Computational Intelligence applied to student's performance evaluation in Higher Education

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Abstract

The assessment of student performance in an Institution of Higher Education is a great problem to manage. There are several elements that influence the overall result. The information extracted from these data is useful for evaluating the performance of students, professors, educational institution, and even the educational system of a country. However, there is a lack of automated systems to support decision making based on knowledge, and very often these assessments are made following a series of rules, but in some cases subjective data can influence the final results. In Brazil, the Ministry of Education and Culture (MEC) has been working to evaluate education institutions based on several criteria, and the data and evaluations of these educational institutions have been available. In this work, was used the data provided by MEC to supply a better understanding and management of education institution information for decision making. Techniques of Computational Intelligence have been used for processing this information in order to address a larger amount of information and treat imprecise data so to teach human evaluators and combine the data from these various reviewers. Here, was chosen an artificial neural network which are indicated to processing large amounts of data, which are fault tolerant and learn by examples. It is possible to extract information from the characteristics which most influence an evaluation, based on assessments of human evaluators. The results show that the approach is promising and allows a quick view of the results in graphical software for quick decision making.

Keywords: Computing intelligence; academic performance evaluation; neural network.

1 Introduction

The evaluation of a Higher Education Institution (HEI) in Brazil has not been an easy task, mainly to analyze and to present the existing data in general systems results. The lack of automated systems has made it difficult to process support for decision making based on knowledge. The existing available data lacks visual correctness and access for decision making. This study aims to present a better understanding of an academic information management, using Computing Intelligence (CI) techniques. Many systems have available data or allow the collect sources of data with the purpose of subsidizing the decision making. However, it will only be effective in complex reports, where some standards and data contain information such as performance of the students in some classrooms, period or between the diverse ones HEI, among others. Checking these data is important to identify specific information to the business. In an automated system applying a CI, such an Artificial Neural Network (ANN), with Multi Layer Perceptron (MLP), trained with a feed-forward and standard Back-Propagation (BP) learning algorithm, is used to classify the evaluations for academic management, which is important for decision making process.

The nature of the supervised training of network MLP requires a set of training composed of an entrance and a desired exit. The entrances are characteristic of the institutions, and the exits are the grades given by professionals. The results presented in this work have been obtained from the ANN trained with available data of a survey, and a part of the information available in the current systems in a HEI. However, it can´t either be found quickly, or be used to offer results for decision making. Different techniques of CI have been applied in evaluation and neural networks have been used in different ways for evaluations.

This work suggests using ANN as a means of learning with data of previous evaluations, and then, to foresee the possible improvements of performance with variations on entrance parameters of the neural network according to (Braga, 2011), (Haykin, 2008), (Lin, 1996), (Nadler, 1993) and (Zeng, 2001). Three tests are carried out to evaluate the performance of the ANN, with an evaluated data according to (Gotti 2011). After that, another test with reduction in the amount of characteristics evaluated from the ANN previously configured. Finally, inserting an evaluation from Enade's grade 5, once again tests with the network, so that the new calculations generate the results and these are compared and analyzed and allowing a new decision making.

2 Academic Management in a HEI

This work is based on a Case Study, from data collected for the National Examination of Performance of Students (ENADE) that it is part of directive of the National System of Evaluation of Higher Education (SINAES) of the Ministry of Education (MEC), and allows HEI to evaluate the education process. This process is part of the new Law and Lines direction Bases (LDB) of 1996 according to (Souza, 2001) through the SINAES, which manages ENADE.

According to (Yin, 2001) a case study is a method well suited for a context in which the investigator has little control of the events which are being searched, considering such events to be contemporaries and real.

The information obtained with the methodology of a case study can be used in the academic management of a HEI. In this work the information presented for the neural network will be used to evaluate the performance of the institution on the basis of Table 3 that presents the data of the sample chosen from Enade. It presents the number of participants in the test, the number of students concluding the courses at HEI and the generated grade for Enade. The characteristics listed are classified in HEI - Institution of Higher Education; Part - number of student's participants; Conc - number of Concluding students, Enade - grade calculated in percentual and Grade_Enade - grade calculated for each IES, associated with the calculated values.

