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FUZZY EVALUATION METHOD USING FUZZY RULE APPROACH IN MULTICRITERIA ANALYSIS

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Abstract: A multicriteria analysis in ranking the quality of teaching using fuzzy rule is proposed. The proposed method uses the application of fuzzy sets and approximate reasoning in deciding the ranking of the quality of teaching in several courses. The proposed method introduces normalizing data which dampen the extreme value that exists in the data. The use of the model is suitable in evaluating situations that involve subjectivity, vagueness and imprecise information. Experimental results are comparable and the method performs better in some domains.

Keywords: Fuzzy evaluation, multicriteria analysis, approximate reasoning, teaching quality.

1. INTRODUCTION

A highly reliable and effective performance evaluation rule is essential in decision making environments. In real problems, evaluation techniques engage in handling cases like subjectivity, fuzziness and imprecise information. Application of the fuzzy set theory in evaluation systems can improve evaluation results [14]. Several researchers have tried to solve this problem through the analytical hierarchy process (AHP), for example in personnel selection [11, 12] and shipping performance evaluation [6] whereby evaluation is done by aggregating all the fuzzy sets. However, the presence of imprecision, vagueness and subjectivity at each level further accumulates the undesired elements in aggregating the marks.

In the literature, various concepts focusing on the combination of fuzzy logic model with multi objective decision have been proposed that can assist in reducing errors in making a judgment [9, 10]. Such research provides approaches of judgment procedure on personnel selection through the development of fuzzy AHP. It is cited as being able to minimize subjectivity. A lot of researches in fuzzy evaluation methods have been discussed in [1, 3, 4, 5, 7, 13]. The authors have proposed algorithms based either on the fuzzy similarity function or the fuzzy synthetic decision and ranking procedure through satisfaction function. Fuzzy set membership enables the interpretations of linguistic variables in a very natural and plausible way to formulate and solve various problems. The expression of the linguistic variable by singleton fuzzy sets such as in [2, 16] could lose much important information and would additionally complicate the course of action.

Although many evaluation methods for selecting or ranking have been suggested in the literature, as yet there is no method which can give a satisfactory solution to every situation. For this reason, a fuzzy evaluation method is proposed by combining the concepts introduced in [5] and [1] and integrating them with a fuzzy rule that is derived automatically from input data. In evaluating student answer scripts, [1] introduced fuzzy set mark and standard fuzzy set for grading. Fuzzy set marks that are given by the examiner are compared to the standard fuzzy set grades obtained through similarity function. Grades are given to the question based on the most similar (the highest similarity value calculated) grade to the fuzzy set mark. From the grade allocated, the mid-point mark is matched and the total mark is computed by aggregating the multiplication of marks and weight of each question respectively. However, evaluations are not consistent because they are given by evaluators. In [5], teaching quality is evaluated by obtaining the fuzzy synthetic decision matrix through the operation of vector dot product between normalized original data and weight. The decision matrix is then computed using the decision criteria set and fuzzy approximate reasoning which uses fuzzy rule that is automatically generated from input data. Lastly, the ranking is determined by calculating the satisfaction function. The authors, however, did not consider data in the form of fuzzy sets.

Higher education learning institutions and the government in particular, have increasingly wanted to be assured of the quality in teaching. In getting this assurance, universities, therefore have to produce tangible evidence of the quality of teaching they provide. In practice, the evaluation of teaching quality depends on several factors and criteria. To evaluate the teaching quality, it is necessary to construct factors and criteria of good teaching by university lecturers. This paper discusses the combination of quantitative methods using fuzzy set theory in analyzing multicriteria teaching quality.

In classical theories, the statement used can define something as either true or false, yes or no, but not both of them, such as the teaching quality is either can be good or not good. On the contrary, in fuzzy set theory approach, a statement can have values in the range of [0, 1], thus the teaching quality can be expressed as bad, moderate, good, very good and so on. This approach will give more option in measuring subjective criteria to improve the expressions and assessments under the fuzzy environment. The fuzzy environment is a situation associated with vagueness, imprecision and/or lack of information regarding a particular element of the problem at hand. The fuzzy set theory can be applied to define subjective characteristics. Further, the application of fuzzy set theory can also provide an effective way to formulate decision problems in a fuzzy environment where the information available is subjective and imprecise. Therefore, fuzzy set theory has the potential to be regarded as an efficient measurement for the subjective performance evaluation.

