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APPLICATION OF LEVENBERG-MARQUARDT ALGORITHM (LMA) FOR THREE PHASE ELECTROCHEMICAL REACTOR DATA PROCESSING

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Abstract
The present work is mainly aimed to illustrate an alternative approach of correlating data wherein the Chemical engineers struggle to handle such data rich experimental systems. One such example is a three phase electrochemical reactor. Such a reactor is a true example of a very complex chemical engineering problem. It involves nearly fifteen parameters. Because of the complexity of this problem, fitting the data into a regression equation by conventional statistical techniques usually yield unsatisfactory results. Therefore, in this work, machine learning techniques such as neural networks have been used to undertake such a task using Levenberg-Marquardt Algorithm(LMA).
Keywords
Three phase fluidized bed, regression, Levenberg-Marquardt Algorithm, neural networks.

1. Introduction

Three phase electrochemical reactors find most important applications in chemical processing, bioprocessing and mineral processing industries. They have potential applications in metal extraction, metal winning, electrodeposition etc. These reactors usually carryout transfer of ions from an electrolyte on to the surface of an electrode under an applied emf. The addition of inert gas and solid phases enhances the rate of transfer of ions. In some systems, the liquid would be flowing in the reaction vessel, and internal elements known as turbulent promoters are employed in order to modify the passage geometry so that much enhanced transfer rates are realized. Such a phenomenon depends on a number of variables such as liquid velocity, gas velocity, liquid viscosity, liquid density, gas density, gas viscosity, geometry of the solid particles, wettability of these particles, solid fraction in the system, geometry of the internal element, temperature and so on. The essential parameter that governs the behavior of the transfer process is the mass transfer coefficient which in turn depends on the above mentioned variables.

In such systems usually, there will be around ten to fifteen independent parameters influencing the process. In the present case, there are ten independent variables that exercise their effect on the dependent variable, which is mass transfer coefficient. The dependent variable is as Y and the independent variables are denoted as X1, X2 and so on upto X10 in the present work. Chemical engineers usually apply non-linear least square regression technique to correlate these data. The data were taken from Ramesh et al[1,2] and the said correlation was reported to have an average deviation of 7.5 percent and a standard deviation of 9.9 percent.

Because of the complexity of this problem, fitting the data into a regression equation by conventional statistical techniques usually yield unsatisfactory results. Therefore, in this work, machine learning techniques such as neural networks have been used to undertake such a task using Levenberg-Marquardt Algorithm(LMA). This algorithm has been chosen because of its superiority in handling the regression type situations [3,4].

2. Methodology

Experimental data were available were taken from Ramesh[2]. More than a thousand experimental runs were conducted, and those data essentially consisted of the of the data set for the present task. A portion of that data set has been employed for training the machine using the LMA. Fig.1 presents the training diagram for the present work.

