FUZZY EVALUATION OF STUDENT ASSIGNMENT SHEETS

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Abstract: Evaluating students' work cannot be always fully automatized. In case of narrative responses or assignment sheets only general scoring guidelines and principal aspects can be set. The teachers try to follow them; however, the final decision is mainly based on their expertise. In such situations the evaluator often feels some kind of uncertainty while categorizing an assignment. The underlying uncertainty makes the area of student work evaluation a perfect field for the development of fuzzy set based solutions. This paper introduces a fuzzy arithmetic based student assignment sheet evaluation method and a software tool that supports the easy practical application of the presented technique.

Keywords: fuzzy evaluation, software, fuzzy arithmetic

1. Introduction

The evaluation of student assignment sheets especially in cases when they contain narrative responses, drawings, or even programming codes could be a so complex task that a scoring guide with in-details definitions for each possible situation would require several tens of pages in a scoring guide. However, when a scoring guide becomes longer than one page its practical applicability heavily decreases. Thus the usual trade-off is that one creates a less complex scoring guide and relies on the expertise of the teacher, who sometimes faces uncertain situations feeling that the current performance of the student would fit into more than one category.

The fuzzy concept has been providing an excellent tool to deal with cases when the boundaries between categories are not sharp or/and the person doing the categorization is not certain or confident enough to do the classification. Successful applications of fuzzy set based solutions cover a wide range of fields like fuzzy control [13], fault detection [10], cognitive maps [16], weather prediction [1], data mining [5], biometrics [11], etc.

Fuzzy concept based student evaluation methods have been proposed in the literature since the early 1990s. Biswas in his FEM method [3] used discrete fuzzy sets defined on the 0..100 grading scale with six points for evaluation. The result was compared to predefined so called standard fuzzy sets. Chen and Lee (CL) [4] used eleven so called satisfaction levels and corresponding membership values as well as the unit interval as grading scale. Both methods were later enhanced into generalized methodologies by applying four aspects in course of evaluation. Wang and Chen [18] extended the CL approach by introducing the degree of optimism as a characteristic of the evaluator Bai and Chen [2] developed a rather complex adjustment method for the ranking of the students that obtained the same scores. Johanyák suggested a fuzzy arithmetic based simple solution (FUSBE) in [7] for the aggregation of the fuzzy scores. Nolan [9] applied a fuzzy classification model for supporting the grading of students' assignments. His aim was to speed up and made more consistent the evaluation. Saleh and Kim [16] enhanced the BC method by excluding some subjective elements. They also applied Mamdani type fuzzy inference. Rasmani and Shen [14] introduced a data driven fuzzy rule identification method. Johanyák published a fuzzy inference based evaluation method (SEFRI) in [8]. Vossen [17] introduced a pattern approach to educational assessment and applied a special reference model.

One can state clearly that several interesting and good student evaluation methods have been developed that offer solution to one or more issues of the traditional scoring system. However, nowadays a method can be considered practically useful only if it is supported by an easy-to-use software tool. Therefor in this paper we present an enhanced version of FUSBE and a software tool that supports the evaluation of individual students and student groups as well as assignment sheets with several questions. The method is based on fuzzy arithmetic and utilizes a fuzzy set based scoring technique.

The rest of this paper is organized as follows. Section 2 overviews some basic definitions that are related the fuzzy arithmetic concepts and operations used in the evaluation method. Section 3 gives a detailed description of the evaluation method and the supporting software, and the conclusions are drawn in section 4.

2. Basics of Fuzzy Arithmetic

In this section some definitions necessary for the fuzzy set based student evaluation are going to be recalled. During the evaluation of the students' assignment sheets trapezoidal shaped fuzzy numbers will be used, which makes possible to apply some simplifications in course of the calculations.

Definition 1 The function $u : \boldsymbol{R} \rightarrow [0,1]$ is a fuzzy number if the following criteria are met [6].

- The function u fulfils the criteria of normality, i.e. $\exists\, x_0 \in \boldsymbol{R}$ so that $u(x_0)=1$;
- The function u is convex, i.e. $u(\lambda x + (1-\lambda)y) \geq \min\{u(x), u(y)\}, \forall x, y \in R, \forall \lambda \in [0,1]$;
- The function u is at least piecewise continuous.
- The support of u (*supp(u)*) is compact on $\boldsymbol{R}$, where $supp(u) = \{x \in R; u(x) > 0\}$.

Definition 2 The α-cut of a fuzzy number is the set

$$[u]^{\alpha} = \{x \in R, \alpha \in [0,1], u(x) \geq \alpha\}. \tag{1}$$

Note: the α-cut is a bounded interval

$$[u]^{\alpha} = [\underline{u}^{\alpha}, \overline{u}^{\alpha}]. \tag{2}$$

Definition 3 The sum of two fuzzy numbers is the union of the sum of their respective α-cuts

$$u + v = \bigcup_{\alpha=0}^{1} \left([u]^{\alpha} + [v]^{\alpha}\right) \tag{3}$$

for each $\alpha \in [0,1]$.