The paper proceeds as follows. The proposed model is introduced in Section 2 while the algorithm of the proposed model is highlighted in Section 3. Section 4 presents the numerical results and concluding remarks are given in Section 5.

2. THE FUZZY MODEL

The teaching quality dataset and the factor weightage are adopted from [5]. The data comprise grades given by students toward the lecturer's teaching qualities in five courses. The five courses that are taught by the lecturer are labeled U_1, U_2, U_3, U_4, and U_5. The respondents were 35 students from one class who observed the teaching quality of the lecturer during the lectures. Grades A, B, C, D and E are used to represent the teaching quality according to various teaching quality criteria f_{ij}, i = 1, 2, 3, 4, 5, 6 and j = 1, 2, 3, 4. The criteria f_{ij} were classified as factor F_i, i = 1, 2, 3,…, 6. The records of the frequency of students who have given various grades according to several factors and criteria, for the courses delivered by the lecturer and the set of factor weightage are shown in APPENDIX. The factor weightage represents the importance of each criterion used in the evaluation. The details of factors and criteria are also depicted in Table 1. The rightmost column explains the teaching quality content for each criterion.

Table 1: Teaching Quality

Factor	Criteria	Teaching quality (Content)
F_1		**Content**
	f_{11}	Accuracy of the basic concepts
	f_{12}	Contents systematically and precisely constructed
	f_{13}	Simple and proper logical reasoning
	f_{14}	Precise materials but with deep and wide range of knowledge, i.e. having high efficiency
F_2	f_{21}	Some description of current tendency of science and technology
F_3	f_{31}	Good accordance with practice
F_4		**Teaching art**
	f_{41}	Stimulating the imagination and cultivating the ability of the students to put forward the problems, analyze them and solve them
	f_{42}	Going on from the present level of the students step by step
	f_{43}	Clear, vivid and refined speech
	f_{44}	Clear writing
F_5	f_{51}	Attractive lecture, inspiring the interest and the desire for knowledge
F_6		**Devotion spirit**
	f_{61}	With warm and attentive attitude toward the students and a good sense of responsibility
	f_{62}	Paying much attention to the attitude of the students towards the study and their behaviour in class
	f_{63}	Feeding the opinion of the students back to teacher himself, catching the tendency of student's studying condition and improving the teaching method readily

The model starts with the calculation of the membership set of score. A fuzzy set A, from the score of grades given by the students in one class is generated to evaluate the teaching qualities of the lecturer which is as follows:

$\mu_A(x)$ describes the degree of membership of $x \in X$ in fuzzy set A. The generated fuzzy set characterizes the membership values $\mu_A(X) \in [0, 1]$. Table 2 depicts part of the membership set of score for the first course. For example, the value 0.0571 is obtained by dividing f_{ij} with the number of students i.e. 0.0571 = f_{11}/35.

Table 2: Membership Set Score

		Factor						
			F_1			F_2	……..	F_6
Course	**Grade**	f_{11}	f_{12}	f_{13}	f_{14}	f_{21}	……..	f_{63}
U_1	A	0.0571	0.4000	0.3143	0.3714	0.3143		0.0286
	B	0.4000	0.3143	0.4571	0.1429	0.4857		0.6000
	C	0.3429	0.2286	0.1143	0.2000	0.1429		0.2286
	D	0.2000	0.0286	0.0571	0.2286	0.0571		0.1429
	E	0.0000	0.0286	0.0571	0.0571	0.0000		0.0000

The scores in Table 2 are mapped into the mid-points, which are calculated from the class range as shown in Table 3. The range and mid-point or mid-interval mark for the grades are illustrated in Table 3. The notion of mid-point is introduced to obtain the range for grades A, B, C, D, and E [15].

Table 3: Grade, Mid-Point and Mid-Interval

Grade					
A	90	92.5	95	97.5	100
B	70	75	80	85	90
C	50	55	60	65	70
D	30	35	40	45	50
E	0	7.5	15	22.5	30

The construction of the fuzzy set membership is undertaken in the third step. For example, the fuzzy set f_{11} can be written as f_{11} = {0.0571/95, 0.4000/80, 0.3429/60, 0.2000/40, 0.0000/15} to represent the degree of belonging of the score for each grade. The results of the calculated fuzzy set membership for each criterion of the first course U_1 are then constructed as shown in Table 4.