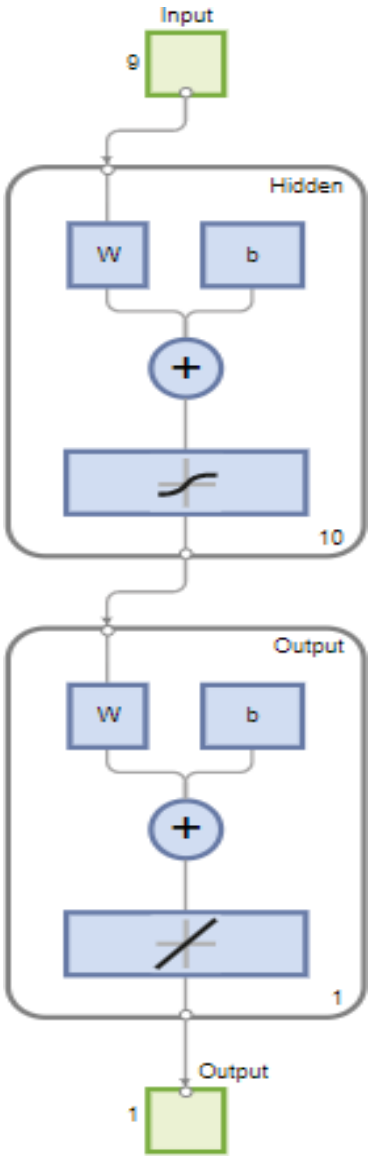

Fig.1. Training performance

3. Results and discussion

Fig.2 comprises of four graphs: the first one corresponds to fitting the training set and the second one corresponds to validation of sample data. The third one is again pertaining to training set where as the fourth one is on all data.

