Ultra Scientist Vol. 25(3)A, 381-390 (2013).

A Fuzzy-Based Assessment Model for the Evaluation of Faculty Teaching Performance

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(Acceptance Date 26th September, 2013)

Abstract

The evaluation of faculty performance plays a great role in monitoring and improving the performance of educational systems. Normally, the evaluation considers their contributions in teaching, research, and professional services. One of the common mechanisms for evaluating teaching performance is through a questionnaire that is distributed to students to express their opinions on the performance of their faculty. However, this questionnaire often contains vaguely-defined linguisitic terms such as strong, competent, unsatisfactory, agree, strongly agree, etc. In this paper, we present a fuzzy assessment model to evaluate the teaching performance of faculty members from the data collected from their students. In this approach fuzzy sets are used to reperesent the impreciseness due to subjective judgements, and a fuzzy inference system is used to provide a crisp score for each faculty member.

Key words: Assessment models, Teaching strategies, Fuzzy sets and logic, Fuzzy inference system (FIS).

1. Introduction

A credible and objective assessment is one of the major components of a good educational system[3]. Assessment is required in many situations; for example, in student placement in schools, staff appraisal, employee screening, program and course improvement, school comparison and ranking, and so on. In such situations, assessment is generally complex and subjective[6]. It is often conducted using various attributes of the situation under consideration. For these to be useful, it has to be accurate, consistent and uniformly implemented for all.

Undoubtedly, the perfomance of faculty members has great influence on the performance of students. At the end of each academic year, the performance of faculty members is evaluated based on his/her teaching, research and service activities. Each faculty member is assigned a score using weighting factors of these components. The weighting factors are set based on the orientation of the institution and vary slightly from school to school and from department to department. In this paper, we focus on the teaching performance evaluation of faculty members. The aim is to describe an assessment model based on fuzzy inference that can be used to provide a crisp value of faculty performance on a particular scale considering a number of input factors.

The remainder of this paper is organized as follows. In Section 2, we review some existing assesment models that have been applied in various fields. Section 3 gives an overview and background of fuzzy inference systems. In Section 4, we describe the poposed evlaution model and experimental work, and discuss the results in Section 5. Finally Section 6 concludes the paper.

2. Existing Assessment Models :

Assessment has been approached in different ways and fields in the literature. However, the common goal is to build a mathematical model which quantifies a complex object or situation and produces an accurate measure taking into considerations various attributes of the assessed object or situation. This can lead to particular actions to be taken such as granting awards, assigning grades, identifying faults, etc. The measure could be in the form of a numerical score of a continuous scale or a category to the situation or object[2,3,13]. The estimated numerical score or category represents the level of criticality or wellness of the situation, with respect to the subject of measure[4,5,15,18]. Fuzzy-based assessments have been suggested and modeled in many areas of human endeavors[13,14].

Tay and Lim[13] investigated and presented the main properties of fuzzy-based assessment models as monotone output property and output resolution properties. These models deploy a fuzzy inference system (FIS) which uses a rulebase to describe the relationship between the inputs and the outputs. One of the key factors of the success of such models is the ability to incorporate human knowledge where information can be described by vague and imprecise statements interpretable by humans. They also demonstrated the ability of these models to be applied in a variety of problem domains e.g. control, modeling and classification.

Examples of applications of fuzzy based systems are evaluating the rate of aggregative risk in software development[8], evaluation of students' project in engineering education[1], grading student writing using fuzzy logic and expert systems[11], assessment of student-centered learning based on fuzzy sets[9], and assessment of risk in Failure Mode and Effect Analysis (FMEA)[12]. Assessment models were also used in healthcare studies to rate the social, occupational and psychological functioning of adults[16]. Mahant[10] presented a fuzzy assessment model for risk management. Fuzzy logic provided a way to specify and characterize the imprecise variables in risk. In another related work, Xinhua and Wenfa[17] presented a fuzzy hierarchical model for selecting shipping operation.

