Validation and Optimization of Experimental Data for Integrated Bamboo Processing Machine

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Abstract: In this research work experimentation on integrated bamboo processing machine for splitting and slicing of bamboo has been carried out. This paper presents the experimental investigation of some parameters of integrated bamboo processing machine. In this research paper simulation of experimental data using artificial neural network is carried out. An attempt of minimum-maximum principle has been made to optimize by range bound process for maximizing production rate of integrated bamboo processing machine.

Key Words: Investigation, Bamboo, Splitting, slicing, experimentation, ANN, optimization.

1.0 INTRODUCTION

Initial process includes Splitting, External and Internal Knot Removing, Slicing, Bamboo sticking making, Stick length setting, Stick Polishing. The initial processes carried out on a bamboo to make it as a useful product is called as bamboo processing. Bamboo and bamboo splits are used as the fencing material and for making various types of tool handles, ladders and scaffolding. Splits as well as slivers are used to make a wide range of products such as baskets, the core of incense-sticks, kites and toys, flutes and a large number of handicraft items. Traditionally the bamboo is processed in different steps and for each step a different machine is required. The main aim is to develop an integrated bamboo processing machine to reduce the number of steps and also to reduce the number of machines required to complete the desired work. So an integrated bamboo processing machine is fabricated which can perform splitting and slicing on a single machine.

2.0 EXPERIMENTAL SETUP

Traditionally bamboo slicing is done manually, or by using a manually operated machine, there was always a need of machine which will gives slices of bamboo without splitting operation. Integrated bamboo processing machine reduces the cost as well as time for processing bamboo in to slices. In this research work dependent and independent variables are identified then experimental data is collected.

Figure 1: Integrated Bamboo Processing Machine

3.0 EXPERIMENTAL INVESTIGATION

The data of Bamboo processing activity is not known to the professionals involved in this type of activity. Hence, formulating the quantitative relationship based on logic is not possible because of presence of human. On account of no possibility of formulation of theoretical logic based model, the only alternative is of formulating experimental data based model. Hence, it is proposed to formulate such model in the present investigation.

The approach adopted for formulating generalized experimental data based model suggested by Hilbert Schenck [7] are stepwise indicated below.

1. Identification of independent and dependent variables or quantities.

2. Reduction of independent variables adopting dimensional analysis.

3. Test planning comprising of determination of test envelope, test points, test sequence and experimental plan.

4. Physical design of experimental study set up.

5. Calibration of instrument.

6. Measurement of experimental data.

The first four steps mentioned above constitute design of experimental study setup. The seventh step constitutes of model formulation whereas eighth and ninth steps are respectively optimization and validation of model. The last step is ANN simulation of model.

The resulting model is an approximate generalized one because as said earlier all independent variables are varied. Identification of dependent and independent variables of the phenomenon is to be done based on known qualitative physics phenomenon. If the system involves large number of independent variables, the experimentation becomes tedious [56], time consuming and costly. By reducing dimensional equation for the phenomenon, one can reduce the number of independent variables. The exact mathematical form of this equation will be the targeted model.

4.0 IDENTIFICATION OF VARIABLES

The parameters which affect the production rate, quality and efficiency of machine are selected are tabulated in the below table 1.

Sr. No.	Variable	Types of Variable	Symbol	Dimensions
1.	Tool Hardness	Independent	H_T	-
2.	Relief Angle	Independent	Ø	-
3.	Condition of Bamboo	Independent	B_T	-
4.	Rake Angle	Independent	α	-
5.	Outer Diameter of bamboo	Independent	Do	L
6.	Inner Diameter of bamboo	Independent	Di	L
7.	Force	Independent	F	MLT^{-2}
8.	Velocity	Independent	Vp	LT^{-1}
9.	Input Energy	Independent	I_E	ML^2T^{-2}
10.	Work Done	Independent	W_d	ML^2T^{-2}
11.	Production Rate	Dependent	P_R	T^{-1}
12.	Quality	Dependent	Q	-
13.	Efficiency	Dependent	η	-

Table 1: Parameters affecting bamboo processing

5.0 TABULATION OF DATA

The collected data from the experimentation is tabulated in a proper manner so that it can be interpreted properly and its analysis can be done.

