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Teacher performance evaluation using Neuro-Fuzzy techniques

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Abstract
The evaluation of Teachers performance in teaching activity is especially relevant for the academic institutions. The performance evaluation is based on Adaptive Neural Fuzzy Inference System (ANFIS). In this paper, we discuss the teacher's performance evaluation using Neuro-Fuzzy System to find out the relationship between the Personal problems and employees' performance in organization. This System consider the various aspects of performance measures of teachers, like students' feedback, teaching practice, teaching learning process, background factors and requirements, research orientation and publications, ICT development of teacher and other performance like personal skills & abilities, etc. that have deep influence on the teachers' performance in technical institutions. By using evaluation result of each teacher, administrator encourages teachers which result is great in their teaching, which result is suitable in teaching, which result is need to training, some teachers need to try hard more and more. In this way, every teacher is attempting to improve their quality, skill, satisfaction, efficiency and innovation in teaching in the technical educational organizations.

Keywords: Neuro-fuzzy, ANFIS, least square, activities of academic institution

1. Introduction

This system uses Neuro-fuzzy logic for evaluating for teachers as well as an integrated approach based on fuzzy logic and neural network including 4 main factors and 16 sub-factors for evaluating performance in education institution. Total numbers of factors are 16 attributes for all teachers. Using these factors, this system supports considering to evaluate in technical education. Learning phase includes neural network and fuzzy logic system. ANFIS (adaptive network based fuzzy inference system) models [1] built to know characteristics of teachers' performance that are either ranked High, Medium, or Low by the academic evaluators in business environment. It helps to define efficient plans to guarantee quality of teachers and the teaching learning process. This system is implemented by using C# programming language.

The combination of fuzzy logic and neural networks constitutes a powerful means for designing intelligent systems. Domain knowledge can be put into a neuro-fuzzy system by human experts in the form of linguistic variables and fuzzy rules [7]. In Myanmar, the function of teachers is essential, as they have to inculcate important values in future generations and ensure the holistic development of their students. The major task of teachers would then be to impart these virtues to their students in addition to the main task of teaching the standard school subjects. The process of education is concerned chiefly with the interaction between the teacher and the students together with the classroom practices that occur within the school environment.

This paper is organized into five sections including this section. Section 2 describes the theory background of Neuro-Fuzzy techniques. In section, Adaptive Neural Fuzzy Inference System (ANFIS), Node Functions in the Layer, Triangular Membership Function, and Consequent Parameters Calculations for ANFIS are also described. Section 3 describes input factors and sub-factors, system design, and experimental result in performance evaluation process. Section 4 describes the step by step processes for teacher performance evaluation. Finally, section 5 includes conclusion, further extension and advantages of the system.

1.1 Objective of the System

The objectives of this system are to achieve and know status of teacher's performance, to know the evaluation of teaching activity is especially important for universities, to improve the quality of teaching and training of teachers and to measure performance of teachers in University and institutions. The motivation of the study is to develop a soft computing model based on neuro-fuzzy techniques to measure performance of teaching staff in technical institutions and a system of evaluation.

2. Theory background for neuro-fuzzy logic

Neural fuzzy inference systems introduce a parallel architecture and learning capability to a fuzzy inference system. Each fuzzy rule is created by using the ANN and it is a data driven process. Fuzzy neural networks embed fuzzy logic into the ANN by fuzzifying the learning algorithms. All the combinations of techniques based on neural networks and fuzzy logic can be called neuro-fuzzy systems [4, 5].

The inputs data for a particular teachers' evaluation comes from University committees that may be administration member, and annual confidential report. Five members give the qualification marks for all teachers through the 1 to 5 parameters. The supervisor in question will propose a performance level on the basis of the evaluation. Most of these inputs are in non-numeric or linguistic form [3, 9].

3. Adaptive neural fuzzy inference system (ANFIS)

A neuro-fuzzy system is defined as a combination of Artificial Neural Networks (ANN) and Fuzzy Inference System (FIS) in such a way that neural network learning algorithm are used to determine the parameters of FIS [4]. Adaptive Neural Fuzzy Inference System (ANFIS) [2] is a system that belongs to neuro-fuzzy category. Structurally, the only limitation of network configuration is that it should be of feedforward type.