Note: in practice it is sufficient to make the calculations only for the levels α=0 and α=1 owing to the piece-wise linear nature of the applied fuzzy number.

Definition 4 The product of a real number and a fuzzy number is also interpreted α-cut wise as follows

$$[\lambda u]^{\alpha} = \begin{cases} \left[\lambda \underline{u}^{\alpha}, \lambda \overline{u}^{\alpha}\right], & ha\ \lambda \geq 0 \\ \left[\lambda \overline{u}^{\alpha}, \lambda \underline{u}^{\alpha}\right], & ha\ \lambda < 0 \end{cases} \tag{4}$$

for each $\alpha \in [0,1]$.

Note: in practice it is sufficient to make the calculations only for the levels α=0 and α=1 owing to the piece-wise linear nature of the applied fuzzy number.

3. Fuzzy Evaluation

In this section the steps of the proposed fuzzy student evaluation are going to be introduced parallel with the presentation of the functionality of the developed software. The method covers the evaluation of student assignment sheets usually containing more than one task/problem/assignment/question/exercise. The program maintains the evaluation data of a whole group of students.

First, the software loads the student related data, like names, identifiers, etc. Usually these are exported from the academic administration software in Excel or CSV format. Another data file containing information about the assignments and the associated weight values also has to be provided to the program. It should be also prepared either in Excel or in CSV format.

Having the necessary data files loaded into the program the teacher can start the evaluation process. First, the current assignment sheet is selected, and then the student, and finally the exercise being evaluated (see Figure 1). On the right hand side appears a figure containing a trapezoidal fuzzy number, which is the default fuzzy score associated to the exercise. The interval represented by the horizontal axis (universe of discourse) is defined by the maximum points associated to the current exercise. For example in Figure 1 it is the [0,10] interval. The default trapezoidal shaped fuzzy number can be modified with the mouse by dragging the circles representing the breakpoints of the membership function, or one can move the whole shape at once as well.

