Fuzzy System for Grade Assignment in Competence Assessment Based Educative Models

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Abstract. Mexico is adopting the competence-based model for education improvement. One of the major problems is to quantify the results of assessment to provide a grade considering subjective data. It commonly results in the assignation of an arbitrary grade which is estimated by the experience of the teacher using the evidence from the students. This paper presents a fuzzy system for calculating the grade assignment at undergraduate courses considering the student competences. The obtained results are compared against the grades that are calculated with the traditional average method and those obtained with the pass-fail checklists method.

Keywords: Fuzzy logic, competence education, assessment, scholar grade

1 Introduction

The twentieth-century educative models were focused more on teaching than learning. Today people need to develop the constant learning ability to be adapted to their life changing circumstances in a globalized environment. An overview of the educational paradigms in Colombia is shown in [1], which are very similar to those of many countries in Latin America.

The Mexican Technological Universities Subsystem (TUS) has adopted the professional competencies (PC) educative system for its educational programs since 2009. The competence-based education (CBE) system, proposes the integration of knowledge, competencies, and attitudes for preparing a student to solve problems throughout his life and when interacting with others. It is expected that a person could be adapted to changing contexts and show evidence of creativity, innovation, motivation, and values [2].

As CBE is a relatively recent model, there is still discussion on the development of curricula and assessment methods, so the need for research to face the challenges and limitations of the model exists [3, 4].

In the CBE, one of the most widespread methods for assessment in Latin America is the evidence portfolio [5, 6]. It is evaluated by observing the results of learning (ROL) and a grade is assigned in function of compliance checklists. For the TUS, the grade is given in alphabetical and numerical scale according to the following levels: SA (Satisfactory = 8), when the student has attained the ROL; DE (Prominent = 9), when the student has achieved the ROL and exceeds the requirements; AU (Autonomous = 10), when the student exceeds the ROL in different contexts [7]. When learning outcomes are not achieved, a grade of NA (Not Proficient) is assigned. The paradigm transition in assessment has been slow due to the habit of evaluating by closed tests which provide numerical results. Traditionally, the test results are averaged to calculate the final grade. In some cases, each periodical assessment is rated in different proportion corresponding to the "weight" it has into the content of the educational program.

Some major problems are quantifying and standardizing the results of the evaluation due to the linguistic nature of ROL, which causes subjectivities in the evaluation [8]. In the TUS the teachers have chosen one of two assessment methods: a) Continue with the traditional method using closed tests, averaging results and rounding the corresponding grade to the alphabetical and numerical scale; or b) assessing the ROL through checklists and grading in a pass-fail scheme.

The average method is not appropriate for the CBE as it only tests the knowledge and neglects the student's performance and attitude. The pass-fail method fits the observation of ROL and the performance criteria, but it commonly causes an injustice feeling in the teacher and frustration in the student. This is because the failure in a single item in the checklists can lead to fail in the subject regardless of the effort to meet the rest of the checklist items.

The fuzzy logic exposed in [9, 10] is a useful tool to assess competencies due to its linguistic nature. In this sense, there are some software tools to quantify those results as in [11, 12]. Fuzzy systems allow to process the measures of assessment instruments through membership functions that fit more to the teacher's linguistic criteria to declare when a level of compliance is acceptable.

In this paper, the use of fuzzy systems, as described in [13], is proposed as an alternative for calculating the grade in competency-based educative models. The results are compared with the traditional methods average and pass-fail.

The paper is organized as follows: Section II describes the current scoring methods and fuzzy method is presented. In Section III, the resulting scores between the three methods are compared and the remarkable changes are highlighted. Section IV discusses which method works best in terms of accreditation rate, and finally section V is related to the conclusions and future work.

2 Methods

Tests were made with two different data sets for the student grades. Due to verification purposes, the first set was constructed with 100 random data values in [0, 100]. The second data set contains the real grades applied to five different university groups. The subject, content, learning outcomes and the teacher were the same for each group and were applied in three different scholar periods. The evaluated parameters were: Attendance (A), assignments (T), practices (P), exams (E) and project (Y).

In order to test the three mentioned methods, their operating conditions were the same for all. Each test used the same weight, thresholds and identical membership functions for each evaluation parameter. The calculation methods were programmed using LabVIEW.

