JCAMECH

Vol. 51, No. 1, June 2020, pp 170-183
DOI: 10.22059/jcamech.2019.265225.325

A New Method for Assessment of Engineering Drawing Answer Scripts Using Fuzzy Logic

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ARTICLE INFO

Article history:
Received: 9 September 2018
Accepted: 22 April 2019

Keywords:
Fair Assessment
Answer Script
Engineering
Drawing Fuzzy

ABSTRACT

Popular method for assessment of final exam answer scripts in university and among the engineering drawing answer scripts based on absolute true or false judgment and assigning a single number or letter to answer of each problem cannot be so fair. To obtain a fair assessment method, we considered “imagination”, “accuracy”, “drawing” and “innovation” that are objectives of engineering drawing course to be separately assessed for each problem. Flexibility and linguistic properties of fuzzy logic made us use it as the basis of our method. In addition, fuzzy variables and membership functions are easily linguistic explainable, and adjustable to different conditions. “Answering time” was added as a factor with only a positive effect on the final grade. Between these five factors, imagination has special importance because it supports one of seven human intelligences which is spatial ability Finally, however we applied the proposed method to engineering drawing course, it can be applied to other courses with considering their properties.

1. Introduction

The use of mesh generation methods for dividing a complex problem into small elements plays a crucial role in the finite element simulation, which determines the accuracy of the finite element model and the required computational time. The effectiveness of the mesh size distribution on the accurateness of numerical analysis results has been inspected by many researchers. Based on the finite element methods, as the mesh is fine with a small size as the precision of the results will be high but may take longer computational time. Furthermore, the simulation with coarse mesh leads to reduce the precision of the results with less computational time.

One of the most important courses in bachelor curriculum of engineering that is mostly compulsory is engineering drawing [1, 2]. This course consists of projection theory, basic drawing, and mechanical drawing. Among them, the projection theory is the most important part because it supports one of seven human intelligences called “spatial ability”[3, 4] and each engineer will need this in his/her future job [5-9]
Popular methods in assessment of answer scripts in engineering drawing such as other university answer scripts is based on the absolute true or false judgment on answers to each drawing problem which seems that cannot be so fair regarding to several important considered factors in this course.

From the early 90’s, researchers have worked on applications of fuzzy logic theory established in 1965 by Professor Zadeh L.A. [10] in assessment of university educations. First efforts in this category refer to 1993 by Chang & Sun, which was a method of evaluation of performance of junior high school students[11]. After it, in 1994, Chiang & Lin suggested a method for evaluation of teaching [12] and in 1995 by Biswas, applications of fuzzy logic in assessment of students were considered and evaluation of answer scripts discussed. He named his method as fem (fuzzy evaluation method) which is a vector valued marking, and finally, he generalized his method by the use of matrix-valued marking and called it gfem [13]. The major weakness of this method was assigning the same final grades to different fuzzy scores. In that year, Echauz et al. represented another fuzzy scoring method and said that the nature of traditional scoring system was fuzzy. Withal, they considered both teacher and student performances in scoring system and suggested a compensation method to increase the validity of grades [14]. A similar paper was written by Law in 1996. He tried to represent a structural fuzzy grading system and a method to identify membership functions to indicate points of each problem [15]. In 1998, Cheng & Yang imparted that the main difficulty of grading

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system is subjective judging problem of teachers and represented grade membership functions to express their characteristics; although, they did not described how these membership functions could be made [16]. In this year, Wilson et al. offered a method based on fuzzy logic and genetic algorithm that was flexible, adaptive, and automatic at that time [17]. Chen and Lee in 1999 presented two new ways for answer script's evaluation by using fuzzy logic and without the drawbacks of Biswas method. This method was faster than Biswas method because it does not need its complex matching operations. In addition, Biswas method sometimes assigns same grade to different fuzzy scores that is not fair; but in this paper, they have overcome this weakness [18]. In 2000 and 2001, other efforts were accomplished to obtain a new fuzzy strategy in evaluating the educational results. Ma and Zhou represented a procedure based on fuzzy theory to evaluate outcomes of student-centered learning according to their peer and lecturer [19]. Weon and Kim offered a fuzzy logic base algorithm for identifying the membership functions for evaluating answer scripts by considering the complexity, importance and difficulty factors [20].

In 2008, Bai and Chen in three papers represented procedures that could identify the final grade by using fuzzy logic in three levels: strict, normal, and lenient. They represented an automatic method to generate grade membership functions and normal type grades of fuzzy rules for assessment of student's performance. In this method, they used fuzzy reasoning to infer the scores of students; thus, it was fairer and smarter than previous methods [21-23]. At this year, Chen & Wang offered two methods for assessment of answer scripts associated with degrees of confidence [24]. In 2009, Li and Chen brought up a new way to evaluate student's results through using the automatically generating of the weights of accuracy, time rate, difficulty, complexity and answer cost with fuzzy reasoning capability. Finally, for increasing the fairness, they normalized the results [25]. At this year, Saleh & Kim presented a method by envisaging the importance, difficulty, and complexity of each problem using Mamdani fuzzy inference[26]; however, their procedure was not sufficiently sensitive and sometimes gave unfair grades to students [27]. In 2010, Gokmen et al. discussed a way for fuzzy evaluation of students' performance in control-laboratory. Then they compared it with classic method, expressed flexibility advantages of fuzzy systems, and concluded that this method could be extended to the other courses [28]. In 2011, a method was generated by Li & Chen which weighted rate of accuracy, time, difficulty, complexity, answer cost, and importance automatically, and was fairer compared to the procedure of Saleh & Kim because it was more sensitive. After it, Prokhorov and Kolikovskikh proposed a fuzzy assessment model formalized according to Reiter's Theory of Diagnosis to reduce uncertainty and to draw a distinction between the level of students' ability and the degree of guessing [29]. In 2018, Kumari et al, focused on the performance analysis of emerging engineers during the course by using Fuzzy Logics evaluation methods. The results of the model are indexed with simulation process to use as continuous evaluation method in student progression [30].
Therefore, we have three principal questions in this paper:

(1) What are characteristics of a fair assessment of answer script?
(2) How can we implement the fair assessment mentioned in question 1?
(3) What are the advantages of such a method for students and education system?

Therefore, we seek to provide a new definition of "fair assessment in engineering drawing answer scripts" in an innovative research process, then "a proper approach to implement it using appropriate tools", and finally, "the benefits of this new definition and implementation method for the student and the educational system".

In the present paper, we first describe the traditional assessment methods with their properties. Then, characteristics of a fair assessment are discussed and it is expressed that a fuzzy based method can be useful. In section 4, privileged factors in assessment of engineering drawing answer scripts are argued which are "imagination", "accuracy", "drawing", "innovation" and "time". The proposed method with its variables, fuzzy systems, and query tables are represented in sections 6, 7. Then, in section 7, a sample answer script is evaluated by both traditional and the proposed method. These two evaluations are compared in section 8; and conclusions are represented in section 9 which consist of answers to principal questions of the paper; and finally, section 11 includes the references.