Table 4: Fuzzy Set Membership

		Factor					
			F_1		F_2	……..	F_6
Course	**Grade**	f_{11}	… …	f_{14}	f_{11}	f_{12}	f_{13}
U_1	A	0.0571/95		0.3714/95	0.3143/95		0.0286/95
	B	0.4000/80		0.1429/80	0.4857/80		0.6000/80
	C	0.3429/60		0.2000/60	0.1429/60		0.2286/60
	D	0.2000/40		0.2286/40	0.0571/40		0.1429/40
	E	0.0000/15		0.0571/15	0.0000/15		0.0000/15

In the fourth step, the fuzzy set grade is then defined as shown in Table 5. In this study, the fuzzy set grade as used in [1] is adopted.

Table 5: Fuzzy Set of Grade

Grade	Linguistic Variable	Fuzzy Set
A	Excellent	{1.0, 1.0, 0.9, 0.8, 0.0}
B	Very Good	{0.8, 0.9, 0.9, 0.8, 0.0}
C	Good	{0.2, 0.4, 0.9, 0.8, 0.1}
D	Satisfactory	{0.0, 0.2, 0.4, 0.9, 0.4}
E	Unsatisfactory	{0.0, 0.0, 0.2, 0.4, 1.0}

The grade for each criterion for the five courses is obtained by solving the fuzzy similarity function discussed in [1]:

$$S(F,M) = \frac{\hat{F} \bullet \hat{M}}{\max(\hat{F} \bullet \hat{F}, \hat{M} \bullet \hat{M})},$$

where $\hat{F} = (\mu_F(x_1), (\mu_F(x_2),\ldots)$, $\hat{M} = (\mu_M(x_1), (\mu_M(x_2),\ldots)$ are the vectors and $\hat{M}$ denotes the transpose vectors of the fuzzy set of grades A^T, B^T, C^T, D^T and E^T as tabulated in Table 5. $\hat{F}$ represents transpose vector of fuzzy set f_{ij} where i = 1,2,3,4,5,6 and j = 1,2,3,4. Set $X = (x_1, x_2, \ldots, x_n)$ represents the set of universe of discourse and '•' is the dot product.

Table 6: Similarity Value

		Factor						
		***F*₁**				***F*₂**	…….	***F*₆**
Course	**Grade**	f_{11}	f_{12}	f_{13}	f_{14}	f_{21}	…….	f_{63}
U_1	A	0.2683	0.2733	0.2667	0.2542	0.2824		0.2749
	B	0.3015	0.2867	0.2798	0.2719	0.2975		0.3044
	C	0.3855	0.2633	0.2410	0.3012	0.2599		0.3408
	D	0.3399	0.1731	0.1710	0.2753	0.1710		0.2815
	E	0.1238	0.0714	0.0857	0.1571	0.0429		0.0857

For example, S(A, f_{11}) is the similarity value between grade A and criteria f_{11}. Then the computation of S(A, f_{11}) = ((0.0571, 0.4000, 0.3429, 0.2000, 0.0000)^T • (1.0, 1.0, 0.9, 0.8, 0.0)^T)/ max((0.0571, 0.4000, 0.3429, 0.2000, 0.0000)^2 , (1.0, 1.0, 0.9, 0.8, 0.0)^2) = 0.2683). The values in Table 6 exhibited similarity between the criterion f_{ij}, i = 1, 2,…, n and j = 1, 2, 3, …, m and the score grade.

The maximum similarity value is determined by identifying the maximum of the similarity values in Table 6. Next, the grade is mapped to the appropriate mid-interval mark. In this step the similarity value and the similarity curve are used to map the mark. To note, similarity curve is derived from the similarity values. The following guideline is used in allocating the mid-point mark.

If the S(f_{ij}, Grade) ≥ 0.3 then take the mid-point mark
Else
    If skew of similarity curve to the left then ¾ of mid-point
Else
    If skew of similarity curve to the right then ¼ of mid-point.
Else
    If the similarity curve distributed evenly to two grades then takes the mid-point mark enclose by the two grade.