3 CI applied to an evaluation

Among the evaluation models applied to the data analysis are: the intelligent models, which use the approach algorithms and some techniques of artificial intelligence; and the traditional models, which use the statistical classifying model.

Developing and implementing systems for analysing data, which are able to perform as humans do, is still a problem to be studied. Many theories have been used based on the research in biological and computational systems. Techniques of recognition of standards and artificial intelligence, as ANN, genetic algorithms and the diffuse logic are used for data analysis as proposed by (Braga, 2011), (Haykin, 2008) and (Zeng, 2001). In this work these three techniques are used for evaluation of the academic management of a HEI.

3.1 Artificial Neural Network

The RNAs explore the intrinsic of the parallel processing and are fault tolerant. These properties make them appropriate for application in recognition of standards, signal processing, image processing, financial markets, computational vision, engineering, and others, according to (Braga, 2011), (Haykin, 2008), (Lin, 1996), (Nadler, 1993) and (Zeng, 2001).

ANNs have two stages of training in an application. During the learning phase, the corresponding weights and thresholds of the networks to each connection are adjusted. For the activation, the exit is obtained based on the weights and thresholds of the training phase.

ANNs is composed of simple elements of processing (neurons). A model of artificial neuron consists basically of a linear combination followed by an activation function given by (1):

$$y_k = \varphi\left(\sum_{j=1}^{n} w_{kj} x_j + b_k\right) \quad (1)$$

Where: w_{kj} are the synaptic weights, b_k the threshold, x_j is the entrance vector and y_k the exit in k-th neuron in the activation function of the neuron.

The ANN will solve non-linear problems, if non linear functions of activation have been used in the hidden layers and/or the exit.

Among the several functions, the sigmoid and the hyperbolic tangent are highly used.

There are different architectures of an ANNs which are dependent on the learning strategy adopted. In the present work, the network MLP trained with BP algorithm of the error was used. It is composed of a front layer of entrance, a hidden layer of exit and one or more layers, whose objective is to extract high-order statistics from its entrance data.

Network MLP with BP algorithm of the error has a supervised learning that requires the pair of entrance and desired exit. Such pairs allow of the calculation of the error of the net, as the difference between the desired exit and the calculated exit. The weights are adjusted through the BP algorithm of the error, governed by the adjustment rule.

The weights are adjusted by a proportional from error to error. More details can be found in (Braga, 2011) and (Haykin, 2008).

3.2 Tools for implementation and tests

With the increase of the amount of work that make use of an ANN, tools for development and tests have been presented and used, for instance, the traditional Software for Programming Language as (FORTRAN, Delphi, Paschal, C and others) languages and the most modern tools. For example: EasyNN, WEKA (Waikato Environment will be Knowledge Analysis), SNNS (Stuttgard Neural Network Simulator). Also the library of neural networks of the traditional Mat Lab is widely used in the academic labs. The EasyNN is commercial software with graphical interface for training and tests and it provides a friendly interface for accomplishment of the experiments.

Another tool is the WEKA, which has a set of algorithms of machine learning for tasks of data mining. It possesses tools for processing, classification, regression, association and visualization. The SNNS is a neural network simulator, developed by the University of Stuttgard, which simulates many models of ANNs, one of them, MLP, Functions of Radial Bases and Cascade Correlation. The Mathworks company has a library of a NN for the Mat Lab that makes possible the development, implementation, visualization and the simulation of different models of neural networks, (Gotti, 2011). The tests in this work were carried out with a developed program in FORTRAN language and performed a proper tool and library in PC platform with the operating system Windows XP, and Microsoft Excel for graphics presentation (Bloch, 2004).

4 ANN applied to an evaluation of a HEI

In this work, neural networks have been used to evaluate data from several higher education institutions based on information from ENADE. Was choven, twelve (12) HEI's data and it have been used and are presented in Tables 1 and 2. Together with other data such as the following: C1: Part – number of participants, C2 Enade – grade calculated in percentual, C3: Av_Conc_G – average of the grades of the concluding students in General subjects, C4: Av_Conc_S – average of the grades of the concluding

students in Specific subjects, C5: Grade_enade – grade calculated for each IES, C6: Av_Beg_G – average of the grades of the beginning students in General subjects, C7: Av_Beg_S – average of the grades of the beginning students in Specific subjects, C8: Idd - indicator of the performance difference between observed and expected, C9: Cpg – preliminary grade of course and C10: Cpg_fx – standard preliminary grade. Figure 1 illustrates the assessment.

