An Optimization of a Planning Information System Using Fuzzy Inference System and Adaptive Neuro-Fuzzy Inference System

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Abstract: - This paper aims to design Mamdani-Fuzzy Inference System(FIS) and Sugeno-Adaptive Neuro-Fuzzy Inference System model (ANFIS) for the development of an effective Information System. The comparative study of both the systems provided that the results of ANFIS model are better than the Fuzzy Inference System [6]. This was ascertained after testing of the models. Sugeno-type ANFIS has an advantage that it is integrated with neural networks and genetic algorithm or other optimization techniques therefore the IS Planning Model using ANFIS adapt to individual user inputs and environment. In this research paper, the datasets loaded into FIS and ANFIS have the responses of 86 managers regarding the factors responsible for the success, challenge and failure of Information System. A Fuzzy Inference System has been designed having input fields of various factors under three sub dimensions (strategic planning, top management and IS infrastructure) responsible for the Information System Planning whereas output fields are success, challenge or failure of IS planning. In the development of ANFIS model for IS planning, input values of various planning factors like strategic planning, top management and IS infrastructure determine the success/challenged/failure of IS planning. Comparison of two systems (FIS and ANFIS) results shows that the results of ANFIS model are better than FIS when these systems designed and tested. In ANFIS model, for IS planning output fields, the training, testing and checking errors are 0.0204, 0.4732 and 0.27607 where as FIS results in average error of 4.87.

Key-Words: Information System (IS), Critical Success Factors (CSFs), Critical Failure Factors (CFFs), ANFIS, FIS, Planning Information System.

1 Introduction

For the development of an effective Information System Planning, MATLAB is found to be a suitable platform because of its user-friendly programming language, refined graphics features, statistics and optimization tools. The MATLAB tool stands for matrix laboratory. It is a powerful platform for high-performance mathematical computation and graphical representation, whose basic data element is an N dimensional matrix Hanselman and Littlefield [1].

Inspired by human's remarkable capability to perform a wide variety of physical and mental task without any measurement and computations and dissatisfied with classical logic as a tool for modeling human reasoning in an imprecise environment, Lotfi A. Zadeh [2, 3] developed the theory and foundation of fuzzy logic in 1965 in research paper titled "Fuzzy Sets". The most important application of fuzzy system (fuzzy logic) is in uncertain issues. When a problem has dynamic behavior, fuzzy logic is a suitable tool that deals with this problem. FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both.

Fuzzy Logic provides a simple way to arrive at-a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy logic is an extension of Boolean logic dealing

with the concept of partial truth whereas classical logic holds that everything can be expressed in binary terms (0 or 1, black or white, yes or no), fuzzy logic replaces Boolean truth values with degrees of truth. Degrees of truth are often confused with probabilities, although they are conceptually distinct, because they need not add up to 100%. Fuzzy logic allows for set membership values between and including 0 and 1, shades of gray as well as black and white, and in its linguistic form, imprecise concepts like "slightly", "quite" and "very". Specifically, it allows partial membership in a set. It is related to fuzzy sets and possibility theory.
The activities involved in fuzzy expert system are designing, membership functions, fuzzy rule base, fuzzification and defuzzification. MATLAB FIS Mamdani model [16] has been developed and debugged with the data obtained from the sample questionnaire. Three inputs have been loaded in FIS. The model for Information System Planning using fuzzy logic has been elaborated. The fuzzy logic toolbox allows doing several things, but the most important thing it creates fuzzy inference systems.

The aim of this study is to design Fuzzy Inference System which determines that if the planning of the Information System is going to be a success, challenge or failure. In case of challenge and failure of IS planning, the organization may take necessary measures for its successful implementation. The datasets which have been loaded into FIS contain three inputs sub dimensions which are further constituted by 32 variables based on sample questionnaires filled by the managers of the two prominent IS based organizations. Input fields of this system are the factors under the sub dimensions viz. strategic planning, top management and IS infrastructure.

2. Fuzzy Inference System (FIS)

2.1 Fuzzy set theory

The major difference between fuzzy logic and Boolean (standard) logic is that possible values range from 0.0 to 1.0 (inclusive), not just 0 and 1. For example, you could say that the fuzzy truth value (FTV) of the statement "Graham is tall" is 0.75 if Graham is 2 meters tall. To write this more formally:
m (TALL (Graham)) = 0.75
m is a membership function and is the function that would map 2 meters to an FTV of 0.75. Membership functions can be incredibly simple, or incredibly complex. For example, a relatively simple membership function could be:

$$m(TALL(x)) = \left\{ \begin{array}{c} 0\ ;\ x < 5 \\ \dfrac{x-5}{2}\ ;\ 5 \le x \le 7 \\ 1\ ;\ x > 7 \end{array} \right\}$$

A formal definition of a membership function can be stated as a function that maps each point of fuzzy set A to the real interval [0.0, 1.0] such that as m(A(x)) approaches the grade of membership for x in A increases.

2.2 How is fuzzy logic used?

1) Define the control objectives and criteria: What am I trying to control? What do I have to do to control the system? What kind of response do I need? What are the possible (probable) system failure modes?
2) Determine the input and output relationships and choose a minimum number of variables for input to the FL engine (typically error and rate-of-change-of-error).
3) Using the rule-based structure of FL, break the control problem down into a series of IF X AND Y THEN Z rules that define the desired system output response for given system input conditions. The number and complexity of rules depends on the number of input parameters that are to be processed and the number fuzzy variables associated with each parameter. If possible, use at least one variable and its time derivative. Although it is possible to use a single, instantaneous error parameter without knowing its rate of change, this cripples the system's ability to minimize overshoot for a step inputs.
4) Create FL membership functions that define the meaning (values) of Input/Output terms used in the rules.
5) Create the necessary pre- and post-processing FL routines if implementing in S/W, otherwise program the rules into the FL H/W engine.
6) Test the system, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

2.3 How does fuzzy logic work?

Fuzzy Logic (FL) requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. For example, a simple temperature control system could use a single temperature feedback sensor whose data is subtracted from the command signal to compute "error" and then time differentiated to yield the error slope or rate-of-change-of-error, hereafter called "error-dot". Error might have units of degree (deg.). F and a small error considered to be 2F while a large error is 5F. The "error dot" might then have units of deg. /min with a small error-dot being 5F/min and a large one being I5F/min. These values don't have to be symmetrical and can be "tweaked" once the system is operating in order to optimize performance. Generally, FL is so forgiving that the system will probably work the first time without any tweaking.

