Applying Fuzzy Logic and Rule-based Approach to Facilitate Teachers in eAssessment

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Abstract

The teachers play an important role in eAssessment not only as evaluators, but also as designers of assessment activities which have to be created according to the course curriculum and suitable pedagogical scenario. During three pilots performed in Technical University of Sofia, the TeSLA system as an innovative solution with its five instruments was tested. The teachers had to decide which instrument/instruments to use according to the type of an assessment activity as well as which instruments are suitable for the course at whole to achieve its aim, keeping the specifies of pedagogical strategies.

The paper proposes a solution for decision making that gives the teachers a rating list with appropriated instruments according to the type of an assessment activity and suggests suitable instruments when two or more assessment activities must be performed. For this purpose, the Fuzzy sets theory and rule-driven approach is applied.

Keywords: *eAssessment, Fuzzy set theory, rule-based approach, TeSLA.*

1. Introduction

eAssessment is a process for students' knowledge examination and competences evaluation in blended-learning, online and distance-learning environment. From the teachers' point of view, the eAssessment includes several procedures related to the assessment activities design, their implementation, recording the students' results and providing an appropriate feedback [1]. eAssessment because of its nature always is realized through support of suitable technological solutions – eAssessment functions of a Learning Management System (LMS) or software with features for eAssessment management. One solution for support the teachers' tasks during the eAssessment process is the TeSLA system that proposes functionality for students' authentication and recognition the author of the performed assessment activities. The TeSLA system is developed under the H2020 project "An Adaptive Trust-based e-assessment System for Learning" with aim to propose a system suitable for implementation in a wide variety of assessment scenarios and in different educational context. The TeSLA system is under development and it is realized in the form of plugins integrated in LMS [2]. In Technical University of Sofia (TUS), the TeSLA system is a part of Moodle LMS and this approach is tested during three different pilots involving around 2000 students and 20 teachers from different faculties. The tested TeSLA system consists of five instruments: three for students' authentication – instrument for face recognition (FR), voice recognition (VR), keystroke dynamics (KD) and two instruments for authorship verification – forensic analysis (FA) and plagiarism check (PL).

In eAssessment, the teachers play an important role not only as evaluators, but also as designers of assessment activities which have to be created according to the course curriculum and suitable pedagogical scenario. It requires the assessment activities to be implemented through appropriate tools concerning their specifics and applicable context. The TeSLA system as an innovative solution with its five instruments requires re-design of existing assessment activities that were previously created without usage of such instruments in online environment or they are only offline performed. It puts the teachers in a position to adapt their assessment activities and assessment strategy to the TeSLA functionality. They have to decide which instrument/instruments to use for a given assessment activity to retain the course pedagogical strategy. Sometimes, this task is not easy, especially for those teachers who are new to the project. They have to decide whether a given assessment activity will be realized through instrument for authentication or for authorship confirmation or for both. Also, they have to decide whether they will use one or more instruments for one assessment activity. In this work a solution for teachers' facilitation in their decision process at assessment activities design is presented. It is based on multi-criteria analysis through utilization of fuzzy set theory that leads to alternatives rating according to the assessment activity type. Also, rule-driven approach is proposed in the case when teachers have to implement in the TeSLA system two or more assessment activities during one course.

The paper summarizes and analyses the gained experience concerning the designed assessment activities and used instruments from teachers' point of view during the performed three pilots in the scope of the TeSLA project in TUS. Based on this information, including the authors experience with the TeSLA system, an approach for TeSLA instruments rating list is proposed through applying the Fuzzy set theory. Also, a model driven by rules is developed to support teachers in their decision process when in a course two or more assessment activities incorporating the TeSLA instruments have to be designed.

2. Some Preliminaries of the Fuzzy Sets

The idea of fuzzy sets is proposed by Zadeh in 1965 [3] and originated in the areas of pattern classification and information processing. Zadeh defines a fuzzy set A of a nonempty set X as a real function, denoted by μ_A, with a membership values in the unit interval [0,1]. Then μ_A is the characteristic function which defines a subset A of X. The value 0 corresponds to the absolute non-membership and the value 1 corresponds to the full membership. Therefore, a fuzzy membership function $\mu_A(x)$ indicates the degree of belonging of the element $x \in X$ in the set A. A membership function can be also described as a curve that defines how each point in the input space is mapped to a membership value between 0 and 1. The input space is sometimes referred to as the universe of discourse. For representing fuzzy sets are used different kinds of membership functions, such as Triangular, Trapezoidal, Gaussian. One of the most popular is Triangular membership function, which depends on three scalar parameters a, b, c and is defined as is shown:

$$\mu_A(X) = \begin{cases} \frac{x-a}{b-a} & if \quad a \le x \le b \\ \frac{c-x}{c-b} & if \quad b \le x \le c \\ 0 & otherwise \end{cases} \qquad (1)$$

