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THE USE OF BACK-PROPAGATION ALGORITHM IN THE ESTIMATION OF FIRM PERFORMANCE

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ABSTRACT
Recently, many researches have been made to find the impact of human resources on firm performance. Many of these studies are conducted on the basis of statistical approaches and find the correlation between the human resource management (HRM) measures and firm performance. In this paper, the main aim is to estimate the firm performance through the use of nonlinear model. One method which is used for this nonlinear approach is Artificial Neural Networks (ANN). Artificial Neural Networks are computing systems made up of a number of simple highly interconnected signal or information processing units that are called as artificial neurons. In this work, we used one of the ANN approaches which is called as back-propagation algorithm. In order to collect data, a questionnaire is structured that contains questions related with human resource management and firm performance measures. The data are collected mainly from the manufacturing companies operating in Turkey. Using the data collected, the model is checked whether it is capable of forming the relationship between the HRM input variables and firm performance output variables or not. The experimental results show that through the use of this algorithm, the relationship between the input and output variables can be constructed and moreover, the model can be used as an estimator of firm performance for the companies that are not used in the training of the model.

Keywords: Human Resource, Back-propagation, Firm Performance

GERİYE YAYILMA ALGORİTMASI KULLANILARAK FİRMA PERFORMANSININ TAHMİN EDİLMESİ

ÖZET
Son zamanlarda, insan kaynaklarının firma performansı üzerindeki etkisini incelemek için birçok araştırma yapılmıştır. İstatistiksel yöntemler temel alınarak yapılan bu çalışmalar sonucunda, insan kaynakları yönetimi göstergeleri ile firma performansı arasında ilişki olduğu tespit edilmiştir. Bu çalışmanın esas amacı, doğrusal olmayan ve geriye yayılma algoritması olarak da bilinen model kullanılarak firma performansını tahmin etmektir. Bu amaçla kullanılan, doğrusal olmayan yöntemlerden bir tanesi de yapay sinir ağlarıdır. Yapay sinir ağları, yapay nöron olarak adlandırılan birimlerin birbirine bağlanarak sinyal ve bilgi işleme amacıyla kullanılan hesaplama sistemleridir. Bu çalışmada, geriye yayılma algoritması olarak adlandırılan yapay sinir ağları yaklaşımlarından birisi kullanılmıştır. Veri toplama amacıyla, insan kaynakları yönetimi performans göstergeleri ve firma performans göstergeleri ile ilgili sorulardan oluşan bir anket tasarlanmıştır. Veriler Türkiye'de üretim sektöründe faaliyet gösteren firmalardan toplanmıştır. Toplanan veriler kullanılarak insan kaynakları yönetimi performans göstergeleri ile firma performansı göstergeleri arasında bu model yardımı ile bir ilişki kurulup kurulamayacağı test edilmiştir. Deneysel sonuçlar, bu algoritma kullanılarak girdi ve çıktı değişkenleri arasında ilişki kurulabileceğini göstermiştir. Buna ek olarak, modelin eğitilmesinde kullanılmayan firmalar için de bu algoritmanın firma performasının tahmini için kullanılabileceği sonucu elde edilmiştir.

Anahtar Kelimeler: İnsan Kaynakları, Geriye Yayılma Algoritması, Firma Performansı

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1. INTRODUCTION

Nowadays, firms are operating in a rapidly changing market and environment. To be competetive with its competitors in a market is not enough for the companies. Firms should generate competitive advantage and more importantly, they have to sustain this advantage. Human resources which a company owns can play an important role for the companies in order to sustain a competitive advantage.

Human Resource Management (HRM) is a formal structure within an organization responsible for all the decisions, strategies, factors, principles, operations, practices, functions, activities and methods related to the management of people. All of these factors have a positive effect on business results, because Human Resources are key assets. HRM practices have a significant impact on firm performance.