2. What are the characteristics of a fair answer script assessment?

The most important characteristic of a fair answer script assessment is that we evaluate things that were the course objectives. Therefore, first we need to determine the course objectives and extract our evaluation factors from them.
The assessment of each problem as a single mathematically calculated number or a single letter grade could not be so fair since based on the course objectives, we should separately evaluate several factors in each problem and the nature of these factors is qualitative and linguistic. Hence, we need to separate our evaluation factors based on the course objectives, find a method that can evaluate these factors qualitatively and linguistically and then, combine them as a whole.

Another important thing is that we explain our assessment method for students; thus, they can adapt themselves to it, know how they can achieve better grades, and after assessment, they can understand why their score became high or low and satisfy it. Then, our evaluation method needs to be easily and linguistically explainable.

The same evaluation parameters for different semesters and different classes are fair when all conditions remain constant in them and we know that this is impossible. Therefore, we need to adjust our parameters for different semesters and classes. This means that our assessment method should be easily adjustable and flexible enough to be adapted to these conditions.

Another feature of a fair assessment method is to consider privileges for talented students. Such students are self-confident and can quickly make decision; hence, they can answer the problems faster than normal students can. In addition, they are creative that can help them in more quick answers. Despite all of these positive characteristics of talented student, they have an obvious weak point that is probability of junior mistakes in their answer because of their speed and the use of creative solutions when they are completely dominant to answer. Therefore, this is fair to consider positive privileges for quick answering time (without any penalty for longer answering times up to the allowed time) only when there are junior mistakes or no mistake (and not when there are major mistakes) in answer. In addition, we should consider some privileges for creative answers.

Finally, we should set different weights for different problems based on their complexity, difficulty and importance and these weighting rules can be adjusted based on different conditions.

3. Fuzzy Logic at a Glance:

As a method to express linguistic vagueness, the fuzzy logic theory was originally introduced by professor Zadeh in 1965

[10]. Based on this theory, factors and their criteria can be classified without precise limits. Thus, this theory can be very useful for real-world problems that always encounter some uncertainty.

Modeling systems sometimes involve uncertain variables. These uncertainties are classified in two categories: statistical uncertainties and non-statistical uncertainties (in form of vagueness or imprecision). Statistical uncertainties are discussed in probability theory while non-statistical uncertainties are treated in fuzzy logic.

Fuzzy logic deals with vagueness, imprecision and linguistic variables; therefore, expressions such as “a little”, “normal” and “high” can be located in this theory’s framework instead of “yes/no” or “true/false”. Fuzzy sets are known with their membership functions. Membership function of a fuzzy set is shown as μA(x) and degree of membership is identified as a number between zero and one. If factor x completely belongs to the set A, then μA(x) =1; and if factor x is completely out of the set A, then μA(x) =0. Higher amounts of μA(x) (up to 1) indicate that factor x belongs to the set A more.

To perform fuzzy inference, we need to represent our knowledge in form of “if-then rules”. Structure of an if-then rule is as follows:

- If x is A then y is B

Where A and B are linguistic values defined by fuzzy sets. A rule is also called a “fuzzy implication”, “x is A” are called “antecedent” or “premise” and “y is B” is called consequence or conclusion. This rule can be presented as a relation; so, “x is A” and “y is B” were presented as the following in Eq. 1:

- If A(x) then B(y) or R(x, y): A(x) → B(y) (1)

Where R(x, y) can be considered as a fuzzy set with 2-dimensional membership function as shown in Eq. 2:

- μR(x,y)=f(μA(x),μB(y)) (2)

Where f is fuzzy implication function. The output of a fuzzy inference can be a fuzzy set in Mamdani method [26] and a linear combination of inputs in Takagi-Sugeno method [31]. For practical applications with Mamdani method, a crisp value is often needed. The process of converting a fuzzy answer into a crisp value is called “defuzzification”.

Therefore, we can say fuzzy inference process comprises of four parts:

- Fuzzification of input variables
- Implication from the antecedent to consequent
- Aggregation of consequents across the rules
- Defuzzification

Please pay note that “AND method” and “OR method” in fuzzy rules, implication, aggregation, and defuzzification can be performed in different ways based on characteristics of our system.

Based on the mentioned above in this section, we can say fuzzy systems are adequate for systems with linguistic variables. They are easily explainable (because of linguistic if-then rules) and adjustable (because their membership functions can be easily adjusted); hence, we can conclude that based on what mentioned in section 2, the fuzzy logic is a useful mean for assessment of answer scripts.

4. What are privileged factors in engineering drawing answer scripts?

As discussed in section 2 paragraph 1, the first important thing in assessment of answer scripts of engineering drawing course is to determine its objectives. Haghshenas Gorgani in 2016 and Olkum in 2003 described that engineering drawing course consists of three sections: projection theory, basic drawing, and mechanical drawing; and the most important section is projection theory[1, 5]. Therefore, we can say the most important factor in assessment of engineering drawing course is learning of projection theory or “imagination” factor. The other factors are basic and mechanical drawing formality and we can represent both of them as “drawing” factor. Another point is accuracy of answer which is important not only in engineering drawing, but also in all other educations; thus, we can generate the third factor as “accuracy” as represented by Li & Chen [32].

Based on section 2 paragraph 5, we should consider privileges for talented students who are self-confident, quick decision makers, and creative but have junior mistakes. They answer the problems faster than others do, but it is possible for them to make junior mistakes when they are dominant to the solution. According to this, it is adequate to define a normal time for answering all problems of exam and generate a factor as “time scale” which is the portion of answering time to normal time as discussed in another way by Li and Chen [32]. This is fair to consider positive privileges for quick answering time (without any penalty for longer answering time up to the allowed time) only when there are junior mistakes or there is no mistake (and not when there are major mistakes) in answer.

In addition, we should consider some privileges for creative answers because it is one of the obvious characteristics of talented students. Therefore, another important factor is usage of invention ability in problem solving which is presented as “Innovation”. Haghshenas Gorgani discussed it in 2016 [1, 33].

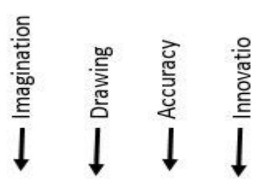
Again, all of problems should not have the same point and it is necessary to weight each problem based on its complexity, difficulty, and importance as mentioned in section 2 paragraph 6 and performed by Li & Chen [32] and Kim & Saleh [27].

As a result we can spot five factors “imagination”, ”drawing”, ”accuracy”, ”innovation”, and “time” as privileged factors in assessment of engineering drawing answer scripts. Simultaneously, each problem should have special weight.

Above factors should be separately evaluated for each problem by a quantitative and linguistic manner and then inferred by an adequate mean such as fuzzy logic to extract a number or letter as the result of our assessment.