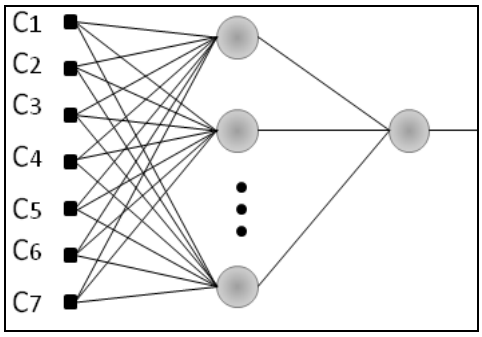

Figure 1: Artificial Neural Network. Source: Adapted from (Haykin, 2008).

The data has been divided into three subsets of input / output, with 16 elements for training, as shown in Table 1. For the validation three sets of information have been chosen, as shown in Table 2. To finalize further 6 have been chosen for generalization, as shown in Table 3. The training and validation sets are used during training, while the generalization tests of RNA. The network is trained with a subset consisting of eight sets of training input / output.

Table 1: Choosen Data of HEI.

Part	Enade	Av_Conc_G	Av_Conc_S	Grade_Enade	Av_Beg_G	Av_Beg_S	Idd	Cpg	Cpg_fx
136	4,8	62,3471	57,0699	5	55,3086	44,0691	3,6196	4,19	5
29	2,24	45,4897	36,8897	3	45,1400	28,4000	2,4414	2,19	3
52	3,29	47,6077	46,2577	4	39,8129	31,5620	2,7001	3,02	4
262	1,93	37,2847	35,8794	2	37,5515	28,8235	2,2998	1,81	2
28	2,89	58,4750	40,0679	3	53,4600	32,1244	3,1203	2,64	3
40	3,87	56,0725	49,8100	4	48,9753	33,4188	3,1672	3,47	4
51	3,08	51,4235	43,4549	4	48,8485	33,7303	3,2029	2,90	3
47	4,09	58,6702	51,2128	5	45,0055	32,0534	4,9076	3,30	4
60	3,38	61,6067	43,9483	4	50,4652	36,4011	3,5782	3,14	4
106	3,49	57,5623	45,8953	4	50,0300	34,0362	3,2714	3,24	4
158	4,02	61,1601	49,9861	5	64,8894	41,5816	2,5559	3,53	4
30	4,03	61,2667	50,0667	5	31,4727	29,4273	2,2195	3,38	4
78	2,09	45,6103	35,4808	3	42,6586	30,0186	2,0131	2,24	3
36	4,46	60,3194	54,3667	5	60,0611	41,9000	4,5116	3,62	4
141	3,93	57,4801	50,0447	4	55,7974	36,1658	3,6855	3,30	4
506	3,41	53,2630	46,0658	4	38,1419	29,7941	2,4363	3,43	4

Source: INEP / Enade 2009 (www.inep.org.br).

To test the cross-validation data three institutions have been presented as in Table 2. Institutions have been selected with evaluation 3 and 4.

Table 2: Data used in cross-validation.

Part	Enade	Av_Conc_G	Av_Conc_S	Grade_Enade	Av_Beg_G	Av_Beg_S	Idd	Cpg	Cpg_fx
16	3,65	56,9375	47,5125	4	45,2789	33,5158	3,0845	2,92	3
37	3,16	57,0108	42,9162	4	47,2847	29,7757	2,6684	2,96	4
93	2,13	39,3538	37,2538	3	37,7645	29,2097	2,2074	2,46	3

Source: Adapted from INEP – Enade 2009. From www.inep.org.br

For the test of generalization, data from six institutions have been used, which have been evaluated by the evaluators with score in 2 and 5. These data are presented in Table 3.

Table 3: Data used in generalization tests.