The effects of HRM systems on firm performance are analyzed statistically by many researchers in the literature (Ağdelen, 2003; Becker and Huselid, 1998; Huselid, 1995). Recently, significant research attention has been devoted to examining the relationship between HRM practices and firm performance (Christopher and Ken, 2006; et al, 2005; Kent, 2007; Mabesh, 2006; Shay, 2006). Almost all of the studies about the impact of the HRM performance on firm performance attempted to estimate the statistical relationship between a firm's HRM and firm performance (Chandler and McEvoy, 2000; Delaney and Huselid, 1996; Fey and Björkman, 2000).

However there are very few nonlinear approaches in literature for finding the relationship between Human Resource Management (HRM) and firm performance (Sexton and Mcmurtey, 2005; Haydar and Ağdelen, 2006). Artificial neural networks is one of the approaches that can establish any nonlinear relation and they are widely used in many fields in the literature (Huang and Jaw, 2004; Saraç, et al, 2006; Akaya and Gökçen, 2006). An ANN consists of a large number of simple processing elements that are interconnected and layered (Li, 1994). In this paper, our aim is to find whether a relation can be obtained between the input variables and the output variables through the use of back-propagation multilayer perceptron (BPMLP) algorithm or not.

2. MODEL DESCRIPTION

Artificial Neural Networks are systems that are deliberately constructed to make use of some organizational principles resembling those of a human brain (Chin-Teng and George Lee, 1996). In its most general form, a neural network is a machine that is designed to model the way in which the brain performs a particular task or a function of interest (Simon, 1999). This model can be used in many different problem solutions including nonlinear modeling. Hence we decided to use one of the modeling techniques of ANN approach which is called as BPMLP in Human Resource Management.

The BPMLP algorithm is a type of supervised, error correction learning that calculates an error on the output layer and propagates that error backwards through the network to determine how each individual weight factor contributes to the output error. BPMLP model is shown in Figure 1.

In this paper, we used a BPMLP algorithm with 2 hidden layers that consist of N1 and N2 neurons respectively. The steepest-descent gradient approach used by the BPMLP to minimize the mean square error function (Cichoclar and Unbehaven, 1993) is defined as:

$$E_p = \frac{1}{2}\sum_{j=1}^{n}\left(d_{jp} - y_{jp}\right)^2 = \frac{1}{2}\sum_{j=1}^{n} e_{jp}^2 \qquad (1)$$

where, d_{jp} is the desired output signal of the jth output neuron for the pth example, n is the number of output neurons and y_{jp} is the actual output signal.

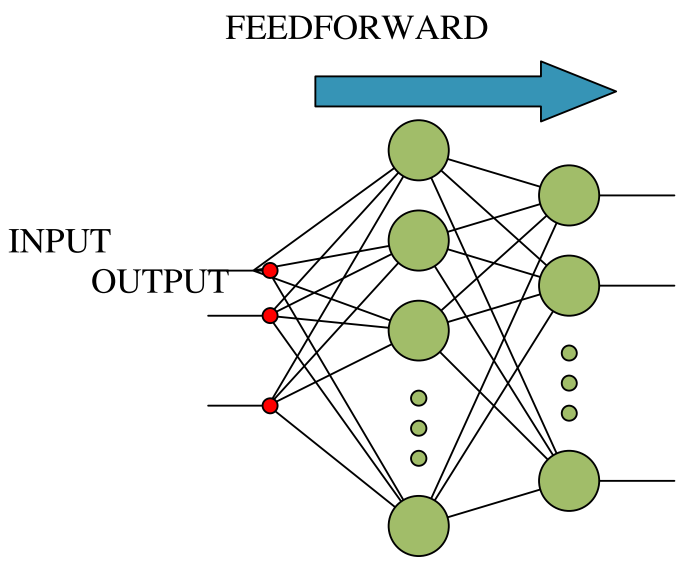


Figure 1. **Architecture of Backpropagation Multilayer Perceptron Model**

The total error function is defined as:

$$E_T = \sum_p E_p = \frac{1}{2}\sum_p \sum_j \left(d_{jp} - y_{jp}\right)^2 \qquad (2)$$

For each learning example, the synaptic weights w_{ij} are changed by an amount of

$$\Delta w_{ij} = -\eta \frac{\partial E_p}{\partial w_{ij}} \quad , \quad \eta > 0 \qquad (3)$$

The general formula for updating the weights are

$$\Delta w_{ij} = \eta \delta_j o_i \qquad (4)$$

where η is the learning rate , ∂_j is the local gradient of the hidden neuron j and o_i is the function signal at the output neuron i.

