Predicting Usability of Library Websites: Fuzzy Inference System and Artificial Neural Network based Approach

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ABSTRACT: *We report soft computing approach for predicting usability of library websites using Fuzzy Inference system (FIS) and Artificial Neural Network (ANN). Proposed model is the fusion of these two computing paradigms to create a successful synergic effect. The website usability dataset is derived from doctoral thesis on Usability Evaluation of Library Websites [1]. Usability index (UI) determinants such as visibility, SR_world, user control, consistency, error, recognition, flexibility, aesthetic, recovery, documentation, effectiveness, efficiency, memorability, learnability, satisfaction and motivation are considered here for computing. The reported investigations depicts optimum ANN architecture achieved by tuning the parameters viz. network type, training function, transfer function and number of neurons in hidden neurons. ANN architecture, thus derived entails nonlinear sigmoid activation function for hidden layer and Levenberg-Marquardt back propagation method for training the model. Moreover the performance of the model is evaluated with reference to Mean Squared Error (MSE), Pearson Correlation Coefficient (r) and Gradient (g). Validation of the model has portrayed reasonably good prediction accuracy.*

Keywords: Website Performance Evaluation, Usability Index, Artificial Neural Network, Fuzzy Inference System, Machine Learning

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1. Introduction

Scholarly Literature reveals that soft computing is more powerful in providing practicable solutions to the problems that deal with uncertainties. Fuzzy logic handles uncertainty in a natural manner by providing a human oriented knowledge representation and ANN is capable to capture the non-linear relationship than statistical methods which makes the network to provide higher forecast accuracy.

Information technology and soft computing are playing major role in analyzing library resource utilization in academic institutes [11-13]. Amanatiadis et al have approximated the relations among user satisfaction and its determinants using artificial neural network with the explanation of a wide survey on user contentment with reference to website attributes [2]. Nagpal et al have identified that affect the usability of an educational websites and then designed a model for usability assessment using the Adaptive Neuro Fuzzy Inference System Approach [3]. Rekik et al have presented quality assessment methodology with a model that measures the performance of dynamic websites [5]. Their model is a Fuzz-Web system that shows a comprehensive and natural manner of reasoning based on multiple criteria decision making process. Yet another paper Mirdehghani et al presents an automatic system for web pages aesthetic evaluation based on the image processing techniques and ANN [6]. Nikov et al have reported neuro-fuzzy approach for the assessment of website usability [7].

Thus the literature review indicates a crystal-clear possibility to exploit soft computing approach for websites' usability index modelling. This has in fact served as motivation for us to develop the conception of computing and modeling of UI using FIS and ANN in the present investigations. Quantifying performance dimensions is a challenging job since the decision may include approximated data and linguistic terms. The proposed model encompassed with fuzzy rating for converting numerical values of UI determinants into linguistic grades. FIS is employed here to compute Usability Index, the target column of dataset. Thus derived dataset is exploited to train ANN to get optimized network architecture.

The rest of the paper is structured as follows; after a brief introduction, the second section deals with FIS for UI computation. The third section portrays computational details of the proposed ANN model. The results and discussion are reported in the fourth section. The conclusion at the end divulges aptness of the ANN for websites' UI modelling.

2. FIS for Usability Index Computation

A statistical or an arithmetical method does not inevitably propose the suitable means to evaluate website performance since the parameters which determine UI are actually fuzzy concepts. Such imprecise data can be handled by using fuzzy logic reasoning which reflects human way of thinking [4].

The website usability dataset is derived from doctoral thesis on Usability Evaluation of Library Websites [1]. Dataset consists of UI determinants such as Visibility, User control, Matching among system and the reality, Prevention of errors, Consistency, Recognition, Minimalist design, Flexibility of use, Help and documentation, User friendly, Effectiveness, Efficiency, Memorability, Learnability, Satisfaction and Motivation. The architecture of FIS employed in the present investigation to compute target column of this dataset is shown. (Figure 1) Scores of these input parameters are converted as fuzzy inputs by applying fuzzification. Fuzzifying of these parameters includes crisp value passing via each membership function (MF)associated to that value [9]. MF defines the mapping of each point in the input space to a membership value from 0 to 1. Table 1 explains linguistic terms, their crisp value and corresponding Gaussian MF parameters for inputs. The parameters represent the standard deviation and center for the Gaussian curve.

