Multi Input Single Output Fuzzy Model to Evaluate the Performance of Distance Education Media

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Abstract: Distance learning is being the preferred mean for continuous learning at any educational center and there is urgent need to adapt with the technological requirements for such open learning methods. A fuzzy logic based model has been introduced in this work to estimate the overhaul efficiency of the distance education media to meet specific training objective. This fuzzy model has been tested to simulate the Tony Bates "ACTIONS" model (Bates, 1995). The performance of the model has been validated by comparing the model results with actual examples which have been obtained by conducting practical survey. The fuzzy ANFIS model has been trained using back-propagation and least-square methods.

1 INTRODUCTION

The impact of the rapid development in the fields of telecommunication and digital technologies have helped in delivering online and distant learning which in turn has expanded the learning opportunities; because of this rapid technology development and the availability of different educational tools, organizations are facing many challenging decisions to enhance their educational systems. Learning centres are working seriously to meet the fast growing needs for continuous learning by redefining their systems to be more attractive for the new and old learners. Universities, schools, and training centres are developing new contents and medias to make it easy for any person to reach out to the learning resources at any time, with minimum cost and easy access throughout the world (Teixeira and Bates, 2019; Kappel and Lehmann, 2002; Zhang and Jiang).

There are very limited practical theories for selecting the most suitable learning media for certain systems and the most common practice is to have the organization management or a special committee of experts to decide the best technology tools for each specific case. The ACTIONS model (Bates, 1995) is the most famous model for selecting the optimal learning media which was developed for campus-based as well as distance education. More detailed approaches are also available at more micro-level when it comes to designing specific multimedia educational materials (Holden and Westfall, 2007) (Simonson and Zvacek, 2019).

A model for technology selection is very important to help covering a wide variety of learning contexts and suggests strategic and tactical institutional and instructional plans on both of educational and operational issues. The optimal design of an educational model should accommodate new technology development and create a cost effective system. As an example, SECTIONS is found to be one of the best models to provide the required needs. SECTIONS stands for: Student, Ease of use, Cost, Teaching function, Interaction, Organizational issues, Networking, and Security & privacy.

This work is introducing a new model which is based on multi input signals; easiness to access the teaching or learning, estimated costs, user-friendliness & interactivity, organizational issues, novelty, and speed of the required change. The suggested model is designed by using Adaptive Neuro-Fuzzy Inference System (ANFIS) method of fuzzy based modelling.

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2 ANFIS MODEL DEFINITION

Modelling any specific system by using conventional mathematical tools can be a very difficult process especially when dealing with ill-defined or uncertain systems, a process of several pages of decision-trees, which are completely impractical to apply. While a fuzzy inference system employing fuzzy if then rules is much easier to human knowledge and reasoning processes without employing precise quantitative analyses. This fuzzy modeling is first explored by Takagi and Sugeno (Mehran, 2008; Yulianto and Komariyah, 2017). Generally, there is no standard method to transform the human experience into the rule base of a fuzzy inference system in addition to the need to design a tuning method to define the membership functions in order to optimize the criteria of the output error and performance index

ANFIS is an adaptive network based fuzzy inference system which can be used as a basis for constructing a set of fuzzy if-then rules with appropriate membership functions to state the required initial input-output pairs.

The basics of fuzzy if-then rules, fuzzy inference systems, the structures and learning rules of adaptive networks are described in (Al-Hmouz and Shen, 2011). In using ANFIS, there are almost no constraints on the network structure and node functions, but the network should be of feed forward type (Salleh and Talpur, 2017). Figure 1 below shows a simple example of a two input – nine rules ANFIS system structure. A more complicated structure of six input ANFIS model is used in this work to model the distance education media selection system.

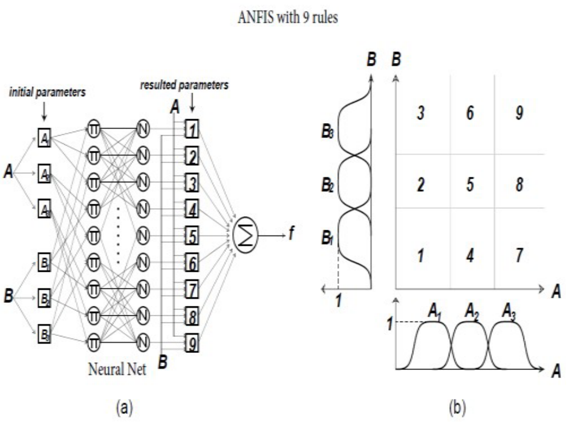

Figure 1: Simple example of ANFIS structure with two input – nine rules ANFIS.

3 DISTANCE EDUCATION MODEL

The objective of designed ANFIS model is to evaluate and enhance the media selection process and to avoid the associated problems facing the universities or education centers. Also, this ANFIS model is introduced to estimate the overhaul efficiency of the appropriate media for any suggested distance education system using the designing the parameters of Bates model.