In education, student assessment could be based on various criteria not only on the academic performance but also on other qualities such as aptitude, creativity, leadership, initiative and so on. However, in order for the assessment to be effective there is a need to design rubrics for performance based evaluation. Due to subjectivity in the considered criteria, fuzzy set theory can be a useful tool in such assessment systems. Nolan[11] reported that any type of grading system is a classification problem, hence, the use of a classification model based on a particular scoring rubrics will help to standardize the grading. He introduced an expert fuzzy classification for grading student writing samples and reported that the result increased consistency in the application of the scoring rubrics. Zhu and Li[20] presented a combination of fuzzy logic system and neural network model and applied it to teaching quality assessment. Their results had a better appraisal effect and compared with other methods, their approach is simple and operable.

3. How Fuzzy Systems Work :

Fuzzy set theory is useful in representing human knowledge in a specific domain and in reasoning with that knowledge to make useful inferences or actions[7]. It was invented by Prof. Zadeh in mid-1960s, at the University of California at Berkeley, for handling uncertain and imprecise knowlegde in a real world application[19]. Fuzzy logic is close to human thinking or reasoning using natural langauage. It provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy systems consist of four cardinal components (as shown in Figure 1): fuzzification, knowlegde base (rulebase and database of facts), decision making mechanism (fuzzy resaoning or inference engine) and defuzzification.

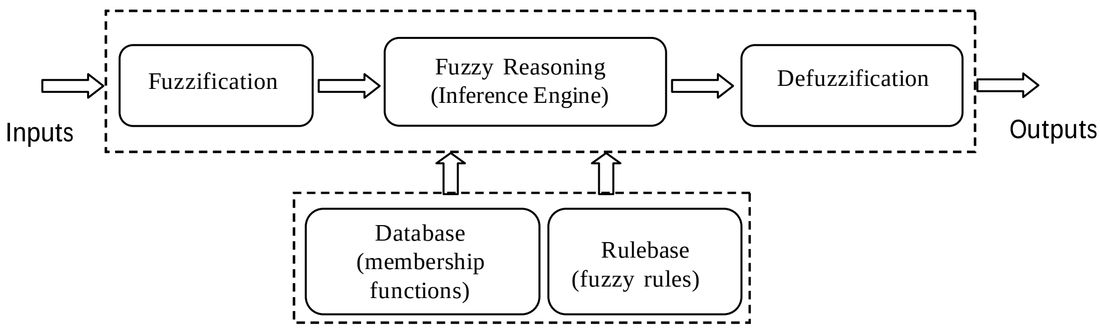

Figure 1. Components of a fuzzy inference system

3. 1 Membership Functions :

The membership function (MF) is a graphical representation of the magnitude of participation of each input; a graph that defines how each point in the input space is mapped to a membership value between 0 and 1. Input space is often referred as the universe of discourse or universal set, which contains all the possible elements of concern. There are different memberships functions associated with each input and output response. Some typical examples are triangular, bell, trapezoidal, sigmoidal, pi-shaped, Guassian and exponential. More complex functions are also possible but require greater computing overhead to implement. A typical membership function with some its common properties are shown in Figure 2.

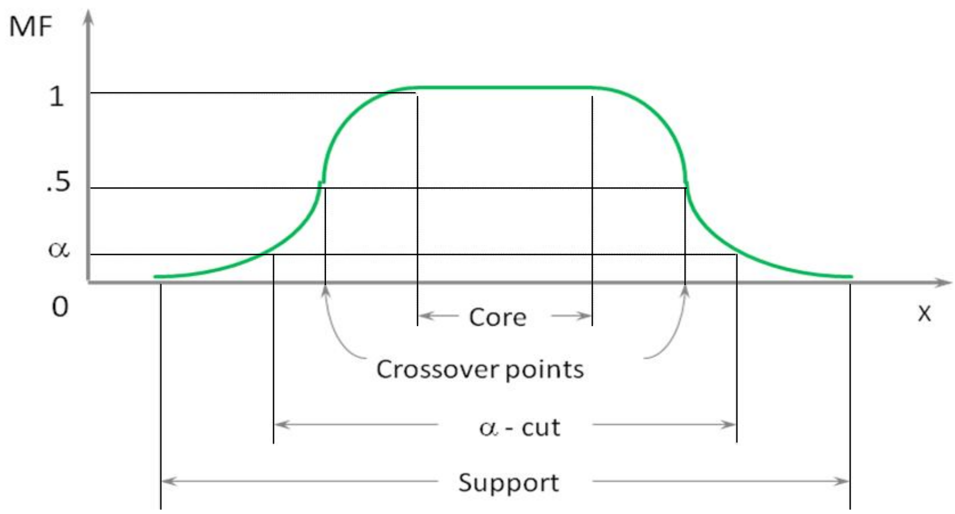

Figure 2. The features of a membership function.