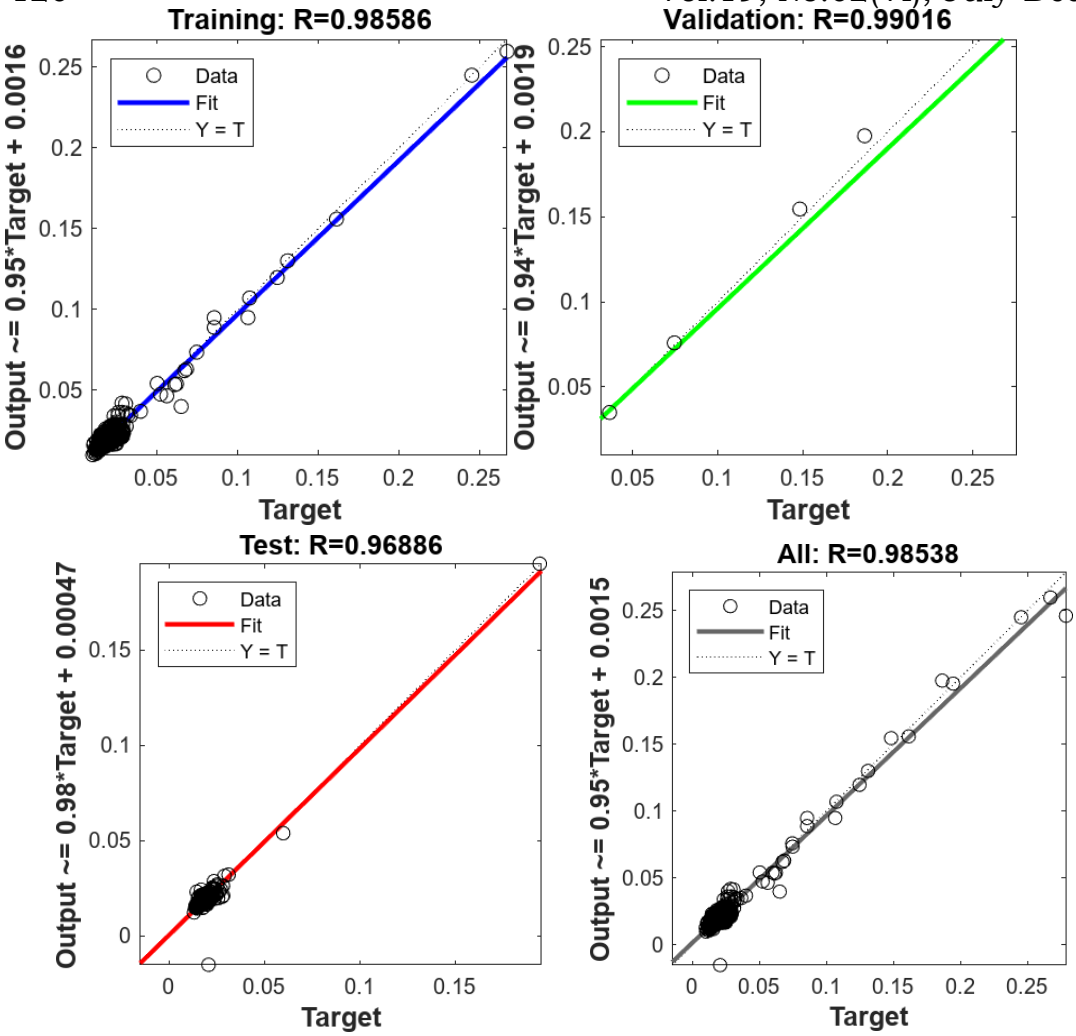

Fig.2. Training and validation

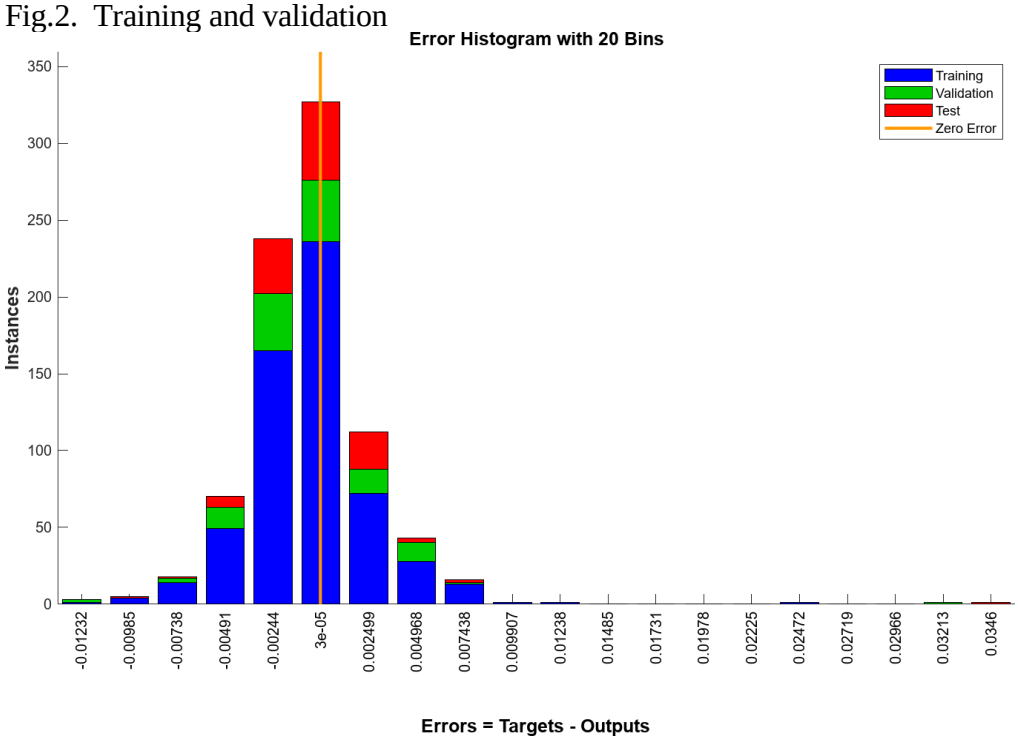

Fig.3. Histogram

Fig.3 shows the histogram of errors with distribution of errors. These data are spread over twenty bins. Fig.4 represents the validation performance and the best is observed at 21st epoch where the total number of epochs was 27. The performance is examined using mean square error. It was found that the best performance was in the 21st epoch as is revealed from the plots of Fig.4. Figure 5 shows the gradient plots pertaining to the present study at 27th epoch.