2.1 Average Method

In this method, the average score (c_p) is calculated by the simple average of the five parameter measures:

$$c_p = \frac{A+T+P+E+Y}{5}. \quad (1)$$

The average grade (n_p) is assigned as:

$$n_p = \begin{cases} NA, & c_p \leq 75 \\ SA, & 75 < c_p \leq 85 \\ DE, & 85 < c_p \leq 95 \\ AU, & 95 < c_p \leq 100 \end{cases}. \quad (2)$$

2.2 Pass-fail Method

The threshold for the pass-fail method is set to 80% compliance, corresponding to the minimum mark to pass. Each parameter has assigned a value of 1 (accepted) if its measurement is equal to or greater than the threshold, or 0 (rejected) if it is less than the threshold, as follows:

$$a_t = \begin{cases} 0, & A < 80 \\ 1, & A \geq 80 \end{cases}, \quad (3)$$

$$t_t = \begin{cases} 0, & T < 80 \\ 1, & T \geq 80 \end{cases}, \quad (4)$$

$$p_t = \begin{cases} 0, & P < 80 \\ 1, & P \geq 80 \end{cases}, \quad (5)$$

$$e_t = \begin{cases} 0, & E < 80 \\ 1, & E \geq 80 \end{cases}, \quad (6)$$

$$y_t = \begin{cases} 0, & Y < 80 \\ 1, & Y \geq 80 \end{cases}. \tag{7}$$

The pass-fail score (c_t) is the sum of the parameter values:

$$c_t = a_t + t_t + p_t + e_t + y_t. \tag{8}$$

Finally, the pass-fail grade (n_t) is assigned as:

$$n_t = \begin{cases} NA, & c_t < 3 \\ SA, & c_t = 3 \\ DE, & c_t = 4 \\ AU, & c_t = 5 \end{cases}. \tag{9}$$

2.3 Fuzzy Method

The Mamdani model [14] is used to calculate the fuzzy grade (c_d). The measures from the five input parameters are described by five linguistic variables. Each variable is defined by two membership functions as in figure 1. The membership function for accepted (μ_a) is a triangular function whereas for rejected (μ_r) is a trapezoidal function defined by:

$$\mu_r(x) = \begin{cases} 0, & x < 0 \\ 1, & 0 \leq x \leq 60 \\ \frac{80-x}{20}, & 60 < x \leq 80 \\ 0, & x > 80 \end{cases}, \tag{10}$$

$$\mu_a(x) = \begin{cases} 0, & x < 70 \\ \frac{x-70}{30}, & 70 \leq x \leq 100 \\ 0, & x > 100 \end{cases}. \tag{11}$$

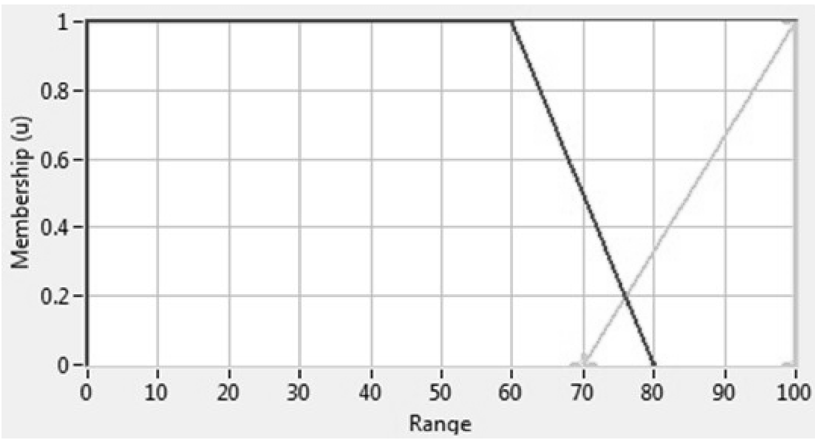

Fig. 1. Input membership functions. μ_r in the left and μ_a in the right.

The output fuzzy set is defined by four membership functions as in figure 2. In this case, a trapezoidal MF is used for no proficient (μ_{NA}), and triangular functions are used for satisfactory (μ_{SA}), prominent (μ_{DE}) and autonomous (μ_{AU}), defined as follows:

$$\mu_{NA}(x) = \begin{cases} 0, & x < 5 \\ 1, & 5 \leq x \leq 7 \\ 8 - x, & 7 < x \leq 8 \\ 0, & x > 8 \end{cases}, \quad (12)$$

$$\mu_{SA}(x) = \begin{cases} 0, & x < 7 \\ x - 7, & 7 \leq x < 8 \\ 9 - x, & 8 \leq x < 9 \\ 0, & x \geq 9 \end{cases}, \quad (13)$$

$$\mu_{DE}(x) = \begin{cases} 0, & x < 8 \\ x - 8, & 8 \leq x < 9 \\ 10 - x, & 9 \leq x < 10 \\ 0, & x \geq 10 \end{cases}, \quad (14)$$

$$\mu_{AU}(x) = \begin{cases} 0, & x < 9 \\ x - 9, & 9 \leq x \leq 10. \\ 0, & x > 10 \end{cases} \quad (15)$$