Input Variable											Output Variable		
Sr. No.	**Tool Hardness, H_T (BHN)**	**Relief Angle, ø**	**Condition of Bamboo, B_T**	**Rake Angle, α**	**Outer diameter of Bamboo, do (mm)**	**Inner diameter of Bamboo, di (mm)**	**Force, F (N)**	**Velocity, Vp (m/sec)**	**Input Energy (KJ)**	**Work Done (KJ)**	**Production Rate (No. of Slice/sec.)**	**Quality (degree)**	**Efficiency, (%)**
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Y_1	Y_2	Y_3
1	260	25	2	0	50	30	122.63	0.53	0.197	0.176	2.21	160	89.35
2	260	25	2	0	53	21	147.15	0.54	0.259	0.226	1.49	165	87.05
3	260	25	2	0	52	25	141.26	0.56	0.238	0.212	1.56	155	89.18
4	260	25	2	0	45	27	117.72	0.54	0.174	0.149	1.55	155	85.91
5	260	25	2	0	45	0	153.04	0.56	0.224	0.194	0.97	170	86.42
6	260	25	2	0	43	0	152.06	0.51	0.207	0.182	0.88	180	87.99
7	260	25	2	0	51	0	159.90	0.56	0.266	0.235	0.96	180	88.12
8	260	25	2	0	53	0	163.83	0.54	0.282	0.251	0.94	180	89.02
9	260	25	1	0	51	30	126.55	0.56	0.212	0.186	1.70	140	87.44
10	260	25	1	0	53	21	147.15	0.56	0.259	0.226	1.49	145	87.05

Table 2: Experimental data (sample readings)

6.0 ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural network is a type of mathematical function which replicates the functioning of human brain. The data is abstracted, analyzed and purified according to the logic of neurons in human brain. The data passes through various artificial layers and ultimately a simulated and improved model is obtained.

The ANN simulation is carried out for the experimental data to validate the model for large number of readings [32]. The simulation also improves the model which is obtained by multiple linear regression model. The simulated model ensures more accurate prediction of values as compared to previous model.

6.1 SIMULATION BY USING MATLAB

As sampling is the basis of the hypothesis carried out for the study of the operation based on the experimental data. There are always controversy about the accuracy and validity of result in actual condition. As the hypothesis includes limited number of observations and readings, there are chances and a question that whether this hypothesis works for infinite and large number over a period of time and occurrences. So, by simulating the readings under aforesaid conditions and distribution on Artificial Neural Network ANN on MATLAB software developed by Math Works Ltd. with the help of Neural Network tool in MATLAB, the simulation for 1296 readings is carried out on artificial neurons.

6.2 Production Rate (Y_1)

ANN is used for validating the input data and output data (Y_1).

