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A Framework to Design Sugeno type ANFIS System for Course Selection

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***Abstract*—Advice on course selection is needed for students at different stages in their education. Course advisor should be equipped with wide knowledge about the different courses. This paper is based on design and implementation of Sugeno type ANFIS system implemented using Matlab. Human like reasoning style of fuzzy system when combined with learning the structure of artificial neural networks, enhance the course selection process. This course advisory system is designed for the students to choose courses at undergraduate degree according to the courses available in Christ University, Bangalore.**

***Keywords* — ANFIS, Artificial neural networks, fuzzy system, Matlab, Sugeno**

I. INTRODUCTION

Existing advisory systems have certain limitations in their design, be it database advisory systems, or artificial neural based stand alone systems, or fuzzy based stand alone systems, or web based systems. Neuro fuzzy systems can solve the complex real world problems in an efficient way and its usage in this domain is highly recommended.

Adaptive Network based Fuzzy Inference System ANFIS is implemented as a Sugeno fuzzy inference system. ANFIS system allows the user to choose or modify the parameters of the membership functions based on the data. The parameters are adjusted automatically by the neuro adaptive learning techniques like back propagation algorithm or hybrid method (which is a combination of back propagation and least squares method). These techniques allow the fuzzy inference system to learn information about the data set. During the learning process, the parameters of the membership functions will be changed. The computations of these parameters can be controlled by using the optimization procedure which is defined by the sum of squared differences between actual and desired outputs.

Sugeno systems are more compact and computationally efficient representation than a Mamdani system. The general rule of the Sugeno system is given by

if x is A and y is B then z=f(x,y)

where A, B are fuzzy sets and x, y are the inputs. f is a crisp output function. Based on f, Sugeno model can be classified as:

- First order Sugeno model
- Zero order Sugeno model

If f is a polynomial function, then the system is a first order Sugeno model. If f is a constant, then the system is a zero order Sugeno model.

Structure of the Sugeno model is designed in such a way that the input is mapped to input membership function, the input membership function is mapped to rule, then the rule is mapped to output membership function and then the output membership function is mapped to the output. Thus the system takes five layers.

Each node in the first layer generates a membership grade. Each node in the second layer calculates the firing strength of the rule. Each node in the third layer calculates the ratio of the ith rule's firing strength to the total of all firing strength. Each node in the fourth layer is an adaptive node which maps to the output membership functions. The node in the fifth layer gives the overall output.

A. Fuzzy inference process:

Fuzzy inference is a method that takes the values from the input vector and based on some set of rules, assigns values to the output vector.

Steps involved in fuzzy inference process are:

1. *Fuzzification of the input variables*

   Fuzzification process determines the degree to which the input belongs to a fuzzy set. The degree of membership is in between 0 to 1.

2. *Application of the fuzzy operator (AND or OR) in the antecedent*

   If a rule has more than one part, antecedent part of a rule can be combined by using fuzzy operators AND or OR. Matlab supports two types of AND (min, prod) methods. Matlab supports two types of OR (max, propor) methods.

3. *Implication*

   Every rule has a weight between 0 and 1. The input to the implication process is a mark which is in number and the output is a fuzzy set. Two built-in methods supported are min (minimum), which truncates the output fuzzy set, and prod (product), which scales the output fuzzy set. Sugeno model uses min as implication method.

4. *Aggregation*

   Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. The methods available are max (maximum), probor(probabilistic OR), and sum (simply the sum of each rule's output set). Sugeno model uses max as aggregation method.

5. *Defuzzification.*

   The input to the defuzzification process is fuzzy set and the output is a single number. The methods supported are centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum. The default defuzzification method for Sugeno type is whatever (weighted average).

II. LITERATURE SURVEY

The usage of technology in the course advising domain helps the advisor to select the best course. Technology-based advisory systems are no longer used for data storage but it facilitates the course selection process through knowledge base

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and reasoning ability. The existing technology based advisory systems are designed as standalone decision support systems, or web based decision support systems. These advisory systems were implemented as traditional data base systems or object oriented systems [1]. Such systems have their own limitations. Decision support systems can be designed with artificial neural network [7]. Design of neuro fuzzy system [8] shows its application in the real world problems. Neuro Fuzzy Model for the student domain with feed forward architecture with five layers of neurons and four connections is discussed in [12]. MATLAB implementation of neuro fuzzy system is discussed in [13]. Neural network construction for precollege students is discussed in [14]. Decision making, using fuzzy based system is studied in [15].

III. Framework Development

The design process is shown in Fig 1.