The data from the input neurons is propagated through the network via the interconnections such that every neuron in a layer is connected to every neuron in the adjacent layers. Each interconnection has associated with it a scalar weight, which acts to modify the strength of the signal passing through it. The neurons within the hidden layer perform two tasks: they sum the weighted inputs to the neuron and then pass the resulting summation through a nonlinear activation function.

The unipolar sigmoid activation function with its output in the range (0, 1) used in this study is as follows:

$$y_j = \varphi(u_j) = \frac{1}{1 + \exp(-\gamma_j u_j)} \qquad (5)$$

where, $\varphi(.)$ is the unipolar sigmoid activation function and u_j is defined as the weighted sum of inputs together with its bias value θ_j and is obtained using the formula

$$u_j = \sum_{i=1}^{n} w_{ji} x_i + \theta_j \qquad (6)$$

In the above equation a bias is included in order to shift the space of the nonlinearity.

In this study, the number of inputs to BPMLP is 12 and the number of outputs are 9. The three parameters, namely the learning parameter η, the number of neurons in hidden layer 1, N1, and the number of neurons in hidden layer 2, N2, should be selected in such a way that the total error is minimized. The software for the BPMLP model is written using a C program developed by authors and simulated by Pentium IV computer.

3. EXPERIMENTAL RESULTS

In this study, we have 2 main aims. The first aim is to establish a relation between the input variables and the output variables through the use of a nonlinear model called as back-propagation multilayer perceptron algorithm. The second aim is to see whether this model can be used as an estimator for the firm performance measures of some companies that are not used in the training of our model.

Questionnaire Design

A questionnaire consisting of 2 sections was structured for the purpose of analyzing the relationship between the human resource management and firm performance. The first section composed of 24 questions was structured to measure the human resource performance measures. Out of these 24 questions, 14 of them were used to measure perceptional human resource performance. For each of these questions two factors, namely importance and satisfaction levels were taken from the respondents. Both for importance and satisfaction levels, the 6 points likert type scale changing from 1 to 6 were used. 1 corresponds to very low importance/satisfaction and 6 correspond to very high importance /satisfaction. It is a common application to use the multiplication of importance and satisfaction levels as a numerical value for each perceptional question and the same procedure was used in determining the values of the these 14 variables. From these 14 perceptional human resource performance measures two components namely, IKPGFAK1 and IKPGFAK2 were obtained by using factor analyzing commonly used in multivariate statistics. The remaining 10 questions were structured to measure the objective human resource performance measures adapted from Delaney and Huselid (1996). So, as a total of 12 variables are used as an input and explained briefly in Table 1.

The second section of the questionnaire composed of 16 questions that aims to measure the firm performance. Out of these 16 questions, 9 of them were used to measure perceptional firm performance. The values of these measures were calculated using the same approach used for measuring the values of the perceptional human resource measures as it was mentioned above. From these 9 perceptional firm performance measures two components namely, FPGFAK1 and FPGFAK2 were obtained by using factor analyzing commonly used in multivariate statistics. The rest of the measures are the most commonly used financial firm performance measures in the literature (Huselid, 1995; Ağdelen 2003). As a total, 9 output variables are obtained and their brief explanations are given in Table 2.

The data that are used in this work are collected from 54 companies in Turkey by means of a questionnaire. These companies are selected from different sectors but mostly they are from the manufacturing sector.

For 54 companies in Turkey, the 21 variables are collected for two years. Hence there are, all together, 108 data set each consisting of these 21 variables. Among these 54 companies, 10 of them are randomly selected as testing data and the rest are used as training data. Hence there are 20 testing data set and 88 training data set.