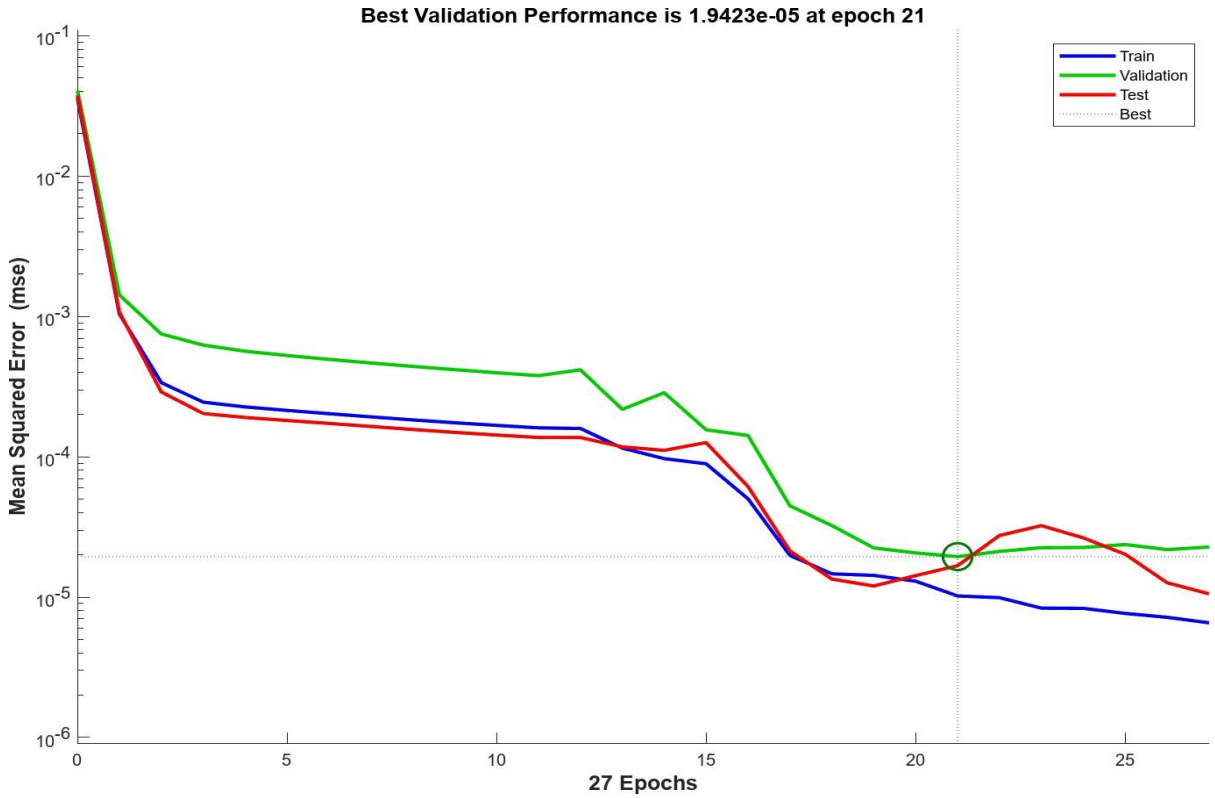

Fig.4. Best performance

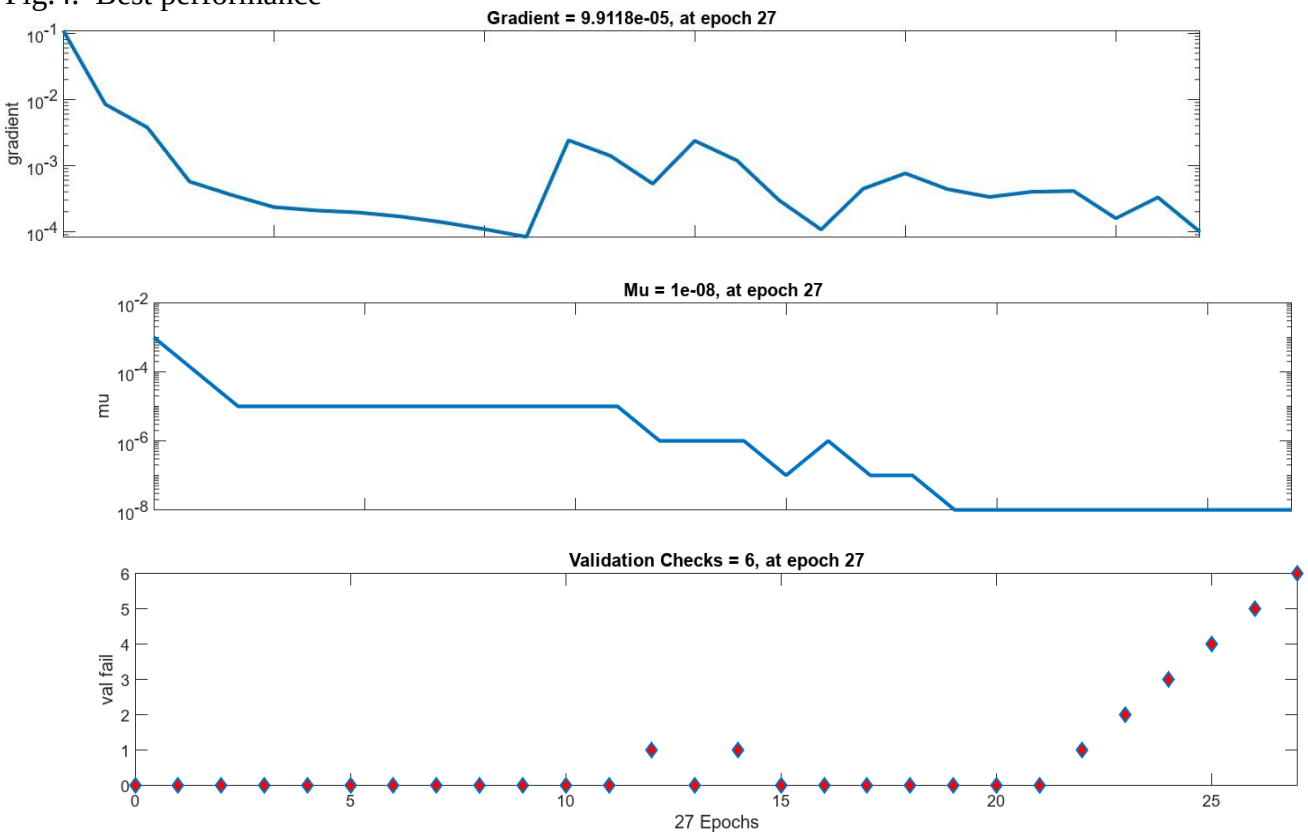

Fig.5. Gradient plots

The screen shot shown in Fig.6 gives a glance of the neural network response.

Train a neural network to map predictors to continuous responses.

Data

Predictors: input1 - [837x9 double]

Responses: output - [837x1 double]

input1: double array of 837 observations with 9 features.

output: double array of 837 observations with 1 features.

Algorithm

Data division: Random

Training algorithm: Levenberg-Marquardt

Performance: Mean squared error

Training Results

Training start time: 18-Jan-2024 15:47:33

Layer size: 10

	Observations	MSE	R
Training	585	1.0194e-05	0.9859
Validation	126	1.9423e-05	0.9902
Test	126	1.6733e-05	0.9689

Fig.6. Screen shot

Fig. 7 gives a view of the computer screen while the program is under processing.

Training Progress

Unit	Initial Value	Stopped Value	Target Value
Epoch	0	27	1000
Elapsed Time	-	00:00:00	-
Performance	0.0358	6.56e-06	0
Gradient	0.11	9.91e-05	1e-07
Mu	0.001	1e-08	1e+10
Validation Checks	0	6	6

Fig.7. Screen shot

4. Conclusions

In this work, experimental multivariate data pertaining to three phase electrochemical reactor was considered. Such data were not easily amenable for regression analysis using conventional statistical techniques. When subjected to neural networks approach, these data were better handled by Levenberg-Marquardt Algorithm by machine learning. The data were found to be fit excellently in this way. The results were very much satisfactory.

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