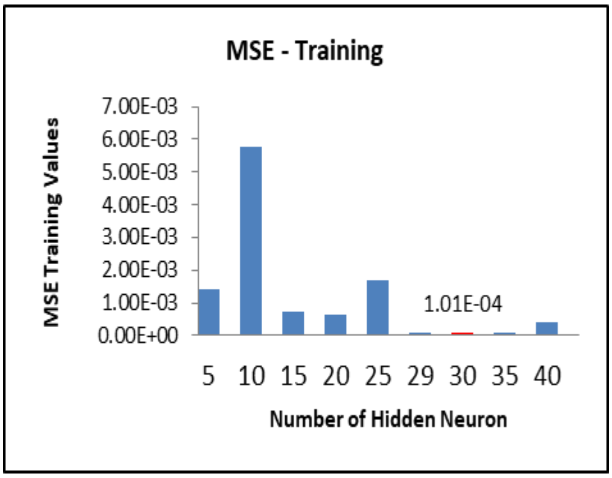

Figure 9: Readings of MSE – Training

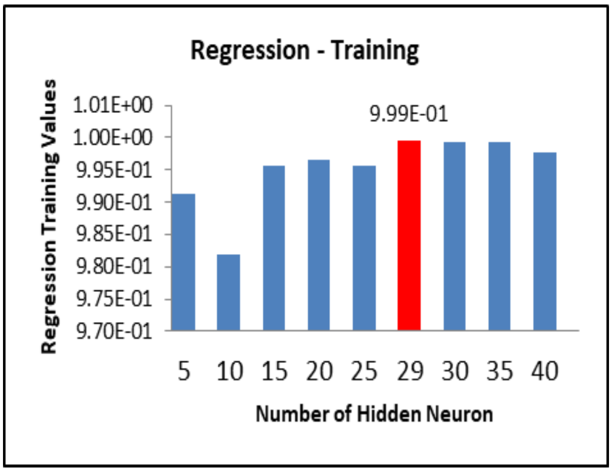

Figure 10: Readings of regression –Training

B. MSE and Regression (Testing)

The second activity that is taken into consideration is the testing activity. The same procedure, from 5 till 40 hidden neurons were generated. Figure 11 shows the lowest value is from hidden neuron 29 (0.00244028). Start from hidden neuron 30, the bar chart starts to increase indicates the error getting bigger than from hidden neuron 30. In figure 12, hidden neuron 29 (0.987708) approaches 1 compared to other hidden neuron. Therefore, hidden neuron 29 is most suitable.