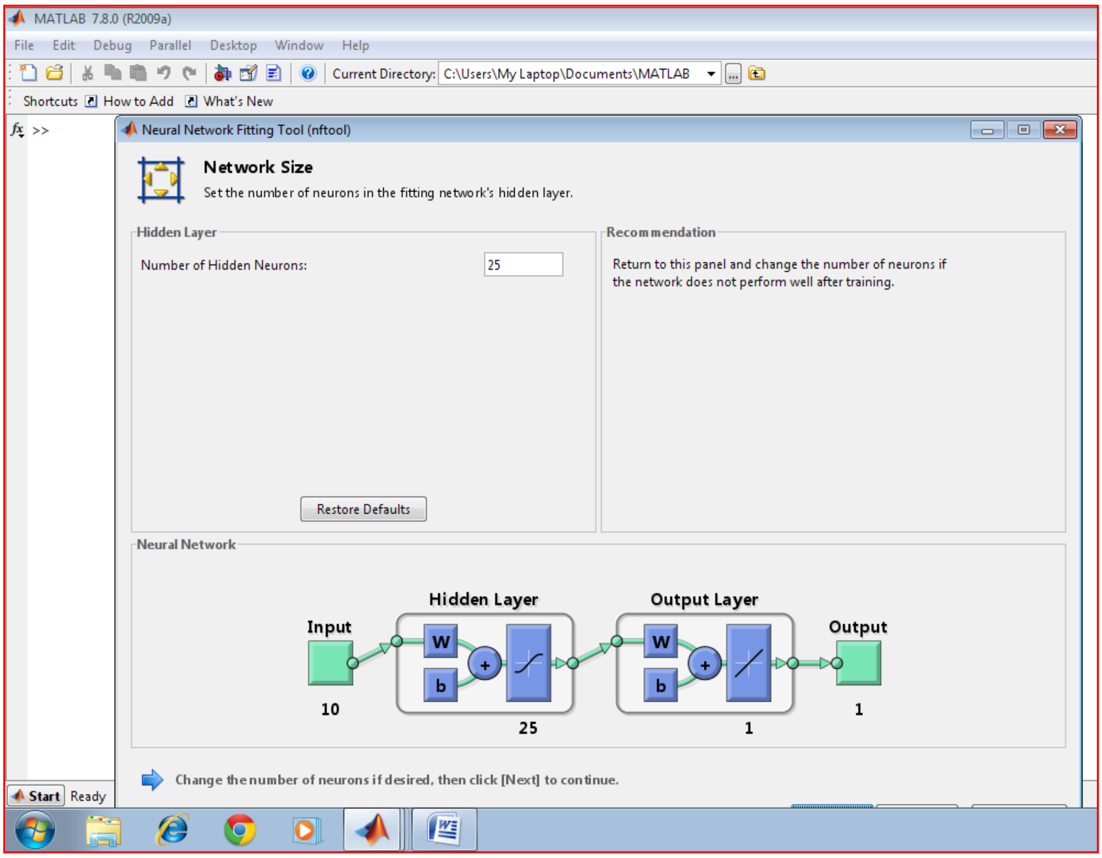

Fig. 7.4 Network size with 25 neurons hidden factor

Figure 7.4 shows that ready to create a network and train it. It is tried for a two layer network, with sig-mod transfer function in hidden layer and a linear function in an output layer. This is mostly useful for function approximation (or regression problems). As an initial guess, here 25 hidden neurons in hidden layers are used. The network has 10 inputs and 1 output.

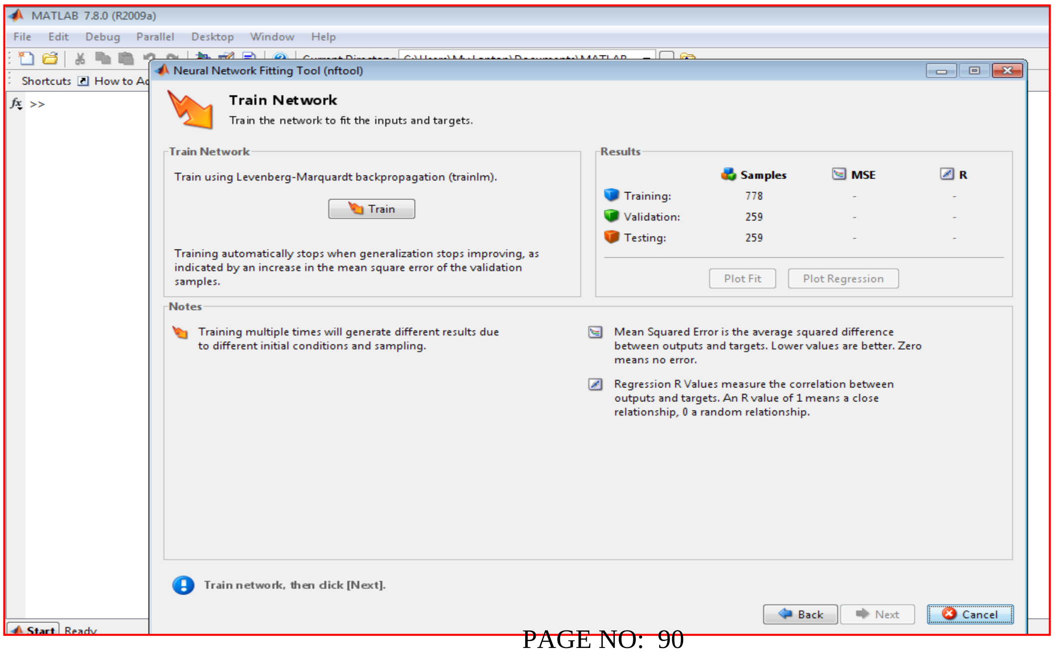

Fig. 7.5 Training of networks for data sampling

Here Leven berg – Marquartt algorithm for training is used as shown in figure 7.5. The network is trained for 20 iterations only and three targets, training, validations and testing of data samples.