For example, if the $S(f_{ij}, C) \geq 0.3$, then the score of criteria f_{ij}, is given grade C and mid-point mark 60. The results of allocating an appropriate mid-point and mid-interval mark to each criterion for the first course are shown in Table 7. The fuzzy mark is calculated and tabulated in the rightmost column of Table 7. For example, the fuzzy mark for F_1 is calculated as,

$$F_1 = 0.35 \times 60 + 0.30 \times 85 + 0.25 \times 85 + 0.10 \times 60 = 73.75.$$

where the values 0.35, 0.30, 0.25, 0.10 are the weightages for f_{11}, f_{12}, f_{13}, and f_{14} respectively (see APPENDIX).

Table 7: Maximum Similarity Value

Course	Factor		Max Similarity Value	Grade	Mid-Point	Fuzzy Mark
U_1	F_1	f_{11}	0.3855	C	60	73.75
		f_{12}	0.2867	B	85	
		f_{13}	0.2798	B	85	
		f_{14}	0.3012	C	60	
	F_2	f_{21}	0.2975	B	85	85
	F_3	F_{31}	0.3442	C	60	60
	F_4	f_{41}	0.3563	C	60	65.25
		f_{42}	0.3305	C	60	
		f_{43}	0.2680	B	85	
		f_{44}	0.2759	B	75	
	F_5	f_{51}	0.3356	C	60	60
	F_6	f_{61}	0.2926	B	85	72.5
		f_{62}	0.3133	C	60	
		f_{63}	0.3408	C	60	

The normalized synthetic score is then built as shown in Table 8. Each element in the table is the normalization of the fuzzy mark. For example, the normalized synthetic score F_1**,** for course U_1 is 73.75/100 = 0.7375.

Table 8: Normalized Synthetic Score Value

	Factor					
Course	F_1	F_2	F_3	F_4	F_5	F_6
U_1	0.7375	0.8500	0.6000	0.6525	0.6000	0.7250
U_2	0.6350	0.8500	0.8000	0.6000	0.4500	0.7600
U_3	0.7150	0.6000	0.6000	0.6600	0.6000	0.8300
U_4	0.7475	0.6000	0.6000	0.7700	0.6000	0.7450
U_5	0.7125	0.6000	0.8500	0.6300	0.6000	0.6250

The decision criteria C_i, $i = 1, 2, 3, \ldots, 7$, is the intersection or combination of factor rules which is the antecedent of the rule (refer to Table 9). The combination multicriteria rules are described in Table 9 and can be generalized as follows:

If ($C_i = F_j \cap or \cup F_{j+1}, \ldots, \cap or \cup F_{j+n}$) then A_k

where C_i is the decision criteria, F_j is the factor rules, A_k is the linguistic variables and k represents the grade. For example, the decision criteria C_1 rule can be written as

If $C_1 = F_1 \cap F_4$ then A_1 satisfactory $A_1(v) = v$,

The appraisal set, v, is defined as $v = \{A_k\}$, where $v \in V$, $A_k = \{0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ and $l = 1, 2, ..., 11$. V is the unit appraisal space in [0,1] and l is the number of appraisal set in V. The last row Table 9 shows the combination of factors F_1 and F_6. Factor F_6, is tabulated as $F_6 * F_6$ which means "very" small as can be seen in Table 9. In fuzzy set theory "very" is defined as the modifier concentrator and is depicted by symbol H_2.

Table 9: Multicriteria Rules Combination

Decision Criteria	Factor Rule	Linguistic Variable	Description	Appraisal Set
C_1	$F_1 \cap F_4$	A_1	Satisfactory	v
C_2	$F_1 \cap F_5$	A_1	Satisfactory	v
C_3	$F_1 \cap F_4 \cap F_6$	A_2	Very satisfactory	$v^{3/2}$
C_4	$F_1 \cap F_4 \cap F_6 \cap (F_2 \cup F_3)$	A_3	Very very satisfactory	v^2
C_5	$F_1 \cap F_4 \cap F_5 \cap F_6$	A_3	Very very satisfactory	v^2
C_6	$F_1 \cap F_4 \cap F_5 \cap F_6 \cap (F_2 \cup F_3)$	A_4	Perfect	$\begin{cases} 1, & v = 1 \\ 0, & v \neq 1 \end{cases}$
C_7	$\tilde{F}_1 \cup (\tilde{F}_4 \cap H_2 \tilde{F}_6)$	A_5	Unsatisfactory	$1 - v$