Part	Enade	Av_Conc_FG	Av_Conc_S	Grade_Enade	Av_Beg_G	Av_Beg_S	Idd	Cpg	Cpg_fx
73	1,59	34,4068	33,3849	2	38,2717	29,8264	1,2208	1,69	2
30	3,31	52,0000	45,5033	4	45,7833	36,4306	3,4618	2,94	3
46	3,13	48,6348	44,5565	4	54,8599	34,8374	3,4954	2,64	3
76	3,43	58,8987	44,9803	4	50,2276	32,6678	3,2929	3,17	4
70	4,14	57,5914	52,0100	5	43,5029	31,9304	2,8408	3,49	4
206	4,75	62,4325	56,5854	5	60,2422	45,2969	3,2366	4,16	5

Source: Adapted from INEP – Enade 2009. From www.inep.org.br

In the training, the number of neurons in the hidden layer has been varied in order to find a better neural network topology. This process is necessary for optimum performance of the classification. Table 4 presents the mean errors of these ratings. Following the methodology for training and testing, the results of the validation tests are presented in Table 4, where there are varied numbers of neurons in the hidden layer.

During the training phase, the network must be trained so to learn sufficiently on the basis of the set of training, but to be able to generalize with new data. Crossed validation will prevent the network from not getting specialized in the trained data. It consists of presenting the validation subgroup and stopping before the specialization for (Braga, 2011).

The quadratic error of the evaluation is gotten by (2):

$$\text{Erro} = \frac{1}{2}\left(N^{\text{Evaluator}} - N^{\text{Neural network}}\right)^2 \qquad (2)$$

Where $N^{\text{Evaluator}}$ is the grade presented for the professional and $N^{\text{neural network}}$ is the grade estimated by the neural network.

In the training, the neural network of subgroups, 16 evaluations of validation have been used containing 2 pairs of input/output. The number of neurons in the layer hidden has been varied in order to find a better architecture of neural network. This process is necessary for a better performance of the classification. Table 4 shows the average of these Errors.

Figure 2 illustrates an example of evaluation of the training of the neural network. The stop criterion used in the training was cross validation in the function (Haykin, 2008).

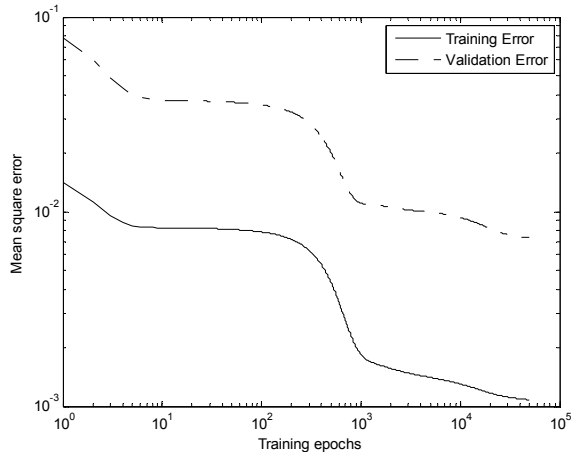

Figure 2: Example of a training error.

Table 4: Errors obtained in the validation tests.

Neurons	Mean Square Error
4	11.9915×10^{-3}
5	$\mathbf{2.8255} \times 10^{-3}$
6	3.1293×10^{-3}
7	4.1286×10^{-3}

When evaluating the weights of the neural network, one can determine which features have most influenced the final evaluation. This assessment can be made with the analysis of the weights of the neural network. Table 5 presents the average weights of the first layer of the neural network used.

Table 5: Neural network weights.

Features	C1	C2	C3	C4	C5	C6	C7	C8	C9
Weights	**0.5129**	0.2335	**0.5581**	**0.4185**	0.1875	**1.7584**	**1.0957**	0.3112	**9.5990**

Based on information extracted from the weights shown in Table 5, new training was carried out, as in Table 6, where it is possible to analyze the errors obtained in the generalization tests which are close to those obtained considering all the features.

Table 6: Neural Network weights.