In the base of fuzzy set theory lies the idea of linguistic variables, because for the decision makers sometimes it is very difficult to express his/her opinion by a numerical value. A linguistic variable (fuzzy variable) is a variable whose values are sentences in a natural or artificial language. For example, the values of the fuzzy variable height could be tall, very tall, somewhat tall, not very tall, tall but not very tall, quite tall, more or less tall. The statement "Mary is tall" implies that the linguistic variable Mary takes the linguistic value tall. The range of possible values of a linguistic variable represents the universe of discourse of that variable. For present study, various linguistic variables used for input and output variables are: very high, high, medium, low, very low.

3. Obtained Ratings for Assessment Tasks

TUS is a university preparing engineering professionals in blended-learning environment and the typical assessment activities are related to evaluation of theoretical knowledge, practical skills and multiple competences. Taking into account that the courses can be addressed engineering, mathematics and science or social science related topics, the most appropriated assessment activities are: Quizz, Quizz with short answer, Essay, Project/Course work, Short answer, Oral task, Online task (simulation, role play). These assessment activities form seven criteria C1÷C7 to select the appropriate TeSLA instrument/instruments (alternatives). For this study, the fifteen alternatives A1÷A15 are prepared that offer teachers the use of one or combination of two or more TeSLA instruments for one assessment activity. The rating list with recommended alternatives is created after applying Fuzzy set theory considering the published theoretical knowledge and practical experiments in [4], [5], [6], [7]. The applied algorithm consists of six steps.

Step 1 includes definition of seven criteria C1÷C7. In this case the criteria are selected among the most applied assessment activities during the TeSLA pilots. Linguistic variables are assigned to them according to the authors' experience gained during the three pilots of the TeSLA project. For each criterion $C_j, j = 1, 2, \dots, 7$, a set with triangular fuzzy numbers is selected in the following form $C_j\ (a_j, b_j, c_j)$, where the real numbers a_j, b_j, c_j range from 0 to 1 and show lower bound a_j, upper bound c_j and mean value b_j. The membership function $\mu(x)$ of the triangular fuzzy numbers is shown on Figure 1 and the linguistic variables and assigned to the criteria fuzzy numbers are presented in Table2. The meaning of the linguistic variables and their transformation into fuzzy numbers are shown in Table 1.

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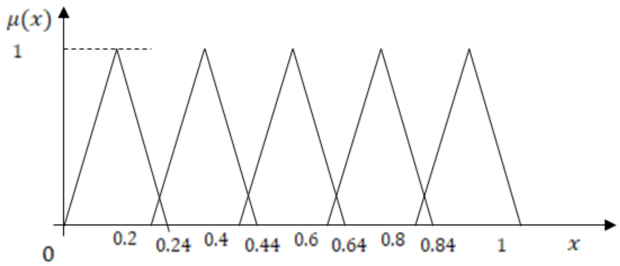

Fig. 1. Membership function $\mu(x)$ of the triangular fuzzy numbers assigned to criteria

Table 1: Linguistic variables and their transformation into fuzzy numbers

Linguistic variable	**Meaning**	**Fuzzy numbers**
VH	Very high	(0.8, 0.9, 1)
H	High	(0.6, 0.72, 0.84)
M	Medium	(0.4, 0.52, 0.64)
L	Low	(0.2, 0.32, 0.44)
VL	Very low	(0, 0.12, 0.24)

Table 2: Linguistic variables, assigned fuzzy numbers to the criteria and obtained defuzzified values

Criteria C_j, j=1, 2, …, 7	**Linguistic variable**	**Fuzzy numbers**	**Defuzzified value of $C_j(DVC_j)$**
C1-Quizz	VH	(0.8, 0.9, 1)	0.9
C2-Quizz with short answer	H	(0.6, 0.72, 0.84)	0.72
C3-Essay	M	(0.4, 0.52, 0.64)	0.52
C4-Project/Course work	H	(0.6, 0.72, 0.84)	0.72
C5-Short answer	M	(0.4, 0.52, 0.64)	0.52
C6-Oral task	L	(0.2, 0.32, 0.44)	0.32
C7-Online task (simulation, role play)	M	(0.4, 0.52, 0.64)	0.52

Step 2 consists of obtaining the crisp score for each criterion by applying defuzzification to the fuzzy sets, according to the equation for triangular fuzzy numbers [8]:

$$DVC_i = \frac{(a+2b+c)}{4} \quad (2)$$

The calculated non-fuzzy scores are presented in Table 2 for each criterion.