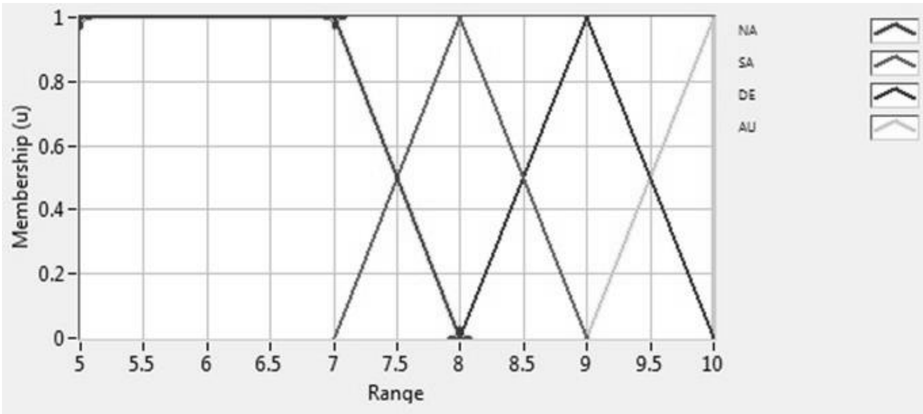

Fig. 2. Output membership functions. From left to the right, μ_{NA}, μ_{SA}, μ_{DE} and μ_{AU}.

The rule set is defined as in the case of the pass-fail criteria, so that, if the student has approved in three items, a fuzzy grade (n_d) of SA is assigned. When the student has four items approved, DE is assigned. When the student has five items approved an AU grade is assigned. In any other case, the assigned grade is NA. Thus, a 32 rule set was obtained according to Table 1. The antecedent for each rule is a compound of the joint of the five items using AND operators as in the form of equation (16). All the rules have the same weight and the consequence implication is the minimum. The defuzzification method is the center of area.

$$\text{IF (A and T and P and E and Y) THEN } (n_d). \tag{16}$$

Table 1. Rule Set

A	T	P	E	Y	n_d	A	T	P	E	Y	n_d
0	0	0	0	0	NA	1	0	0	0	0	NA
0	0	0	0	1	NA	1	0	0	0	1	NA
0	0	0	1	0	NA	1	0	0	1	0	NA
0	0	0	1	1	NA	1	0	0	1	1	SA
0	0	1	0	0	NA	1	0	1	0	0	NA
0	0	1	0	1	NA	1	0	1	0	1	SA
0	0	1	1	0	NA	1	0	1	1	0	SA
0	0	1	1	1	SA	1	0	1	1	1	DE
0	1	0	0	0	NA	1	1	0	0	0	NA
0	1	0	0	1	NA	1	1	0	0	1	SA
0	1	0	1	0	NA	1	1	0	1	0	SA
0	1	0	1	1	SA	1	1	0	1	1	DE
0	1	1	0	0	NA	1	1	1	0	0	SA
0	1	1	0	1	SA	1	1	1	0	1	DE
0	1	1	1	0	SA	1	1	1	1	0	DE
0	1	1	1	1	DE	1	1	1	1	1	AU

1 = accepted, 0 = rejected.

3 Results

In the first test, the grades were calculated by the three methods using the same random values. The results are shown in figure 3.

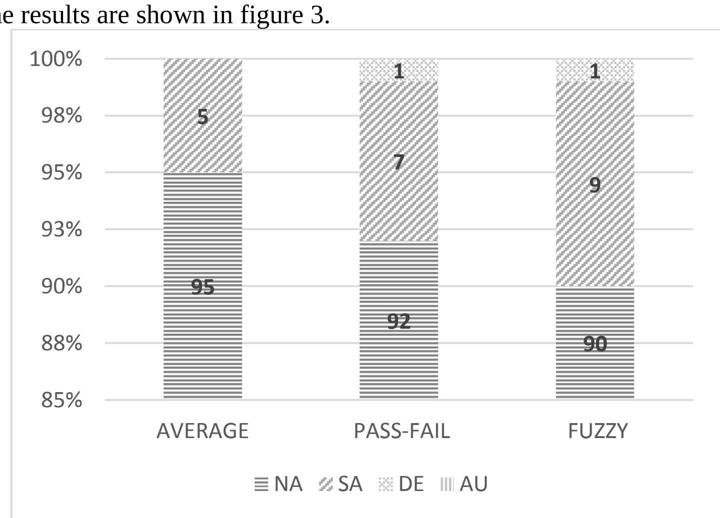

Fig. 3. Grades calculated using random values for the three methods.