Neurons	Quadratic Error
5	14.4650×10^{-3}
6	2.8936×10^{-3}
7	3.1861×10^{-3}
8	3.0079×10^{-3}
9	3.8957×10^{-3}

According to the results obtained, it can be noticed that for this configuration, the neural network presented grades closer to the evaluators using 5 neurons in the hidden layer. The generalization test also showed that the neural network presents grades closer to the evaluators, as shown in Figure 4, also with 5 neurons in the hidden layer. Figure 3 shows the results obtained in tests of generalization considering: all the features of the courses (column 1), most relevant information (column 2) and the grades given by the evaluators (column 3).

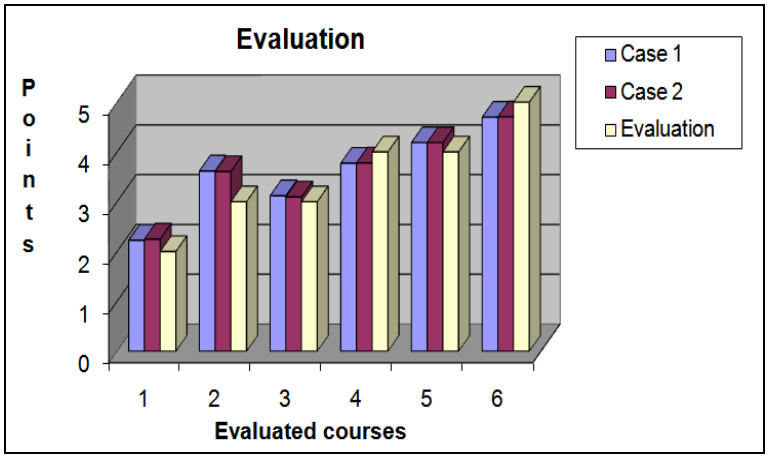

Figure 3: Generalization and tests..

For academic management, it is possible to tell which characteristics most influence in the evaluation with the use of information and the weights of the neural network. These characteristics are presented in Table 7.

Table 7: Characteristics influence in the evaluation.

	1	2	3	4	5	6
C1	0.43	0.35	0.66	0.96	0.81	0.51
C2	**0.84**	**1.10**	**1.52**	**1.96**	**2.06**	**2.22**
C3	**1.76**	**1.87**	**3.24**	**3.97**	**4.40**	**4.26**
C4	0.06	0.11	0.33	0.84	0.70	0.96
C5	**1.29**	**1.43**	**2.49**	**3.22**	**3.50**	**3.32**
C6	0.15	0.78	0.58	0.31	1.00	1.88
C7	**2.02**	**1.53**	**3.40**	**4.85**	**4.47**	**3.60**

With the calculations of the RNA presented in Table 7, the characteristics that most influence in the result are C2 Enade – grade calculated in percentual, C3: Av_Conc_G – average of the grades of the concluding students in General subjects, C5: Grade_enade – grade calculated for each IES and C7: Av_Beg_S – average of the grades of the beginning students in Specific subjects. With this identification it was possible to evaluate that it is possible to make a simulation for the improvement of the characteristics, making the evaluations of performance of the Institution closer to reality.

Table 8: Errors obtained in validation tests.

Neurons	Quadratic error
1	1.1285×10^{-3}
2	1.7345×10^{-3}
3	1.5665×10^{-3}
4	2.3130×10^{-3}
5	$\mathbf{0.0845}\times10^{-3}$
6	0.8825×10^{-3}
7	1.4480×10^{-3}
8	1.8490×10^{-3}

According to the results, it can be observed that, for this configuration, the neural network presented grades n close to the ones of the appraisers using 5 neurons in the hidden layer, when compared with the previous experiment Table 8. The generalization test also showed that the neural network presents grades closer to the ones of the evaluators, as presented in Figure 4, also with 5 neurons in the hidden layer.