3.2 Fuzzy Rulebase :

Fuzzy logic classification systems are generally implemeted in the form of an expert decision support system. The rulebase contains decision rules and forms the major part of the complete knowlegde embedded in the system. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Mostly rules are supplied by a domain expert or derived from historical data.

3.3 Fuzzification :

The fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. It also refers to as the transformation of an objective term into a fuzzy concept.

3.4 Fuzzy Inference :

This step is to determine the firing strength of each rule. The logical products for each rule must be combined or inferred before being passed on to the defuzzification process for crisp output generation. Several inference methods exist, the max-min method tests the magnitudes of each rule and selects the highest one. This method does not combine the effects of all applicable rules but does produce a continuous output function and is easy to implement. The max-dot or max-product method scales each member function to fit under its respective peak value. This method combines the influence of all active rules and produces a smooth continuous output. Others are the averaging method and the root-sum-square (RSS) method.

3.5 Defuzzification :

When the inferencing is over. There is need to compute a single value to represent the outcome. This process is called defuzzification.This can be achieved with different methods.A common method is the defuzzification of the data into a crisp output is accomplished by combining the results of the inference process and then computing the "fuzzy centroid" of the area. The weighted strengths of each output member function are multiplied by their respective output membership function center points and summed. Finally, this area is divided by the sum of the weighted member function strengths and the result is taken as the crisp output.

4. The Evaluation Model :

We considered a sample faculty evaluation form from the Southwestern College in USA, form A (http://www.swccd.edu/Docs/FacEvalformA.doc). The assessment criteria that have been used are listed in Table 1. Each criterion is ranked in a scale of 10 into the following four attributes: Strong, *S* (10-8); Competent, *C* (7-6); Marginal, *M* (5-4); and Unsatisfactory, *U* (3-1). The faculty performance is assessed on a scale of 100 as: Excellent (100-80); Good (80-60); Fair (60-45); and Poor (45-0). We assume that each of the criteria conforms with the monotone output property of assessment model[13]; Figure 3. We also assumed that each critrion has equal effect on the perfomance of the faculty been evaluated (but the model is flexible and different weights can be assigned for different criteria). Each criterion is assigned a membership function. Since there are ten linguistic variables (inputs) each has four linguistic values (terms), the total number of rules[10] is 4. To illustrate the concept of the proposed system, in this paper we concentrated on two criteria only. The considered criteria are: the teaching methodology (TM) and the presention and delivery (P&D). The assigned membership functions for these criteria are shown in Figures 4 and 5 repectively. Also the membership functions assigned to the output, faculty performance, are shown in Figure 6. In this case there will be 4^2 rules only. Table 2 summarizes the rules used in our model. The fuzzy model is shown in Figure 7.

Table 1. Performance evaluation criteria

No.	Criteria
1	Organization of lesson plan: Organized progression from each activity to the next
2	Use of class timing: Puntuality and use of class time
3	Classroom management: Control of class room environment
4	Subject matter expertise: Mastery of and currency in subject matter
5	Teaching methodologies (Pedagogy/Adragogy): Mastery of teaching skills and strategies
6	Presentatuion and delivery: Awareness of demeanore, vocabulary and articulation
7	Student involvement: Evidence of active engagement and participation by students
8	Learning environment: Creates an environment conductive for learning
9	Rapport: Evidence of mutual respect and professionalism
10	Overall class visitation scale

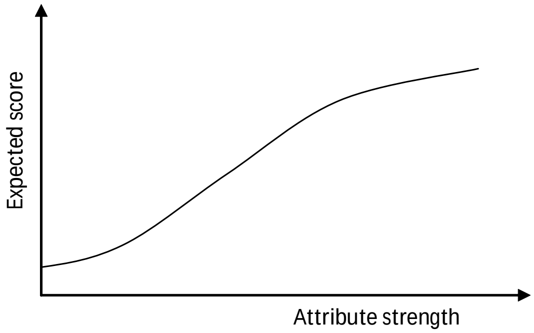

Figure 3. The expected score versus the attribute strength is an ogive function.