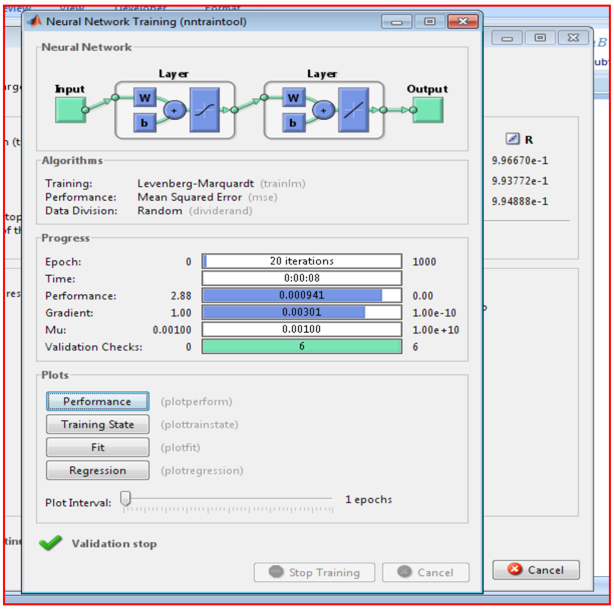

Fig 7.6 Network train for data validation

Network train for data validations as shown in figure 7.6 results in progress of 20 epochs, time required training the network and various performances of parameters. It clearly shows the size validation checks.

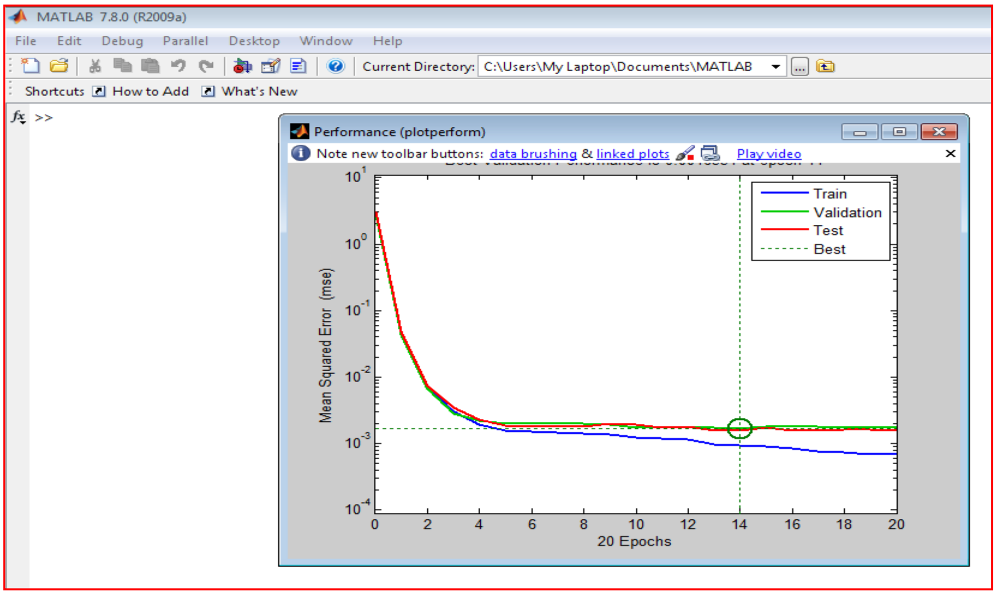

Fig. 7.7 Performance of the learning algorithm train over 20 epoch

The training stops after 20 iterations because validations error increased as shown in figure 7.7. It is useful diagnostic tool to plot the training, validations and test error to check the progress of training. The results are shown in figure 7.7. The test error and validation set error have similar characteristics and does not appear that any significant over fitting has occurred. The goal is to design the production rate and having minimum errors. The best validation performance is 10^{-3} at 14 epochs.