5. Defining Variables and Answer Script Assessment Process:

As discussed in section 4, there are four factors of “imagination”, ”drawing”, ”accuracy”, and ”innovation” for evaluating the engineering drawing answer scripts. If the total number of problems is “j”, we generate matrix “P” that each column of it attached to one variable, as following:



$$P=\begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ \vdots & \vdots & \vdots & \vdots \\ p_{j1} & p_{j2} & p_{j3} & p_{j4} \end{bmatrix}$$

Each p_{ik} can be valued from 0 to 100; for example p_{23} is stator of drawing value in 2nd problem which can be from 0 to 100. We give matrix P as the input of a fuzzy system called "Score" with 4 inputs (columns of matrix P) and one output whose name is "S Matrix" which is j×1. Matrix S is containing scores of each problem in its rows as following:

$$S=\begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_j \end{bmatrix} \begin{matrix} \longrightarrow \text{Score of problem} \\ \longrightarrow \text{Score of problem} \\ \\ \longrightarrow \text{Score of problem} \end{matrix}$$

We call weight of ith problem as Wi by knowing $\Sigma_1^J w_i = 1$ Therefore, we can define matrix W as following:

$$W = [\, W1 \quad W2 \ \cdots \quad Wj \,]$$

After it, we define variable "correctness" as in Eq.3:

$$\text{Correctness} = \Sigma_1^J w_i \times s_i = [W_1 \quad W_2 \quad W_3] \times \begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix} = W \times S \qquad (3)$$

It is clear that correctness shows final score of answer script without spotting answering time. Thus, we define variable T as the answering time and variable Tn as the normal time for answering all problems by usual student and variable Ts as Eq.4:

$$T_s = \frac{T}{T_n} \qquad (4)$$

We know that $0 \leq$ Ts ≤ 1, and as Ts is smaller, the student is more qualified for higher score than similar correctness with larger Ts.

Now define another fuzzy system with two inputs and one output that gets correctness and Ts as inputs and gives "Final grade" as output. This fuzzy system is called "Final Grade". Filling the table 1 can help for easier evaluation; whilst, procedure of assessment of answer script is shown in flowchart of figure 1.

Table 1: Evaluation table for engineering drawing answer scripts

Problem No.	Imagination	Accuracy	Drawing	Innovation	Score of problem	Weight	Weight × Score
1	P_{11}	P_{12}	P_{13}	P_{14}	S_1	W_1	$W_1 \times S_1$
2	P_{21}	P_{22}	P_{23}	P_{24}	S_2	W_2	$W_2 \times S_2$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
j	P_{j1}	P_{j2}	P_{j3}	P_{j4}	S_j	W_j	$W_j \times S_j$
					correctness		$\sum W_j \times S_j$
					Time	Normal Time	Time Scale
					T	T_n	T_s
					Final Grade		Final Grade

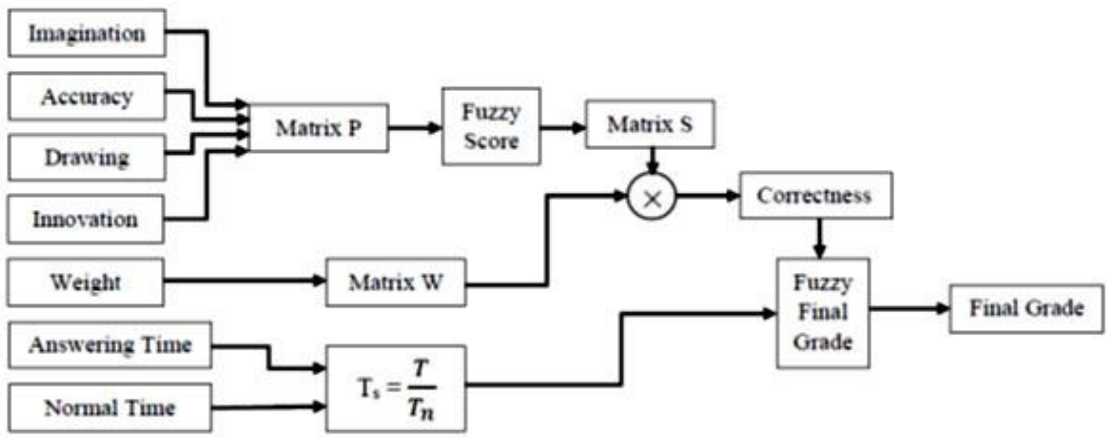


Figure.1. Procedure of assessment of answer script

6. Defining Fuzzy Systems:

Regarding to section 5, we need two multi-input and single-output fuzzy systems. In these systems, fuzzy inference can be Sugeno type or Mamdani type. These two types are different in output. Mamdani type is the most common fuzzy system and is very adequate for human systems and systems which are controlled by human because the output of this type is a fuzzy set while the output of Sugeno is a composition of inputs and is not proper for human controlled systems[26, 31]. In addition, in both "score" and "final grade" fuzzy systems we define:

And method: Min.
Or method: Max.
Implication: Min
Aggregation: Max
Defuzzification: Centroid

Now, regarding to the mentioned points in this section, we can define two needed fuzzy systems as following:

6.1. Definition of "Score" Fuzzy System:

This system has four inputs consisting of "imagination", "accuracy", "drawing", and "innovation", and one output called "score". Shape of membership functions of all four inputs are the same and shown in figure 2. From the figure, we can see that each input variable has three membership functions consisting of "Bad", "Mod", and "Good". Each variable can be valued from 0 to 100 and higher values show better state. Whilst, output of this system has seven membership functions as shown in figure 3. These membership functions from worst to best are "impassable", "very bad", "bad", "fair", "good", "very good", and "excellent".