Step 3 includes definition of a set with alternatives relating to the most possible instrument or combinations of instruments to use in one assessment task. Fifteen alternatives are selected by the TeSLA teachers during the three pilots and they are presented in Table 3. The teacher can choose one TeSLA instrument for implementation of one assessment activity or combination of two, three, four or five instruments per assessment activity.

Table 3: Alternatives with instrument or combinations of instruments for usage in one assessment task

A1-FR	A6-FR+VR	A11-FR+VR+KD
A2-VR	A7-FR+KD	A12-FR+VR+FA
A3-KD	A8-VR+KD	A13-FR+VR+KD+FA
A4-FA	A9-FR+FA	A14-FR+VR+KD+PL
A5-PL	A10-FR+PL	A15-FR+VR+KD+FA+PL

Step 4 contributes to the formation of the matrix of expert decision. For this purpose, the alternatives are evaluated according to a given criterion by authors who put themselves in the role of experts. In Table 4 the expert evaluation of alternatives expressed in linguistic variables is presented.

Table 4: Linguistic variables for each alternative regarding a given criterion

A_i/C_j	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	VH	VH	VH	VH	VH	VH	VH
A2	M	M	VL	VL	M	VH	VH
A3	VL	VH	VH	VH	VH	VL	VH
A4	VL	VH	VH	VH	VH	VL	H
A5	VL	VL	VH	VH	VL	VL	VL
A6	M	M	L	L	M	VH	H
A7	VL	VH	VH	VH	VH	VL	H
A8	VL	M	L	L	VL	VL	L
A9	VL	H	VH	VH	VH	VL	M
A10	VL	VL	VH	VH	VL	VL	VL
A11	VL	M	L	L	L	VL	M
A12	VL	M	L	L	L	L	M
A13	VL	L	L	L	VL	VL	L
A14	VL	VL	VL	VL	VL	VL	VL
A15	VL	VL	VL	VL	VL	VL	VL

Step 5 consists of formation the matrix for decision making with the defuzzified values of alternatives (see Table 5). The applied defuzzification process is the same described in Steps 1 and 2 e.g. the linguistic variables from Table 4 are converted to the fuzzy sets according to Table 2 and then the non-fuzzy scores are obtained taking into account the equation 1. Then, normalized weight NW_j for each criterion C_j is calculated according to the formula:

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$$NW_j = \frac{DVC_j}{\sum_{i=1}^{15} DVA_i|_{C_j}}, \qquad (3)$$

where the numerator is the defuzzified value of C_j, obtained in Step 2 and the denominator is the sum of all defuzzified values of alternatives for the chosen criterion C_j.
Thus, we obtain the following result:

$$NW_j = [0.266\ 0.091\ 0.062\ 0.087\ 0.075\ 0.073\ 0.068]^t.$$

Finally, the total score for each alternative is aggregating through applying the equation:

$$TSA = M_{ij}.NW_j, \qquad (4)$$

where NW_j is normalized weight for each criterion, calculated according to formula (3), and M_{ij} is the matrix for decision making.

The obtained values for non-fuzzy scores of the alternatives regarding the criteria, the normalized weight for each criterion and aggregated total scores for alternatives are presented in Table 5.

Table 5: Matrix for decision making with non-fuzzy scores of the alternatives regarding the criteria Cj, normalized weight for each criterion and alternative total score

M_{ij}	C1	C2	C3	C4	C5	C6	C7	TSA
A1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.647
A2	0.52	0.52	0.12	0.12	0.52	0.9	0.9	0.368
A3	0.12	0.9	0.9	0.9	0.9	0.12	0.9	0.379
A4	0.12	0.9	0.9	0.9	0.9	0.12	0.72	0.371
A5	0.12	0.12	0.9	0.9	0.12	0.12	0.12	0.200
A6	0.52	0.52	0.32	0.32	0.52	0.9	0.72	0.387
A7	0.12	0.9	0.9	0.9	0.9	0.12	0.72	0.371
A8	0.12	0.52	0.32	0.32	0.12	0.12	0.32	0.166
A9	0.12	0.72	0.9	0.9	0.9	0.12	0.52	0.341
A10	0.12	0.12	0.9	0.9	0.12	0.12	0.12	0.200
A11	0.12	0.52	0.32	0.32	0.32	0.12	0.52	0.195
A12	0.12	0.52	0.32	0.32	0.32	0.32	0.52	0.230
A13	0.12	0.32	0.32	0.32	0.12	0.12	0.32	0.148
A14	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.087
A15	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.087
$\sum_{i=1}^{15} DVA_i\|_{C_j}$	3.38	7.84	8.26	8.26	6.9	4.34	7.54	
Normalized weight – NW_j	0.266	0.091	0.062	0.087	0.075	0.073	0.068	