Set of rules defined to relate input parameters to UI. These rules are based on phrases rather than mathematical definitions. We have formulated four such rules as shown. (Figure 2)The human expertise assists in formation of membership function and generation of fuzzy rules. Fuzzy reasoning applied to compute UI, output parameter. Deffuzzification is employed to convert fuzzy output to crisp value which denotes usability index of website.

3. ANN Modelling: Computational Details

An artificial neural network is a computational model based on the structure and functions of biological neural networks. ANNs are generally offered as systems of interconnected neurons, which exchange information between each other. The connections have numeric weights that can be tuned based on experience, making networks, adaptive to inputs and capable of learning. A schematic diagram of ANN model designed in the present investigation is shown. (Figure 3) ANN architecture consists of linear activation function and nonlinear activation function for output layer and hidden layer respectively. The Levenberg-Marquardt feed-forward technique is used by network for trained. There exists one output layer and one hidden layer in network. Each layer consists of multiple ANN nodes to perform intelligent accomplishment. Following equations show net input function 'η' and equation present the nonlinear sigmoid activation functions.

$$\eta = \Sigma^{n}{}_{i=1} W_i X_i + b$$

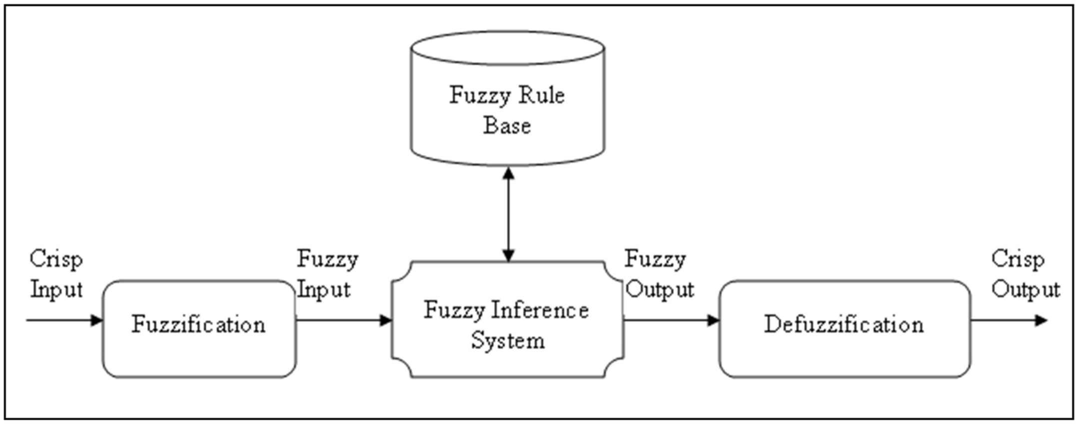

Figure 1. Fuzzy inference system architecture of UI

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If all inputs are 'low' then UI is 'low'
    Else If all inputs are 'average' then UI is 'average'
      Else If all inputs are 'good' then UI is 'good'
         Else UI is 'excellent'
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Figure 2. Pseudocode for Rule base

Linguistic term	Crisp Range	Gaussian MF Params
Excellent	[4-5]	[0.5864, 5]
Good	[3-4]	[0.5864, 3.668]
Average	[2-3]	[0.5864, 2.332]
Low	[1-2]	[0.5864, 1]

Table 1. Linguistic terms and corresponding parameters

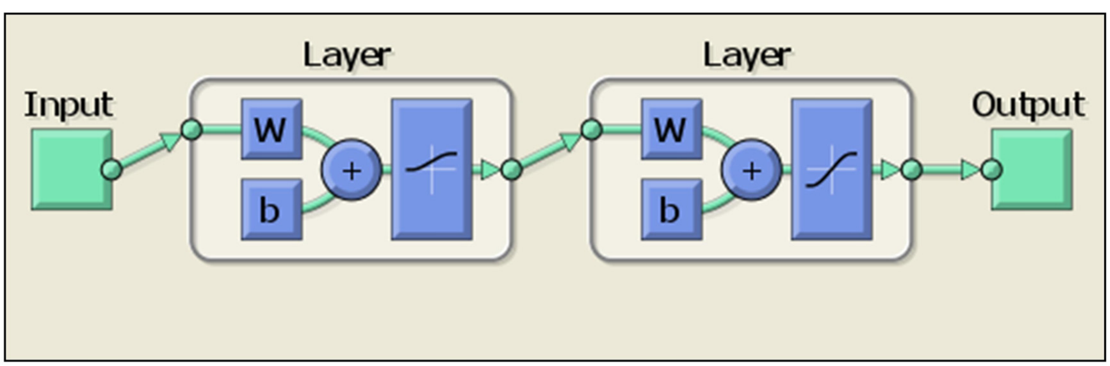

Figure 3. Schematic representation of ANN model[8]

$$S(\eta) = \frac{1}{1+e^{-\eta}}$$

Where, X_i is input of network, W_i is a weight of input, and b is a bias of network.