For example, the first rule in row two of Table 9 is called decision criteria C_1, which consists of the following fuzzy reasoning:

IF $F_1 \cap F_4$ **THEN** A_1 = Satisfactory = v,

where, IF contents and teaching art are good THEN the teaching quality is considered as satisfactory. The appraisal set for hedges "Satisfactory", "Very satisfactory", "Very very satisfactory", "Perfect" and "Unsatisfactory" are defined as "v", "$v^{3/2}$", "v^2", "1" or "0" ("v" =1 or "v" $\neq 0$), "$1 - v$" as used in [5]. The factor rule value, $\tilde{c}(u_m)$ of Table 10 is obtained by processing the elements of Table 8 using the fuzzy rules given in Table 9. For example, for decision criteria C_1 and course U_1, the factor rule value is identified by choosing the minimum between 0.7375 and 0.6525.

Table 10: Factor Rule Value

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
U_1	0.6525	0.6000	0.6525	0.6525	0.6000	0.6000	0.2625
U_2	0.6000	0.4500	0.6000	0.6000	0.4500	0.4500	0.3650
U_3	0.6600	0.6000	0.6600	0.6000	0.6000	0.6000	0.2850
U_4	0.7475	0.6000	0.7450	0.6000	0.6000	0.6000	0.2525
U_5	0.6300	0.6000	0.6250	0.6250	0.6000	0.6000	0.2875

Then the appraisal fuzzy value, $(d_j(m,l))$, of Table 11 is computed as follows [5]:

$$d_j(m,l) = 1 \wedge (1 - \tilde{c}(u_m) + A_k(v_l))$$

where j = 1, 2, 3, …,7, m = 1, 2, 3, …, 5, l = 1, 2, ..., 11 and $\tilde{c}(u_m)$ is the factor rule value. For example, the appraisal fuzzy value for decision criteria C_1 (the value of row 2, column 1) is calculated as,

$$d_1(1,1) = 1 \wedge (1 - 0.6525) + 0) = 0.3475$$

Table 11: Appraisal Fuzzy Value for Decision Criteria C_1

	Appraisal Set										
U_1	0.3475	0.4475	0.5475	0.6475	0.7475	0.8475	0.9475	1	1	1	1
U_2	0.4000	0.5000	0.6000	0.7000	0.8000	0.9000	1	1	1	1	1
U_3	0.3400	0.4400	0.5400	0.6400	0.7400	0.8400	0.9400	1	1	1	1
U_4	0.2525	0. 3525	0. 4525	0. 5525	0. 6525	0. 7525	0. 8525	0. 9525	1	1	1
U_5	0.3700	0.4700	0.5700	0.6700	0.7700	0.8700	0.9700	1	1	1	1

Similarly, the appraisal fuzzy values for the other decision criteria are calculated. Next, the appraisal product value is calculated by multiplying appropriate appraisal fuzzy values for all the decision criteria. The result of calculating the appraisal product value in each entry of Table 12 is depicted as below.

Table 12: Appraisal Product Value

	Appraisal Set										
U_1	0.0027	0.0050	0.0098	0.0199	0.0408	0.0831	0.1655	0.2782	0.3703	0.3350	0.7375
U_2	0.0106	0.0177	0.0314	0.0579	0.1085	0.1940	0.3289	0.4511	0.4593	0.4043	0.6350
U_3	0.0030	0.0055	0.0108	0.0217	0.0440	0.0886	0.1748	0.2933	0.3660	0.3260	0.7150
U_4	0.0016	0.0034	0.0072	0.0156	0.0333	0.0697	0.1418	0.2537	0.3678	0.3390	0.7475
U_5	0.0033	0.0060	0.0116	0.0213	0.0464	0.0927	0.1820	0.2958	0.3650	0.3250	0.7125

The achievement score can be ranked using the satisfaction value, *SV(m)*, as proposed by [8] and this is calculated as follows:

$$SV(m) = \frac{1}{\alpha_{\max}} \sum_{l=1}^{11} H_l(E_{m\alpha}) \Delta\alpha_l$$

where α = degree of appraisal product value

$\Delta\alpha_l = \alpha_l - \alpha_{l-1}$, $\alpha_0 = 0$

$H_l(E_{m\alpha})$ = mid-point V_l (l = 1,2,3…,11)

$\alpha_{\max}$ = maximum degree of appraisal product value.