3.1 Model Structure

Numerical and statistical data-based methods can be complemented by the human expertise and knowledge to design the required set of fuzzy rules for a certain system. The modeling of distance education media selection is designed using ANFIS modeling techniques with six input parameters and single output parameter. The Adaptive Neuro-Fuzzy inference system (ANFIS) is a hybrid technique which is based on fuzzy and neural networks to enhance the performance of the system accuracy for modeling and simulating complex systems with none linear characteristics (Ritika and Bhardwaj, 2020). The required membership function parameters for the designed fuzzy inference system are calculated by feeding the given information that is embedded in relation among the input/output training data sets. The ANFIS embedded learning capabilities makes it more efficient and works similarly to neural networks. The membership functions parameters are tuned by using a combination of back propagation and least squares error minimization learning technique. Throughout the learning process, the suggested membership functions will continue to evolve until reaching the required target error value. The calculation of fuzzy membership functions is interpolated by gradient vector to provide a measure of how well the implemented fuzzy inference system is capable of modeling the input/output data for a given set of variables. The optimization process is applied to adjust the network weights and parameters to continuously reduce a previously designed output error measure. This system is based on Sugeno-type system to simulate the required model and analyze the mapping relation between the input and output data values and to determine the optimal distribution of membership function (Qun, 2015). It is mainly based on the fuzzy "if-then" rules from the Takagi and Sugeno type. The equivalent Takagi and Sugeno

ANFIS architecture is shown in Figure 2. It contains five successive layers and each layer involves several nodes, with different node function per layer.

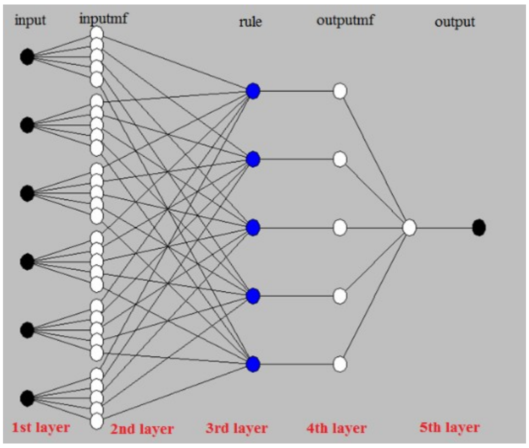

Figure 2: The equivalent Takagi and Sugeno ANFIS Architecture.

The output signals from each node in the previous layer is fed to the input signals in the present layer. Each node is firing its output value depending on its embedded activation function and accumulated input from the previous layer. The node output will be fed to the nodes in the next layer.

The below bullet points describe the designed ANFIS model:

- Total number of network nodes: 30 + 5 + 1
- Total number of the network linear parameters: 932
- Total number of the network nonlinear parameters: 28
- Total number of the model parameters: 6 inputs + 1 output
- The total number of the training data pairs: 500
- The total number of used fuzzy rules: 19

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3.2 Model Input/Output Parameters

The fuzzy logic part of the ANFIS based model is initially determined by the fuzzy sets of input/output values which represent the possible values of these variables. Figure 3 shows the general three stages of the suggested model to simulate the distance learning media selection system. Figure 3 shows a sequence of six inputs to generate target single output as a measure of the selected distance learning media performance. That means, it is a multi-input single output ANFIS model with six input parameters (accessibility, cost, teaching, interactivity, organization, and speed) and one output parameter to indicate the selected distance learning system performance.

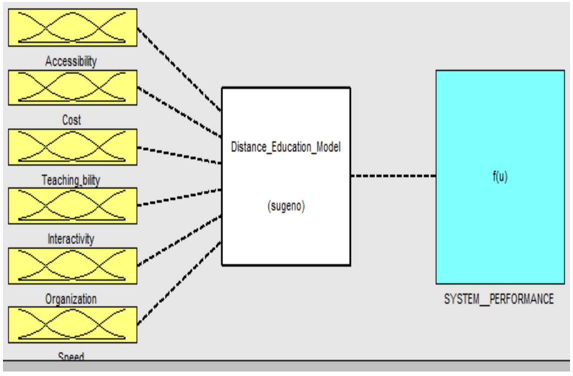

Figure 3: The schematic model of the distance learning media selection.

For each suggested set on these six input parameters, the resulted output value is considered as the estimated goodness of the distance learning media for this specific state of input.