Step 6 presents the rating list with alternatives scored with the highest values taking into account the obtained results in the previous steps. It can be seen that the highest rating is achieved for the A1 alternative - the TeSLA instrument face recognition. The second place is taken from the alternative A6 that consists of combination of two instruments face recognition and voice recognition. At third place with close scores are instruments for voice recognition and keystroke dynamics. The forth place is for two alternatives with the same obtained scores – the first alternative consists of a single instrument forensic analysis and the second alternative includes a combination of two instruments: face recognition and keystroke dynamics.

The results show that the high scored alternatives for conduction of one assessment activity consists of one instrument or combination of two instruments. When the alternative includes a single instrument, it is with function of student' authentication. When the alternative presents a combination of two instruments – it can be formed from a). two instruments for student's authentication or b). one instrument for authentication and one instrument for authorship verification.

Table 6: The rating list with alternatives with the highest scores

Rating	**1**	**2**	**3**	**4**
Alternative	A1	A6	A2, A3,	A4=A7
Obtained total score	0.647	0.387	0.368, 0.379	0.371
Alternative meaning	FR	FR+VR	VR, KD	FA, FR+KD

4. RULE-BASED APPROACH IN EASSESSMENT

In the previous section was described an algorithm for TeSLA instruments rating suitable for performance in one assessment activity using fuzzy inference system. This is rule-based system or expert system, which uses the fuzzy set theory and fuzzy logic for reasoning tasks. In practice, during a course, two or more assessment activities could be planned for evaluation of students' knowledge, skills, competences. In this case a model for suitable alternative/alternatives is proposed that is based on fuzzy inference system [9], [10] and includes the following structure:

$$\text{IF } \mathbf{C_{j1}} \text{ AND } \mathbf{C_{j2}} \text{ THEN } \mathbf{A_i} \qquad (5)$$

In the case when several rules are suitable for the same output membership function, there is a need of only one membership value to be chosen, which is called *fuzzy decision* or *fuzzy inference*. There have been developed a variety range of techniques for fuzzy decision-making and fuzzy inference [11]-[14].
Then, the calculation of the score of criteria SC_j is according to the following equation:

$$SC_i = NW_i \otimes DVC_i \tag{6}$$

and the obtained score for suitable alternative is calculated through the equation (7):

$$Al \approx \oplus_{j=1}^{n} SC_j. \tag{7}$$

Let us note, that in the present work, $\otimes$ is the usual multiplication, $\oplus$ is the usual addition and $n = 7$.
For example, if the teacher in her/his course is planed two different assessment activities: C1-Quizz and C4-Project/Course work, then she/he is looking for suitable TeSLA instruments for activities implementation. If the rule (5) and equations (6) and (7) are applied, then the result will be the following:

$$SC_1 = NW_1 \otimes DVC_1 = 0.266 \otimes 0.9 = 0.2394,$$
$$SC_4 = NW_4 \otimes DVC_4 = 0.087 \otimes 0.72 = 0.0626,$$
$$Al \approx SC_1 \oplus SC_4 = 0.2394 \oplus 0.0626 = 0.302.$$

The closest alternatives to the obtained score Al are alternatives A12 and A9, including instruments for students' authentication and authorship confirmation.

If the teacher has to perform two equal assessment activities during a course, for example, two quizzes C1, then the obtained score Al is 0.4788 that is close to the alternatives A1 and A2.

In the case when the teacher has to design three assessment activities and two of them are the same, then she/he has to take into account just two different assessment activities at alternative Al calculation. For example, the teacher designs three assessment activities during a course – two quizzes C1 and one online task C7, the she/he will consider just one quiz and one online task and the obtained alternative Al is with score 0.2747. It leads to the alternatives A12 and A9 with instruments for students' authentication and authorship check.

4. Conclusions

In this paper we suggested our ideas how to support teachers to decide which instrument to integrate in their courses and whether they will use one or more TeSLA instruments for one assessment activity. A possible solution for teachers' facilitation in their decision process at assessment activities design is presented. It is based on multi-criteria analysis in fuzzy set theory that leads to alternatives rating according to the assessment activity type. Also, evaluation with fuzzy logic is proposed in the case when teachers have to implement in the TeSLA system two or more assessment activities during one course. At the application stage, it is important for the teachers to understand the advantages of different TeSLA instruments before taking the decision. For this reason, the teachers of the TeSLA team should communicate with them and present the instruments, membership functions and the developed criteria.

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