The calculated values of the range of appraisal product value (α), the difference in range of appraisal product value ($\Delta\alpha_l = \alpha_l - \alpha_{l-1}$), and mean value of $E_{m\alpha}$, ($H_l(E_{m\alpha})$) are tabulated in Table 13.

Table 13: Calculated range of α, $\Delta\alpha_l$, and $H_l(E_{m\alpha})$

l	Range α	$E_{m\alpha}$	$H_l(E_{m\alpha})$	$\Delta\alpha_l$
1.	0.0000 < α ≤ 0.0027	{0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}	0.50	0.0027
2.	0.0027< α ≤ 0.0050	{0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}	0.55	0.0023
3.	0.0050< α ≤ 0.0098	{0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}	0.60	0.0048
4.	0.0098< α ≤ 0.0199	{0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}	0.65	0.0101
5.	0.0199< α ≤ 0.0408	{0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}	0.70	0.0209
6.	0.0408< α ≤ 0.0831	{0.5, 0.6, 0.7, 0.8, 0.9, 1}	0.75	0.0422
7.	0.0831< α ≤ 0.1655	{0.6, 0.7, 0.8, 0.9, 1}	0.80	0.0825
8.	0.1655< α ≤ 0.2782	{0.7, 0.8, 0.9, 1}	0.85	0.1127
9.	0.2782< α ≤ 0.3350	{0.8, 0.9, 1}	0.90	0.0568
10.	0.3350< α ≤ 0.3703	{ 0.8, 1}	0.90	0.0353
11.	0.3703< α ≤ 0.7375	{1}	1	0.3672

The calculated similarity, normalized synthetic score value, multicriteria rule combination, factor rule value, appraisal fuzzy value, appraisal product value and the calculated range of α , $\Delta\alpha_l$, and $H_l(E_{m\alpha})$ are used to calculate the satisfaction value of teaching quality. For example, to calculate the satisfaction value, consider course U_1,

$S(1) =$

$$\frac{1}{0.7375}(0.5(0.0027-0.0000)+0.55(0.0050-0.0027)+0.60(0.0098-0.0050)+0.65(0.0199-0.0098)$$
$$0.7(0.0408-0.0199)+(0.75(0.0831-0.0408)+0.80(0.1655-0.0831)+0.85(0.2782-0.1655)$$
$$+0.9(0.3350-0.2782)+0.9(0.3703-0.3350)+1(0.7375-0.3703) = 0.9088$$

The courses are ranked according to the satisfaction value where the bigger value indicates a higher rank as indicated in Table 14, [8].

Table 14: Satisfaction Value and Ranking

Course	**Satisfaction value**	**Ranking**
U_1	0.9088	2
U_2	0.8319	5
U_3	0.9039	3
U_4	0.9156	1
U_5	0.9024	4

3. FUZZY EVALUATION ALGORITHM

The fuzzy evaluation algorithm consists of 9 steps as listed below:

Step 1 : Calculate membership set of score
Step 2 : Determine grade range and mid-points.
Step 3 : Construct fuzzy set membership for each criterion.
Step 4 : Define student fuzzy sets for the grades
Step 5 : Calculate maximum similarity value and determine grade
Step 6 : Calculate the normalized synthetic score value
Step 7 : Determine multicriteria rules combination and calculate factor rule value
Step 8 : Calculate appraisal fuzzy value and the appraisal product value
Step 9 : Compute satisfaction value and ranking.

The proposed method uses the data that are represented in terms of frequency. This presentation of data is simpler and easier to gather compared to the approach in [1] that uses fuzzy set data constructed by the evaluator. The method takes advantage of Chu's approach in representing data. The proposed method differs from [5] where the frequency data are transformed into membership set score. The main advantage of the proposed method is that the membership set score are not predetermined by the expert. This is important to ensure the consistency of the decision. The transformation enables much information to be gathered. The model used the similarity function to normalize the data in order to dampen fluctuation among the data.