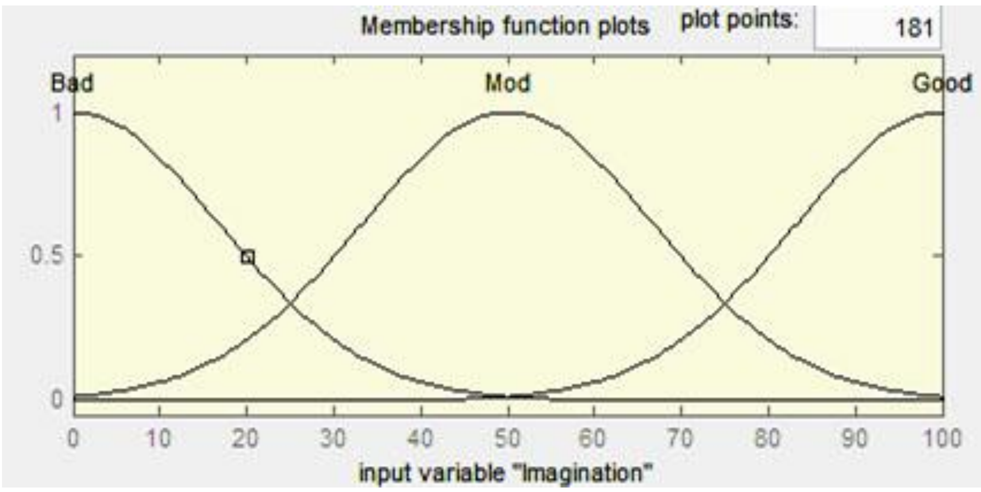


Figure .2. Membership functions for inputs of "Score" fuzzy system

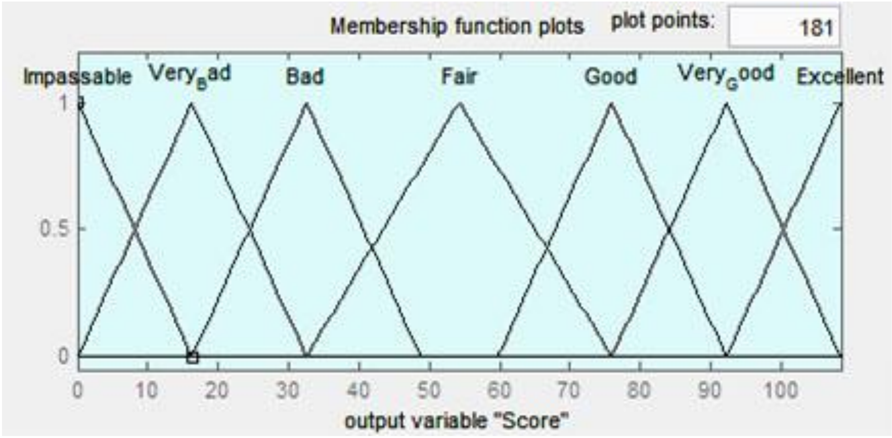


Figure .3. Membership functions for output of "Score" fuzzy system

Regarding to the shape and number of membership functions, we have:

Number of possible fuzzy rules = 3×3×3×3 = 81

Therefore, we can write 81 fuzzy rules. In these rules, we should note that the importance of "imagination" is more than other factors. Therefore, for example problem that has a low quality in imagination and a high quality in other factors should not be evaluated "excellent" and vice versa, problem that has a high quality in imagination and low in other factors should not be evaluated "very bad" or "impassable". Some of these 81 fuzzy rules are as following:

- 1. If (Imagination is Good) and (Accuracy is Good) and (Drawing is Good) and (Innovation is Good), then (Score is Excellent) (1)
- 2. If (Imagination is Good) and (Accuracy is Good) and (Drawing is Good) and (Innovation is Mod) ,then (Score is Excellent) (0.7)

⋮

- 16. If (Imagination is Good) and (Accuracy is Mod) and (Drawing is Bad) and (Innovation is Good), then (Score is Good) (1)

⋮

- 28. If (Imagination is Mod) and (Accuracy is Good) and (Drawing is Good) and (Innovation is Bad), then (Score is Good) (0.4)

⋮

- 40. If (Imagination is Mod) and (Accuracy is Mod) and (Drawing is Mod) and (Innovation is Bad), then (Score is Bad) (0.4)

⋮

- 56. If (Imagination is Bad) and (Accuracy is Good) and (Drawing is Mod) and (Innovation is Good), then (Score is Bad) (0.4)

⋮

- 80. If (Imagination is Good) and (Accuracy is Bad) and (Drawing is Bad) and (Innovation is Mod), then (Score is Fair) (1)
- 81. If (Imagination is Mod) and (Accuracy is Good) and (Drawing is Good) and (Innovation is Good), then (Score is Very_Good) (0.8)

In addition, the obtained fuzzy surface is as shown in figure 4.

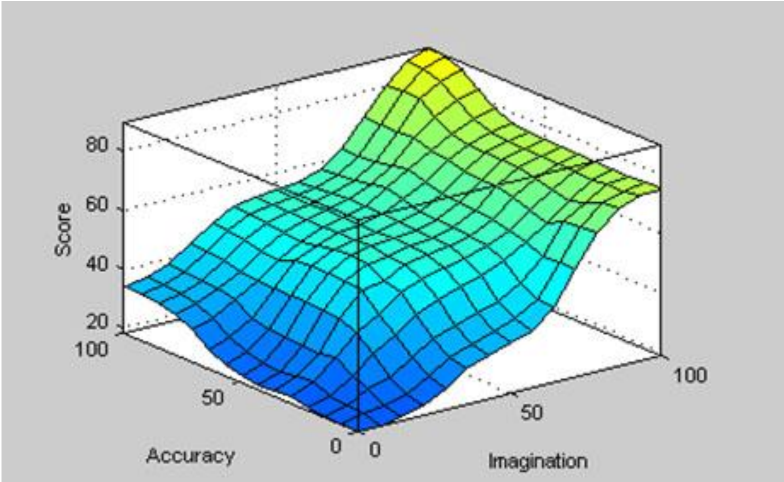


Figure. 4. Fuzzy surface for "score"

6.2. Definition of "Final Grade" Fuzzy System:

This system has two inputs consisting of "correctness" and "time scale", and one output called "final grade". Variable "correctness" has seven membership functions similar to the output of "score" fuzzy system as shown in figure 5. In fact, correctness is the matrix product of W matrix and S matrix (when S matrix is output of "score" fuzzy system) and can be valued from 0 to 100. The other input variable is "time scale" which is obtained from T/T_n and has three membership functions called "Normal", "Quick", and "Express" as shown in figure 6. Output of this system, "final grade" has seven membership functions similar to the output of "score" system as shown in figure 7 and can be valued from 0 to 100. In addition, the obtained fuzzy surface is shown in figure 8.