The present investigation of website usability index modelling is simulated in MATLAB environment. The model is conceived as a Multi-Input Single-Output (MISO) configuration. The experiment is tuned with set of network properties such as the network type, training function, transfer function and number of neurons in hidden neurons[10]. Table 2 gives the details of network properties for present modelling. The network learning is administered by cross-validation technique. This technique divides the data sets into three types namely training, validation and testing by adopting random sampling method. The training data set is used for the weight adjustment of network whereas validation set is used to control learning process.

Network Properties	**ANN Model for Protein Expression**
Network Type	Feed Forward Back Propagation
Training Function	Levenberg Marquardt
Learning Function	Gradient descent with momentum weight and bias learning
Transfer Function	Log-sigmoid transfer
Performance Function	Mean square error, correlation coefficient and gradient
Data division	Random

Table 2. Network properties for UI Modelling

The test dataset is used for quality assessment has been further evaluated in terms of mean squared error (MSE) and correlation coefficient (r). Mean squared error is given by following equation. The Y_i represents the observed value, where, $i = 1, 2, \ldots\ldots n$ denote the values of the class variable of the i^{th} observation and $\hat{Y}_i$ denote the predicted value of the i^{th} observation. The difference $(Y_i - \hat{Y}_i)$ is termed as mean square error and it is defined as,

$$MSE = \frac{1}{n} \Sigma^n_{i=1} (Y_i - \hat{Y}_i)^2$$

4. Results and Discussion

We explored ANN modeling with different network architectures. This section explains predicting UI for library website. MATLAB is used to analyze model structure, neuron number of concealed layer, and training function[8].

We have demonstrated ANN modeling with network types such as Feed Forward Back Propagation and Cascade Forward Back Propagation per variation in the hidden layer neurons. To get optimized network architecture maximum epochs 100 set aside as constant. MSE of the model for variation in hidden neurons represented. (Figure 4)The result concludes that the error between final output and output formed by network reduces at lesser number of hidden neurons and MSE is tending to increase with the increase in hidden neurons. Experiment also reveals that training reached maximum epoch for hidden neurons 30 and 40 as shown. (Figure 4b and Figure 4d)

The present study measured performance of the model with reference to Mean Squared Error (MSE), Pearson Correlation Coefficient (r) and Gradient (g). Correlation Coefficient depicts the correlation of the expected output and output provided by the network. Minimal value of gradient indicates no further requirement of training. Details of the experiment conducted for Feed Forward Back Propagation and Cascade Forward Back Propagation by changing hidden neurons counts are explained in Table 3 and Table 4respectively. The outcome indicates that the correlation coefficient is higher for lesser hidden neurons and correlation coefficients tend to decrease as the hidden neurons increases. The gradients are the individual error for each of the

