Selection of the Best Pre-Diploma Science Student Using a Fuzzy Approach

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Abstract: Evaluating students' academic performance using appropriate techniques is crucial to ensure a fair assessment of their qualities.This paper proposes a fuzzy logic method for specifically selecting the best pre-diploma science student in Universiti Teknologi MARA (UiTM) Cawangan Sabah. The method considers not only academic achievement, but also soft skills and other abilities in the evaluation process. A case study was conducted based on the results of the students of the November 2013 – March 2014 intake. It was found that our proposed approach had the unique advantage of clearly distinguishing every single score obtained by the students. Also, the results showed that the approach is highly beneficial for problem-solving under uncertainty data sets environment.

Keywords: Fuzzy approach, fuzzy goal and constraints, students' performance evaluation

1. Introduction

Evaluating students' academic performance using appropriate techniques is needed to motivate students and ensure a fair assessment of their qualities. A high quality evaluation system provides grounds for individual improvement and ensures that students receive fair grading so as not to limit their present and future opportunities (Saleh & Kim, 2009). In addition, as employers are concerned about the need for fundamental soft skills (e.g. communication, leadership, teamwork etc.), there is a need to include these factors in the evaluation of student performance. Thus, evaluating students' performance, which takes into consideration both academic achievement and soft skills, has become a challenge for universities to ensure that students are rewarded accordingly (Nureize et al., 2006).

Underconventional methods of evaluation, the performance of students is assessed numerically through examination results together with on-going assessments (e.g. tests, quizzes, assignments etc.) by using simple arithmetic and statistical analysis, based on percentages and averages. It gives students a final single-letter grade (A, B or C) based on numerical interval-value that refers to a certain category of achievement. Linguistic terms such as "excellent", "good", "pass" or "fail" are also considered an evaluation method. However, these current methods of grading and classifying students' academic performance do not necessarily offer the best way to evaluate human acquisition of knowledge and skills (Rasmani et al., 2013). In some cases, the quality defined in linguistic terms is associated with imprecision and vagueness (Patil et al., 2012).

Due to the drawbacks of the traditional grading system, in recent years, the application of fuzzy sets theory (Zadeh, 1965) for evaluating students' academic performance has been presented.and several innovative methods have been proposed to deal with the fuzziness and vagueness in the process of students' evaluation (Bai & Chen, 2008; Saleh & Kim, 2009; Chen & Li, 2011; Yildiz et al., 2012; Ignoley & Bakal, 2012; Rasmani et al., 2013; Chen and Li, 2013; Yadav et al., 2014).

Bai and Chen (2008) presented a method to automatically construct grading membership functions of fuzzy rules for students' evaluation. Their method automatically constructs the grade membership functions of lenient-type grades, strict-type grades and normal-type grades of fuzzy rules. Saleh & Kim (2009) also presented a fuzzy system for evaluating students' learning achievement. However, their method was not sensitive enough to reflect students' learning achievement, and resulted in unfair assessments in certain situations. Consequently, Chen & Li (2011) presented a new method to deal with the evaluation of students' learning achievement using fuzzy membership functions and fuzzy rules. Their method was more sensitive to reflect students' achievement, providing fairer and more reasonable results, compared to the method proposed by Saleh & Kim (2009).

Moreover, Yildiz et al., (2012) applied fuzzy logic and genetic algorithms to evaluate and predict students' performance in distance education. Ingoley & Bakal (2012) too, presented a method which applies fuzzy inference system and fuzzy logic to evaluate students' performance. In Chen & Li (2013), a new method for evaluating students' answer scripts based on interval-valued intuitionistic fuzzy sets was applied, where the fuzzy marks awarded were represented by interval-valued intuitionistic fuzzy sets. Yadav et al., (2014) proposed a new fuzzy expert system for students' academic performance evaluation based on fuzzy logic and fuzzy rule induction approach. Their method proved to be more suitable for students' performance evaluation compared to classical fuzzy logic. A recent study was conducted by Alibek et al., (2016) in which they proposed a fuzzy model of performance evaluation of students. They have proven the effectiveness of the method in evaluating students' performance.

From a review of the literature above, it can be observed that existing researches rarely explore the advantages of intersection operators, especially using a fuzzy concept which is related to uncertainty environment. Thus, the main objective of this study is to propose the intersection of fuzzy goal and constraints to identify the best pre-diploma science student for recognition purposes. To do so, this paper is structured as follows: Section 1 is the introduction, Section 2 briefly discusses the problem statement, Sections 3 and 4 provide the background theory and empirical study for illustration purposes, while Section 5 ends with the conclusion.