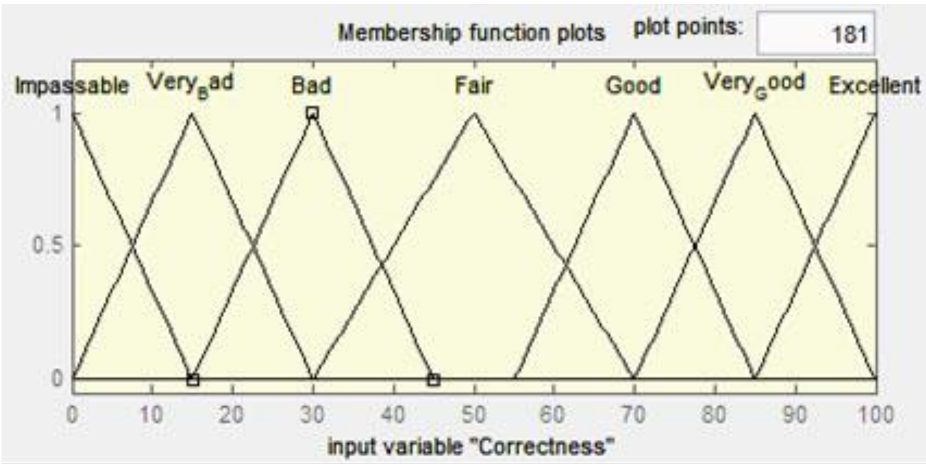


Figure .5. Membership functions for "correctness" variable

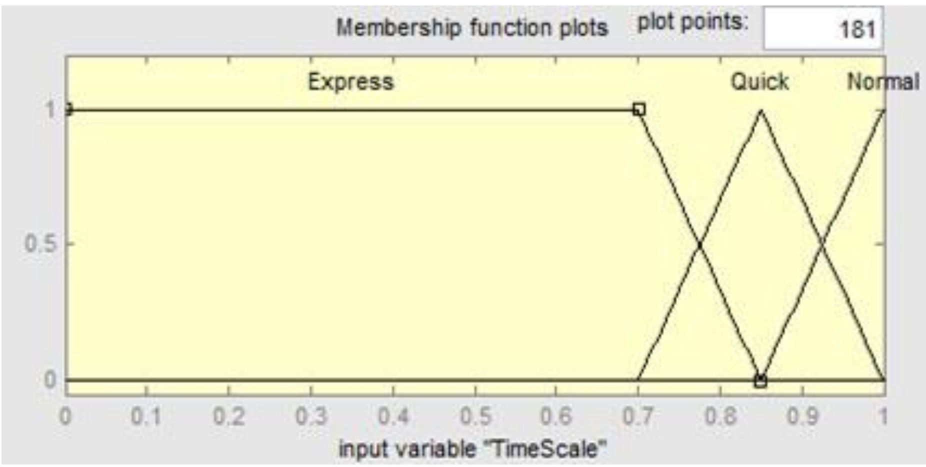


Figure. 6. Membership functions for "time scale" variable

Regarding to the shape and number of membership functions, we have:
Number of possible fuzzy rules = 7×3 = 21

Thus, we have maximum 21 fuzzy rules; but after analysis, we find out that 19 rules are sufficient. Among the input variables, "correctness" has priority and this should be spotted in generating of fuzzy rules, whilst, sensitivity to "time scale" should be observed as a synergic factor. Some of fuzzy rules are as following:

- 1. If (correctness is Excellent) and (TimeScale is Express), then (FinalGrade is Excellent) (1)
- 2. If (correctness is Excellent) and (TimeScale is Quick), then (FinalGrade is Excellent) (0.8)

⋮

- 8. If (correctness is Good) and (TimeScale is Express), then (FinalGrade is Very_Good) (0.8)
- 9. If (correctness is Good) and (TimeScale is Quick), then (FinalGrade is Good) (1)

⋮

- 18. If (correctness is Very_Bad) and (TimeScale is Normal), then (FinalGrade is Very_Bad) (1)
- 19. If (correctness is Impassable), then (FinalGrade is impassable) (1)

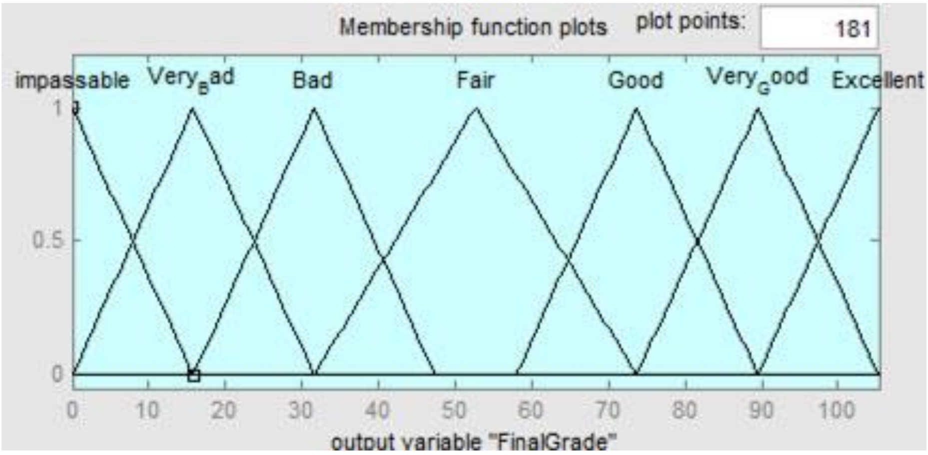


Figure. 7. Membership functions for "final grade" variable

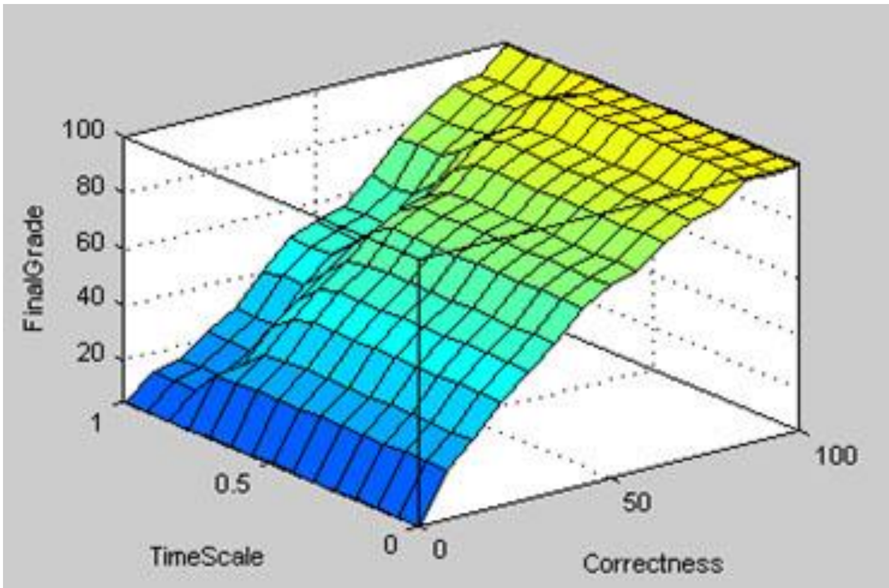


Figure 8. Fuzzy surface for "final grade"

We should note that, membership functions and fuzzy rules are not unique and every skillful person can define his/her special functions and rules based on his/her science and experiments and obtain desirable results.

7. Applying the Proposed Method on a Sample Answer Script:

Assume that we have an exam with four problems as following:
Problem 1: Draw 3D isometric view in 1st angle for given front and left views shown in Figure 9a:
Correct answer is shown in Figure 9b, and the student's answer to this problem is shown in Figure 9c. Weight of this problem is 0.2.