Table 1. Input Variables Used in the Model

		Variable	Description
INPUT VARIABLES	1	IDO	Turnover Rate: The ratio of the number of employees who terminated for any reason in a year to average total number of employees
	2	DEV	Absence Rate: The ratio of the days lost for a year to the product of the average number of employees in a year and the days available for work
	3	KBIKM	Human Resource Expense per employee: The ratio of human resource expenses to average total number of employees in a year
	4	IKMBO	The ratio of human resource expenses to total personnel expenses
	5	IKMTMO	The ratio of human resource expenses to total operating expenses
	6	TPMTMO	The ratio of total personnel expenses to total operating expenses
	7	KBEGM	The ratio of training and development expenses to average total number of employees in a year
	8	EGITSAATM	The average training time as hour in a year per blue collar employee
	9	EGITSAATB	The average training time as hour in a year per white collar employee
	10	IKFI	Human Resource Index: An index which is calculated by using several human resources practices known as High Performance Work Systems in literature
	11	IKPGFAK1	First perceptional human resource performance measure calculated by using factor analizing method
	12	IKPGFAK2	Second perceptional human resource performance measure calculated by using factor analizing method

Table 2. Output Variables Used in the Model

OUTPUT VARIABLES	1	IV	Labor Productivity: The ratio of total sales to average total number of employees in a year
	2	KO	Profitability Ratio: The ratio of net profit to total sales in a year
	3	YGDO	Rate of return on investment: The ratio of net profit to total investment in a year
	4	VGDO	Rate of return on assets: The ratio of net profit in a year to total assets
	5	KBK	Profit per employee: The ratio of net profit to average total number of employees in a year
	6	SGDO	Rate of return on capital: The ratio of total sales in a year to stockholders equity
	7	TVO	The ratio of total assets to total personnel expenses
	8	FPGFAK1	First perceptional firm performance measure calculated by using factor analizing method
	9	FPGFAK2	Second perceptional firm performance measure calculated by using factor analizing method

From the 21 variables used in this study, 11 of them are normalized using logarithm. This is because these variables are statistically analyzed (Ağdelen, 2003) and the results show that they are log normal variables. The other 10 variables are normalized linearly. The normalization is performed in order to get rid of the great difference between the values of these variables. The formulas used to normalize the variables are given below;

1. IDO = IDO/20
2. DEV = DEV/10
3. KBIKM = log10(KBIKM+1)
4. IKMBO = log10(IKMBO+1)
5. IKMTMO = IKMTMO/10
6. TPMTMO = log10(TPMTMO)
7. KBEGM = log10(KBEGM+1)
8. EGITSAATM = EGITSAATM/60
9. EGITSAATB = EGITSAATB/60
10. IKFI = IKFI/50
11. IKPGFAK1 = (IKPGFAK1+3)/4
12. IKPGFAK2 = (IKPGFAK2+3)/5
13. IV = log10(IV)
14. KO = log10(KO+26)
15. YGDO = log10(YGDO+32)
16. VGDO = log10(VGDO+21)
17. KBK = log10(KBK+6000)

18. SGDO = log10(SGDO)
19. TVO = log10(TVO)
20. FPGFAK1= FGFAK1+3)/5
21. FPGFAK2 = (FPGFAK2+3)/5

In the model description section, we mention that the 3 parameters have to be selected for BPMLP in order to minimize the total error. These parameters are the learning parameter η, the number of neurons N1 in the first hidden layer and the number of neurons N2 in the second hidden layer. Figure 2 shows the total training error for different learning parameters calculated for different number of neurons.