3.3 Membership Function

The fuzzy theory is based on the overlapped triangular membership logic with a predefined suitable width and values. Each element accordingly can belong to a particular set with partial membership value to each set. Depending on the addressed problem, it is possible to define a suitable membership function with certain environment and limitation for each of the required variables. Table 1 below shows the initial description of the fuzzy sets for a system with six input variables and the related fuzzy classification

3.4 Fuzzy Rules Characteristics

Each of the six inputs of the designed system is assigned to different levels of linguistic variables. These variables have been tuned to generate only nineteen rules. Keeping in mind that there are many rules might be classified as 'not applicable' conditions and accordingly are not included in the designed set of accepted rules.

This ANFIS model for Bate's ACTIONS parameters is designed and trained by using MATLAB fuzzy toolbox. The membership functions are generated by using clustering algorithm.

Table 1: The definition of the fuzzy input variables.

Input	Cat.1	Cat.2	Cat.3	Cat.4
Accessibility	V. Simple	Simple	Difficult	
	0-4	3-7	5-10	
Cost	V. Cheap	Cheap	Expensive	V. Expensive
	0-3	2.5-5	3-6	6-10
Teaching ability	Bad	Good	V. Good	
	0-3	2-6	5-10	
Interactivity	Not user friendly	User friendly		
	0-4	4-10		
Organization	Bad	Suitable	V. Suitable	
	0-3	2.6-6	5-10	
Speed	V. Slow	Slow	Fast	V. Fast
	0-2	1.8-4	3.5-6.7	6-10

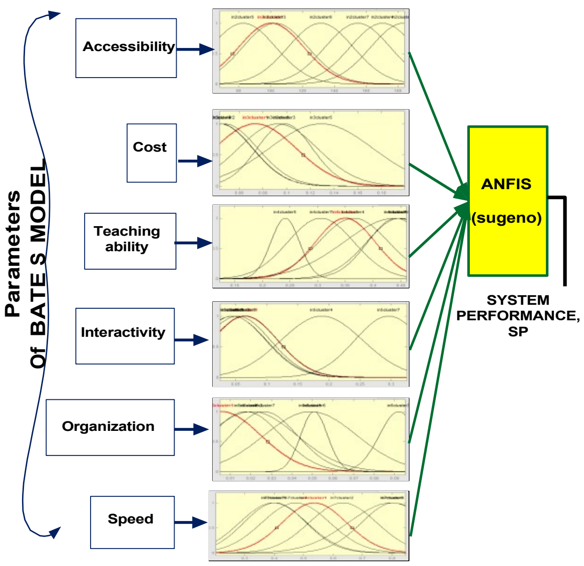

Figure 4: The membership functions after the ANFIStraining.

The training parameters are: Influential radius (Rc) is 0.5, Quash factor (η) is 1.5, Accept ratio (R_{Accept}) is 0.5, and the Reject ratio (R_{Reject}) is 0.15. The applicable rules formulated for the model and the memberships are given in Figure 4 below. The core of the proposed ANFIS system is designed by using fuzzy linear model type Sugeno which converts a fuzzy inference engine into an adaptive network that learns the relationship between inputs. The designed system is defined by the Bate's model input parameters (accessibility, cost, teaching ability, interactivity, organization, speed) while the single output is defined as the related performance of the tested distance learning system (sp).

The six input/single output bate's model is used to improve the converge speed of the ANFIS hybrid leaning algorithm. The available data set is randomly partitioned into a training set and a checking (testing) sets. The training sets are a practical description of the desired input/output data which is used during the training stage to train the model by minimizing the target output error. While the checking data sets are used for the testing phase and to carry out the cross validation of the ANFIS model.

The first-order (linear) ANFIS is trained using the hybrid algorithm of the back-propagation and least-square methods available through the MATLAB toolbox. The rule viewer is used to generate the below example of value-relations for a certain state of training parameters shown in Figure 5.

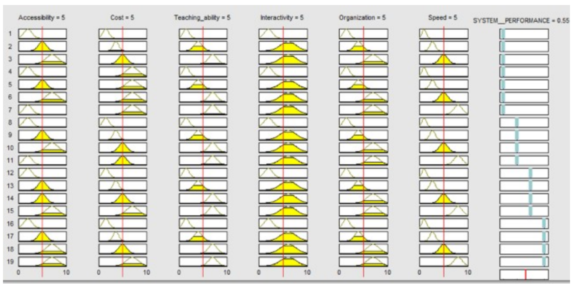

Figure 5: ANFIS rules shown by rule viewer.

The designed rules along with membership function are also shown in rule viewer of fuzzy model as given in the above Figure 5. This Figure 5 clearly shows the characteristic of the six input parameters for a certain example to present their accumulated effect on the output variable.