4. NUMERICAL RESULT

The comparison of results between [5], [1] and the proposed method are depicted in Table 15. The accuracy of ranking the teaching quality between [1] and the proposed method are computed based on the results given by [5]. The higher value of the satisfaction value implies that the students are satisfied with the teaching quality. From the results, the selection of courses based on satisfaction values can be ordered as U_4, U_1, U_3, U_5, and U_2 respectively. The experimental results show that the proposed method is comparable to [5] and performed better than [1] (see Figure 1).

Table 15: Comparison of Results

Model	**Chu**		**Biswas**		**Proposed**	
Courses	**Satisfaction**	**Rank**	**Satisfaction**	**Rank**	**Satisfaction**	**Rank**
U_1	0.8339	2	0.6767	1	0.9088	2
U_2	0.7530	5	0.6663	3	0.8319	5
U_3	0.8258	3	0.6675	2	0.9039	3
U_4	0.8453	1	0.6529	5	0.9156	1
U_5	0.7527	4	0.6550	4	0.9024	4
accuracy %				20%		100%

The proposed model with the concepts of combining [1] and [5] present the advantages of generalizing the evaluation of the performance achievement where the evaluation process can be conducted consistently with the use of the membership set score. Furthermore, the ranking could be done through formulation of the similarity function and approximate reasoning of the fuzzy set theory.

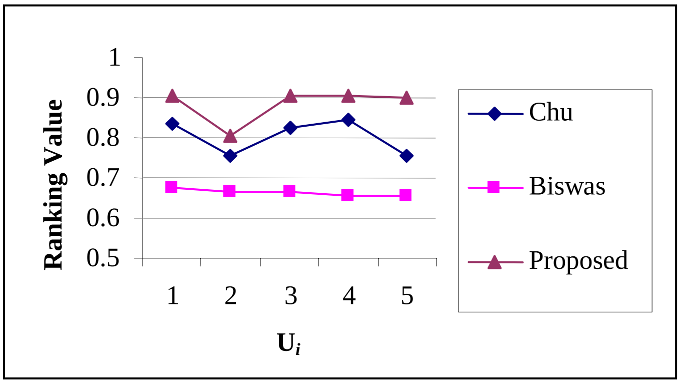

Figure 1: Graph of Ranking versus Courses

5. CONCLUSION

A new fuzzy model using multicriteria analysis has been proposed for the evaluation of the teaching quality. The produced experimental results are comparable to other results obtained from models by Biswas and Chu. The model has been implemented using C++ programming language and is suitable for various fuzzy environments. The model could be used as an alternative approach in solving the problems that involve uncertainty. The main contribution of the research model was the usage of the fuzzy expert system consisting of set of rules in the form of IF (antecedent) THEN (Conclusion). The evaluation output comes nearer to precision if the combination factors were accurately defined. To extend this effort we propose further research to obtain a universal view on appropriate combination factors and the classification of mid-points, which could improve the performance of the proposed model.

REFERENCES

[1] Biswas, R., "An application of fuzzy sets in student's evaluation", *Fuzzy Set and systems*, 74 (1995) 197-194.

[2] Capaldo, G., and Zollo, G., "Applying fuzzy logic to personnel assessment: A case study", *Omega The International Journal*, 29(6) (2001) 585-597.

[3] Chen, S.M., and Lee, C.H., "New methods for students' evaluation using fuzzy sets", *Fuzzy Sets and Systems*, 104 (1999) 209-218.

[4] Chu, F., "Fuzzy multicriteria decision-making in distribution of factories- An Application of Approximate Reasoning", *Fuzzy Sets and Systems*, 71 (1995) 197-205.

[5] Chu, F., “Quantitative evaluation of university teaching quality – An application of fuzzy set and approximate reasoning”, *Fuzzy Sets and Systems*, 37 (1990) 1-11.

[6] Chou, T.Y., and Liang, G.S., “Application of a fuzzy multi-criteria decision-making model for shipping company performance evaluation”, *Maritime Policy & Management*, 28(4) (2001) 375-392.