FL was conceived as a better method for sorting and handling data but has proven to be an excellent choice for many control system applications since it mimics human control logic. It can be built into anything from small, hand-held products to large computerized process control systems. It uses an imprecise but very descriptive language to deal with input data more like a human operator. It is very robust and forgiving of operator and data input and often works when first implemented with little or no tuning.

2.4 Why use fuzzy logic?

Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand.
  The mathematical concepts behind fuzzy reasoning are very simple. What makes fuzzy nice is the “naturalness” of its approach and not its far-reaching complexity.
- Fuzzy logic is flexible.
  With any given system, it’s easy to massage it or layer more functionally on top of it without starting again from scratch.
- Fuzzy logic is tolerant of imprecise data.
  Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.
- Fuzzy logic can model nonlinear functions of arbitrary complexity.
  We can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like ANFIS (Adaptive Neuro-Fuzzy Interference Systems), which are available in the Fuzzy Logic Toolbox.
- Fuzzy logic can be built on the top of the experience of experts.
  In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already under your system.
- Fuzzy logic can be blended with conventional control techniques.
  Fuzzy systems don’t necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.
- Fuzzy logic is based on natural language.
  The basis for fuzzy is the basis for human communication. This observation underpins many of the other statements about fuzzy logic.

2.5 Fuzzy control

Fuzzy control, which directly uses fuzzy rules, is the most important application in fuzzy theory. Using a procedure originated by Ebrahim Mamdani [17] in the late 70s, three steps are taken to create a fuzzy controlled machine:

1) Fuzzification (Using membership functions to graphically describe a situation)

2) Rule evaluation (Application of fuzzy rules)

3) Defuzzification (Obtaining the crisp results)

Fuzzy logic is not really "fuzzy” A fuzzy controller has a set of rules that it uses to decide the final action. Each rule is in linguistic expression about the control action to be taken in response to a given set of process conditions. There are several types of rules, having a general format as shown in section

2.6 If (condition) then (action) in fuzzy control

The CONDITION may include "AND" and "OR" connections. The entire operational action of a fuzzy controller can be broadly divided into two functions, they are as follows:

1) The inference process, which is composed of several rule processes and which produces a single logical sum. Each of the rule processes can be divided into conditions (The antecedent block) and a conclusion (the consequent block). The conclusion is reached when the conditions are satisfied. The

inference process proceeds from the conditions to the conclusion, and then to the logical sum.

2) The defuzzifier operation, which unifies the result of the rule processes and calculates a final value of the output.

Defuzzification allows fuzzy- based products to be in interfaced to all types of output devices commonly available today.

3. IS Planning FIS Design

3.1 Data sets

First step of FIS designing is determination of input and output variables. There are three inputs (Table 1) and one output. After that, membership function's (MFs) designing of all variables will be started.

Table 1: Classification of Factors of IS

Input Field	Range	Fuzzy Set
Three Inputs	< 2	Low
	1.7 -3.3	Medium
	3 >	High

First of all, input variables of FIS with their membership functions (MFs) will be described as shown in Fig. 1 (clearer view in Appendix). In the second step, output variables of FIS with their membership functions will be shown in Fig. 2 (clearer view in Appendix). Three input variables of FIS are strategic planning, top management and IS infrastructure.

3.2 Fuzzy Rule Base for IS Planning

Rule base is the main part of FIS; and quality of results in fuzzy system depends on the fuzzy rules. A reasoning procedure known as the compositional rule of inference enables to draw conclusions by generalization from the qualitative information stored in the knowledge base. The fuzzy rules can express with the natural language in the following way: if x is small and y is great, then z is great. The variables x, y and z are type linguistic. This system includes 27 rules. Results with these rules tend to be an expert's ideal results. The rules for IS planning FIS are designed in Fig. 3 and 4(clearer view in Appendix).