2. Problem Statement

Many public universities, including Universiti Teknologi MARA (UiTM) are currently practicing an educational grading system based on numerical interval-value that refers to a certain category of achievement in assessing students' academic performance. In this system, the students' performance,based on examination results and on-going assessments (e.g. tests, quizzes, assignments etc.) is evaluated using simple arithmetic and statistics. By using the pass or fail benchmark, this traditional method of assessment can be considered inadequate to evaluate the actual performance of the students. This is because, besides examination results, the evaluation of student achievement needs also to take into account other factors such as soft skills. Therefore, this study proposes a fuzzy logic method for evaluating students' performance to identify the best pre-diploma science student. The approach considers not only academic achievement but also the importance of soft skills in the assessment process, making the evaluation system precise, more equitable and fair to all students. The proposed method provides an alternative for the Academic Affairs Department of UiTM to have a complete measurement in evaluating students' performance, which can then be used for recognition purposes.

3. Theoretical Background and Evaluation Approach

3.1 A Brief Review of Fuzzy Sets Theory

Definition 1 A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$ which is associated with each element x in which X is a real number in the interval [0,1]. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$.

Definition 2 A fuzzy number is a fuzzy subset in a universe of discourse X. This is called a normal fuzzy set, implying that $\exists x_i \in X$, $\mu_{\tilde{A}}(x_i) = 1$.

Definition 3 A triangular fuzzy number (TFN) $\tilde{A}$ as shown in Figure 1, can be defined by a triplet (a, b, c). The membership function $\mu_{\tilde{A}}(x)$ is defined by Kaufmann & Gupta (1988) as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a, \\ \dfrac{x-a}{b-a}, & a \le x \le b, \\ \dfrac{x-c}{b-c}, & b \le x \le c, \\ 0, & x \ge c \end{cases}$$

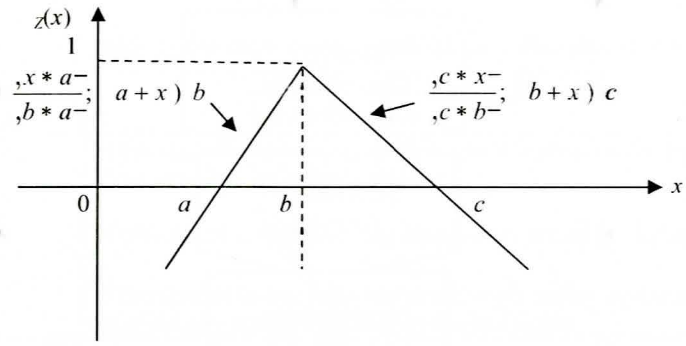

Figure 1: A triangular fuzzy number $\tilde{A}$

3.2 Our Evaluation Approach

In this study we propose a similar approach which was successfully employed in Zamali et al. (2014), namely, the intersection of fuzzy goal and constraints method. However, we will adopt the method for a different problem and environment, aimed at specifically identifying the best pre-diploma science student for UiTM Cawangan Sabah, for recognition purposes.

Let us consider a simple decision-making model which consists of a goal described by a fuzzy set G with membership function $\mu_G(x)$. A constraint described by a fuzzy set K with membership function $\mu_K(x)$ where x is an element of the crisp set of alternatives A_{alt}. Hence, the decision is a fuzzy set M with membership function $\mu_D(x)$, expressed as an intersection of G and K.

$$M = G \cap K = \{(x, \mu_M(x)/x \in [/_1, /_2], \mu_M(x) \in [0, h \leq 1]\} \quad (1)$$

where

$[/_1, /_2]$ is the crisp set of selection from the set of alternatives (L_{alt})

$\mu_M(x)$ is the degree to which any $x \in [/_1, /_2]$ belongs to the decision M

Here, the operation intersection of P and Q denoted as $P \cap Q$ is defined by

$$\mu_{P \cap Q}(x) = \min(\mu_P(x), \mu_Q(x)), \ x \in U; \quad (2)$$

$$\text{if } \mu_P(x) = 0_1 < 0_2 = \mu_Q(x), \ \min(0_1, 0_2) = 0_1$$

Using the membership functions and intersection operator from equation-(2), equation (1) gives

$$\mu_M(x) = \min(\mu_G(x), \mu_K(x)), \ x \in A_{alt} \quad (3)$$

Hence, the goal and constraint in Equation-(1) can be formally interchanged as follows:

$$M = G \cap K = K \cap M \quad (4)$$

To obtain $[/_1, /_2]$ with the highest degree of membership in set M, the maximization decision is expressed by

$$X_{max} = \{x / \max \mu_M(x) = \max \min(\mu_G(x), \mu_K(x))\} \quad (5)$$

Thus, equations-(1), (3)-(4) have been generalized with many goals and constraints. For goals G_i, $i = 1,2,3, \ldots, n$, and constraints K_j, $j = 1,2,3, \ldots, m$, the decision is given by

$$M = G_1 \cap G_2 \cap G_3 \cap \ldots G_n \cap K_1 \cap K_2 \cap K_3 \ldots \cap K_m \quad (6)$$