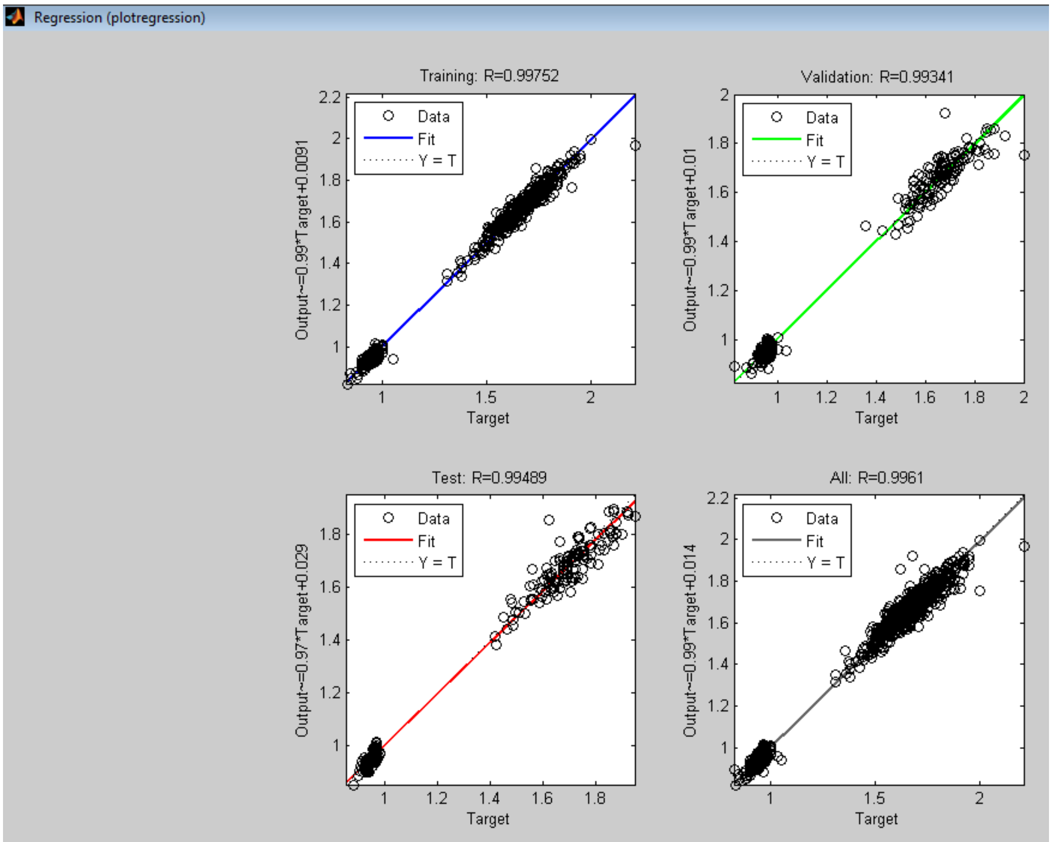

Fig. 7.8 Linear regression performance fitness curve

The next step is to perform sum analysis of the network response. Put the entire data set through the network (training, validation and test) as shown in figure 7.8, and perform a linear regression between network outputs and the corresponding targets. First calculate the network outputs, in this case there are single outputs and three targets. As shown the result of first three figures, the regression values around 0.9 to achieve the targets.

7.3.3 Quality (Y_2)

ANN is used for validating the input data and output data (Y_2).