[7] Kuo, Y.P., and Chen, L.S., “Using the fuzzy synthetic decision approach to assess the performance of university teachers in Taiwan”, *International Journal of Management*, 19(4) (2002) 593-603.

[8] Lee, K.M. Cho, C. H., and Kwang, H.L., “Ranking fuzzy values with satisfaction function”, *Fuzzy Sets and Systems*, 64 (1994) 295-309.

[9] Liang, G., and Wang, A., “Personnel placement in a fuzzy environment”, *Computers Operations Research*, 19 (1992) 107-121.

[10] Pedrycz, W., and Gomide, F., *An Introduction to Fuzzy Sets Analysis and Design*, The MIT Press, England, 1998.

[11] Saaty, T.L., *The Analytic Hierarchy Process*, RWS Publications, Pittsburgh, 1995.

[12] Sonja, P.L., “Personnel selection fuzzy model”, *International Transactions in Operational Research*, 8(1) (2001) 89-105.

[13] Trajkovski, G., "A fuzzy framework for expert system evaluation", *Proceedings Joint Meeting of the 5th World Multiconference on Systematics, Cybernatics and Informatics*, Orlando, Florida, 2001.

[14] Turban, E., Zhou, D., and Ma, J., “A methodology for grades of journals: A fuzzy set-based group decision support system”, *Proceedings of the 33rd Hawaii International Conference on System Science*, 2000.

[15] Turksen, I.B., and Wilson, I.A., “A fuzzy sets preference model for consumer choice”, *Fuzzy Sets and Systems*, 68 (1994) 253-266.

[16] Weon, S., and Kim, J., “Learning achievement evaluation strategy using fuzzy membership function”, *ASEE/IEEE Frontiers in Education Conference*, 2001, 19-24.

APPENDIX

Teaching Quality Statistics

		Factor													
		F_1				F_2	F_3	F_4				F_5	F_6		
Course	**Grade**	f_{11}	f_{12}	f_{13}	f_{14}	f_{21}	f_{31}	f_{41}	f_{42}	f_{43}	f_{44}	f_{51}	f_{61}	f_{62}	f_{63}
U_1	A	2	14	11	13	11	7	2	15	14	12	7	17	2	1
	B	14	11	16	5	17	13	14	8	9	10	13	11	18	21
	C	12	8	4	7	5	14	9	6	7	6	9	6	7	8
	D	7	1	2	8	2	1	8	6	2	5	6	1	5	5
	E	0	1	2	2	0	0	2	0	3	2	0	0	3	0
U_2	A	13	6	5	6	16	8	2	6	6	10	8	12	6	10
	B	10	13	7	11	15	18	14	4	14	12	13	11	21	13
	C	10	12	17	12	3	9	17	13	10	12	1	7	6	8
	D	2	2	5	5	1	0	1	11	4	1	7	4	2	3
	E	0	2	1	1	0	0	1	1	1	0	6	1	0	1
U_3	A	10	3	15	7	3	0	15	5	6	4	7	15	13	12
	B	14	14	10	7	14	9	8	17	17	16	9	14	12	15
	C	7	15	6	13	14	16	8	9	4	9	12	3	9	3
	D	3	2	4	8	3	6	4	4	5	4	5	2	1	4
	E	1	1	0	0	1	4	0	0	3	2	2	1	0	1
U_4	A	24	15	3	7	6	2	10	12	4	6	3	15	6	1
	B	9	12	11	7	17	11	17	14	9	7	15	16	18	10
	C	2	5	2	13	8	14	8	8	16	14	9	4	9	16
	D	0	3	11	8	3	7	0	1	4	5	7	0	0	3
	E	0	0	8	0	1	1	0	0	2	3	1	0	2	5
U_5	A	6	9	10	15	2	12	1	6	13	11	8	3	8	17
	B	11	17	10	9	8	16	10	11	10	11	10	20	11	12
	C	15	5	7	4	16	4	16	12	5	7	11	7	7	4
	D	1	2	4	4	6	3	4	3	5	6	3	3	6	2
	E	2	2	4	3	3	0	4	3	2	0	3	2	3	0

Factor Weightage

	Factor													
	F_1				F_2	F_3	F_4				F_5	F_6		
Weight	0.35	0.3	0.25	0.1	1	1	0.35	0.4	0.15	0.1	1	0.5	0.4	0.1