A. Student Information

Personal details include Name, Gender, Date of Birth, Nationality and Address. Family details include Father's name, Mother's name, Father's profession, Mother's profession, Father's monthly income, Mother's monthly income, Sibling details, number of degree holders in the family. Tenth mark details include subject details, marks of each subject, school in which student studied. XII standard (PU) mark details include, subject details, marks of each subject, school in which student studied. Information regarding student's interests in co – curricular activities, the preferred degree course is also collected.

B. Data Cleaning

Data cleaning involves handling noise, inconsistency and missing values in the input data. By designing student interface form with all validations, data cleaning process is accomplished.

C. Data Transformation

Data format conversion is performed for student marks. X standard marks to be normalized in number format. XII standard marks to be normalized in number format. Students are from different countries. Marks are to be processed in a uniform format as number. Language strength of the student is considered for further processing.

D. Input Selection for ANFIS system

Generally real world problems will take tens to hundreds of input. Therefore the priorities of the inputs are identified and then the significant inputs are considered to model the ANFIS system. Among many inputs, the significant inputs, four core subject marks in twelfth standard, tenth standard performance and interest of the student are considered. ANFIS model is constructed

- To find the strength of the four core subjects
- To find the strength of the tenth standard

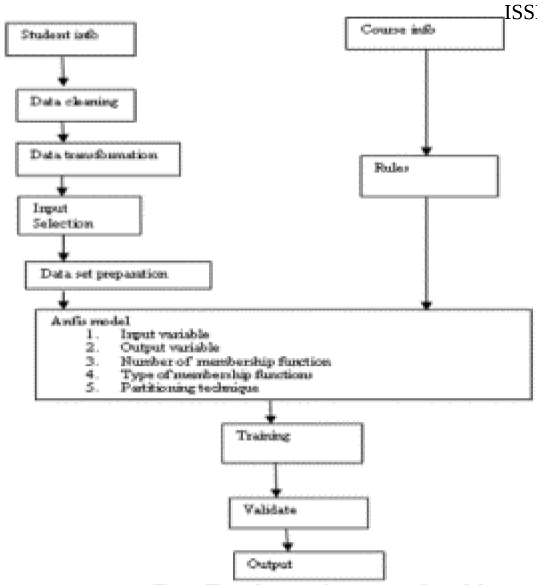

Fig 1 *Flowchart of the proposed model*

- To check the interest with the strength

Significant input selection is essential because of the following reasons:

1. Training many ANFIS models with minimum input involves less computation than training one ANFIS model with many inputs.
2. Grid partitioning is the most frequently used method to design ANFIS system. The partitioning technique works efficiently when the system has minimum number of inputs.
3. The dimension of the training data can be reduced if the ANFIS model uses a minimum number of inputs.

E. Data set preparation

The data set is classified into three sets, namely training data set, checking data set and validation data set. Input data set contains 600 data records and each set contains 200 data records. Training data set is used to create the FIS model. The testing data set is used for model validation. The output column should contain data. If this column is empty, then data cannot be loaded into ANFIS and training cannot happen.

1. The number of epoch will be minimum if the data set is perfect that is, and output is given correctly in the training data set.
2. The number of epochs needed to train the ANFIS will be increased if the training data set contains wrong data or missing data.
3. ANFIS can be trained for many training data sets.

F. Input from the Department

Each department has a prerequisite for the students to select a particular course. The minimum 60% is needed in the core subject offered by the department. This information is used to build the department interface for the Neuro Fuzzy system. Fuzzy rules can be defined based on the subjects offered by the department.

G. Model construction

FIS model can be generated by specifying the input variable, number of membership functions, type of membership functions of input variables, output variable, type of membership function for output variable. Once the data is loaded, FIS model can be generated using any one of the

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partitioning techniques (Grid partitioning, Subtractive Clustering).

H. Training FIS

Training plot should be a curve that increases initially, reaches maximum and then decreases during the training period. The Sugeno type supports only one output variable and the type can be linear or constant. The parameters are adjusted using any one of the following learning methods.

Bac kpropagation:

Parameters of input membership functions and output membership functions are updated using backpropagation algorithm.

Hybrid method:

This method uses backpropagation algorithm to update the parameters of input membership functions and least square method to update the parameters of the output membership functions.

IV. Design of ANFIS Model

ANFIS model to compute the strength of tenth standard is designed as follows:

1. *Identification of linguistic variables:*

There are five main linguistic variables used in the design of course advisory system. These variables are Excellent (E), Very Good (VG), Good (G), Average (A) and Poor(P).

Table 1 Identification of linguistic variable

Linguistic variable	Notation	Range
Excellent	E	>=76
Very good	VG	66 to 75
Good	G	56 to 65
Average	A	46 to 55
Poor	P	<45

Fig 2 shows the input and output variable of the fuzzy inference system.