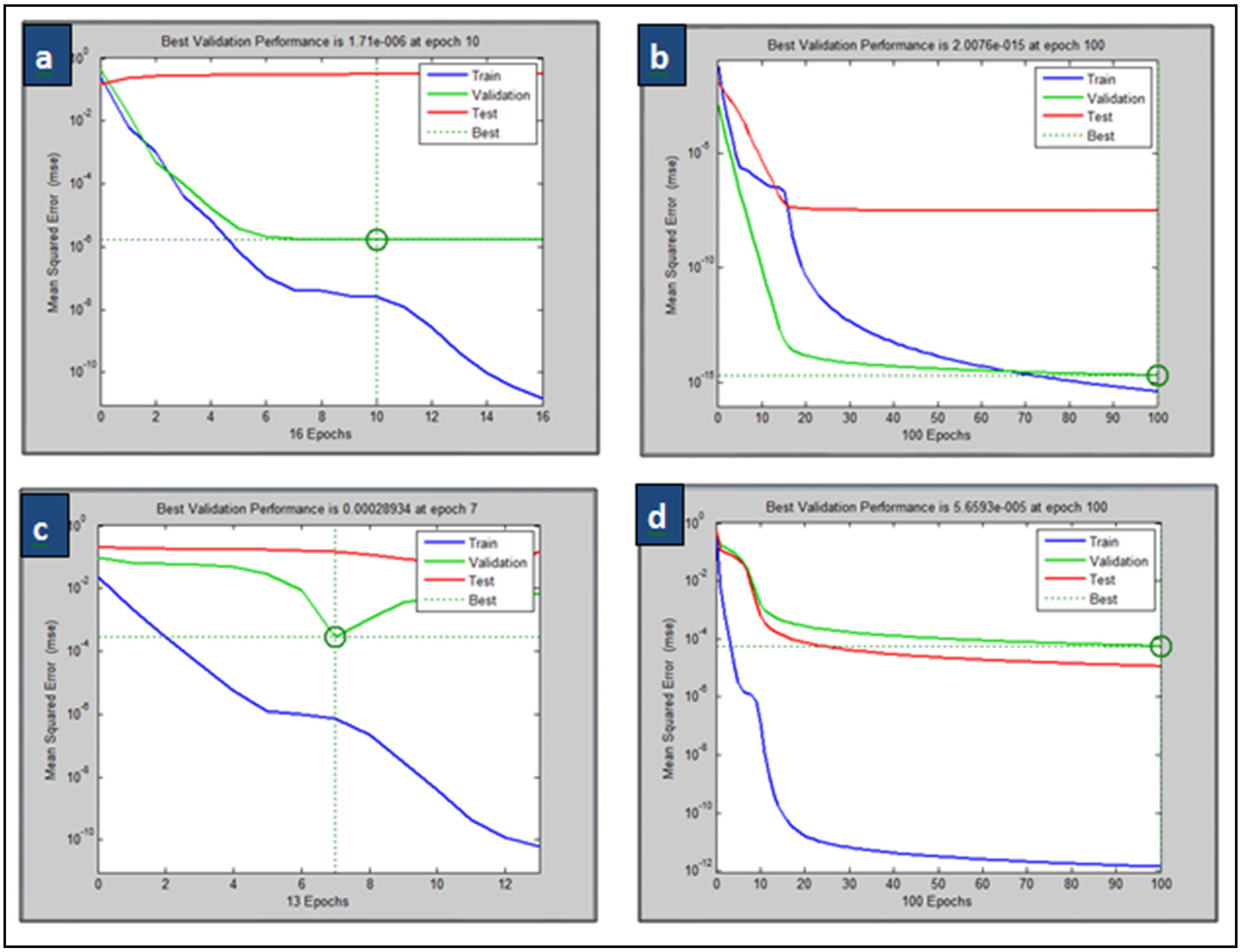

Figure 4. Variation of MSE with various network architectures. (a) shows MSE for Feed Forward with 10 hidden neurons; (b) shows MSE for Feed Forward with 30 hidden neurons; (c) shows MSE for Cascade Forward with 15 hidden neurons; (d) shows MSE for Cascade Forward with 40 hidden neurons

weights in the neural network. Minimum the value of gradient coefficient better will be training and testing of networks.

The optimized ANN structure selected for the UI modelling has nonlinear sigmoid activation function for hidden layer, Levenberg-Marquardt back propagation method for training the model and 5neurons in the hidden layer. The performance of ANN modelling pertaining to this is shown. (Figure 5a-c). The MSE between training, testing and validation data is shown in (Figure 5a) The gradient, mu, validation fail plot for the present model is shown. (Figure 5b) In this case, MSE is found to be 7.0377e-010at epoch 6 while the correlation coefficient (*r*) is 1, Gradient is 1.2759e-007and Mu is 1e-008. It shows variation in gradient coefficient with respect to a count of epochs. The final value of gradient coefficient at epoch number 6 is 1.2759e-007 which is approximately tending to zero. The gradient attains the minimal range at epoch 6 which also leads to linear training graph indicating that there is no further training.