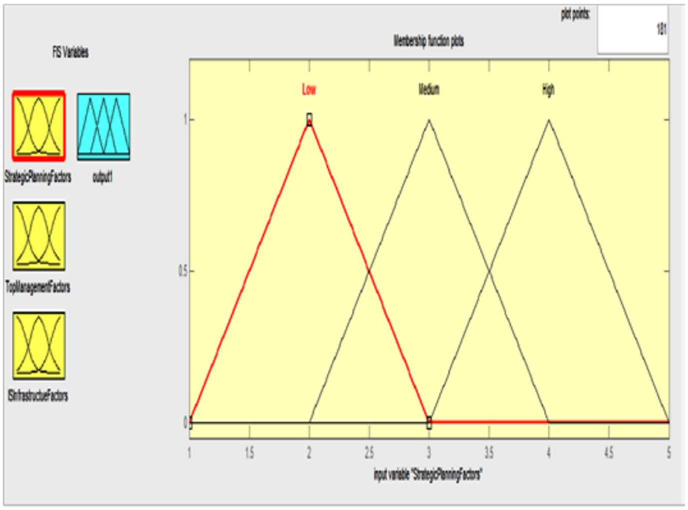


Fig.1: Fuzzy Inference System with three (3) inputs

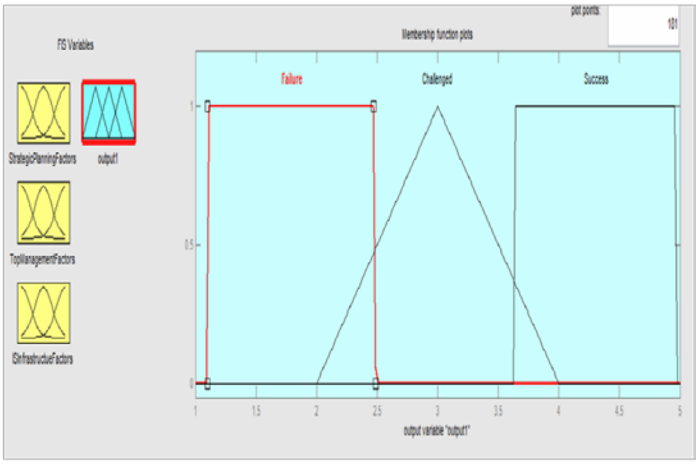


Fig.2 Fuzzy Inference System with one output

3.3 Fuzzification and Defuzzification

The designed system follows the Mamdani approach to inference mechanism [16]. The FIS system uses AND logical combination of inputs in the rules. The FIS system has the following properties:

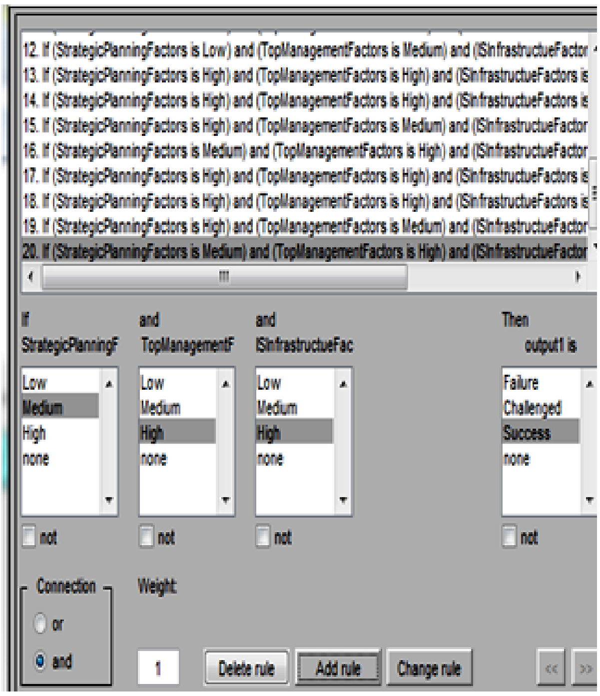
And Method: Min;

Or Method: Max;

Implication: Min;

Aggregation: Probor;

Defuzzification: Centroid.



12. If (StrategicPlanningFactors is Low) and (TopManagementFactors is Medium) and (ISinfrastructueFactor
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20. If (StrategicPlanningFactors is Medium) and (TopManagementFactors is High) and (ISinfrastructueFactor

Fig. 3: FIS rule viewer with three (3) inputs and one output.

3.4 System Testing

The under mentioned Table 2 shows the designed system using FIS which had been tested. The obtained results had been compared with the actual means and had found that the average error for IS planning comes out to be 4.87 i.e. 6.80%.

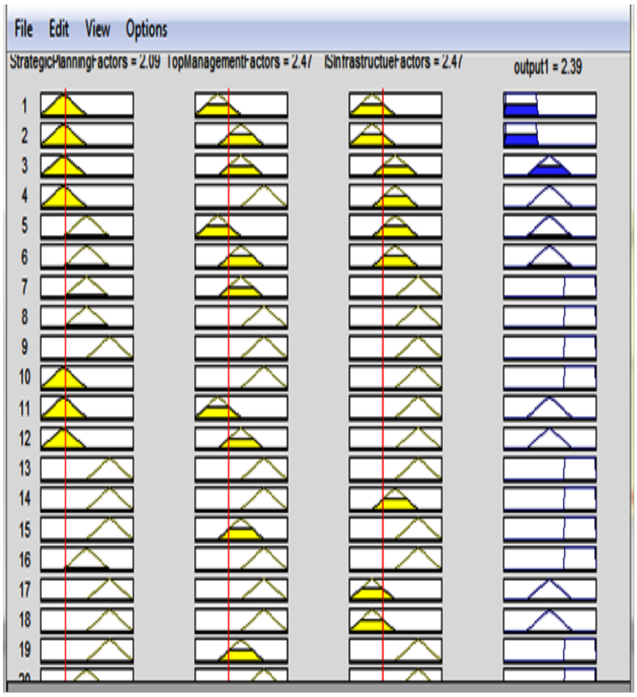


Fig. 4: FIS rule editor with three (3) inputs and one (1) output

Table 2: Results of FIS IS Planning Testing

Strategic Planning factors	Top Management Factors	IS Infrastructure	Actual Mean	FIS Output	Error
2.20	1.70	1.66	1.85	1.80	0.05
2.54	2.31	2.79	2.54	2.71	0.16
3.57	2.96	3.52	3.35	3.66	0.31
4.5	4.7	4.70	4.63	4.03	0.60
3.81	3.82	3.73	3.78	3.98	0.19
3.06	2.94	3.19	3.06	3.25	0.18
1.89	1.93	1.81	1.87	1.79	0.08
1.81	1.26	1.43	1.50	1.81	0.31
2.62	2.56	2.46	2.54	2.50	0.04
3.03	3.61	3.59	3.41	3.72	0.31
1.99	2.98	2.31	2.42	2.21	0.21
1.89	1.68	1.93	1.83	1.79	0.04
1.91	3.17	4.05	3.04	3.25	0.20
4.50	4.01	4.15	4.22	4.30	0.08
4.05	4.51	4.61	4.39	4.30	0.09
3.15	1.97	4.61	3.24	3.00	0.24
4.19	3.46	3.92	3.85	4.04	0.18
4.61	4.76	2.98	4.11	4.16	0.04
4.59	4.71	2.96	4.08	4.09	0.00
4.45	4.40	2.96	3.93	4.18	0.24
4.30	4.21	2.96	3.82	4.30	0.47
3.71	4.15	4.28	4.04	3.00	1.04
			71.59	71.87	4.8733
			Percentage error 6.807262		

4. Adaptive Neuro - Fuzzy Inference System (ANFIS) Designing

The designed system follows the Mamdani approach to inference mechanism [17]. ANFIS is a multi-layer adaptive network-based fuzzy inference system proposed by Jang [4]. An ANFIS consists of three layers to implement different node functions to learn and tune parameters in an FIS using a hybrid learning mode.