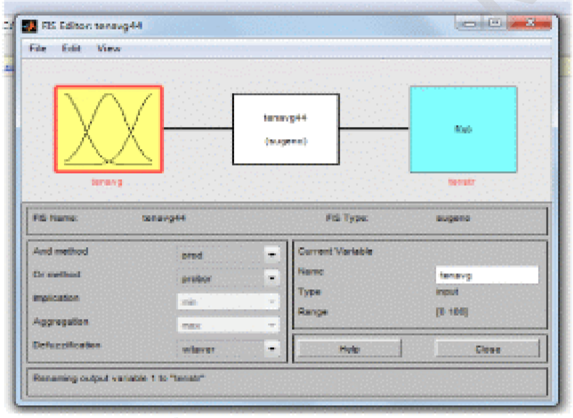

Fig 2 *Fuzzy inference system*

2. *Determination of fuzzy sets:*

The degree an object belongs to a fuzzy set is denoted by a membership value between 0 and 1. Identification of a fuzzy membership function is a key issue in all fuzzy systems. Membership functions can take any form or shape like triangular, trapezoidal, Gaussian, bell shaped etc. This implementation is based on triangular membership function. For tenavg FIS, Input variable is class tenth average (tenavg) and output variable is tenth strength (tenstr). This field accepts value between [0,100].

The interval contains five fuzzy sets such as Excellent (E), Very Good (VG), Good (G), Average (A) and Poor(P).

Table 2: Input variable specifications

Input variable	Range	Fuzzy set
Tenavg	>76	Excellent (E)
	66-75	Very Good (VG)
	56-65	Good (G)
	46-55	Average (A)
	0-45	Poor(P)

Using a number of membership functions represents a complex system in a better way. Thus the efficiency of the system is improved by producing better results. In this case, the fuzzy sets are distinct, and the membership function is not overlapping from fuzzy set to other.

The membership function for the fuzzy set Poor(P) is defined as

$$\mu_P(x, 0, 22.5, 45) = \begin{cases} 0, & \text{if } x < 0 \\ (x)/(22.5), & \text{if } 0 \le x \le 22.5 \\ (45-x)/(22.5), & \text{if } 22.5 \le x \le 45 \end{cases}$$

The membership function for the fuzzy set Average (A) is defined as

$$\mu_A(x, 46, 50.5, 55) = \begin{cases} (x-46)/(4.5), & \text{if } 46 \le x \le 50.5 \\ 1 & x=50.5 \\ (55-x)/(4.5), & \text{if } 50.5 < x \le 55 \end{cases}$$

The membership function for the fuzzy set Good (G) is defined as

$$\mu_G(x, 56, 60.5, 65) = \begin{cases} (x-56)/(4.5), & \text{if } 56 \le x \le 60.5 \\ 1 & x=60.5 \\ (65-x)/(4.5), & \text{if } 60.5 < x \le 65 \end{cases}$$

The membership function for the fuzzy set Very Good (VG) is defined as

$$\mu_{VG}(x, 66, 70.5, 75) = \begin{cases} (x-66)/(4.5), & \text{if } 66 \le x \le 70.5 \\ 1 & x=70.5 \\ (75-x)/(4.5), & \text{if } 70.5 < x \le 75 \end{cases}$$

The membership function for the fuzzy set Excellent (E) is defined as

$$\mu_E(x, 76, 88, 100) = \begin{cases} (x-76)/(12), & \text{if } 76 \le x \le 88 \\ 1 & x=88 \\ (100-x)/(12), & \text{if } 88 < x \le 100 \end{cases}$$

Fig 3 *shows the input membership functions.*

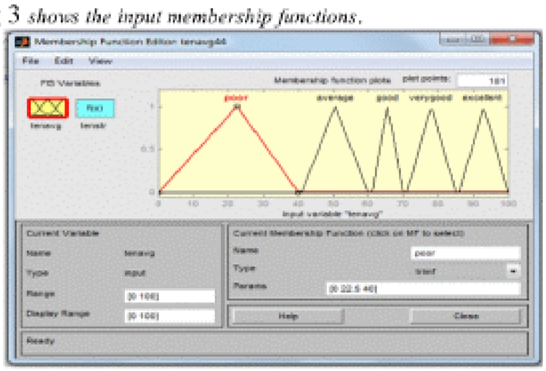

Fig 3 *Input membership functions*

Fig 4 *shows the output membership functions.*

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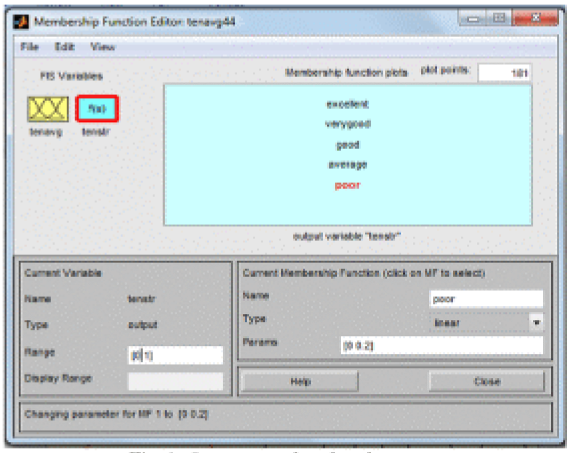