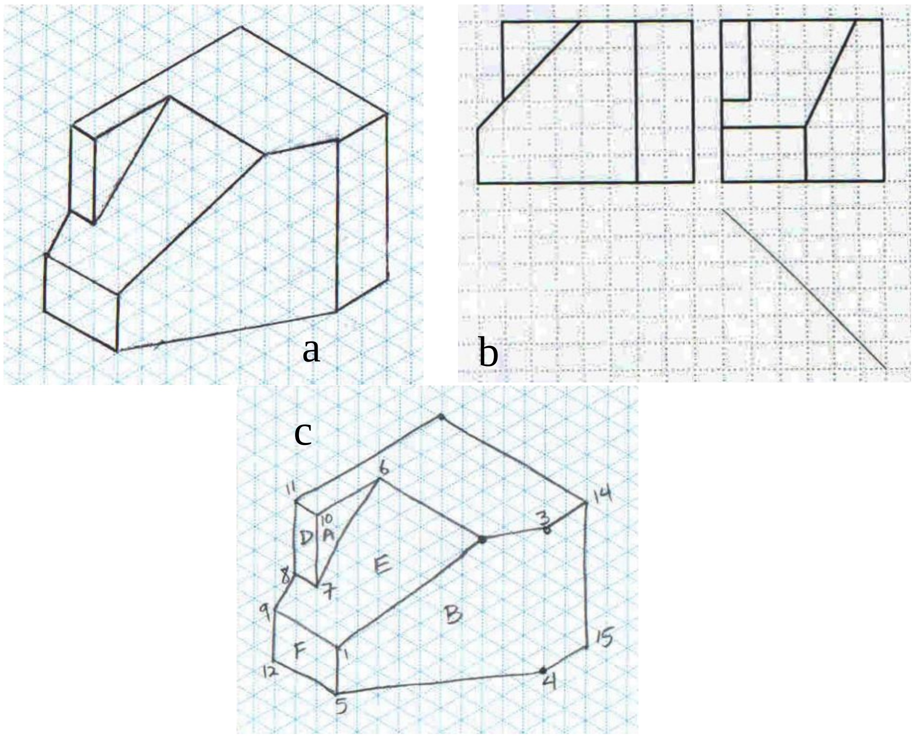
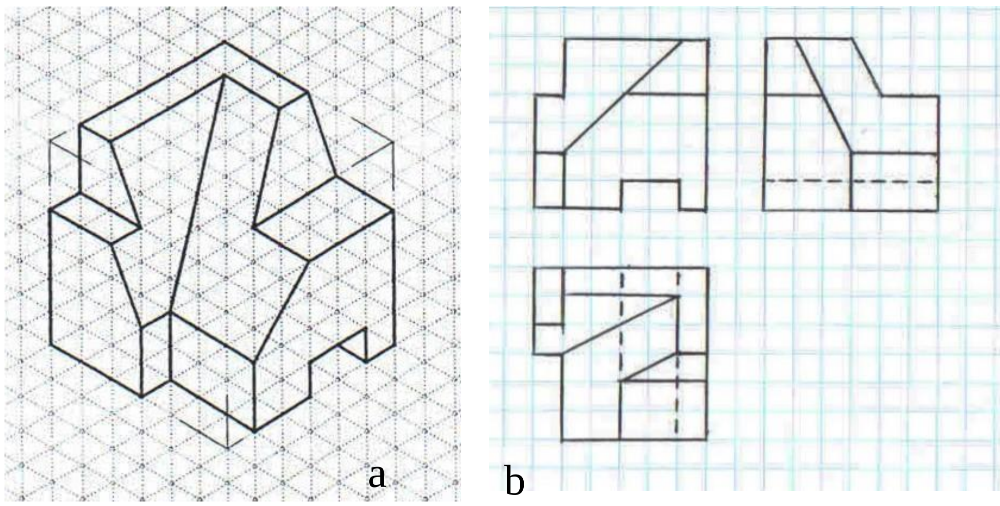


Figure .9. Problem 1: a) Question b) correct answer c) student's answer

Problem 2: For 3D object shown in Figure 10a, please draw 3 standard views in 1st angle (consist of front, left and top views). Correct answer is shown in Figure 10b, and the student's answer to this problem is shown in Figure 10c. Weight of this problem is 0.3.



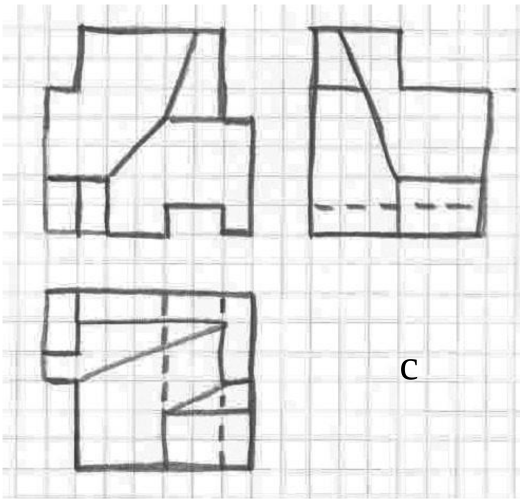


Figure.10. Problem 2: a) Question b) correct answer c) student's answer

Problem 3: For given front and left views shown in Figure 11a, please draw symmetric half-section in top view. Correct answer is shown in Figure 11b, and student's answer to this problem is shown in Figure 11c. Weight of this problem is 0.35.

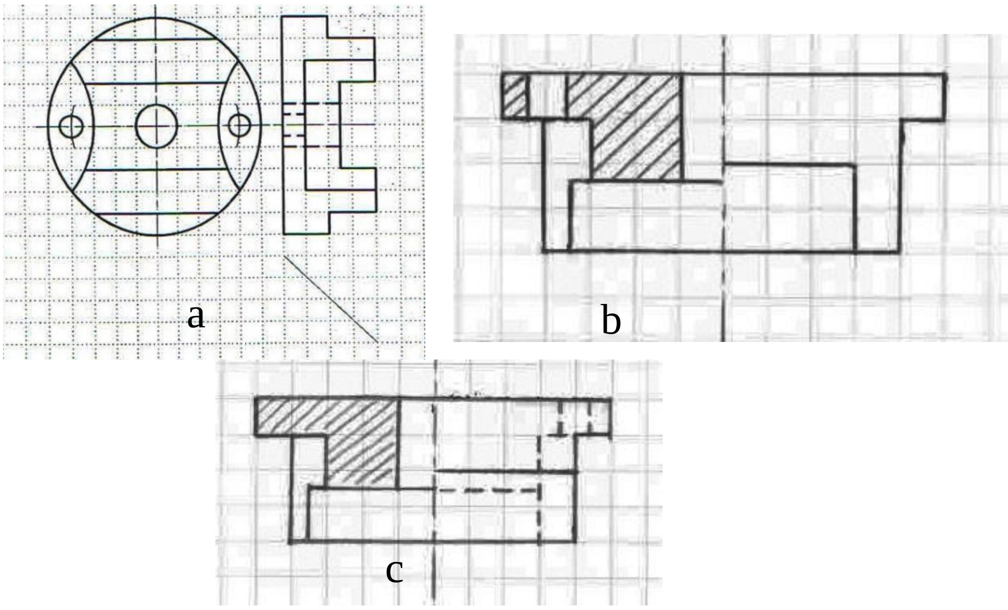
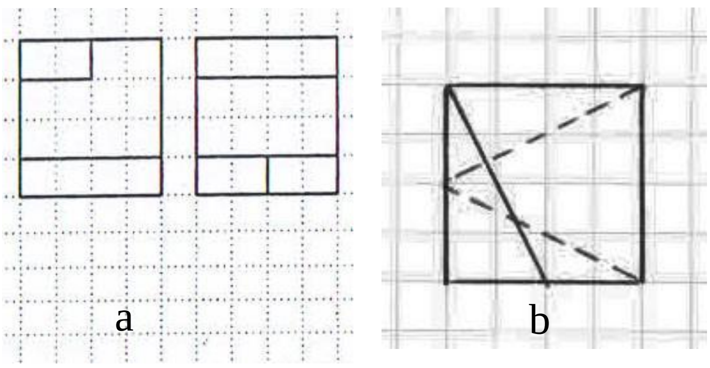