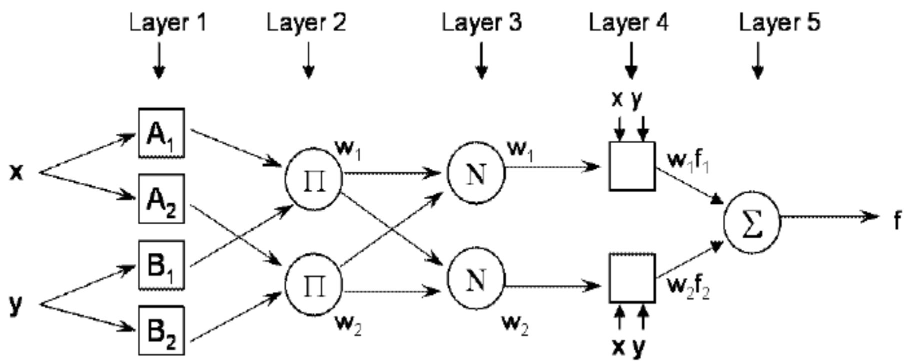


Fig 1: ANFIS Architecture

For simplicity, it is assumed the fuzzy inference system under consideration has two inputs x and y, and one output f. Suppose that the rule base contains two fuzzy if-then rules of Takagi and Sugenos' type [5, 8]:

Rule1: If x is A1 and y is B1 then f1 = p1 × x + q1 × y + r1 (1)

Rule2: If x is A2 and y is B2 then f 2= p2 × x + q2 × y + r2 (2)

A is node values of input x and B is node values of input y for layer 1.2.2 Participant (Subject) Characteristics, Appropriate identification of research participants is critical to the science and practice of psychology, particularly for generalizing the findings, making comparisons across replications, and using the evidence in research syntheses and secondary data analyses. If humans participated in the study, report the eligibility and exclusion criteria, including any restrictions based on demographic characteristics.

3.1 Node Functions in the Layer

The node functions in the same layer are of the same function family as described below [6]:

Layer 1(Input Node): Nodes in this layer contains membership functions $\mu(x)$. Parameters in this layer are referred to as premise parameters. Every node *i* in this layer is a square and adaptive node with a node function:

$$O_i^1(x) = \mu_{A_i(x)} \quad (3)$$

Where *x* - the input to node i, A_i - the linguistic label (small, large, etc.) associated with this node function. In other words, O_i^1 is the membership function of A_i and it specifies the degree to which the given *x* satisfies the quantifier A_i. Usually $\mu_{A_i}(x)$ is chosen to bell-shaped with maximum equal to 1 and minimum equal to 0, such as the generalized bell function where a_i, b_i, c_i is the parameter set. As the values of these parameters change, the Trigular functions vary accordingly, thus exhibiting various forms of membership function on linguistic label A_i. Parameters in this layer are referred to as *premise parameters* [10].

$$\mu(x) = max\left[min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right] \quad (4)$$

Layer 2 (Rule nodes): Every node in this layer is a circle node labeled Π, which multiplies the incoming signal and sends the product out. Every node in this layer is a circle node labeled II, whose output represents a firing strength of a rule. This layer chooses the minimum value of two input weights (*w).* In this layer, the AND/OR operator is applied to get one output that represents the results of the antecedent for a fuzzy rule, that is, firing strength. It means the degrees by which the antecedent part of the rule is satisfied and it indicates the shape of the output function for that rule [8]. The node generates the output (firing strength) by cross multiplying all the incoming signals:

$$O_{2,1} = \omega_i = \mu_{A_i}(x) \times \mu_{B_i}(y), i = 1,2 \quad (5)$$

Layer 3 (Average nodes): Every node in this layer is a circle node labeled N. The i^{th} node calculates the ratio of the i^{th} rules firing strength to the sum of all rules' firing strengths:

$$O_i^3 = \overline{w_i} = \frac{w_i}{w_1+w_2}, i = 1,2, ..., \quad (6)$$

For convenience, output of this layer will be called normalized firing strengths.

Layer 4 (Consequent nodes): Every node *i* in this layer is a square node with a node function where: $\overline{w_i}$ the output of layer 3{p_i, q_i, r_i} - the parameter set. Parameters in this layer will be referred to as consequent parameters in figure 3.

$$O_i^4(x) = \overline{w_i} * f_i = \overline{w_i}(p_i . x + q_i . y + r_i) \quad F = \text{function output of consequent parameters} \quad (7)$$

Layer 5 (Output node): The single node in this layer is a circle node labeled Σ that computes the overall output as the summation of all incoming signals, i.e.

$$O_i^5(x) = overalloutput \qquad O_i^5(x) = \sum_i \overline{w_i} * f_i = \frac{\sum_i w_{i*} f_i}{\sum_i w_i} \quad (8)$$