Fig 4. *Output membership functions*

3. Construction of fuzzy rules.

If part of the rule is called as antecedent and the then part of the rule is called as consequent. Input to the antecedent part is the current value of the input variable. Its value is fuzzified as a number between 0 and 1 by using membership functions. The output is an entire fuzzy set and later it will be defuzzified. The rule editor of tenavg44 is shown in Fig 5.

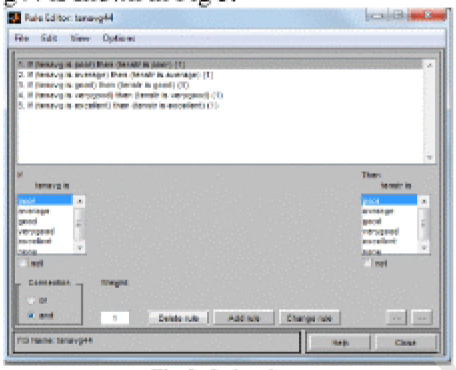


Fig 5. *Rule editor*

4. Tuning the fuzzy system

The training of the system is done by specifying the learning methods, error rate and the number of epochs. The training graph is shown in Fig 6.

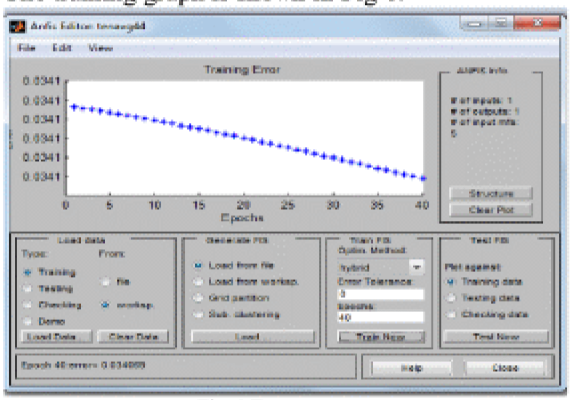
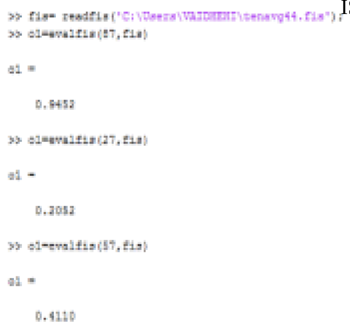


Fig 6 *Training error*

5. Testing

The trained system is tested on the sample data. The resulting result is shown in Fig 7.



```
>> fis= readfis('C:\Users\VAIDEHI\tenavg44.fis');
>> c1=evalfis(87,fis)

c1 =

    0.9452

>> c1=evalfis(27,fis)

c1 =

    0.2052

>> c1=evalfis(57,fis)

c1 =

    0.4110
```

Fig 7. Testing

The structure of ANFIS system designed for ten avg is shown in figure 8.

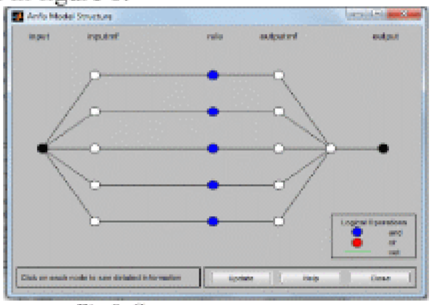


Fig 8. *Structure.*

Similarly the other models to compute core subject's strength respectively s1, s2, s3, s4 are designed and evaluated.

V. LIMITATIONS

The various limitations of ANFIS systems are as follows:

- It supports Sugeno-type systems.
- All output membership functions should be of same type. It can be either linear or constant.
- The number of output membership functions must be equal to the number of rules.
- The weight values for all the rules should be one.
- It cannot accept the various customizations options supported by the basic fuzzy inference systems.

VI. CONCLUSION

The design of Sugeno type ANFIS course advisor is efficient can be constructed easily. This system helps the students to take effective decisions. This system is used to minimize the dropouts in higher education. Enriching the system by adding more data and rules is a continuous process. This implementation concentrates widely on the courses available in the science stream. The system can be improved to satisfy other areas of the student needs like selecting an elective, selecting certificate courses, selecting arts, commerce, engineering and post graduate courses.

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