In ANFIS Planning Model, system computes the measures of all the three input factors and giving out just one output. The model takes three input values of planning dimensions based on strategies based factors, top management based factors and IS infrastructure based factors and then measures these values for its success, challenge or failure against the responses of the managers of the company .

For training ANFIS model, a dataset containing 86 responses were used. These responses were collected through the questionnaires designed for the measurement of success and failure factors of information system.

4.1 ANFIS Model Designing for IS planning

The ANFIS model has been used for IS planning that needs input values of strategic planning, top management and IS infrastructure. For ANFIS designing, model has passed four steps: (1) Load data, (2) Generate FIS, (3) Train FIS, and (4)Test FIS.

There are three different datasets for loading to model as shown in Fig. 5. These datasets include training data, testing data and checking data. At first, usage dataset contains three columns (strategic based factors, top management based factors and IS infrastructure based factors), and 86 rows having managers' responses. After that, this set was further divided into three sets: training set, testing set, and checking set. The checking or testing sets are known as validation set. The validation set monitors the fuzzy system's ability to generalize during training.

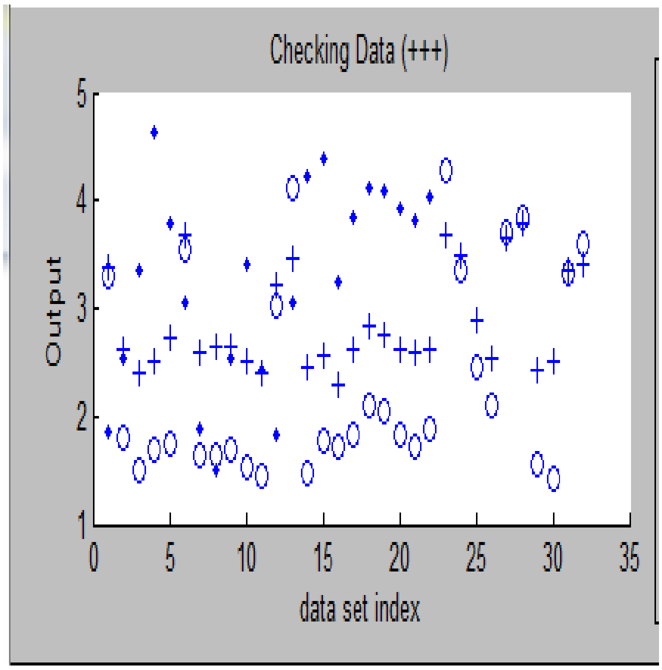


Fig. 5: Loaded Dataset into the ANFIS Planning IS Model

4.2 Generate FIS

For FIS generation, the model has two selections, Grid Partition and Subtractive Clustering. Grid partition divides the data space into rectangular subspaces using axis-paralleled partition based on pre-defined number of membership functions and their types in each dimension Mingzhen et. al [5].

Grid partition divides the data space into rectangular subspaces using axis-paralleled partition based on pre-defined number of membership functions and their types in each dimension. The wider application of grid partition in FL and FIS is blocked by the curse of dimensions, which means that the number of fuzzy rules increases exponentially when the number of input variables increases. For example, if there are averagely m MF for every input variable and a total of n input variables for the problem, the total number of fuzzy rules is m^n. It is obvious that the wide application of grid partition is threatened by the large number of rules .According to Jang[4], grid partition is only suitable for cases with small number of input variables (e.g. .less than 6).

The subtractive clustering method clusters data points in an unsupervised way by measuring the potential of data points in the feature space. When there is no clear idea how many clusters should be used for a given data set, it can be used for estimating the number of clusters and the cluster centers [5].

Subtractive clustering assumes that each data point is a potential cluster center and calculates the potential for each data point based on the density of surrounding data points. Then data point with the highest potential is selected as the first cluster center, and the potential of data points near the first cluster center within the influential radius is destroyed. Then data points with the highest remaining potential as the next cluster center and the potential of data points near the new cluster [5]. Firstly ANFIS model uses Grid Partition method for FIS generation. Generated FIS includes three inputs and one output. Input variables are: Maximum value of IS strategies, Top Management and IS Infrastructure. The number and type of membership functions for each input variable is three and triangular. Output field is the measure estimation of IS planning regarding its success/challenge/failure. Membership function type of output variable is linear.

This model had two problems: high average testing and training errors on testing data. Because of that, second time, the ANFIS model shown in Fig. 6 has been developed using Subtractive Clustering method with following options:

Range of Influence, 0.1, Squash Factor, 1.25, Accept Ratio, 0.5 and Reject Ratio, 0.15. The model contains 31 membership functions for each input.