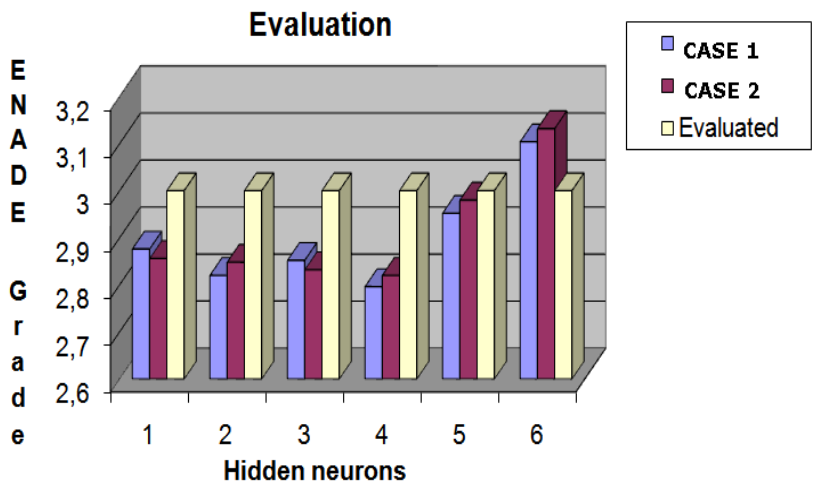

Figure 4: Analyses results.

The neural network presents grades close to the ones of the evaluators. One remark that can be made with respect to the estimated grades with the neural network trained with 6 neurons in the hidden layer: The RNA overestimates the evaluated data and the estimated grade is greater than 3, showing that an adequate amount of neurons in the hidden layer must be used. This amount can be defined with the validation test, as shown in this work.

Table 8: Introduction of a grade 5 in a RNA training data.

C1	C2	C3	C4	C5	C6	C7	C8
38	141	3.93	4	36.855	35.292	3.30	4
129	24	2.24	3	26.251	19.313	2.31	3
192	77	2.62	3	18.135	26.080	2.58	3
317	214	1.66	2	34.556	19.953	2.13	3
175	**136**	**4.80**	**5**	**62.347**	**57.070**	**4.19**	**5**
177	230	2.01	3	22.268	21.553	1.96	3
63	51	2.09	3	20.276	21.827	1.94	2
66	117	1.99	3	21.412	22.182	2.02	3

This work presents a methodology to assist in evaluating the performance of an institution. The management of Brazilian HEI focused on the difficulty of evaluating and presenting the results in their existing academic systems. It is aimed to automate the process of evaluation of HEIs with the purpose of contributing to information management in the institution by using CI systems. From the data available in the database of the MEC, an artificial neural network was chosen, MLP trained with the error BP algorithm, a network consisting of an input layer, an output layer and one hidden layer, whose goal is to extract high-order statistics of their input data. The tests were conducted to evaluate the performance of the neural network, compared with previously published results. It can be observed that the ANN presents similar results to those presented by the evaluators of the MEC, since it uses an adequate number of neurons in the hidden layer, being appropriate for using as a tool in decision making and information management. From the results, we presented the data analysis with neural network trained with information from HEI, ensuring a quick estimate of the grades for quick decision making by managers of an institution (Gotti, 2011).

The MLP was used with BP algorithm of error for the data training. The amount of neurons in the hidden layer varies, and the remaining desired error (0,001) and the initial learning rate (0,5). In Table 9 the errors of validation crossed gotten in the training phase are presented.

Table 9: Validation and tests.

Neurons	Quadratic Error
1	1.4130×10^{-3}
2	4.2685×10^{-3}
3	6.0740×10^{-3}
4	5.1425×10^{-3}
5	$\mathbf{0.7105}\times10^{-3}$
6	5.2880×10^{-3}
7	8.4565×10^{-3}
8	7.3825×10^{-3}

It is observed that the neural network continues presenting errors, close to the ones to the previous experiment in the training phase. The generalization tests are applied in these cases presented in Table 9. The result of these tests is presented in Figure 5.