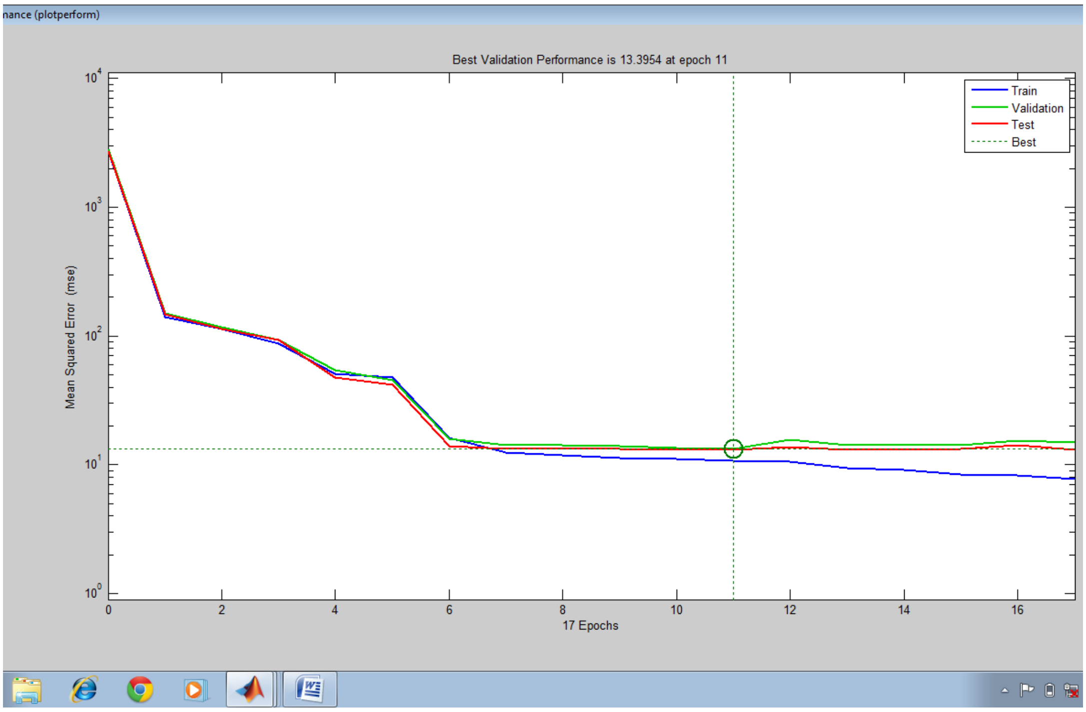

Fig. 7.9 Performance of the learning algorithm train over 17 epoch

The training stops after 17 iterations because validations error increased as shown in figure 7.9. It is useful diagnostic tool to plot the training, validations and test error to check the progress of training. The results are shown in figure 7.9. The test error and validation set error have similar characteristics and does not appear that any significant over fitting has occurred. The goal is to design the quality and having minimum errors. The best validation performance is 10^1 at 11 epochs.

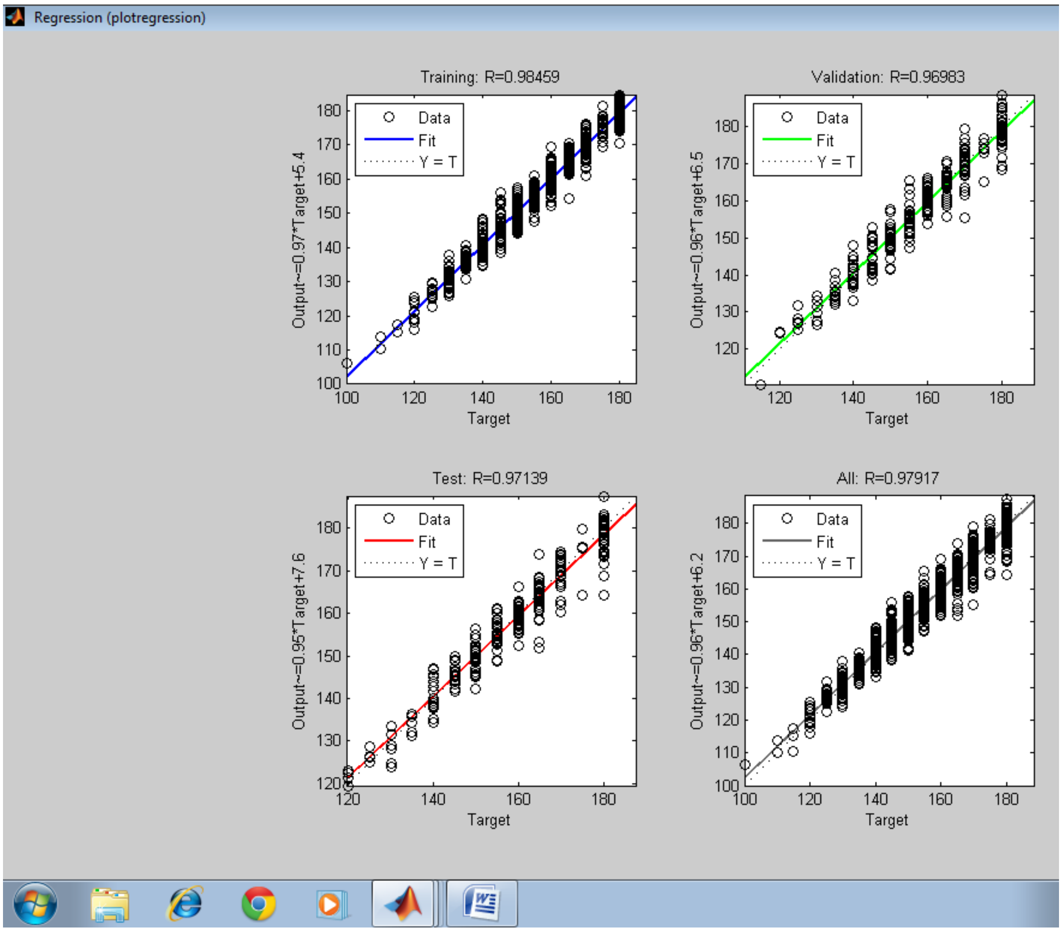

Fig. 7.10 Linear regression performance fitness curve

The next step is to perform sum analysis of the network response. Put the entire data set through the network (training, validation and test) as shown in figure 7.10, and perform a linear regression between network outputs and the corresponding targets. First calculate the network outputs, in this case there are single outputs and three targets. As shown the result of first three figures, the regression values around 0.9 to achieve the targets.