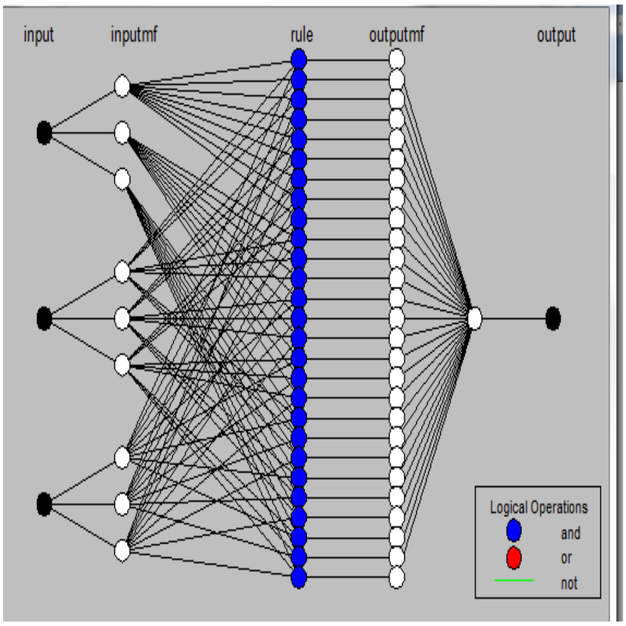


Fig. 6: Structure of the ANFIS Planning IS Model

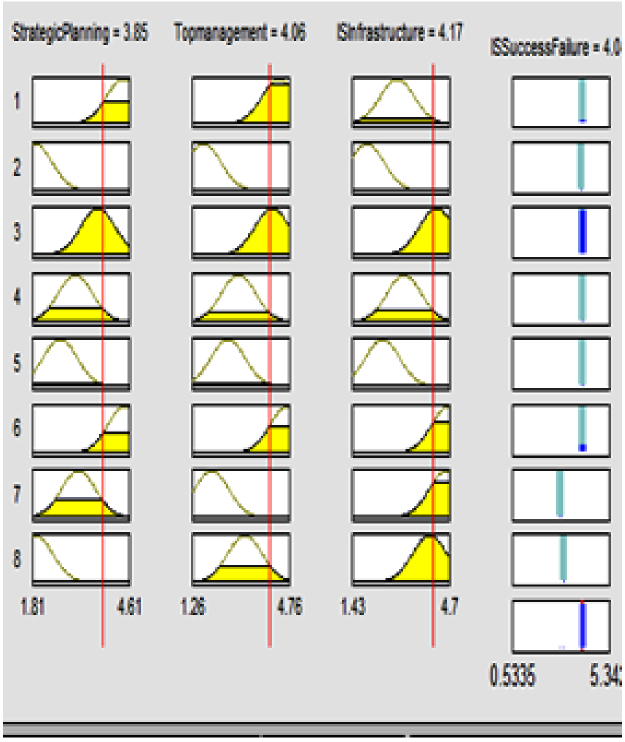


Fig. 7: Rule Viewer for IS Planning

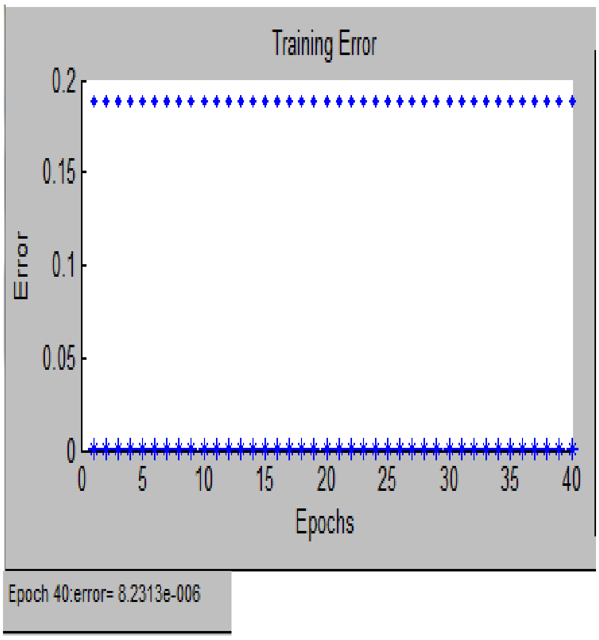
The type of membership functions of input fields is Gaussian. The designed version of the ANFIS model using Subtractive Clustering method shows better result than Grid partition of the model. The results are introduced in Test FIS section. Input ranges of factors of planning dimension and Output field is the success/challenged/failure measurement estimation. Membership function type of output variable is linear.

Rules are generated by ANFIS as shown in Fig. 7. Input ranges of IS Strategic, Top Management and IS Infrastructure are [1-5].

4.3 Train FIS

The optimization methods train membership function parameters to follow the training data. Two optimization methods i.e., Hybrid and Back-propagation optimization method are involved in this step.

The hybrid optimization method is a combination of least-squares and back propagation is a gradient descent method. In hybrid optimization method, model tunes with two pass: forward pass and backward pass. In the forward pass, with fixed premise parameters, the least squared error estimate approach is employed to update the consequent parameters and to pass the errors to the backward pass. In the backward pass, the consequent parameters are fixed and the gradient descent method is applied to update the premise parameters. Premise and consequent parameters are identified for MF and FIS by repeating the forward and backward passes.



Epoch 40:error= 8.2313e-006

Fig. 8: Training Error View

Fig.9: Result of Training with Testing data (=0.0204)

The ANFIS IS planning model uses hybrid optimization method as shown in Fig. 8. For this model, the number of training epochs is 40 and training error tolerance sets to zero. The training process stops whenever the maximum epoch number is reached or the training error goal is achieved. After FIS training, validate the model using a testing or checking data that differs from the one, used to train the FIS. Average testing errors of training and testing data in the ANFIS model are 0.0204 and 0.4732 respectively. These have been highlighted in Fig. 9 and 10, respectively.