Figure .11. Problem 3: a) Question b) correct answer c) student's answer

Problem 4: For given front and left views shown in Figure 12a, please draw top view in 1st angle. Correct answer is shown in Figure 12b, and student's answer to this problem is shown in Figure 12c. Weight of this problem is 0.15.



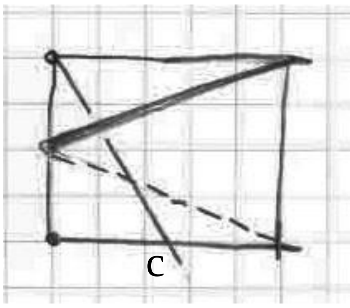


Figure. 12. Problem 4: a) Question b) correct answer c) student's answer

At this step, we requested an experienced instructor (with over 30 years teaching of Engineering Drawing course in Sharif university of technology, Tehran, Iran) to assess the answer script one time traditionally and another time by using the fuzzy-based proposed method. He was asked to express his reasons for each assigned score in brief. His comments are as following:

For traditionally evaluation, if we consider each problem as a whole and want to assign a single score to it, we can say:

In problem 1, the answer is generally Ok but one straight line between points 3 and 4 (see Figure 9c) is not drawn (detract 10 points), in addition, the drawing quality of answer is satisfactory but not very good (detract 5 points), so, we can assign score of 85 to it.

In problem 2, the answer of student has several mismatches to the correct answer (see Figure 10b, Figure 10c) which cause to subtract 25 points and drawing quality is under average which causes to subtract 10 points. Therefore, we assign score of 65 to it.

Comparison between student's answer and correct answer in problem 3 (see Figure 11 b, Figure 11c) shows that left side of answer is generally correct but in right side, serious mismatches are found. In addition, hidden lines should not be drawn. Quality of drawing is good. Therefore, we assign score of 70 to this problem.

Figure 12c and Figure 12b show that student's answer to problem 4 is not completely true; additionally, dimensions of answer are incorrect. For these two reasons, we subtract 25 points and for unsatisfactory quality of drawing, we subtract 15 points. Therefore, the assigned score to this problem is 60.

Now, we can assign the final grade as table 2:

Table 2**:** Assessment of sample answer script based on the traditional method

Problem No.	Score of problem	Weight	Weight × Score
1	85	0.2	17.0
2	65	0.3	19.5
3	70	0.35	24.5
4	60	0.15	9.0
Final grade			70

For evaluation by using the proposed fuzzy method, if we consider features of each problem separately based on what mentioned in section 5, paragraph 1, we can arrange our comments as following:

In problem 1, the answer shows that imagination was excellent (see Figure 9c, 9b) but a little carelessness is the cause of forgetting a slight part of answer. Thus, we can assign 100 for imagination and 80 for accuracy. Quality of drawing and observance of drawing principles are relatively good which cause score of 80 for drawing. Numbering of vertices from two different sides is a creative method that convinces us to give score of 95 to innovation.

Answer of problem 2 shows that imagination was not complete because of mistakes in front and left views, although state of top view is better (see Figure 10b, 10c). Therefore, we assign score of 60 to imagination. Accuracy was unsatisfactory because serious mistakes in dimensions and conformity of views have been occurred and this makes us to give 55 to accuracy. Quality of drawing and observance of drawing principles are under average, so we give score of 60 to drawing. If there was a creative answer, such big mistakes could not be occurred, so the score of innovation is 60.

In problem 3, the answer shows (see Figure 11b, 11c) that imagination was relatively complete because the left side of the answer is Ok expect the hole is not drawn although drawing of hole in right side shows that the cause of this mistake was carelessness and not wrong imagination. Therefore, we assign 85 to imagination and 75 to accuracy. Quality of drawing is good but based on principles of drawing, the hidden lines should not be drawn in such semi-section form and this makes us give the score of 75 to drawing. The answer shows that matching of two given views was used by the student for better imagination and this shows degrees of creative solution. Therefore, score of innovation is 80.

Imagination in answer of problem 4 was not completely true (see Figure 12b, 12c) because a visible line has drawn instead of the hidden line. Moreover, intersection of two visible lines shows wrong imagination. Therefore, we assign score of 70 to imagination. Drawing of visible line instead of the hidden one and wrong dimensions of solution show low degrees of accuracy forcing us to give score of 60 to accuracy. Quality of drawing is low and so, we assign 50 to drawing. The answer shows that the student imagined the given object section by section and this has some creativity and causes score of 80 for innovation.

Now, we can represent the earned points in each factor in sample exam using proposed fuzzy method as table 3:

Table 3: Evaluation of factors of sample answer script based on the proposed fuzzy method

Problem No.	Imagination	Accuracy	Drawing	Innovation
1	100	80	80	95
2	60	55	60	60
3	85	75	75	80
4	70	60	50	80

By giving this data to the “score” fuzzy system, we can get matrix S as following:

$$S=\begin{bmatrix}93.70\\57.80\\80.10\\65.00\end{bmatrix}$$

Now, based on weights of problems, we can generate the following W matrix:

$$W = [\ 0.2 \quad 0.3 \quad 0.35 \quad 0.15\ ]$$

Therefore, for correctness number we have:

Correctness =

$$W \times S = [\ 0.2 \quad 0.3 \quad 0.35 \quad 0.15\ ] \times \begin{bmatrix}93.70\\57.80\\80.10\\65.00\end{bmatrix} = 73.87$$

And if we assume that the normal time for exam is 120 Min and the student answered the problems in 102 Min, we will have:

$$T_s = \frac{T}{T_n} = \frac{100}{120} = 0.85$$

By giving correctness = 73.87 and T_s=0.85 to the “final grade” fuzzy system, we will have:

Final grade = 78.40

That is to say, because the student answers the problems about 15% quicker than normal time, the final grade increases from 73.87 to 78.40 (6.13%). This is synergy of faster answering. Table 4 shows the assessment of sample answer script based on the proposed fuzzy method in brief.