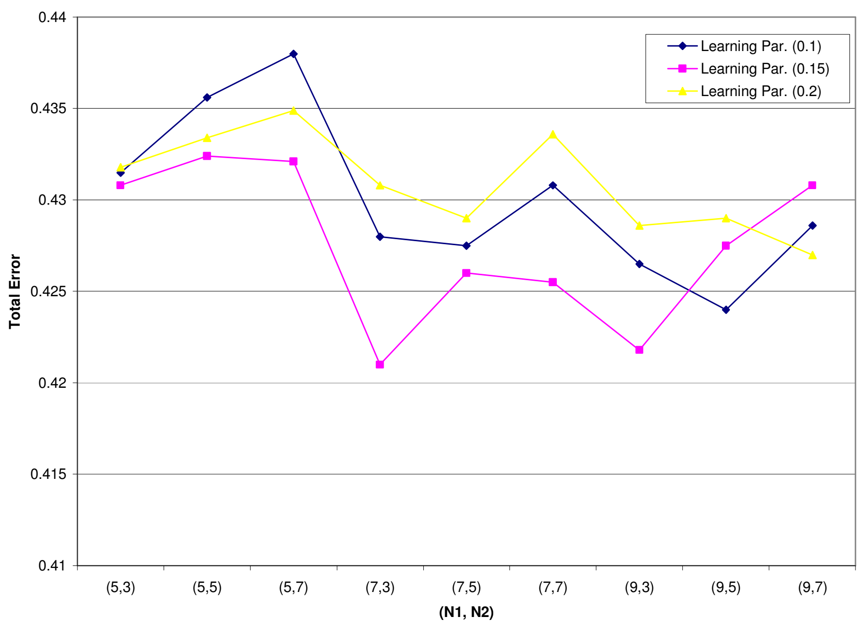
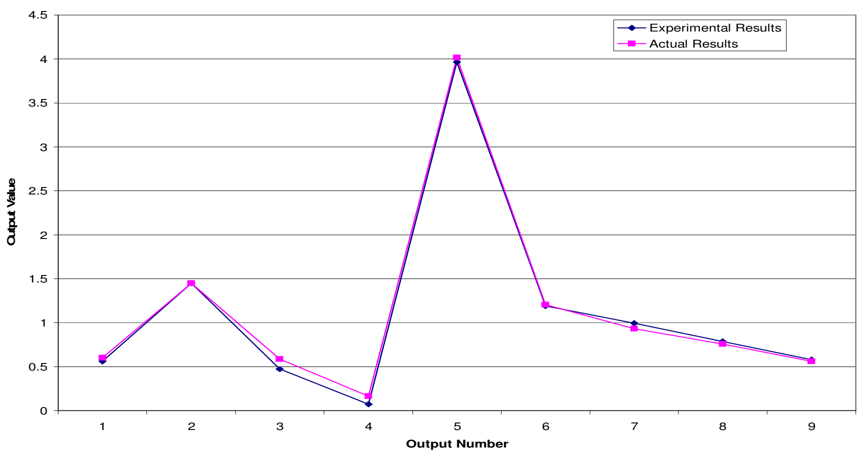


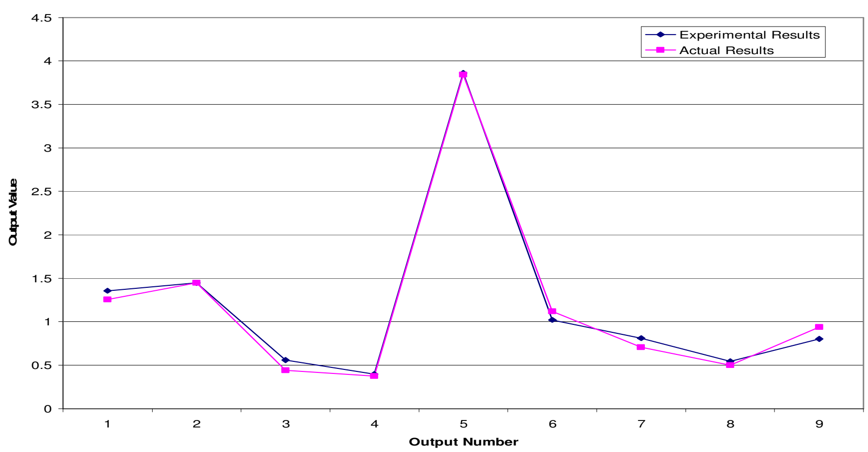
Figure 2. Total Training Error for Different Learning Parameters

The training error is calculated using the formula given in Equation 2. From Figure 2, we observe that η=0.15, N1=7 and N2=3 is a good choice for the data at hand and used for the rest of the experiments performed in this paper.

