Analysis of Methods used to Investigate Engineering Measured Experimental Data

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Abstract: The results of many measured engineering experiments require an analysis and study process in order to determine the relationships between the independent variables and the dependent variables, and accordingly, the accuracy of the values of the adopted variables becomes an urgent necessity. In this research paper we will take a sample of laboratory data and find the necessary relationships between the different variables, and then we will present some models of artificial neural networks to find solutions to these relationships in order to make the necessary comparisons to reach some of the necessary recommendations regarding the handling of measured data.

Keywords: Experimental data, regression, ANN, CFANN, FFANN, EANN, MSE.

1- Introduction

Many experiments and studies are carried out in many laboratories and engineering workshops, the results of which are a set of measurements, which constitute values for a set of values of independent variables and values of a set of approved variables. The values obtained in the laboratory as a result of the measurement process may be large, which creates difficulties in linking these values with each other to find the necessary relationships that can be used with high accuracy to find the values of the variables adopted by knowing the values of the independent variables.

To obtain the relationship between the independent and dependent variables in the measured data we can use regression model [1], [2], this model can be easily solved using matlab, figure 1 shows an obtained experimentally results with 4 independent variables (x1, x2, x3, and x4 and dependent variable y), the regressed out can be obtained applying the following code:
The mean square error between the measured output and the calculated one can calculate using equation 1:

\[ MSE = \text{average}((\text{target} - \text{calculated})^2) \]  

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From figure 1 we can see that solving the regression model for the experimental data provide a very small error which can be accepted, in the following parts we will check whether artificial neural networks [19], [20], [21] gives better results.
2- Artificial Neural Networks

Artificial neural network (ANN) [8], [9] is a powerful mathematical model which can be used to solve various problems such as digital images [3], [4], [5] classification, speech recognition [6], [7], function approximation and many other problems.

ANN is asset of fully connected neurons [10], [11] which are arranged in one or more layers [12], each neuron is a computational cell which as shown in figure 2 performs summation of the products of the weights and inputs [13], then according to the selected activation function calculates the cell output[14].

![Neuron operations](image)

Figure 2: Neuron operations

In order to get ANN desired output it must be trained [15], [16], each training cycle is done in two ways as shown in figure 3: the feedforward phase in which the neurons outputs are calculated, starting from the input layer, and a backward phase to find the error, and according to obtained error adjust the weights [17], [18]. Figures 4 and 5 show an example of one training cycle calculation.

![Training cycle](image)

Figure 3: Training cycle
ANN can be used in different variations, mostly and widely used are feedforward (FFANN), cascade-forward (CANN and Elman (EANN) neural networks [10], [11]. In FFANN (see figure 6) the neurons are organized in layer and each neuron is fully connected to neurons in the previous layer.
In CFANN the inputs weights are connected to the other layers as shown in figure 7.

![CFANN Diagram](image1)

Figure 7: CFANN

In EANN the outputs of the hidden layer feed the input layer and form a context delay nodes.

![EANN Diagram](image2)

Figure 8: EANN

3- Implementation and Experimental Results

To use ANN as a computation tool we have to follow the following steps [8], [9]:

- Select the input dataset.
- Normalize the dataset if needed.
- Select the target output (outputs).
- Create and build ANN architecture by defining the number of layers, defining the number of neurons in each layer, defining the activation function for each layer [10], [11], selecting ANN type.
- Setting all the weights to zeros by initializing the net.
- Setting the number of training cycles.
- Setting the error to zero.
- Training the net.
- Run the net.
- Checking the error and the calculated outputs, if acceptable save ANN to be used later as a computational tool, else modify the architecture of ANN by adding extra hidden layer, or changing the activation function, or by increasing the number of training cycles and train ANN again.
The following matlab code was written and it will be used for results analysis:

```matlab
data={9.5013 1.0420 20.9530 7.4483 2.6723
    2.3114 6.3516 0.4910 13.4965 47.9811
    8.0684 14.6370 17.0319 12.3244 42.4357
    4.8590 0.1775 9.4870 9.6737 16.0143
    8.9130 2.5000 20.7949 12.2696 17.6822
    7.6210 3.6498 12.5703 9.9034 24.1682
    4.5647 3.5770 17.7368 5.1296 -3.2457
    0.1850 10.8683 10.7223 4.3459 11.6848
    8.2141 4.8994 7.6154 5.1179 22.8606
    4.4470 3.5787 4.7413 8.0112 25.0954
    6.1543 0.2749 4.8356 10.9067 29.5693
    7.9194 13.4421 17.0556 4.6394 22.9603
    9.2181 8.0117 7.5691 12.5774 51.3082
    7.3821 16.7727 13.5418 8.5211 44.6495
    1.7627 8.3879 3.7718 5.5562 24.2679
    4.0571 7.5357 17.4475 10.5411 18.7305
    9.3547 15.2320 9.4593 8.1986 51.1746
    9.1690 9.4527 21.5003 6.6732 15.6608
    4.1027 3.6477 21.3414 10.4185 4.8485
    8.9365 12.0985 14.8391 9.3197 38.49051
};
data=data(:,:)/20;

targt={2.6723
    47.9811
    42.4357
    16.0143
    17.6822
    24.1602
    -3.2457
    11.6848
    22.8606
    25.0954
    29.5693
    22.9603
    51.3082
    44.6495
    24.2679
    18.7305
    51.1746
    15.6608
    4.8485
    38.49051
};
The above code was implemented varying ANN type, by replacing newcf to newff to use FFANN and to newelm to use EANN. Figure 9 shows the obtained results using CFANN; figure 10 shows the obtained results using CFANN, while figure 11 shows the obtained results using EANN.

![Image](image.png)

Figure 9: Obtained results using CFANN
From the obtained results we can see that using CFANN gave the best results by minimizing the value of MSE, and the tools sorted according to the accuracy will be as follows:

- CFANN
- Regression method
- FFANN
- EANN

And here we can highly recommend CFANN to be used as a computational tool to find the relationship between any measured experimental data.
Conclusion
A measured experimental data was collected and the relationship between the independent variables and the dependent ones was obtained using regression model. The results of the regression model were good and the can be acceptable.
An experiments were done to see whether we can enhance the accuracy of the regression model. Different computational tools using ANN were built and tested. It was shown that using cascade-forward ANN as a computational tool gave an excellent enhancement, thus it can be highly recommended.

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