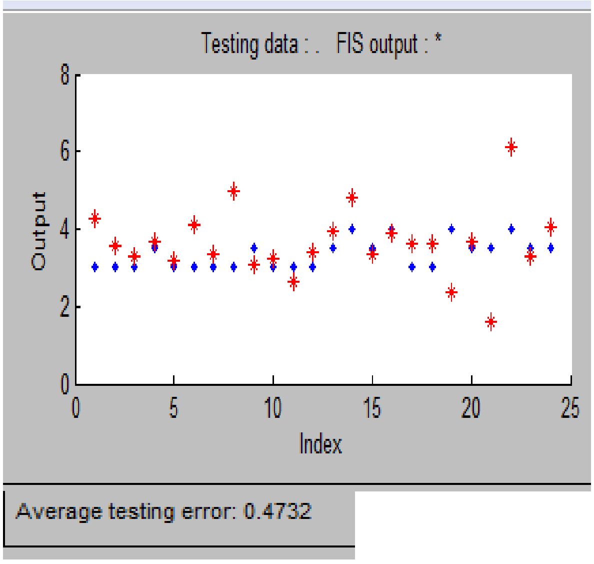


Fig.10: Result of the ANFIS Planning Model Testing with Testing Data (0.4732)

4.4 Checking FIS

After FIS training, validate the model using a testing or checking data that differs from the one used to train the FIS. Average testing errors of training and checking data in the ANFIS model are 0.0204 and 0.27607 respectively. These have been displayed in Fig. 9 and 11, respectively.

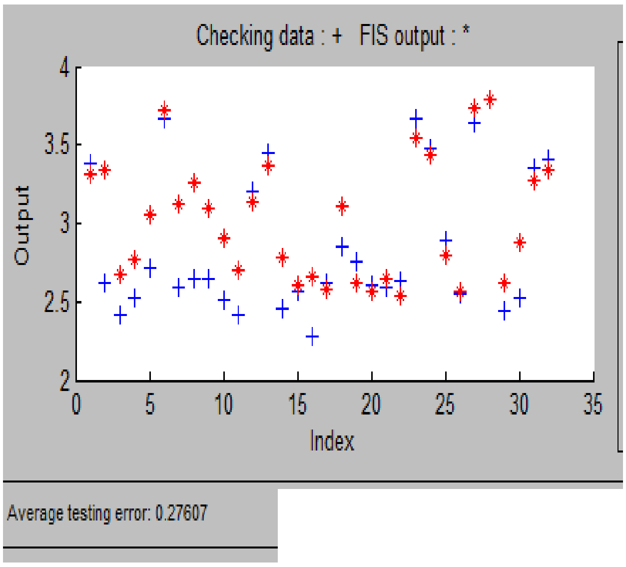


Fig. 11: Result of the ANFIS Planning Model Testing with Checking Data (0.27607)

5. Conclusions

Success or failure of IS is non-linear completely. Therefore fuzzy logic based model is suitable for estimation of success, challenge or failure of IS. In this comparative study, two fuzzy logic based models have been developed to offer good and reasonable IS planning design for its three sub dimensions constituting 32-factors. For the Information System Planning Model, Mamdani-FIS and Sugeno-ANFIS perform in the same way but with the use of Sugeno-ANFIS model, the IS planning model performs at its full potential with very less error rate. Sugeno-type ANFIS has an advantage that it is integrated with neural networks and genetic algorithm or other optimization techniques so that the IS Planning Model can adapt to individual user input and environment. Rules, input/output variables, membership functions and ranges of them based on the questionnaires which were developed after study of extensive research papers, conferences and consultation with the managers of both the companies under study. The FIS and ANFIS model contains a model that is used for the task of estimating the effectiveness of IS planning that is whether the system is a success

/challenge or failure. Therefore the output of all the inputs for IS planning after passing through FIS or ANFIS gives the output whether the IS is going to be success/challenged/failure. After systems designing and testing, a comparison was made between these two systems i.e. FIS and ANFIS; and the results proved that ANFIS model is certainly better than Fuzzy Expert System. In ANFIS model, prediction of success/challenge/failures of IS planning output field are: average training, testing and checking errors are 0.0204, 0.4732, 0.27607 respectively. The results of FIS model in comparison to actual measurements of mean values give predictions with average error 4.87. The future scope of this research paper is the implementation of the same type of ANFIS based IS model in the various phases of software development life cycle model i.e. in the evaluation, stabilization, designing and transformation phases.

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Appendix (Diagrams)