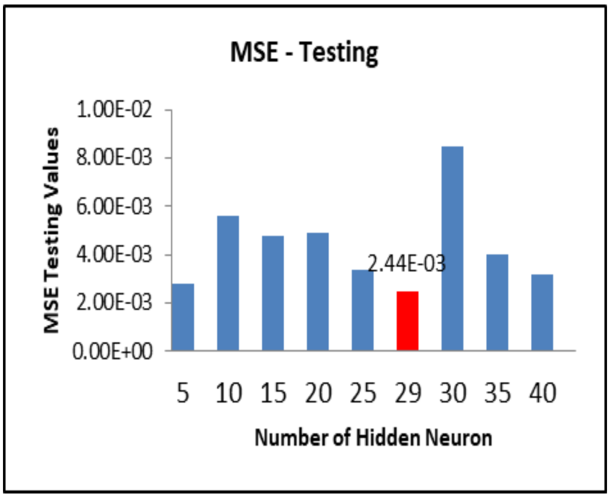

Figure 11: Readings of MSE – Testing

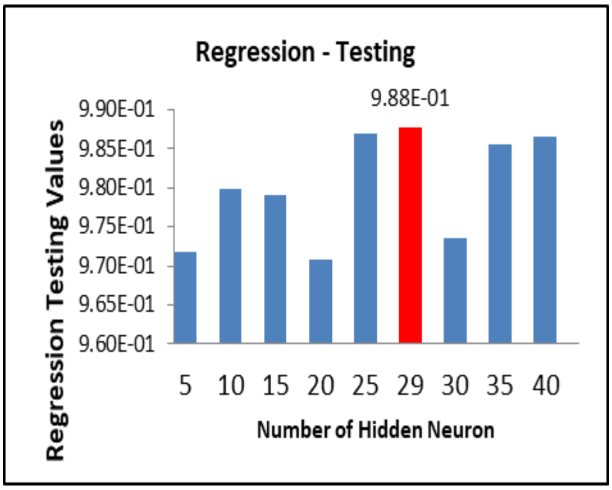

Figure 12: Readings of regression – Testing

C. MSE and Regression (Validation)

The last activity which will be look into is the validation values. For MSE, the hidden neuron 29 gives 0.000882341 closest to zero. However, as for regression value, the hidden neuron 29 (0.990771) and 30 (0.99583) shows approximate close result. Regression value shows that hidden neuron 30 is nearest to 1.

Table 3. Validation value for MSE and regression

Hidden Neuron (Validation)	Mean Square Error (MSE)	Regression (R)
5	3.21969e-3	9.88623e-1
10	5.86933e-3	9.64717e-1
15	1.93177e-2	9.01459e-1
20	2.65675e-2	8.33931e-1
25	2.11026e-3	9.82863e-1
29	8.82341e-4	9.90710e-1
30	1.76084e-3	9.95830e-1
35	3.24713e-3	9.62082e-1
40	8.19945e-3	9.67212e-1

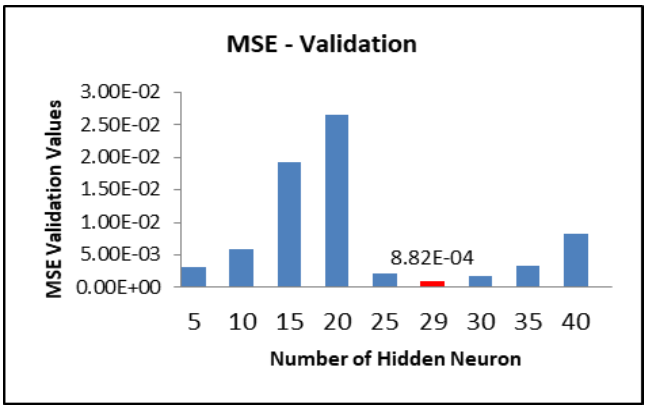

Figure 13: Readings of MSE - Validation

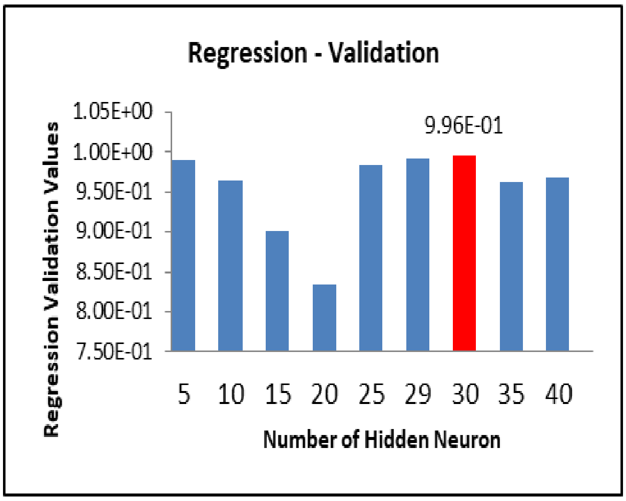

Figure 14: Readings of regression - Validation

D. Summarize Result

Figure. 7 show a plot where all 50 data sample is mapped in the All Regression section. This performance plot shows overall regression summarized from training, testing and validation. Table 4 is the obtained reading from performance plot of hidden neuron 5 to 40.