Most NA grades were maintained in the three methods. The grades that changed between methods are presented in Table 2. Five students increased one level their grade in relation to the average method, and kept the same in the pass-fail and fuzzy methods (samples from A to E). Two samples were equal in the average and pass-fail methods getting better in the fuzzy method (samples F and G). Only one sample (H) resulted in SA in the average method, which was assigned NA in the pass-fail and the fuzzy methods.

Table 2. Random samples with grade changes between methods

sample	A	T	P	E	Y	n_p	n_t	n_d
A	95	96	100	33	85	SA	DE	DE
B	80	85	76	81	39	NA	SA	SA
C	37	85	30	83	95	NA	SA	SA
D	100	2	90	2	80	NA	SA	SA
E	28	22	88	96	85	NA	SA	SA
F	79	14	98	27	80	NA	NA	SA
G	63	38	97	77	89	NA	NA	SA
H	68	100	65	98	45	SA	NA	NA

Applying the same process and using the real data from 135 students a considerable difference was obtained in the approving index. The fail index is 93% in the average method, 49% in the pass-fail method, and 47% in the fuzzy method. The results are compared in figure 4.

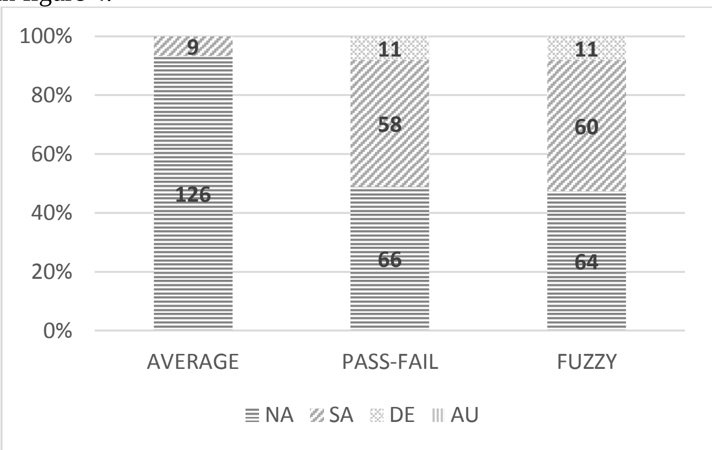

Fig. 4. Grades calculated with real data.

Most of the assigned grades were better by one level in the fuzzy and the pass-fail methods. Eight grades were SA in the average and were DE in the other two methods. Fifty-seven grades changed from NA in the average to SA in the others, reducing the fail index considerably. Table 3 shows the major changes in the grades. Two grades changed from NA to DE (students132 and 135), and two grades were SA only in the fuzzy method (students 64 and 83). None of the students got in the average method a better grade than in the other methods.

Table 3. Major changes in the grades using real data

student	A	T	P	E	Y	n_p	n_t	n_d
12	96	95	80	83	0	NA	DE	DE
64	78	84	80	50	0	NA	NA	SA
83	93	78	80	25	0	NA	NA	SA
132	86	92	80	100	0	NA	DE	DE
135	100	84	80	100	0	NA	DE	DE

4 Discussion

By comparing the grades that were calculated in the three different methods, it was observed that the fuzzy method has the best approval rate in both cases, with random values as with real data. Increasing the approving rate by a 2%.

Out of the three methods, the average has the highest failing index. Most of the grades were improved in the fuzzy method, except for the H sample in Table 2. It had two high and three low random values, resulting in a better grade in the average than in the other two methods.

The fuzzy method has the lowest NA index, as well as the higher notes compensate those notes that are slight below the threshold limit. As we can see in samples F, G from Table 2 and samples 64 and 83 in Table 3. Many students failed in the average method as well as almost all of them didn't accomplish the project.

5 Conclusions

By observing the measures, it is perceived that the fuzzy method is more balanced and is a good option to calculate the grade. Most of its results are nearer to the pass-fail method, which is applied in the educational programs by using checklists.

The advantage of the fuzzy method is that those students who were very close to the approving limits could do it by compensating the highest notes in other parameters. This method could be able to reduce the injustice feeling in the teacher and the frustration feeling in the student, providing a method that considers the subjectivities.

When rating the measures from checklists through the fuzzy method, the arbitrary assignment of the grade is eliminated reducing the student complaints. The students are certain that all of their evidences in the portfolio were considered for their grade, and the teacher assigns a grade based on student achievement data.

As future work, a comparison between the methods where each parameter has different weight in the grade could be performed. This implies different thresholds in the pass-fail method and distinct membership functions in the fuzzy method.

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