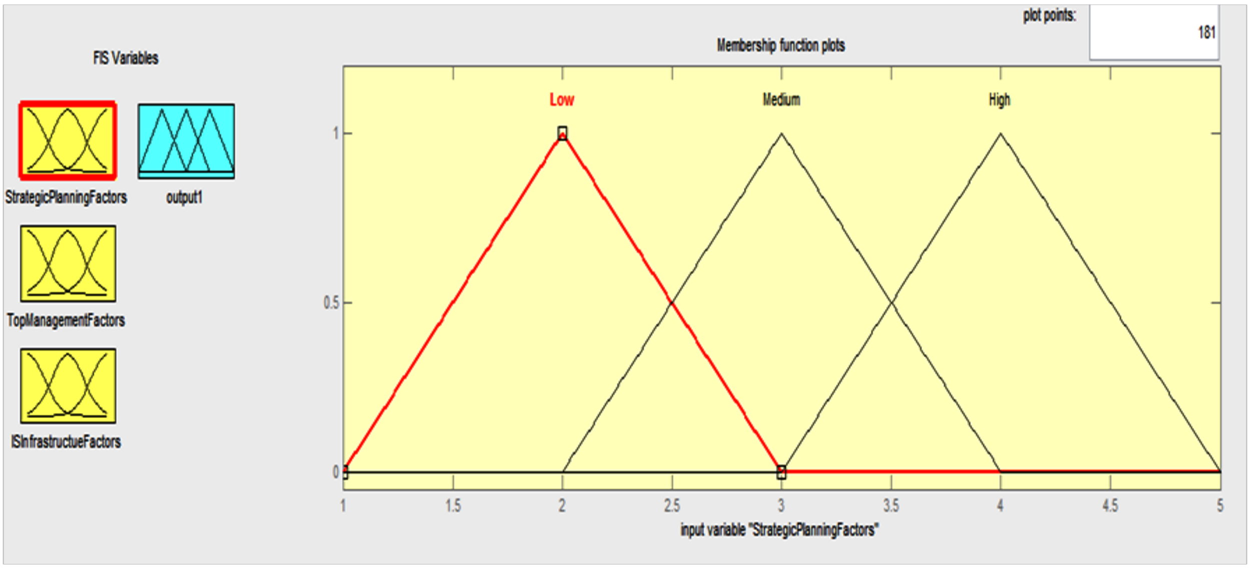


Fig.1: Fuzzy Inference System with three (3) inputs

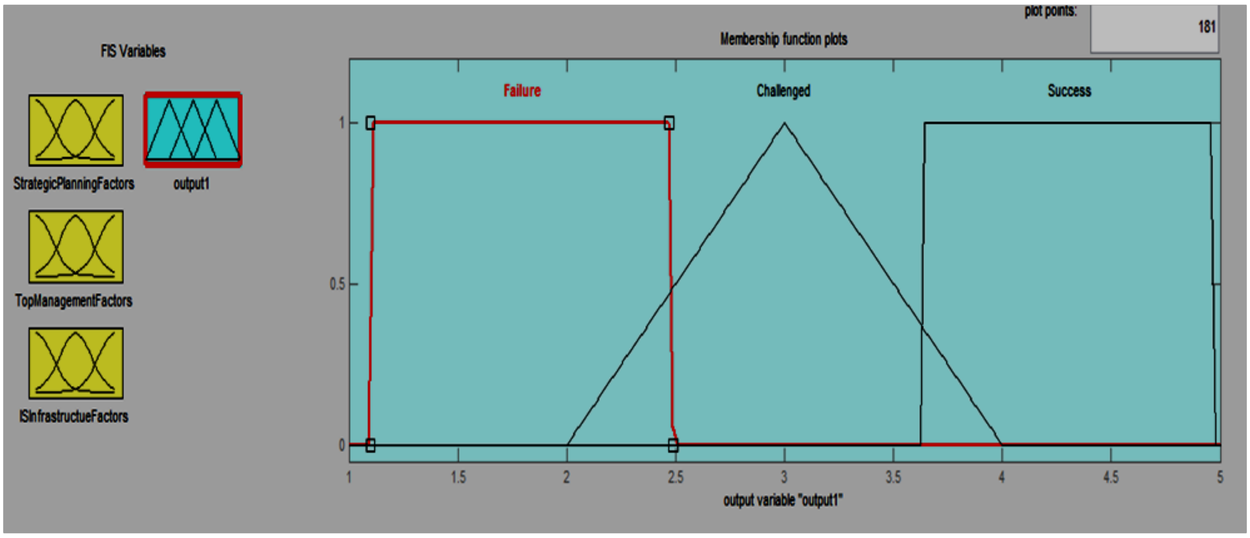
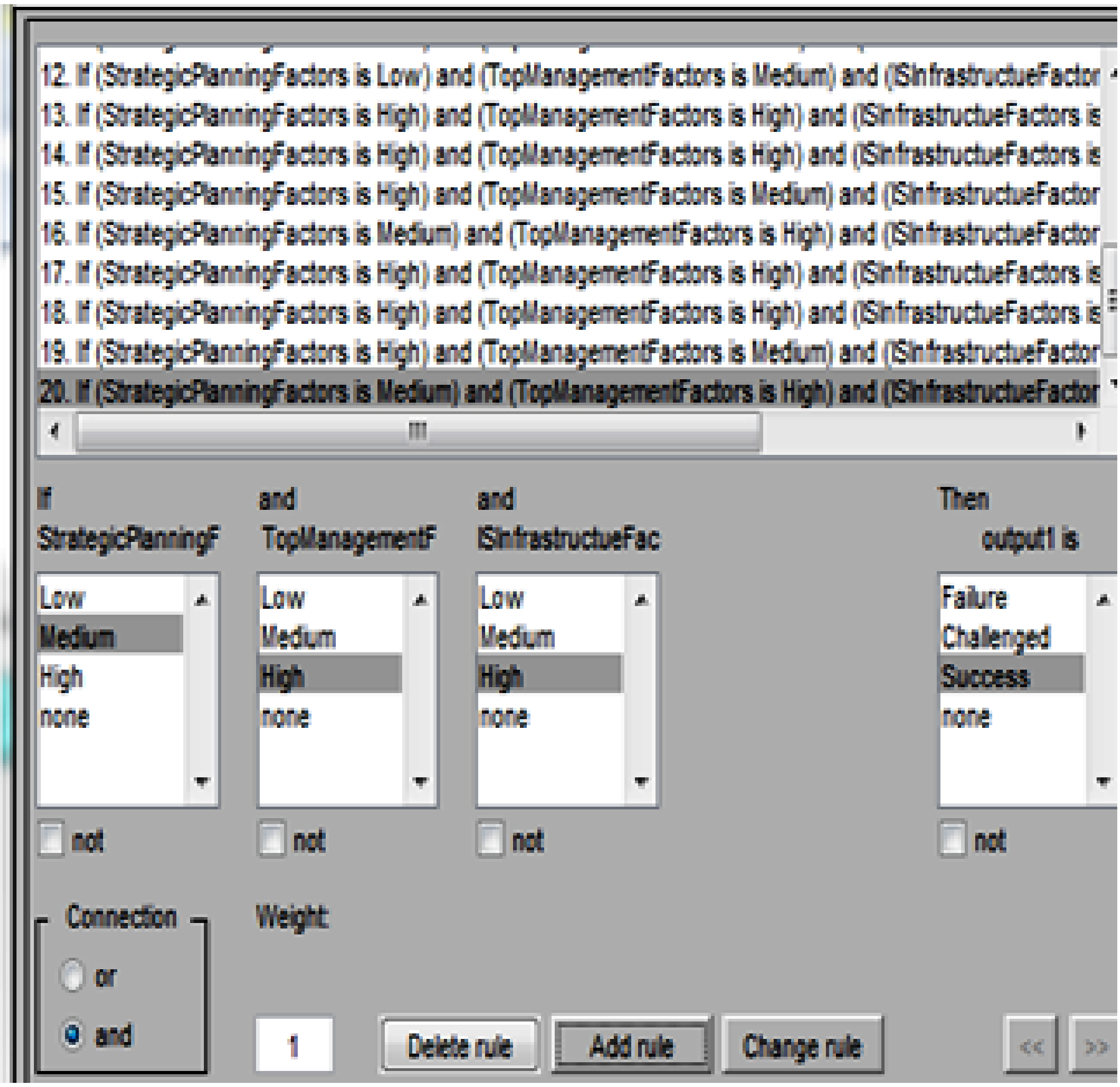