5. Conclusion

Soft computing approach for predicting usability index of library websites using FIS and ANN is presented in this paper. The reported investigation dealt with fuzzy rating for converting numerical values of UI determinants into linguistic grades. FIS is employed here to compute Usability Index, the target column of dataset. This dataset is exploited to train ANN to get optimized network architecture. ANN architecture, thus derived entails hidden layer with nonlinear sigmoid activation function and Levenberg-Marquardt back propagation method for training the model can be used for computing usability index of websites efficiently with very less error. Result concludes that ANN prediction is a suitable approach since the resulting analysis is much

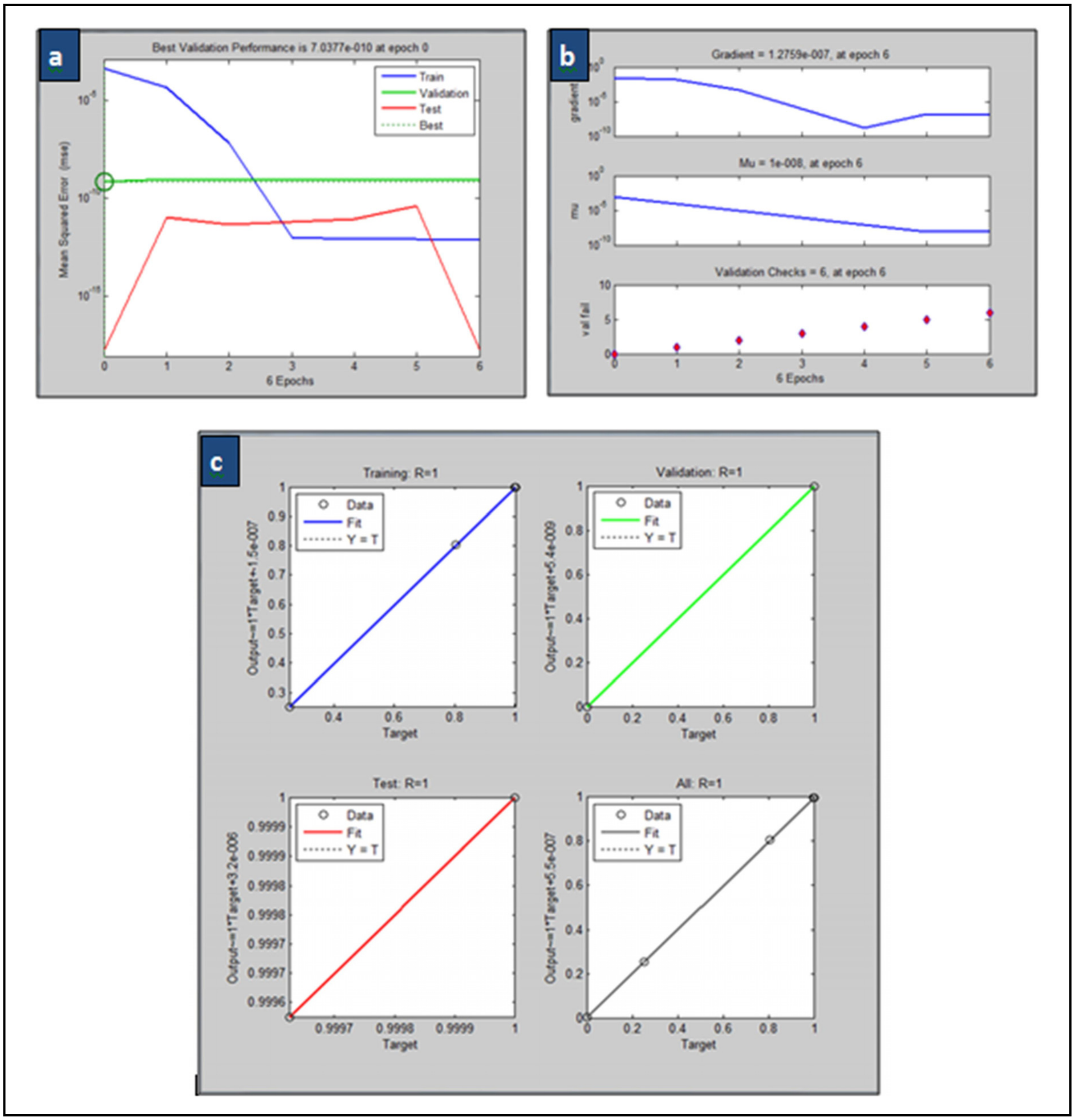

Figure 5. (a). Performance of selected ANN Model for training, validation, and testing data; (b). Performance of selected ANN Model in terms of Gradient, Mu, Validation fail parameters; (c). Correlation coefficient for selected ANN model

more accurate and precise. The lower number of hidden neurons signifies the less memory requirement for prediction of different composition.

References

[1] Kamat, R. R. (2015). Thesis on Usability Evaluation of Library Websites: A Case Study of University Library Websites in the State of Maharashtra and Karnataka, Shivaji University, Kolhapur.