4 TRAINING RESULTS AND DISCUSSIONS

The first phase of the system design is the convergence to the final shape of the ANFIS model to optimize the distance education media selection system for certain set of input variables. Then, verifying the accuracy of the model in the testing phase to demonstrate the designed model performance. Figure 6 below is partially showing the cross-relations among the six input variables and the related interdependency of the model output value on each of these inputs. Eight interdependent relations were selected randomly to show eight examples of the output surface area changing in response to the associated change in two of the input variables as shown in figure 6. The Eight different three- dimensional relations for the system performance shown in this figure prove that each of the six input variables is affecting the final value of the model output in a different way depending on the pre- learning phase and the weighted effect of this input variable and its interdependent relations with the other input variables

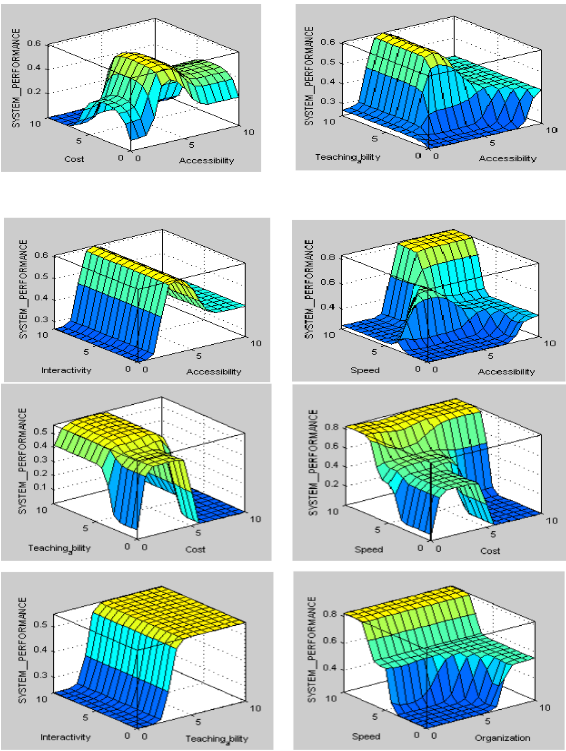

Figure 6: Input/output surface area interdependent relations.

Figures (7a) and (7b) are showing the ANFIS model training to simulate the performance of Bate's ACTIONS model which is carried out by using 600 epochs before converging to the minimum accepted preset error value. Figure (7c), is showing the final ANFIS model output performance (output accuracy) during the validation or checking stage

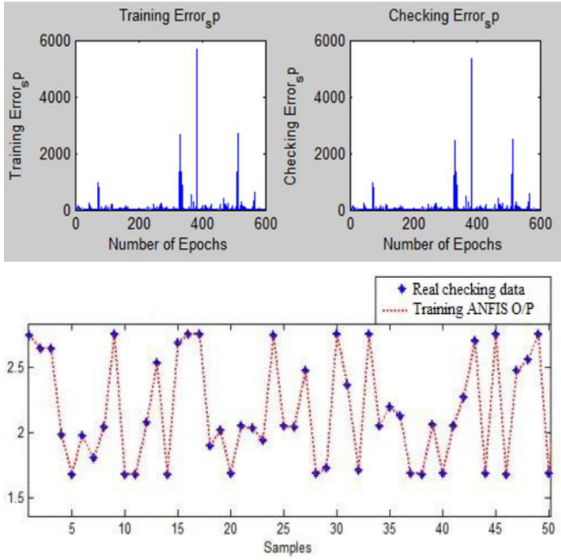

Figure 7: (a) Decrease of error during training phase. (b) Decrease of error during testing phase. (c) ANFIS prediction versus checking data set.

In this model a total of 50 input/output data sets are used as practical examples to verify the model accuracy. It was found that only two input data sets were out of range and couldn't meet the expected target output value and the output error has exceeded five percent. The rest of the validation data sets have shown individual error less than three percent. Thus, the overall average error for the model is about five percent which means that the simulated fuzzy model is giving an overall of 95 percent accuracy. It can be concluded that the designed ANFIS model is very accurate and there is a very small error percentage which is acceptable compared to the huge efforts required to carry out the process by using the tedious conventional methods which depend on using human calculations under different conditions.

5 CONCLUSION

The feasibility of using ANFIS model technique was demonstrated to simulate a simple adaptive system to estimate the optimal choice of distance education media. A multi-input single output adaptive Neuro-Fuzzy model was developed and the designed model was validated by using pre-calculated experimental results for given conditions. The demonstration results proved that the designed fuzzy model accurate enough to be used by the educational organization who are planning to upgrade to new learning systems. It has been concluded that the model is about 95 percentage accurate. A model with such accuracy can be used by the practicing educational system designers who would like to get quick answers by using this optimized simple intelligent tool. This work has emphasized the fact that ANFIS modeling technique can be used as a viable alternative to carry out analysis without conducting actual experiments which might be very expensive and time consuming process. The system was found to be very flexible and easy to use. Modeling using ANFIS techniques was proved to be very cost effective and practical alternative to the conventional methods.

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