3.2 Parametric Identification

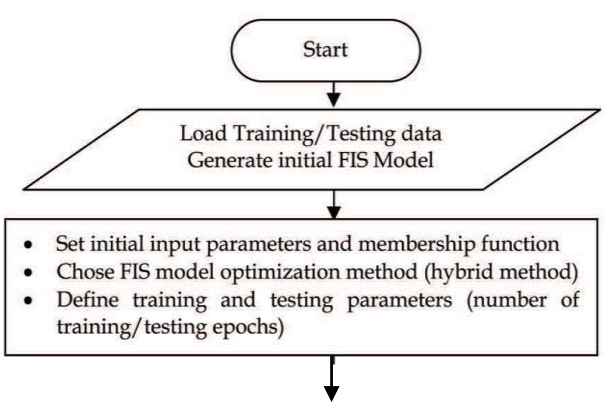
Many neuro-fuzzy systems use direct nonlinear optimization to identify all the parameters of a fuzzy system. From the proposed type-3 ANFIS architecture in Figure 1, it is observed that given the values of premise parameters, the overall output can be expressed as linear combinations of the consequent parameters. More precisely, the output f in Figure 1 can be rewritten as [2]:

$$\begin{aligned} f &= \frac{w_1}{w_1+w_2} f_1 + \frac{w_2}{w_1+w_2} f_2 = \overline{w}_1 f_1 + \overline{w}_2 f_2 \\ &= (\overline{w}_1 x) p_1 + (\overline{w}_1 y) q_1 + (\overline{w}_1) r_1 + (\overline{w}_2 x) p_2 + (\overline{w}_2 y) q_2 + (\overline{w}_2) r_2 \end{aligned} \quad (9)$$

Equation 9 is linear in the consequent parameters (p_1, q_1, r_1, p_2, q_2 and r_2). Therefore, the hybrid learning algorithm can be applied directly.

3.3 Structural Identification

Input MFs (membership functions) were linked by all possible combinations of if-and-then rules defining an output constant for each rule. The flow chart of proposed training methodology of ANFIS system is shown in Figure 2. The modeling process starts by obtaining a data set (input-output data pairs) and dividing it into training and checking data sets. Training data constitute a set of input and output vectors. The data are normalized in order to make it suitable for the training process. This normalized data was utilized as the inputs and outputs to train the ANFIS [1, 5].



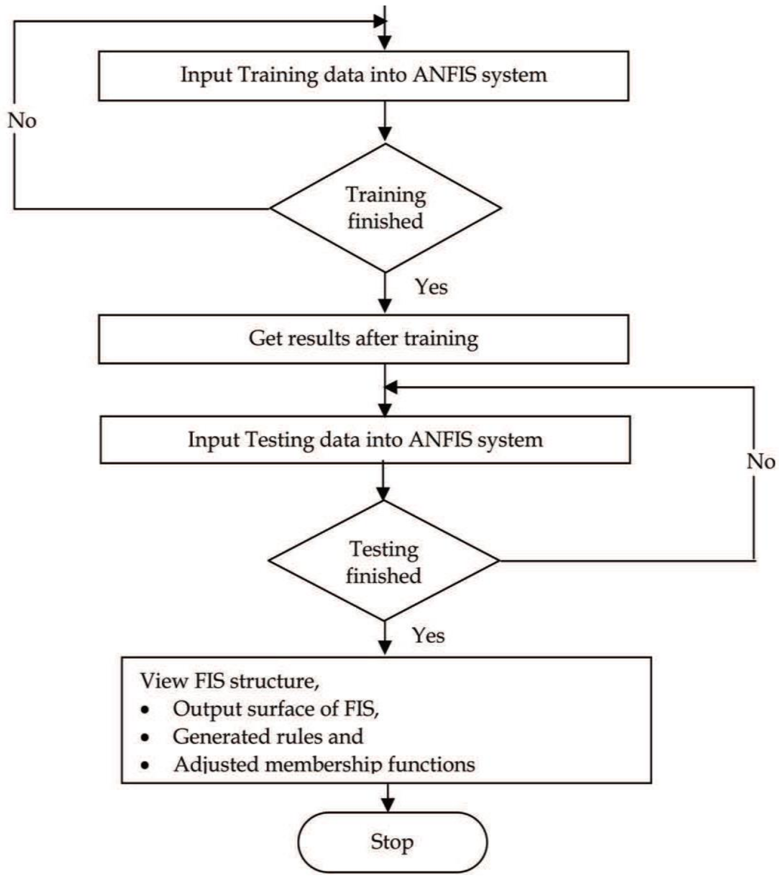


Fig 2: Training methodology of System using ANFIS

3.4 Triangular Membership Function

A *triangular* membership function is piecewise linear, by merging the two shoulder points into one, that is, setting b = c. Triangular curves depend on three parameters *a, b,* and *c* and are given by [1, 10].

$$f(x;a,b,c) = \begin{cases} 0 & \text{for } x < a \\ \dfrac{x-a}{b-a} & \text{for } a \leq x < b \\ \dfrac{c-x}{c-b} & \text{for } b \leq x \leq c \\ 0 & \text{for } x > c \end{cases} \qquad (10)$$

3.5 Consequent Parameters Calculations for ANFIS

In this system, input variables are applied of four types in figure 3.