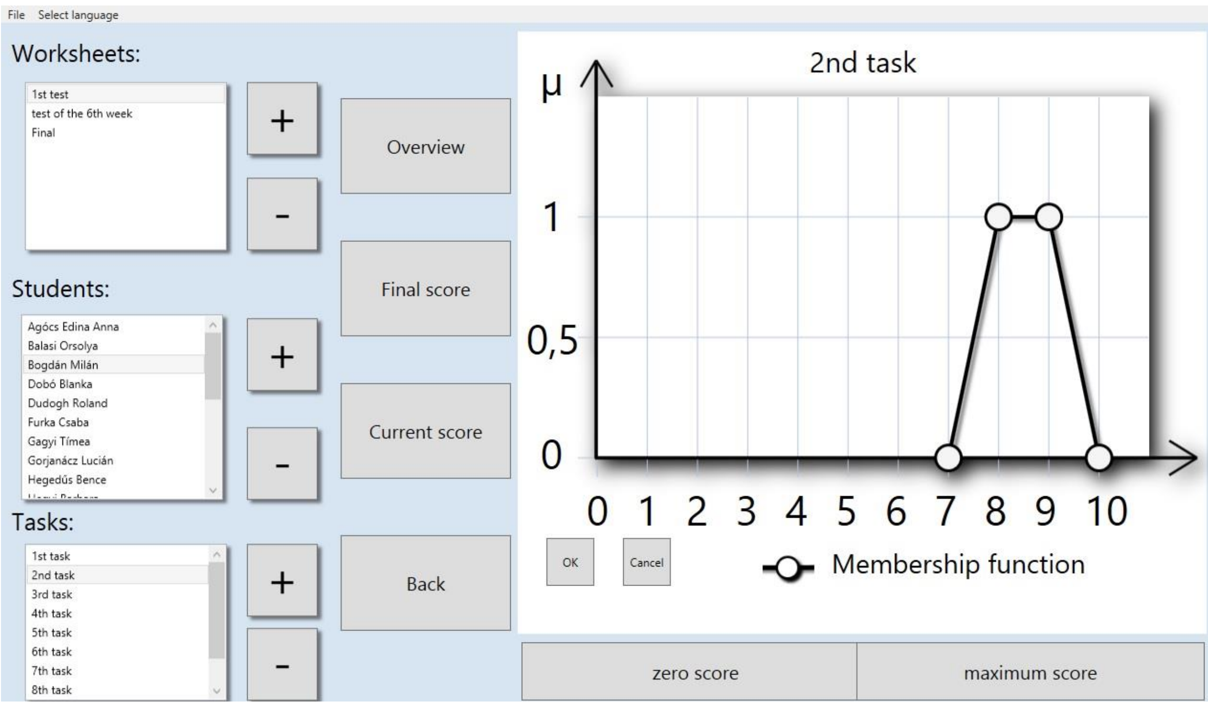

***Figure 1** The opening page of the fuzzy evaluation software*

The program does not allow the creation of invalid fuzzy membership functions. The two possible extreme values (the obvious zero and the flawless solution) can be represented by singleton shaped fuzzy sets (a vertical line at the value of 0 or at the value of the maximum like in Figure 2, second row). In the background they are also created with special trapezoidal fuzzy numbers. For the sake of the faster evaluation there are dedicated buttons for these values on the user interface.

The fuzzy scores given to the different exercises in case of a student can be overviewed easily in a tabular format (see Figure 2). Here one can select a fuzzy score to be edited or modified, or the summarized results grouped by the assignments. If there is an evaluation, which the teacher has not finished yet it will appear in red. By selecting any of the evaluations its magnified version will appear that makes the editing easier. The assignments can be filtered by student names and so one can see all the results of a particular student. The final fuzzy score of a student is calculated by summarizing all the fuzzy numbers achieved by him in case of the individual exercises.

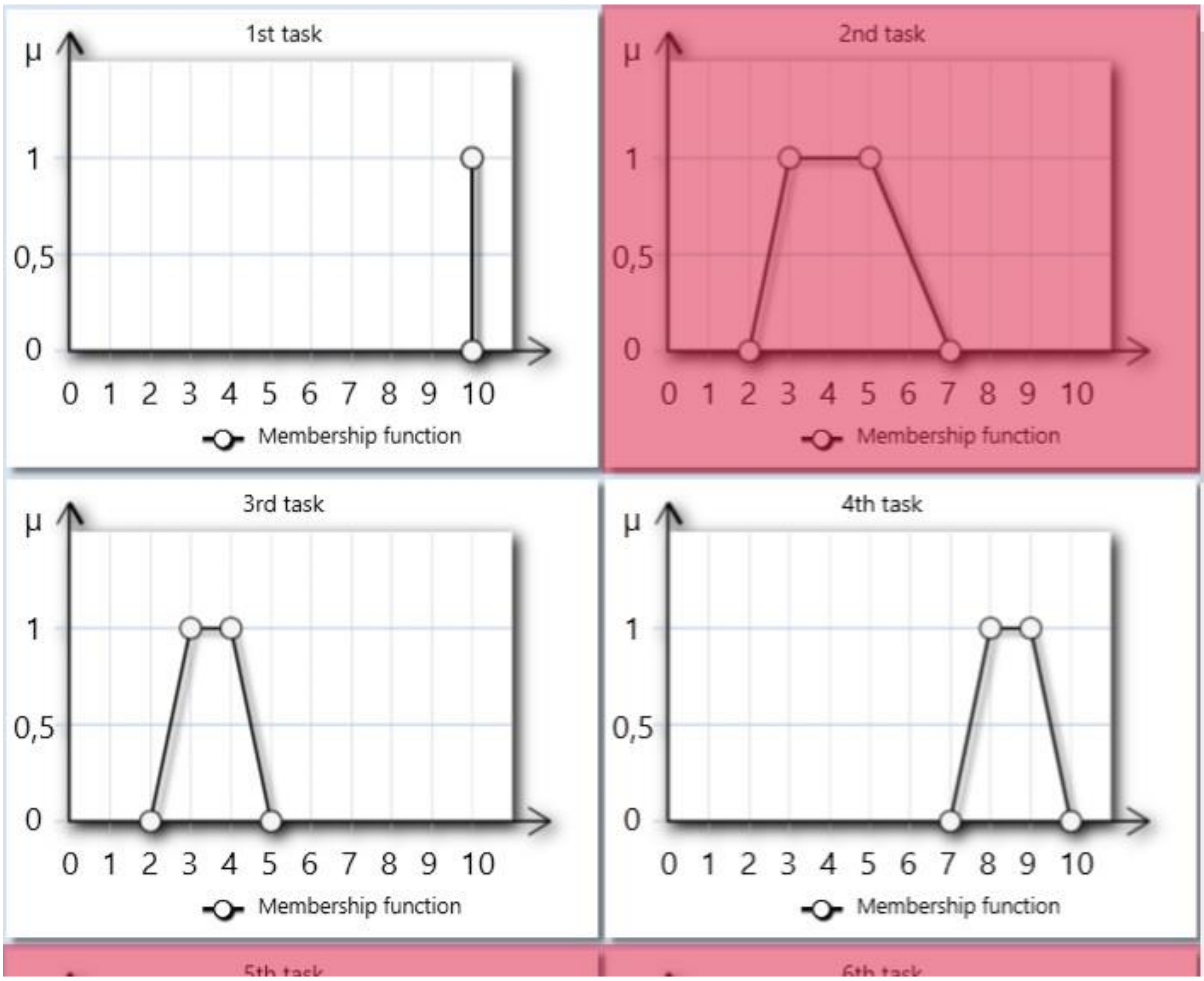

Figure 2 *Table for overview*

The last step is the determination of the student's grade. It is calculated by evaluating the intersection/overlapping between the student's final fuzzy score (marked by black line in Figure 3) and the standardized grading partition (marked by colored lines in Figure 3). The following three rules are used.