7.3.4 Efficiency (Y_4)

ANN is used for validating the input data and output data (Y_4).

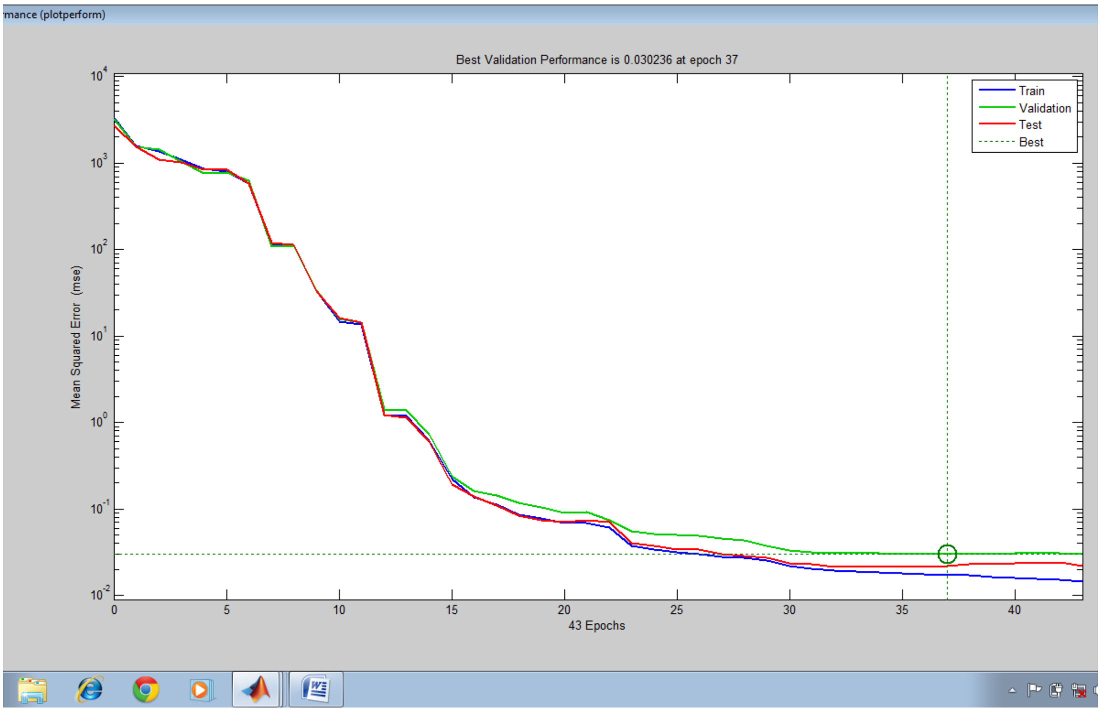

Fig. 7.13 Performance of the learning algorithm train over 43 epoch

The training stops after 43 iterations because validations error increased as shown in figure 7.13. It is useful diagnostic tool to plot the training, validations and test error to check the progress of training. The results are shown in figure 7.13. The test error and validation set error have similar characteristics and does not appear that any significant over fitting has occurred. The goal is to design the efficiency and having minimum errors. The best validation performance is $10^{-1.5}$ at 37 epochs.