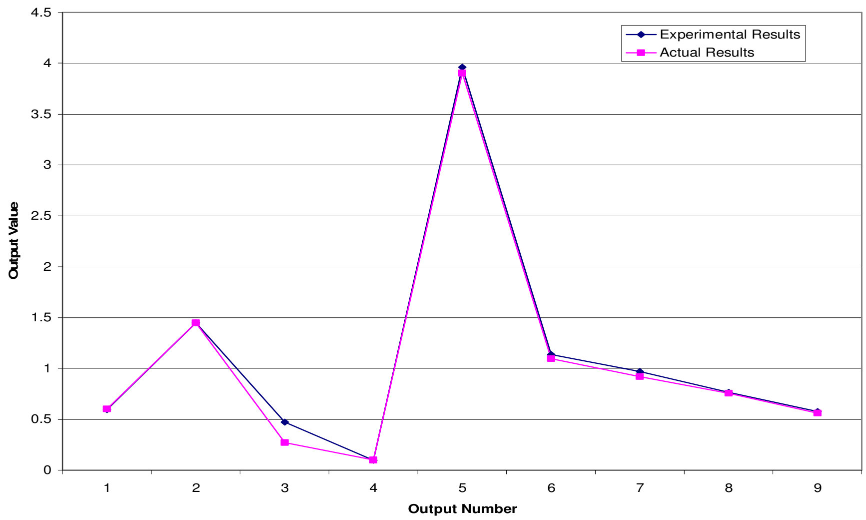
After deciding about these parameters, our first experiment is to check whether the actual training data matches with the experimental output data or not. This is very important since it shows us how well the model suited to this relation. To show this, the actual and experimental output variables are shown for some companies in Figures 3-6.



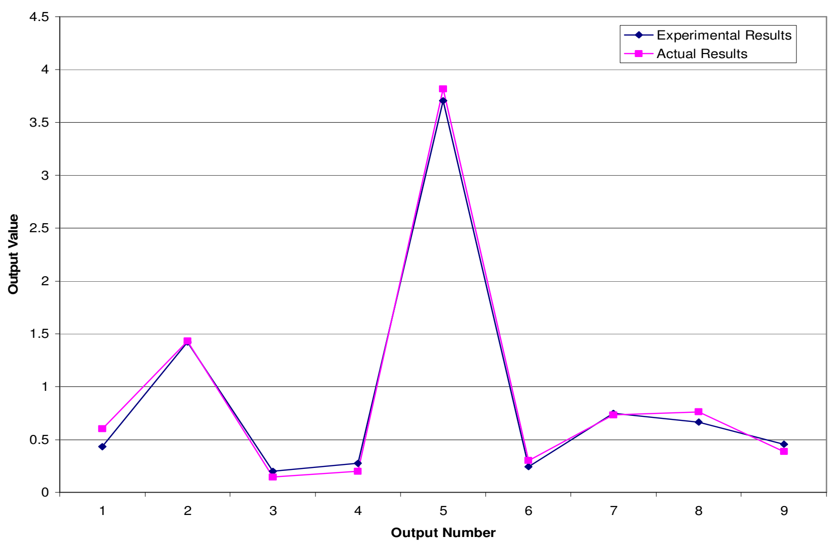
Figures 3. Actual and Experimental Outputs for Training Data for Company 1