Table 1: Four Type of Performance Level.

Performance Type	**Range**
Need (N)	x <= 40
Good (G)	40.1 <x <= 60
Very Good	60.1 < x <=80
Great (Gr)	80 < x <= 100

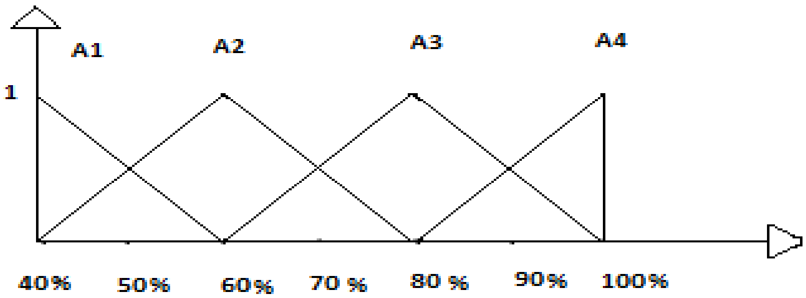


Fig 3: Membership function for Consequent Parameters Calculations

Output process of Layer 4 uses sixteen rules using Least Square Estimate Calculation and value of θ [2, 8]. Performance output result decides according to table 1.

Rule 1: If *x* is A_1 and *y* is A_1 then output is 40.
Rule 2: If *x* is A_1 and *y* is A_2 then output is 50.
Rule 3: If *x* is A_1 and *y* is A_3 then output is 60.
Rule 4: If *x* is A_1 and *y* is A_4 then output is 65.
Rule 5: If *x* is A_2 and *y* is A_1 then output is 50.
Rule 6: If *x* is A_2 and *y* is A_2 then output is 60.
Rule 7: If *x* is A_2 and *y* is A_3 then output is 70.
Rule 8: If *x* is A_2 and *y* is A_4 then output is 80.
Rule 9: If *x* is A_3 and *y* is A_1 then output is 50.
Rule 10: If *x* is A_3 and *y* is A_2 then output is 70.
Rule 11: If *x* is A_3 and *y* is A_3 then output is 80.
Rule 12: If *x* is A_3 and *y* is A_4 then output is 90.
Rule 13: If *x* is A_4 and *y* is A_1 then output is 65.
Rule 14: If *x* is A_4 and *y* is A_2 then output is 80.
Rule 15: If *x* is A_4 and *y* is A_3 then output is 90.
Rule 16: If *x* is A_4 and *y* is A_4 then output is 100.

Least Square Estimate Calculation

For each input data-tuple, there have sixteen values of **ξ**, one for Rule 1, another for Rule 2 and so on, resulting in a total of 256 values.

$$\xi_i(x) = \frac{\prod_{j=1}^{n} max\left[min\left(\frac{x_j-a}{b-a},\frac{c-x_j}{c-b}\right),0\right]}{\sum_{i=1}^{R}\prod_{j=1}^{n} max\left[min\left(\frac{x_j-a}{b-c},\frac{c-x_j}{c-b}\right),0\right]} \quad (11)$$

Calculation of the value of θ

With **ξ**(x) completely specified the transpose of **ξ**(x) is determined and placed into a matrix Φ.

$$\emptyset = \begin{bmatrix} \xi^T(x^1) \\ . \\ . \\ . \\ \xi^T(x^{16}) \end{bmatrix} \quad (12)$$

And the desire outputs placed in matrix Y.

$$Y = \begin{bmatrix} y_1 \\ . \\ . \\ . \\ y_{16} \end{bmatrix} \quad (13)$$

Calculate the value of θ using Y and Φ. $\theta = (\emptyset^T\emptyset)^{-1}\emptyset^T Y$ (14)

Calculation of the output function $f(x|\theta) = \theta\xi(x)$ (15)

4. Performance evaluation process

To evaluate the performance of teacher, Teaching Learning Process, Teaching Practices, Teaching Practices, and Personal Abilities are considered the main Input parameters. Input factors and Sub-factors are as shown in Table1. Initializing the Neural Network with input variables and output variables, for simulation of neural network with private school influencing parameters, it is directed to fuzzy inference system.