Table 4: Assessment of sample answer script based on the proposed fuzzy method

Problem No.	Imagination	Accuracy	Drawing	Innovation	Score of problem	Weight	Weight × Score
1	100	80	80	95	93.70	0.2	18.74
2	60	55	60	60	57.80	0.3	17.34
3	85	75	75	80	80.10	0.35	28.04
4	70	60	50	80	65.00	0.15	9.75
					Correctness		73.87
					Time	Normal Time	Time Scale
					102	120	0.85
					Final Grade		78.40

8. Discussion:

A comparison between scores of problems and final scores of traditional method and the proposed method is shown in Figure 13.

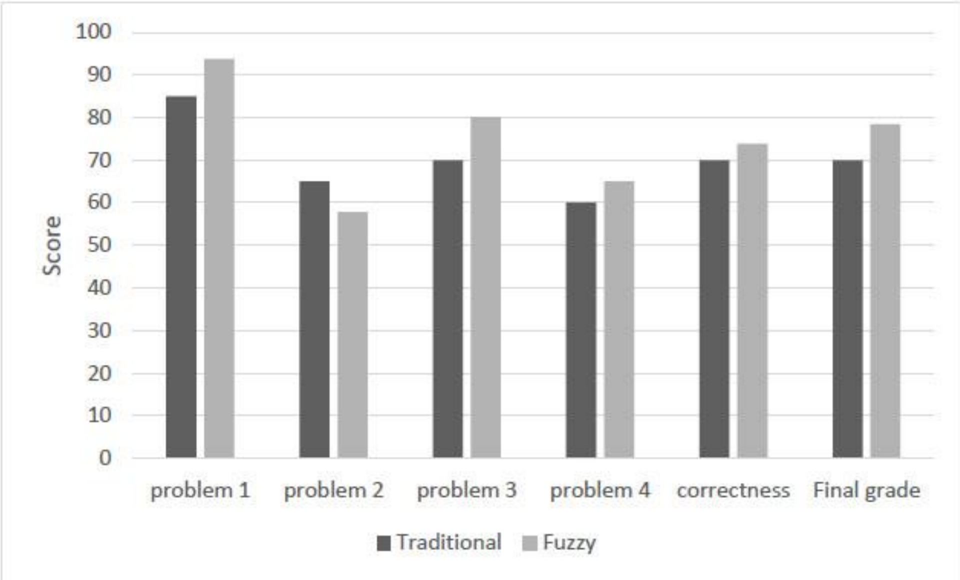


Figure 13. Comparison between scores of traditional method and the proposed fuzzy method

Based on Figure 13, table 2, and table 4, we can say the scores of problems 1 and 3 are increased in the proposed method. High degree of imagination and innovation factors show that the student has the ability to solve these problems but a little carelessness and hurry caused some mistakes; hence, he is worthy to earn a score higher than what evaluated based on absolute true/false judgment in traditional method. Problem 4 has the same state with less intensity. In problem 2, imagination and innovation factors are low; therefore, we can conclude that the student has not been able to solve this problem. In addition, he was careless and unresponsive to the quality of drawing and drawing principles. Thus, it is fair to give a score lower than traditional method. This comparison shows that in the proposed method, we consider course objectives more than true/false judgment of answer.

Based on section 4, paragraph 1, we can say that the most important factor of our evaluation is imagination. A comparison between various problem scores in the proposed method shows that this method is more sensitive to imagination than the other factors. For example, in problems 1 and 4, we can see that imagination factor has a 30% decrease and the mean of changes of other factors is 21.67% decrease, but the total score of this problem decreased 28.7% which is closer to imagination changes and of course, it is under the effect of other factors but not as intensive as imagination.

On the other hand, in Figure 13 we can see that based on scores of factors in each problem, the total score of each problem in the proposed method sometimes is higher and sometimes is lower than the traditional method. This shows that the proposed method is not a lenient or strict method, but it is a new assessment method with its own characteristics. So, increase in correctness from 70 to 73.8 (5.43% increase) cannot show that the increase in score is guaranteed in this method.

In addition, time factor shows that the student answers the problems 15% quicker than normal when he solved all of problems; and expect one problem (problem 2), he has satisfactory degrees of imagination and innovation, but he was a little careless and in a hurry. Therefore, we can say he was a talented student who is self-confident, quick decision-maker, and relatively creative. This shows that it is fair to give some special scores to this; and the proposed method makes is possible and tables 2 and 4 show an increase from 73.87 to 78.40 (6.13% increase).

Final grade has increased from 70 to 78.4 (12% increase) which is the result of considering objectives of course separately and characteristics of talented students. Of course, sometimes this increase (or decrease) can affect the passing or failing result.

9. Conclusion:

In this paper, we found the characteristics of a fair assessment method to evaluate answer scripts of engineering drawing course, how to apply it, and what are its advantages for students and education system.

A fair assessment method is a method evaluating things that were the course objectives. Therefore, we need to separate our evaluation factors based on the course objectives, find a method that can evaluate these factors qualitatively and linguistically, and then combine them. In addition, it needs to be easily linguistically explainable, adjustable, and flexible enough to be adapted with different conditions. Moreover, we should consider positive scores for talented students who are self-confident, quick decision-makers, creative, and a little careless.

In the proposed method, we considered “imagination”, “accuracy”, “drawing”, and “innovation” which are objectives of engineering drawing course to be assessed for each problem separately. Flexibility and linguistic properties of fuzzy logic made us use it as the basis of our method. In addition, fuzzy variables and membership functions are easily linguistic explainable and adjustable to different conditions. “Answering time” added as a factor which only has positive effect on the final grade (and no penalty for longer answering times up to the allowed exam time) to remove effect of slight mistakes and cover the characteristics of talented students.

Figure 13 shows that score of each problem in the proposed method sometimes is higher and sometimes lower than the traditional method; this means that the proposed method is not a lenient or strict method, but it is a new assessment method with its own characteristics. In addition, we can see that sensitivity of our system to imagination as the most important objective of this course is more than other factors.

Therefore, using the proposed method that is fairer than traditional, makes the student more satisfied because he/she is justified why his/her grade becomes high or low. Therefore, the student neither gets the grade lower than his/her abilities to become non-motivated, nor gets the grade higher than his/her abilities to become neglectful about fixing his/her weaknesses. In addition, the proposed method makes it possible to evaluate instructor performance, fixing educational methods, course references, and tools. These are major advantages for education system.

Finally, however we applied the proposed method to engineering drawing course, it can be applied to the other courses such as "Machine Elements Design", "Optimal Design", "Innovative Design", "Injection Mold Design" and "Press Tool and Die Design" with considering their properties.

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