Figure 4. Membership functions for different terms of teaching methodology (TM).

Figure 5. Membership functions for different terms of presentation and delivery (P&D).

Figure 6. Membership functions for different classes of performance.

Table 2: Fuzzy rules using two criteria (Presentation & Delivery (P&D), and Teaching Methodologies (TM)

		P&D			
		U	M	C	S
TM	U	Poor	Poor	Fair	Fair
	M	Poor	Fair	Fair	Good
	C	Poor	Fair	Good	Good
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

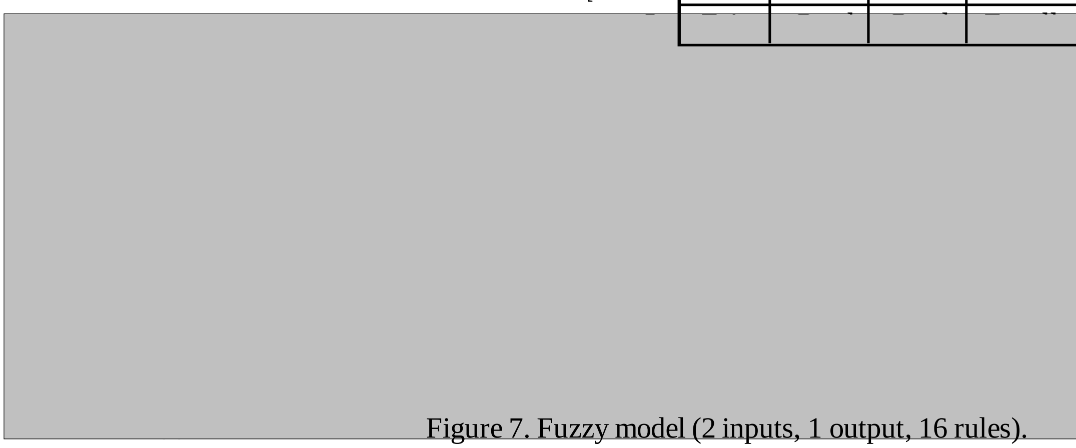

Figure 7. Fuzzy model (2 inputs, 1 output, 16 rules).

5. Results

In this section, we present the results of our experiment using a simplified model with two criteria: Teaching Methodology (TM), and Presentation and Delivery (P&D). As we can observe from the results obtained in Table 3, it satisfy the assessment monotone property which shows the result of the model is reasonable and can be enhanced to include other grading criteria. It is also observed that if one value of the criteria is below some threshold the performance cannot be more than a particular range around 45 in this case as observed from the table. We plot the relationship between the teaching methodology, presentation method, and performance in Figure 8.

Table 3. Some sample model evaluation result.

No.	Criteria (inputs)		Performance (output)	
	Teaching Method Scale (0 -10)	Presentation & Delivery Scale (0 -10)	Scale (0 – 100)	Rank
1	1.48	1.99	17.7	Poor
2	2.92	3.58	18.9	Poor
3	3.62	4.34	45.0	Fair
4	5.0	5.0	45.1	Fair
5	5.06	5.73	48.7	Fair
6	5.88	6.87	65.0	Good
7	7.39	7.5	74.6	Good
8	8.71	7.5	86.5	Excellent
9	8.4	9.2	87.7	Excellent
10	0.505	5.0	17.7	Poor
11	1.97	5.59	31.0	Poor
12	2.8	6.68	45.1	Fair
13	0.96	6.68	45.1	Fair
14	1.61	9.68	45.1	Fair
15	9.04	0.59	45.1	Fair
16	7.57	0.864	45.0	Fair
17	8.58	0.864	45.1	Fair
18	8.58	3.59	45.0	Fair
19	7.66	7.77	80.0	Excellent
20	10	10	87.7	Excellent

Figure 8. Three-dimensional depiction of the inference rules

6. Conclusion

We presented a preliminary work toward the development of an evaluation system for faculty performance based on fuzzy set theory. In this paper after reviewing various assessment models in the literature and presenting a framework of the mode, two criteria were selected (teaching methodology (TM) and presentation and delivery (P&D)) to study their effect on the faculty performance. This model can be improved by using input from experts and real life data. It should also be extended to include other performance criteria.

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