Artificial Neural Network and its respective parameters like Hidden layer, Train and Simulate options is initiated. In the part of this, neural network is trained, based on the input parameters. After training the artificial neural network model, the trained network is simulated to obtain the overall output based on input factors. So, in this connection different simulation data sets are used to predict the simulation output i.e. overall output for performance level. This system defines four type of performance level: Need some training, Good some skills, Very Good and Great Teacher as shown in table 1.

The evaluation of teaching activity is especially important for universities, as guaranteeing the quality of their studies means assuring not only the professional skills of their teachers but also the quality of the teaching-learning.

4.1 Elements of performance evaluation

Performance evaluation system considers the various elements of performance measures of teachers are as shown in Table 2. Minimum number of every input value is defined as 40 %. [3, 9].

Table 2: Various Elements Performance

Sr. No	Main Elements	Sub Elements
1	Teaching Learning Process	F11 - Lecture Preparation and Student Progress F12 - Response to Student Queries F13 - Question Tackling and Content Knowledge F14 - Concept and Skill Attainment
2	Teaching Practices	F21 - Continuous Evaluation and Classroom Management F22 - Presentation and Explanation Skill F23 - Courses Taught and Problem Solving Skill F24 - Proficiency in Teaching and Effective Teaching Tools
3	Research Orientation and Publication	F31 - Paper Publication and Standard Projects or Research F32 - National / International Awards F33 - Membership in Research Societies F34 - Participations and Organization of Seminars, Conferences
4	Personal Abilities	F41 - ICT and Intelligence F42 - Responsibility and Work Experience F43 - Participation and Teamwork at University Activities F44 - Supervision and Leadership

4.2 System flow diagram

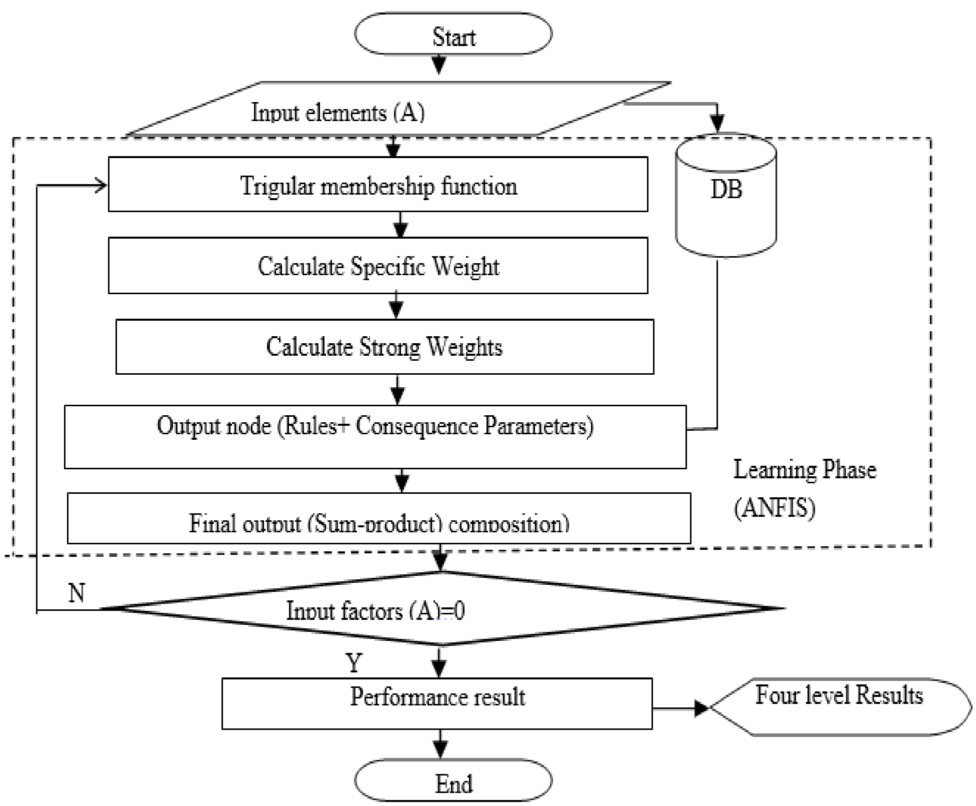


Fig 5: System Flow Diagram

Neural Network is initialized with input of 16 sub-factors of four main factors and four output variables for teacher performance evaluation. Most of these inputs are in non-numeric form. In figure 5, input factors are 16 sub-factors and these factors are processed in ANFIS. Then the system displays the output result for performance evaluation for every teacher. By using trigular membership function, it is converted linguistic variable to fuzzy variables. Neural Network is trained by using trigular membership function. Simulation of Network with different attributes can obtain best results for evaluating of teachers' performance. Fuzzy Inference System is created with respective input and its membership functions. Output of Neural Network is integrated with Fuzzy Inference system using equation 11. An evaluation of teaching activity must take into account all of the procedures carried out and evaluate their magnitude and quality and qualitatively.