[2] Amanatiadisa, A., Mitsinisb, N., Maditinosb, D. (2014). A neural network-based approach for user experience assessment, *Behaviour& Information Technology*, 2014, (34), p. 304-315.

[3] Nagpal, K., Mehrotra, D., Sharma, A., Bhatia, P. (2013). ANFIS Method for Usability Assessment of Website of an Educational

No. of hidden neurons	Max. Epoch reached at	Mean Square Error	Gradient	Pearson Correlation Coefficient		
				Training	Validation	Testing
5	6	7.0377e-010	1.2759e-007	1	1	1
10	16	1.71e-006	2.2405e-006	1	0.71163	0.74934
15	11	0.00013185	0.00037021	1	1	0.970402
20	40	2.81e-008	9.3353e-011	1	0.24994	0.96552
30	Max	2.0076e-015	3.5399e-008	1	0	0.3267
40	6	0.0216	2.603e-006	0.97261	0.99984	0.25064

Table 3. Performance evaluation for accuracy of Feed Forward Back Propagation Configuration

No. of hidden neurons	Max. Epoch reached at	Mean Square Error	Gradient	Pearson Correlation Coefficient		
				Training	Validation	Testing
5	15	9.8608e-033	2.488e-011	0.11724	0	0
10	40	1.2826e-012	1.3322e-011	1	1	0
15	13	0.00028934	3.7068e-006	1	1	0.22798
20	Max	1.2893e-008	1.6312e-009	1	0	1
30	6	0.19472	0.00042845	0.99992	0.24807	0.3114
40	Max	5.6593e-005	4.5716e-008	1	0.99987	0.24602

Table 4. Performance evaluation for accuracy of Cascade Forward Back Propagation Configuration

Institute, *World Applied Sciences Journal*. 23 (11) 1489-1498.

[4] Kamath, R. S. (2014). Design and Development of Soft Computing Model for Teaching Staff Performance Evaluation, *International Journal of Engineering Sciences & Research Technology*, 2014, 3 (4) 3088-3094

[5] Rekik, Rim., IlhemKallel. (2012). Fuzz-Web: A Methodology Based on Fuzzy Logic for Assessing Web Sites, International *Journal of Computer Information Systems and Industrial Management Applications*, Volume 5 (2012) p. 126-136

[6] Mirdehghani, Maryam., S., AmirhassanMonadjemi. (2009). Web Pages Aesthetic Evaluation Using Low-Level Visual Features, International Journal of Computer, Electrical, Automation, Control and Information Engineering, 3 (1), 124-127.

[7] Nikov, Alexander., Svetla Vassileva., StefkaStoeva. (2003). Webuse: An Approach For Web Usability Evaluation, proceedings of 3rd Symposium on Production Research, Istanbul, Istanbul Culture University, April 19-20.

[8] MATLAB version R2009b, Natick, Massachusetts: The MathWorks Inc., (2011).

[9] Fuzzy Logic Toolbox For Use With MATLAB. http://home.agh.edu.pl/~mrzyglod/iw/iw_pliki/MatlabFuzzyLogicToolboxUser'SGuide.pdf. Date accessed: 08/07/2015.

[10] Demuth, Howard. (2015). Mark Beale Neural Network Toolbox For Use With MATLAB. http://www.image.ece.ntua.gr/courses_static/nn/matlab/nnet.pdf. Date accessed: 08/07/2015.

[11] Boopalan, E., Sasireka, I., Arumugam, R. (2016). Influence of Information and Communication Technology on Library Users in Academic Institutions: A Comparative Study, *Indian Journal of Science and Technology*, (May), 9 (20), Doi no:10.17485/ijst/2016/v9i20/91217.

[12] Sharma, Disha., Kaur, Sumit., Diksha. (2016). Neural Network Classification for user Profile Learning over Digital Library Recommendation Engine, *Indian Journal of Science and Technology*, (September), 9 (33), Doi no:10.17485/ijst/2016/v9i33/96317.

[13] Athira Azlan, Nor., Nur Hidayah Mohammad Daud, Zulkifli, Zahidah., Samsuri, Suhaila., Ali, Asma., Hussin, Husnayati. (2016). Library Online Database System for Undergraduate Students, *Indian Journal of Science and Technology*, (September), 9 (34), Doi no: 10.17485/ijst/2016/v9i34/100844.