Figures 4. Actual and Experimental Outputs for Training Data for Company 2



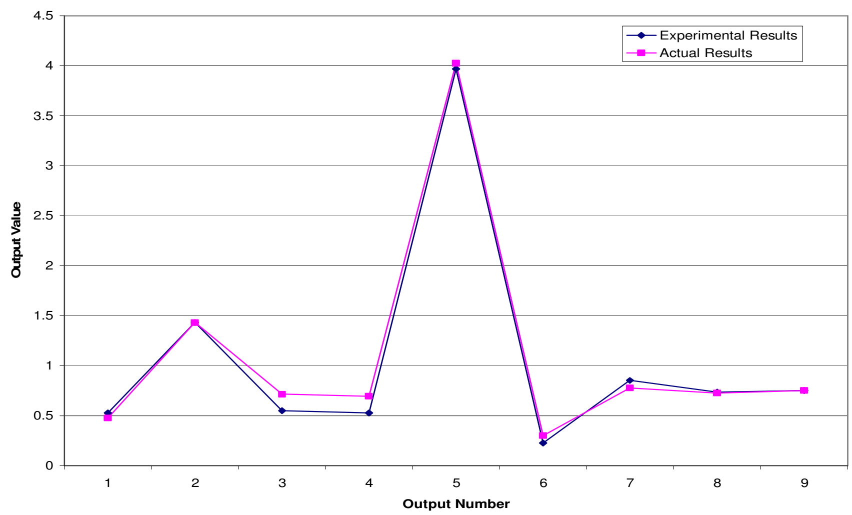
Figures 5. Actual and Experimental Outputs for Training Data for Company 3



Figures 6. Actual and Experimental Outputs for Training Data for Company 4

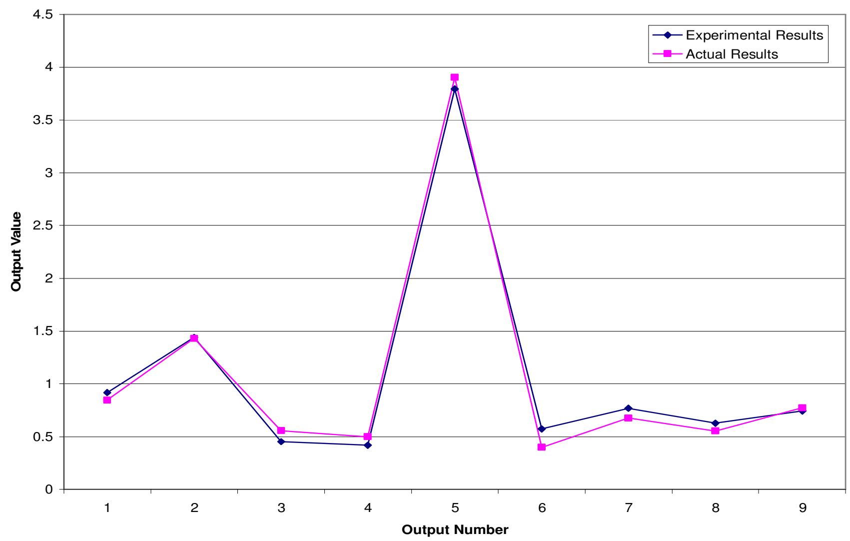
From these figures what we observed is that the actual outputs and the experimental outputs closely match. Also from the total training error we can easily say that the deviation between the actual output and experimental output is not very big. Hence we can conclude that our model learned the relation between the 12 input variables and 9 output variables.

The next step in this study is to find how well the actual output and experimental output matches for the testing data. In order to show this relation, we show the actual and experimental output variables for the two companies in Figures 7-8 .



Figures 7. Actual and Experimental Outputs for Testing Data for Company 1

From these figures our derivation is that the nonlinear model that we used represents the general behaviour of the companies corresponding to the selected variables.



Figures 8. Actual and Experimental Outputs for Testing Data for Company 2

4. CONCLUSION

In this paper, our aim is to find whether the relationship between the Human Resource Management and Firm Performance can be modeled using a nonlinear model or not. To check this claim we use one of the modeling technique, namely the back-propagation multilayer perceptron. From our experimental results, our conclusion can be summarized as follows;

- By using the BPMLP algorithm in the modeling of this relation, we observed that nonlinear model is capable of representing the relationship at hand.
- To check the performance of our model we used the 88 data set obtained from 44 companies. We plotted both the actual and experimental outputs for the 4 companies. From these results, we conclude that the relationship between the input and output variables can be modeled nonlinearly.
- The use of our model as an estimator of firm performance output variables, when the input variable of HRM is known, is checked through the use of the testing data. The results showed that this model can estimate the output variables for the testing data for many cases. This estimation can be improved by using more training data, that is going to represent all kind of relations between HRM and firm performance, in our model.

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