Table 4: Values for Regression (All)

Hidden Neuron (Training)	Regression (R) (All)
5	0.990771
10	0.97424
15	0.97505
20	0.9691
25	0.99418
29	0.99639
30	0.99131
35	0.99263
40	0.9844

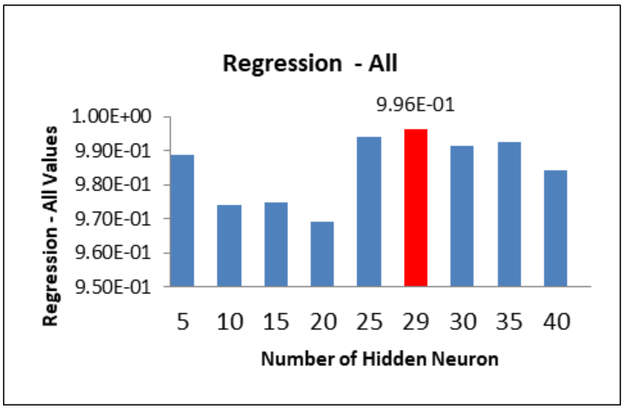

Figure 15: Readings for regression – All

Figure 15 shows that the highest regression value comprises from all three training, testing and validation is hidden neuron 29 with the value of 0.99639. Therefore, hidden neuron 29 is suitable number for Neural Network Algorithm in feed forward regression.

IV. DISCUSSION

This section compares between two plots. The plots that c compared were performance and regression plot. This section will discuss between two hidden neuron which are hidden neuron 29 and 30. The best number of hidden neuron determined based on obeying the parameters mentioned.

A. *Comparison Using Performance Plot*

From four previous sections, observe the hidden neuron can be either 29 or 30. Both MSE value for 29 and 30 shows less zero error. For regression values, the output and target are closely related to each other since all the values are almost reach 1. Both performance and regression plot have been differentiate. From figure 16, shows the performance plot for hidden neuron 29. Observe that the test and validation curve did not increase significantly causing overfitting. The test curve increase about the same region as validation curve. Next comparison made is by comparing the curve from hidden neuron 30. Performance plot with neural network model of 30 hidden neurons is generated.

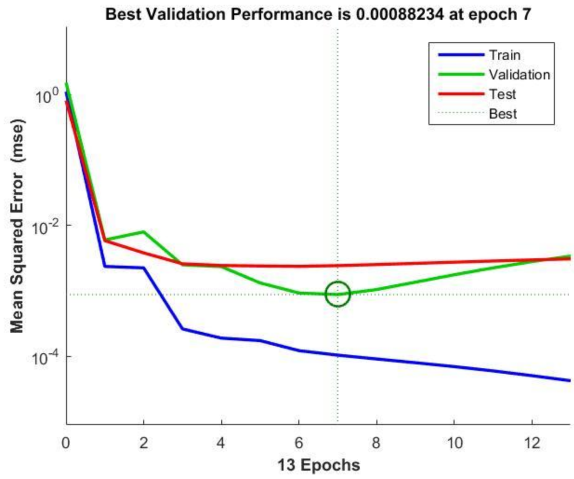

Figure 16: Performance plot for 29 hidden neuron

For hidden neuron 30, the performance plot shows significantly increment between two lines. By referring to figure 17, the red and green curve shows the same appearance as of figure 5.

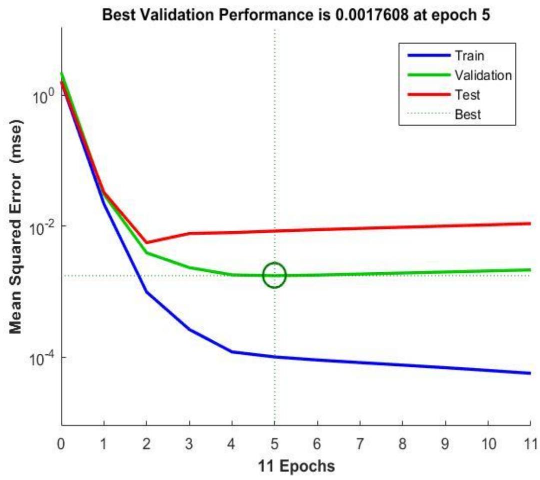

Figure. 17: Performance plot for 30 hidden neuron

B. *Comparison Using Regression Plot*

This section compares regression plot between hidden neuron 29 and hidden neuron 30.