4.3 Experimental result

To put the existing teachers on track, it is very necessary to evaluate their performance, may be in quarterly, in semester or annually, depends upon the resources universities possess. To get system output or performance output for teachers, step by step process of calculation is shown in the following. Further, the experimental results are integrated to the fuzzy inference system; there are sixteen rule-based for output of defuzzification. The input parameters are picked up from expert. Neuro-Fuzzy Method is applied in this system. There are 16 sub-factor of four main factors. After entry of four 16 factors of main factors, the system calculates each percentage to calculate fuzzy number by using Trigular Membership Function. This is started for first layer fuzzification process using every two input parameters. Example calculation five teacher's performance results are the following table:

Table 3: Performance results for five teachers

ID	Input Variables	Output Level
1	60,60,50,50, 60,60,50,60, 50,60,80,60, 80,60,80,60	59.395 (Good)
2	40,50,50,40, 40,50,50,40, 50,40,50,40, 40,40,50,40	43.213 (Need)
3	80,60,60,80, 80,60,80,80, 80,60,80,80, 80,80,100,60	73.75 (Very Good)
4	100,80,80,100, 80,80,80,80, 100,60,80,100, 100,80,80,80	85 (Great)
5	50,80,80,80, 60,100,80,80, 60,80,100,80,60,100,80,80	80 (Great)

In layer 1 for learning phase, the initial input of x=80% and y=80% are calculating membership function by using Equation 4. Example calculation for Input x = 50, y = 80,

Layer1, For A1, a=40, b=40, c=60

μ(x) = max [min (x - a / b - a, c - x/ c - b),0]

μ(50) = max [min (50 - 40 / 40 - 40, 60 - 50/ 60 - 40),0] = max [min (10 / 0, 10/ 20),0] = max [0.5,0] = 0.5

μ(y) = max [min (x - a / b - a, c - x/ c - b),0]

μ(80) = max [min (80 - 40 / 40 - 40, 60 - 80/ 60 - 40),0]= max [min (40 / 0, -20/ 20),0] = max [-1, 0] = 0

μA1(x) = 0.5 μA1(y) = 0 μA2(x) = 0.5 μA2(y) = 0

μA3(x) = 0 μA3(y) = 1 μA4(x) = 0 μA4(y) = 0

In layer 2, weight values are calculated by using Equation 5.

w1= μA1(x).μA1(y)=0 w2= μA1(x).μA2(y)=0 w3= μA1(x).μA3(y)=0.5 w4=μA1(x).μA4(y)=0

w5 = μA2(x).μA1(y)= 0 w6= μA2(x).μA2(y)= 0 w7= μA2(x).μA3(y)=0.5 w8=μA2(x).μA4(y)=0

w9=μA3(x).μA1(y)=0 w10=μA3(x).μA2(y)=0 w11=μA3(x).μA3(y)=0 w12=μA3(x).μA4(y)= 0

w13=μA4(x).μA1(y)=0 w14=μA4(x).μA2(y)=0 w15=μA4(x).μA3(y)=0 w16= μA4(x).μA4(y) =0

In layer 3, strong weight calculated by using Equation 6.

$$\overline{\omega_1} = \frac{\omega_1}{\omega_1 + \omega_2 + \omega_3 + \omega_4 + \cdots + \omega_{13} + \omega_{14} + \omega_{15} + \omega_{16}} = 0$$ (0+0+0.5+0+0+0+0.5+0+0+0+0+0+0+0+0+0)= 0 / 1

$$\overline{\omega_2} = \frac{\omega_2}{\omega_1 + \omega_2 + \omega_3 + \omega_4 + \cdots + \omega_{13} + \omega_{14} + \omega_{15} + \omega_{16}} = 0$$ (0+0+0.5+0+0+0+0.5+0+0+0+0+0+0+0+0+0)=0 / 1

In layer 4, there is calculation for output node using Equation 7.