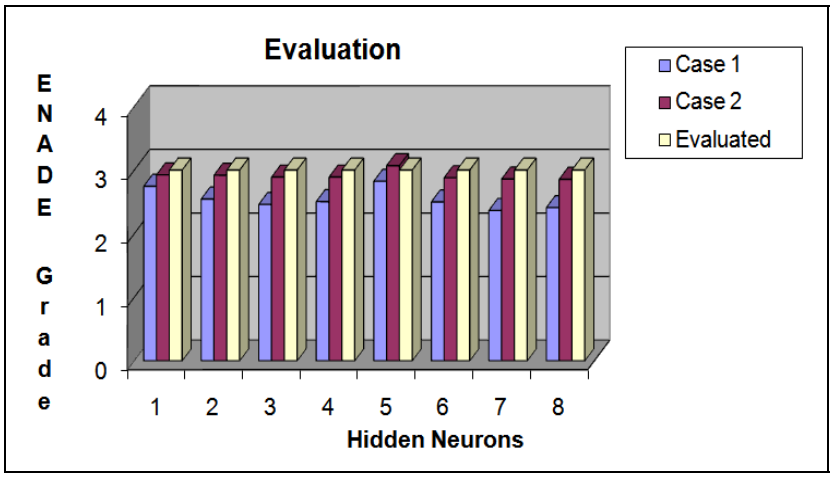

Figure 5: Generalization and Tests.

In this new situation, the generalization test can be seen, with the training of the neural network with data of the Institution with grade 5, the evaluation of the two cases not used in the training phase, they continue presenting results which are close to the data of the evaluators.

5 Conclusion

This work presents a methodology to assist in evaluating the performance of an institution. The management of Brazilian HEI focused on the difficulty of evaluating and presenting the results in their existing academic systems. It aimed to automate the process of evaluation of HEIs with the purpose of contributing to information management in the institution with the use of CI systems. From the data available in the database of the MEC, an artificial neural network was chosen, MLP trained with the error BP algorithm, a network consisting of an input layer, an output layer and a hidden layer, whose goal is to extract high-order statistics of their input data. The tests were conducted to evaluate the performance of the neural network, compared with previously published results. Two groups of data were used and it can be observed that the ANN presents similar results to those presented by the evaluators of MEC. It uses an adequate number of neurons in the hidden layer and a fault tolerance, being appropriate to be used as a tool in decision making and information management. This method allows the researcher to use a large amount of data to analyse all the results quickly. The results presented with this chosen data, the analysis with neural network trained with this information ensure a quick estimate of grades for quick decision making by managers of an institution.

References

Bloch. (2004) BLOCH, S. "*Excel para Engenheiros e Cientistas*". Rio de Janeiro: LTC, 2004.

Braga. (2011) BRAGA, A. P.; CARVALHO, A. P. L. F.; LUDEMIR, T. B. "*Redes Neurais Artificiais – Teoria e Prática*". Rio de Janeiro: LTC, 2011.

Gotti. (2011) GOTTI, F. J. A.; COSTA, I.; SHIGUEMORI, E. H., "*Inteligência Computacional Aplicada às Avaliações da Gestão Acadêmica em uma IE*" in Papers presented at *ICECE'2011* – VII International Conference on Engineering and Computer Education. Guimarães: Portugal, September 2011.

Haykin. (2008) HAYKIN, S. "*Neural Networks: A Comprehensive Foundation*", (2nd ed). NJ: Prentice Hall, 1994.

Lin. (1996) LIN, C., LEE, C. "*Neural Fuzzy Systems: Neuro-Fuzzy Synergism to Intelligent Systems*", NJ: Prentice Hall, 1996.

Nadler (1993) NADLER, M, SMITH, E., "*Pattern Recognition Engineering*". New York: Wiley, 1993, pp. 293-294.

Souza. (2001) SOUZA, P.; SILVA, E., "*Como Entender e Aplicar a Nova LDB*". São Paulo: Pioneira, 2001.

Zadeh. (1965) ZADEH, L. A., "*Fuzzy sets - Information and Control*", *IEEE Transactions on Systems,* Vol. 8: 338–353, 1965.

Zeng (2001) ZENG, X., YEUNG, D. S., "*Sensivity Analysis of Multilayer Perceptron to Input and Weight Perturbsations*". *IEEE Transactions on Systems, Man and Cybernetics.* Vol. 12, No 6, November 2001.

Zhang. (2000) ZHANG, G. P., "*Neural Networks for Classification: A Survey*". *IEEE Transactions on Systems, Man and Cybernetics.* Vol. 30, No 04, November 2000.
Yin. (2001) YIN, R., "*Estudo de Caso. Planejamento e Métodos",* (2nd Ed). São Paulo: Bookman, 2001.