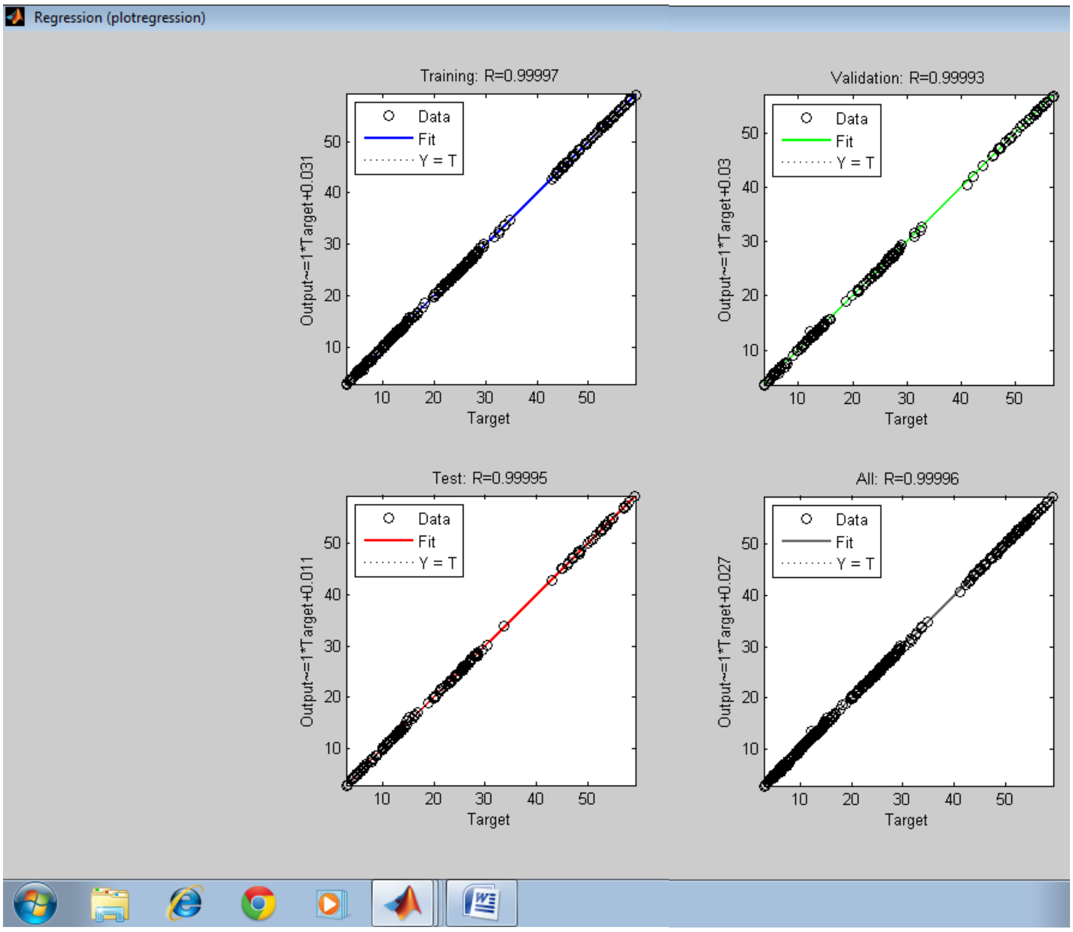

Fig. 7.14 Linear regression performance fitness curve

The next step is to perform sum analysis of the network response. Put the entire data set through the network (training, validation and test) as shown in figure 7.14, and perform a linear regression between network outputs and the corresponding targets. First calculate the network outputs, in this case there are single outputs and three targets. As shown the result of first three figures, the regression values around 0.9 to achieve the targets.

8.1 OPTIMIZATION

The manual optimization is performed by using the Range Bound Optimization [55] method of operations research. The optimization is done for maximum production rate and minimum power consumption.

8.1.1 Maximization of Production Rate

In order to obtain maximum production rate the objective function of production rate is used.

$$\text{Max } Y_1 = 1.154651 - 6.2E\text{-}05X_1 + 0.000347X_2 - 0.00445X_3 - 0.00196X_4 - 0.02525X_5 + 0.028952X_6 - 0.00284X_7 + 1.165921X_8 + 0.27392X_9 + 3.523711X_{10}$$

Subjected to constraints of different variables present in table 2,

$210 \le X_1 \le 269$

$15 \le X_2 \le 25$

$1 \le X_3 \le 2$

$0 \le X_4 \le 4$

$40 \le X_5 \le 56$

$0 \le X_6 \le 36$

$98.10 \le X_7 \le 168.73$

$0.48 \le X_8 \le 0.58$

$0.127 \le X_9 \le 0.408$

$0.114 \le X_{10} \le 0.276$

For obtaining maximum production rate, the input variables with negative sign in model are chosen with lowest value and positive sign in model are chosen with highest value.

$X_1 = 210$

$X_2 = 25$

$X_3 = 1$

$X_4 = 0$

$X_5 = 40$

$X_6 = 36$

$X_7 = 98.10$

$X_8 = 0.58$

$X_9 = 0.408$

$X_{10} = 0.276$

Substituting above optimal values, maximum production rate is given by,

Y_1 = 1.154651 - 6.2E-05×210 + 0.000347×25 - 0.00445×1 - 0.00196×0 - 0.02525×40 + 0.028952×36 - 0.00284×98.10 + 1.165921×0.58 + 0.27392×0.408X_9 + 3.523711×0.276

The maximum production rate is,

Y_1 = 2.66 slices/sec.

7.0 Conclusion

Mathematical model is developed considering multivariable linear regression for various parameters like production rate, quality and efficiency.

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