Ŵ1f1 = 0 * 40 = 0 Ŵ2f2 = 0 * 50 = 0 Ŵ3f3 = 0.5 * 50 = 25 Ŵ4f4 = 0 * 65 = 0

Ŵ5f5 = 0 * 50 = 0 Ŵ6f6 = 0 * 60 = 0 Ŵ7f7 = 0.5 * 70 = 35 Ŵ8f8 = 0 * 80 = 0

Ŵ9f9 = 0 * 60 = 0 Ŵ10f10 = 0*70 = 0 Ŵ11f11= 0*80 = 0 Ŵ12f12 = 0*90 = 0

Ŵ13f13= 0 * 65=0 Ŵ14f14= 0* 80 = 0 Ŵ15f15 =0 * 90 = 0 Ŵ16f16 = 0 * 100 = 0

In layer 5, there is cralculation final output for first input by using Equation 8.
Output = Ŵ1f1+Ŵ2f2+Ŵ3f3+Ŵ4f4+Ŵ5f5+Ŵ6f6 +Ŵ7f7+ Ŵ8f8 + Ŵ9f9+ Ŵ10f10 +Ŵ11f11+ Ŵ12f12 + Ŵ13f13+ Ŵ14f14+ Ŵ15f15+ Ŵ16f16 = 0 +0 +25 +0 + 0+ 0+35 +0 +0 +0 +0 +0 +0 +0+ 0+0 = 60

After processing of first input in 5 layer leaning phase, the output values must input as the secondary inputs of the system.
For Final Output = Ŵ1f1 + Ŵ2f2 + Ŵ3f3 + Ŵ4f4 + Ŵ5f5+ Ŵ6f6 + Ŵ7f7 + Ŵ8f8 + Ŵ9f9 + Ŵ10f10+ Ŵ11f11 + Ŵ12f12 +Ŵ13f13 +Ŵ14f14 +Ŵ15f15+ Ŵ16f16
= 0+0+0+0+0+0+13.125+5+0+0+45+16.875+0+0+0+0 = 80 ("Congratulations! You are Great Teacher.")

After calculating all input values to hidden and output nodes, by using five steps of forward pass and rule base in fuzzy inference system, this system will display the final result for performance value and performance level. In this example, the result is **80** and teachers' performance is Great level.
The performance measuring process is as shown in figure 6 and figure 7.