(1) If the final fuzzy score of the student intersects only one standard grading set the

student gets the mark (linguistic term) that is associated with the given set.

(2) If the final fuzzy score of the student intersects more than one standard grading set the set with the higher intersection value will define the grade. The intersection value is determined by the means of a *t*-norm. We use the minimum *t*-norm in the current implementation.

(3) If the final result intersects more than one set at identical membership values (usually $\mu=1$) the student gets the best grade from the grades (linguistic terms) associated to these sets.

In the example presented in Figure 3 the final result intersects the sets corresponding to the linguistic values *good* and *excellent* at the membership values 0.6 and 1, respectively. Rule no. 2 can be applied, so the student receives an *excellent* grade.

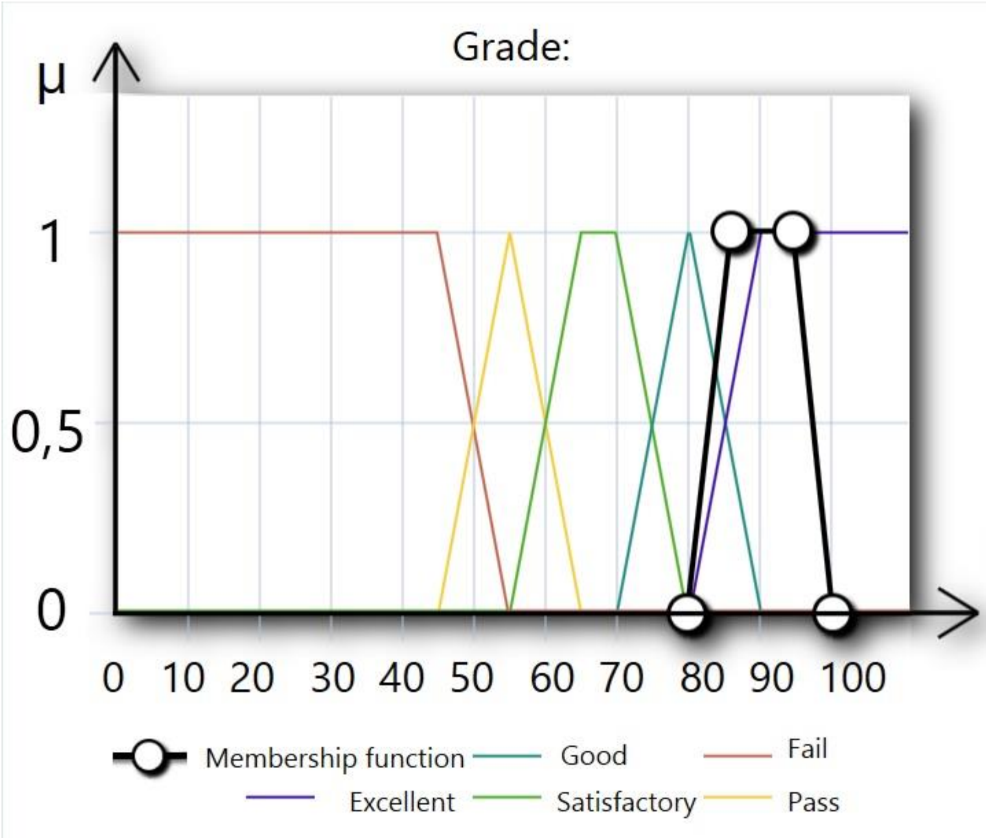

Figure 3 *Determining the grade*

4. Conclusions

The evaluation of any student assignment worksheet that contains not only tick marks or multi-choice tests can always contain uncertainty factors owing to the fact that either a full covering scoring guide is not available or despite being it available it is too complex to use in practice. This situation gives an excellent opportunity for the application of a fuzzy concept based solution. In our paper, we presented an evaluation method based on simple fuzzy arithmetic and its software implementation. With this application one can evaluate and log easily all the assignments and the corresponding individual scores can be represented as fuzzy numbers or crisp values in some obvious situations. Further research will consider the application of other membership functions and the implementation of a summarizing defuzzification method [12].

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