The purpose of doing this activity is to double confirm the best hidden neuron that is so
suitable for learning and will not cause overfitting. Figure 18 and 19 shows regression plot in hidden neuron 29 and 30 respectively. By referring to figure 18, the dotted lines in testing, validate, training and all are mapped nicely align with the coloured line (outputs value). Hidden neuron 29 also shows the data (circle shape) arranged nicely on the line. In figure 19, witness that the dotted lines (targets value) are not in line with coloured line. The dotted lines are separated away from the coloured line. Next is to observe the data scattered across all line. The data scattered not as neat as in hidden neuron 29. The data in figure 19 are aligned well on top of coloured line.

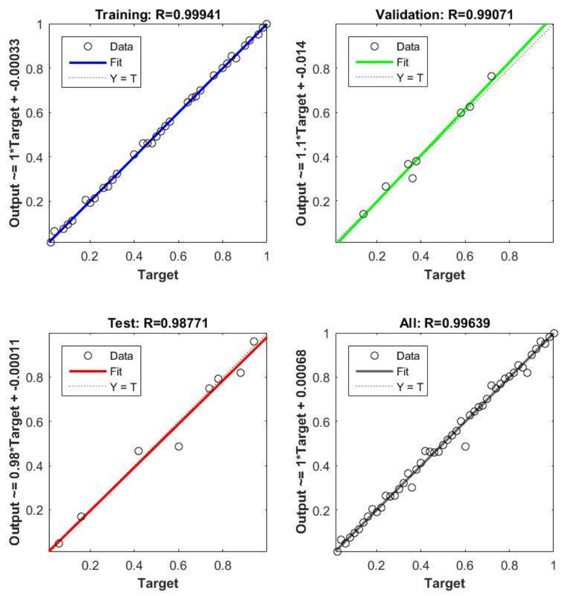

Figure 18: Regression plot for 29 hidden neurons

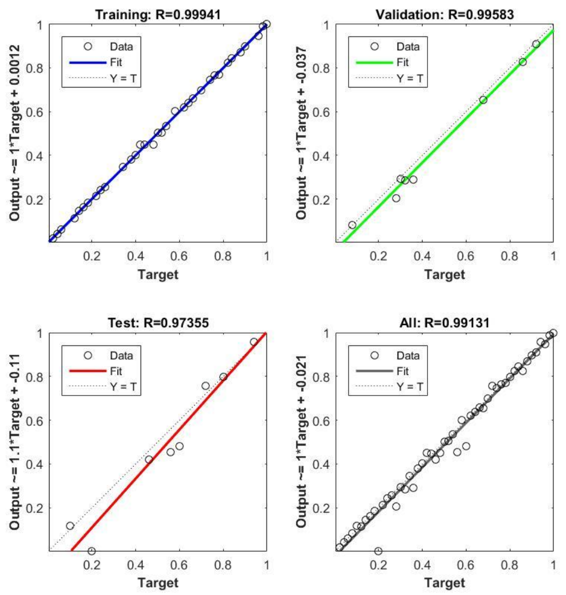

Figure 19: Regression plot for 30 hidden neurons

V. CONCLUSION

To conclude, hidden neuron 29 have close linear relationship between the outputs and targets since the dotted lines are align and the data distribution nicely arranged on the line. Compared to hidden neuron 30, the dotted lines are far from the coloured line. This shows that hidden neuron 30 is not suitable to be used since the output and target does not have any near relationship. To summarize everything, between hidden neuron 29 and 30, the best number of hidden neuron should be 29 due to no overfitting will occur compared to hidden neuron 30. Hidden neuron 29 should also be selected because of near relationship between the outputs and target. The highly suitable number of neuron for 50 data sample and to solve the question mark in figure 2 recommended that hidden neuron 29 to be selected.

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