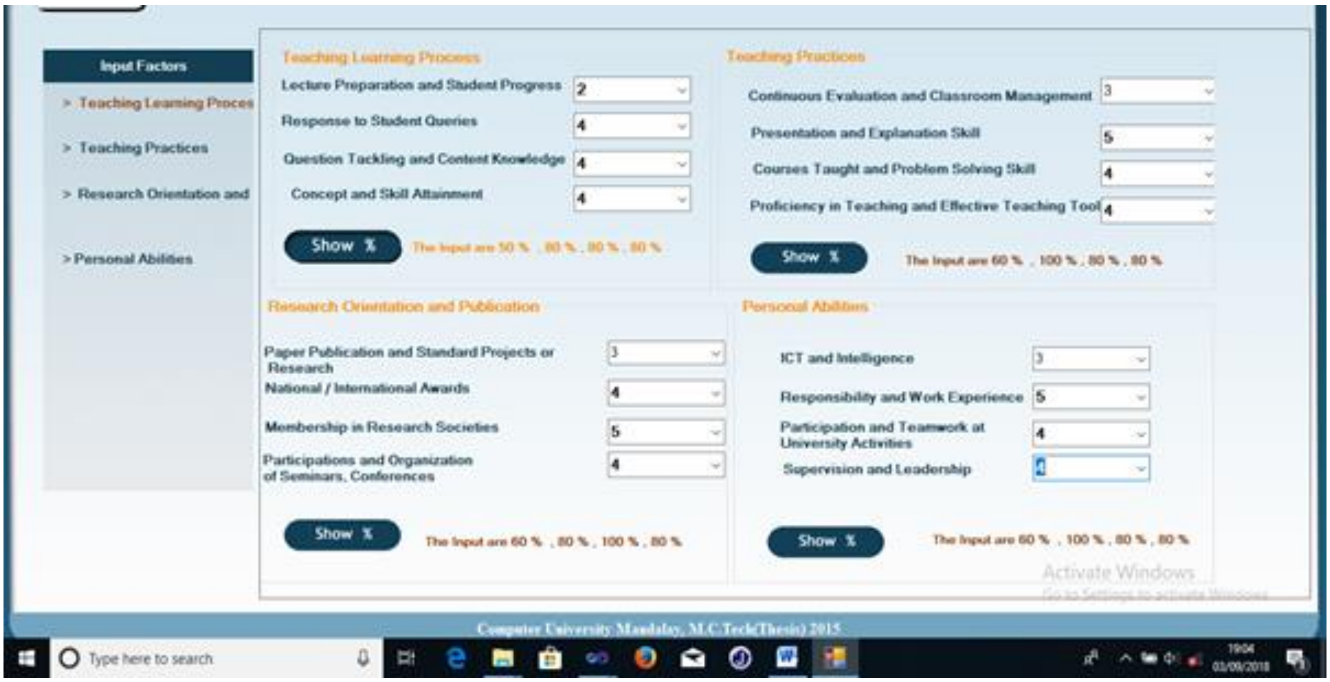


Fig 6: Input variable for performance measure

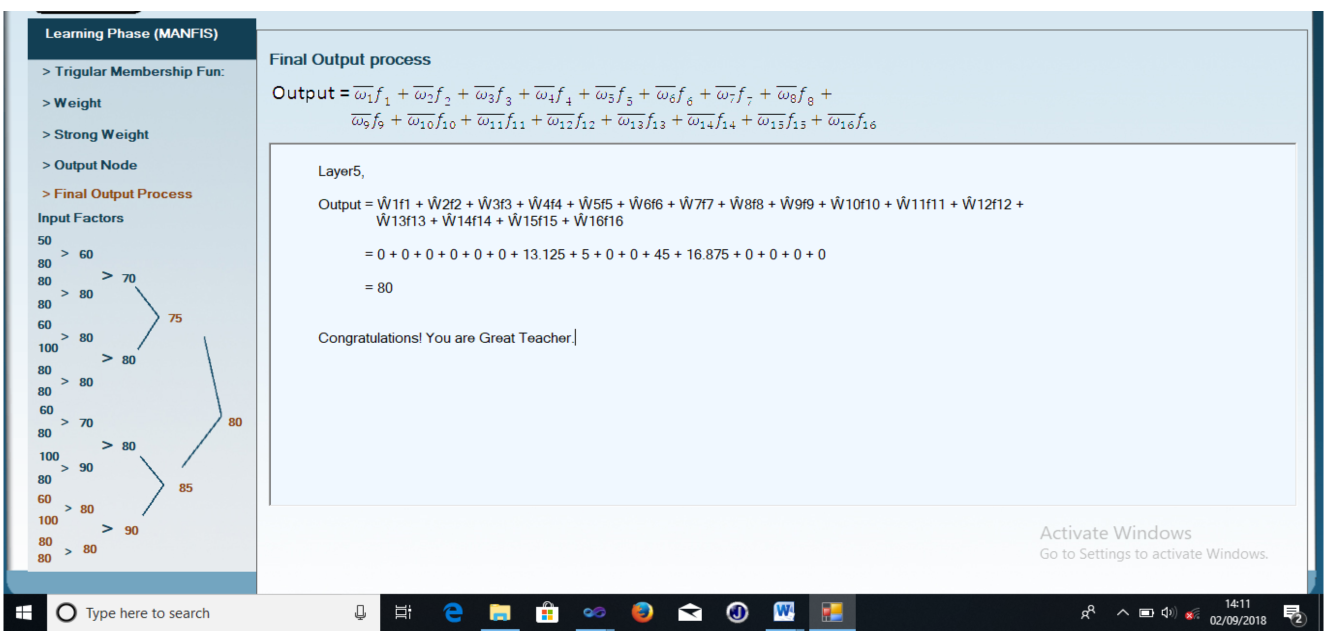


Fig 7: Performance result for sample teacher

5. Conclusion
Teacher evaluation should be a small but significant part of the larger strategy for institute Improvement. Multiple indicators and sources must be utilized for teacher performance evaluation. Teacher performance evaluation is a good approach to bring in the accountability and if implemented in its right spirit and flavor, taking care of various other aspects, it is hoped that performance appraisal will improve the system. Teacher's performance plays a key role in success or failure of any educational institute.
The evaluation of teaching activity is understood to be an internal evaluation that the academic institutions carries out on its teaching staff to guarantee that teaching and other. The use of neuro-fuzzy approach for the evaluation of teacher's performance is introduced in academic institutes. However, it has reached a wide range of application areas in educational systems in addition to evaluation of teacher performance, including the evaluation of teaching learning and that of the teaching practices.

5.1 Advantages of the System
By using Fuzzy Inference of this, System encourages teachers which results in improvement of quality, activities, satisfaction, efficiency and innovation in their teaching. In this way the teaching staffs is encouraged to reflect on quality, skill, satisfaction, efficiency and innovation in teaching in the technical educational institutions. In a typical architecture of an ANFIS, a circle indicates a fixed node, whereas a square indicates an adaptive node. In this connectionist structure, there are input and output nodes, and in the hidden layers, there are nodes functioning as membership functions (MFs) and rules. This eliminates the disadvantage of a normal feed forward multilayer network, which is difficult for an observer to understand or to modify.

5.2 Further Extension
Proper system to motivate the teachers to improve their teaching and learning performance is the primary aim of this system. This system is applied four main elements and 16 sub-elements that can increase different point of factors in education environment. Performance assessment in other applications can be applied using this method. This system can also extend by using different fuzzification functions and other types of neural-fuzzy method.

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