Fig.2 Fuzzy Inference System with one output



12. If (StrategicPlanningFactors is Low) and (TopManagementFactors is Medium) and (ISInfrastructueFactor
13. If (StrategicPlanningFactors is High) and (TopManagementFactors is High) and (ISInfrastructueFactors is
14. If (StrategicPlanningFactors is High) and (TopManagementFactors is High) and (ISInfrastructueFactors is
15. If (StrategicPlanningFactors is High) and (TopManagementFactors is Medium) and (ISInfrastructueFactor
16. If (StrategicPlanningFactors is Medium) and (TopManagementFactors is High) and (ISInfrastructueFactor
17. If (StrategicPlanningFactors is High) and (TopManagementFactors is High) and (ISInfrastructueFactors is
18. If (StrategicPlanningFactors is High) and (TopManagementFactors is High) and (ISInfrastructueFactors is
19. If (StrategicPlanningFactors is High) and (TopManagementFactors is Medium) and (ISInfrastructueFactor
20. If (StrategicPlanningFactors is Medium) and (TopManagementFactors is High) and (ISInfrastructueFactor

If StrategicPlanningF: Medium

and TopManagementF: High

and ISInfrastructueFac: High

Then output1 is: Success

Connection: ○ or ● and

Weight: 1

Fig. 3: FIS rule viewer with three (3) inputs and one output.

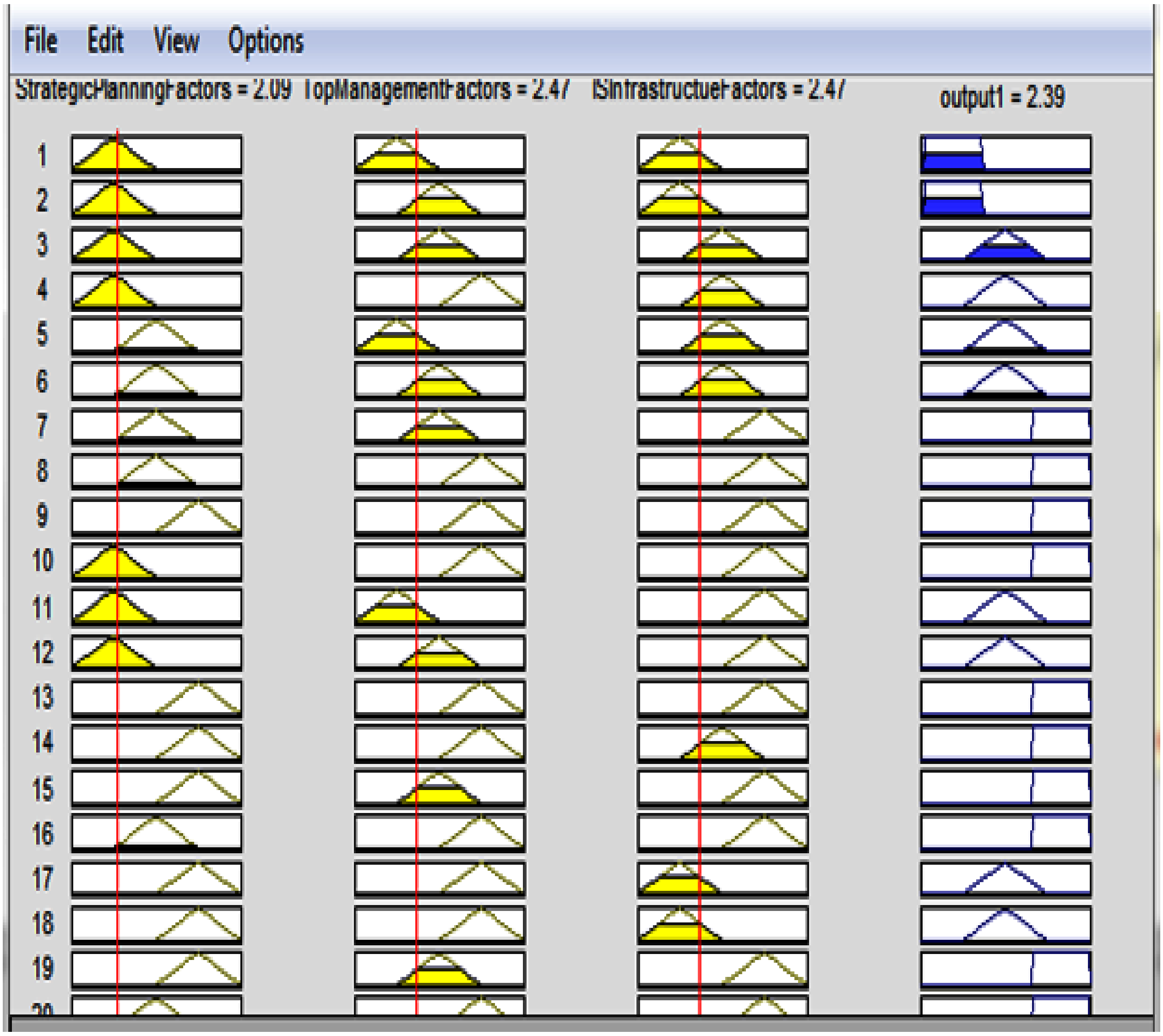


Fig. 4: FIS rule editor with three (3) inputs and one (1) output