The membership function of M is

$$\mu_M(x) = \min(\mu_{G1}(x), \ldots, \mu_{Gm}(x), \mu_{k1}(x), \ldots, \mu_{km}(x))$$

and the maximization decision is given by

$$X_{max} = \{x/\mu_M(x) \text{ is max}\} \qquad (7)$$

The entire evaluation process above can be summarized, as depicted in Figure 2:

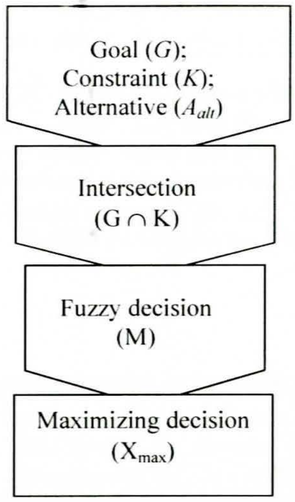

Figure 2: The evaluation process by intersection operator

Source: Modified from Zamali et al. (2014)

4. An Empirical Study

For the sake of illustration, an empirical study of pre-diploma science students was conducted at UiTM Cawangan Sabah based on the semester this study was carried out (Nov 2013 – Mac 2014 semester). The Academic Affairs Department of UiTM Cawangan Sabah identified 31 (i.e., A_1, A_2, A_3,…,A_{31}) students qualified to be shortlisted for this study.The university decided to select only one(i.e the best) candidate for recognition purposes.

There were six specific objectives (goals) which the candidates had to achieve; G_1(MAT081/MAT084), G_2(PHY081), G_3(BIO081), G_4(CHM081), G_5(ELC010) and G_6(CTU001). For G_1 until G_5, the candidates must score at least 70 marks and above (i.e. grade B+) whereas for G_6, a course with no final examination, the candidates had to pass all the on-going assessments throughout the semester. Thus, we constructed two membership functions for the five main objectives (G_1,G_2,...,G_5) and one for CTU001 (G_6) respectively, based on existing available evaluation procedures and our knowledge, as follows:

$$\mu_{\underset{\sim}{SUB}}(x) = \begin{cases} 0 & ; \; x < 70 \\ \dfrac{x}{100} & ; \; x \geq 70 \end{cases} \qquad (8)$$

$$\mu_{\underset{\sim}{CTU}}(x) = \begin{cases} 0 & ; \; if \;\; fail \\ 1 & ; \; if \;\; pass \end{cases} \qquad (9)$$

UiTM Cawangan Sabah also had an additional condition/constraint.The disciplinary status of the candidates was taken into account when it cames to shortlisting the best student. In addition, the level of their soft skills was also evaluated to ensure that those who were selected possess minimum soft skills such as leadership skills, and participate actively in co-curricular activites, such as sports, clubs and societies. Therefore, we considered two categories in the evaluation process, namely, the disciplinary status (K_1) and the soft skills (K_2) of the students. These two categories have three different scores (i.e membership values). Tables 1 and 2 provide a detailed description of the categories, respectively:

Table 1: The three different definitions of disciplinary status

Membership values	Description
0.3	If the student has received a show-cause letter once for light misconduct/for flouting university rules/regulations
0.8	If the student is free from any disciplinary action by the university
1	If the student is free from any disciplinary action by the university, plus has received any related excellent certificate/award

Table 2: The three different levels of students' soft skills

Membership values	Description
0.6	If the student is a member of, and is active in any internal society (i.e. club, faculty, hostel, etc.)
0.8	If the student is a member of, and is active in any external society (i.e. university, state, etc.)
1	If the student is a member of the Students' Representative Council or "Majlis Perwakilan Pelajar (MPP)" and is active in any external society

Based on the results, it was found that only 6 out of 31 students were qualified for further evaluation. The rest of the students were disqualified due to the fact that they had failed to obtain a B+ grade (i.e 70 marks and above) for at least two subjects. Table 3 shows the raw information for the 6 qualified students. Here, we substituted the 6 objectives (i.e. G_1, G_2, G_3, ...,G_6) from the raw data in Table 3 using equation (8) and (9) membership functions. Meanwhile, for both constraints (K_1 and K_2), we derived the membership values directly based on the definitions given in Tables 1 and 2 respectively. All the membership values are shown in Tables 3 and 4:

Table 3: The raw information for six objective attributes and two constraints

Students Objectives/Courses	S_1	S_2	S_3	S_4	S_5	S_6
G_1: MAT081	89	70	65	63	75	76
G_2: PHY081	85	70	74	76	72	74
G_3: BIO081/MAT084*	80*	76	80	74	72	84
G_4: CHM081	87	88	83	80	86	86
G_5: ELC010	85	80	84	70	60	74
G_6: CTU001	83	68	81	88	93	88
K_1: Disciplinary status	0.8	1	0.8	0.8	0.8	0.8
K_2: Soft skills	0.8	0.8	0.3	1.0	0.6	0.8

Table 4: The membership values (i.e. the scores) derived from Table 3

Students Objectives/Courses	S_1	S_2	S_3	S_4	S_5	S_6
G_1: MAT081/084	0.89	0.70	0	0	0.75	0.76
G_2: PHY081	0.85	0.70	0.74	0.76	0.72	0.74
G_3: BIO081	0.80*	0.76	0.80	0.74	0.72	0.84
G_4: CHM081	0.87	0.88	0.83	0.80	0.86	0.86
G_5: ELC010	0.85	0.80	0.84	0.70	0	0.74
G_6: CTU001	1.0	0	1.0	1.0	1.0	1.0
K_1: Disciplinary status	0.80	1.0	0.80	0.80	0.80	0.80
K_2: Soft skills	0.80	0.80	0.30	1.0	0.60	0.80

Based on the membership values shown in Table 4 above, both the 6 objectives and 2 constraints can be represented in matrix form as follows:

$$\tilde{M} = \begin{bmatrix} 0.89 & 0.70 & 0 & 0 & 0.75 & 0.76 \\ 0.85 & 0.70 & 0.74 & 0.76 & 0.72 & 0.74 \\ 0.80 & 0.76 & 0.80 & 0.74 & 0.72 & 0.84 \\ 0.87 & 0.88 & 0.83 & 0.80 & 0.86 & 0.86 \\ 0.85 & 0.80 & 0.84 & 0.70 & 0 & 0.74 \\ 1 & 0 & 1 & 1 & 1 & 0.74 \\ 0.80 & 1 & 0.80 & 0.80 & 0.80 & 0.80 \\ 0.80 & 0.80 & 0.30 & 1 & 0.60 & 0.80 \end{bmatrix};$$

or the 6 objectives (G_i ; i = 1,2,3, …, 6) can be written as

$G_1 = \{0.89/S_1, 0.70/S_2, \ldots, 0.76/S_6\}$

$G_2 = \{0.85/S_1, 0.70/S_2, \ldots, 0.74/S_6\}$

$\ldots = G_6 = \{1/S_1, 0/S_2, \ldots, 0.74/S_6\}$

and the 2 constraints (K_i ; i = 1,2) can be represented as

$K_1 = \{0.80/S_1, 1/S_2, \ldots, 0.80/S_6\}$

$K_2 = \{0.80/S_1, 0.80/S_2, \ldots, 0.80/S_6\}$

Next, we have from equation-(6)

$$\mu_M(x) = \min(\mu_{G1}(x), \ldots, \mu_{G6}(x), \mu_{k1}(x), \mu_{k2}(x))$$
$$= \{0.80/S_1, 0/S_2, 0/S_3, 0/S_4, 0/S_5, 0.74/S_6\}$$

and we can derive from equation-(7)

$\boldsymbol{X}_{\max} = \{x/\mu_M(x) \text{ is max}\}$

$\mathbf{X} = \{0.80/S_1\}$

Thus, from the above calculations, it is evident that student S_1 is the preferred choice for the best pre-diploma science student award for UiTM Cawangan Sabah, due to the highest score on membership values obtained.

5. Conclusion

In this study we have applied the intersection of fuzzy goals and constraints concept in a judgmental process to select the best pre-diploma science student at UiTM Cawangan Sabah. Since the evaluation generally involved uncertainty, it is important to incorporate the fuzzy approach to derive precise results in any proposed method. From the numerical example, it is obvious that the proposed method is beneficial for evaluation purposes. The significant fuzzy environment has been utilized to derive the membership values in the range of [0, 1], which provide some straightforward procedures via constructing the relevant membership functions. Furthermore, although the given empirical study may derive a different and/or same result for other cases, it still depends greatly on how the evaluators evaluate the relevant attributes during the judgment process. Also, the approach has a unique advantage in the sense that it can distinguish clearly every single score obtained by the students. Thus, it is highly beneficial for problem-solving under uncertainty data sets environment. Future work will entail conducting a comparative study with other methods that apply a fuzzy logic approach in students' performance evaluation.

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