Students' Evaluation based on Fuzzy Sets Theory

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1. Introduction

The traditional students' evaluation method is a process designed to evaluate the qualitative aspects but, in fact, its final result is a grade that values the quantitative aspect. The challenge of this work is to consider a modifying, dynamic and coherent method of evaluation in the industrial automation area.
Especially in the academic area, online laboratories are a commonly used distance learning model where the student practices the theoretical knowledge using a fieldbus simulator. These practical sessions can be performed in any location, as long as an authenticated, secure access is provided.
At the Sao Carlos Engineering School, University of Sao Paulo (EESC/USP), a FOUNDATION Fieldbus™ simulator named FBSIMU (Function Block Simulator) is being used as on online laboratory (Mossin, 2007). Engineering students can get involved with automation system technologies, as well as control theory, by implementing an application, therefore being able to explore and practice their knowledge.
Considering the training and learning environment, it is important to implement a robust evaluation system to help teachers in the industrial automation area identifying students' strong and weak points. The traditional evaluation method is a process designed to evaluate the qualitative aspects but, in fact, its final result is a grade that values the quantitative aspect (Rosa, 1999). Our challenge is to consider a modifying, dynamic and coherent method of evaluation.
A graduated student in Automation must know the technologies related to programmable controllers, computer networks and manufacture automation. Besides these technologies, the student must also know how to configure and specify industrial communication systems, supervise instrumentation and control projects, identify control strategies in industrial processes, tune and optimize control loops in industrial processes, etc.
Furthermore, there is a large amount of industrial protocols (FOUNDATION Fieldbus™ HSE, FOUNDATION Fieldbus™ H1, HART, PROFIBUS, DeviceNet, among others) available in the market and each one of those requires different particularities from the student.
If we look at the traditional teaching method, even an excellent student in a certain area could fail the course and miss great opportunities for not having the formal education the teacher was ideally expecting.
Regarding the inadequacy of the traditional method, this paper proposes the use of the fuzzy set technique that will be applied in the evaluation process of the industrial

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automation systems learning area, aiming to lessen the evaluation complexity and ambiguity in this area. It is also important to emphasize that this fuzzy learning evaluation methodology may be methodology may be used when training industrial plant operators and engineers who have already been working in the area but must be trained in new, emerging technologies.
Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets have been introduced as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition - an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1]. Fuzzy sets generalize classical sets, since the indicator functions of classical sets are special cases of the membership functions of fuzzy sets, if the latter only take values 0 or 1.
The next two sections will present in details the description and the solution for the problem, respectively. Section 4 details the evaluation methodology proposed in this research and section 5 outlines its results. Finally, section 6 delineates the conclusions related to the applications of this study.

2. Problem description

Industrial automation is a broad area and it would not be fair to grade a student simply as approved or not approved. This type of classification provides no information whether the approved student has capabilities in every area. The same misjudgement can occur with a student who failed the course. The student may be extremely good in one particular area but he may fail in other aspects.
Note that the traditional evaluation, besides being not fair in some aspects, makes it difficult to define a student's profile.
Considering the traditional teaching method, an excellent student in a certain area could fail the course and miss great opportunities for not having an ideal formal education. Using fuzzy sets as an evaluation method, the student would have a report indicating the excellence in a specific area (for example, identifying control strategies). The same report could also inform that the student did not succeed in another area, for example, in programmable controllers. If an organization is looking for a specialist in control strategies, this student could be fairly indicated and chosen for this position. Using the traditional evaluation method, this student could have missed the position.
It is possible then to determine, in a clearer way, the capabilities and the deficiencies of a student in different areas of knowledge in industrial automation using an evaluation system based on fuzzy sets.
Some works have been developed related to evaluation systems based on Fuzzy sets. Some authors presented a method based on fuzzy rules to assign grades to students (Chen & Lee, 1999), (Cheng & Yang, 1998) and (Bai & Chen, 2006). Chang & Sun (1993) presented a method to measure the performance of the students in Junior High School. Another author (Chiang & Lin, 1994) presented a method to evaluate teachers. Another work (Law, 1996) presented a method using fuzzy numbers to assign grades to the students. To finish, another author (Weon & Kim, 2001) created a system that considers the difficulty, the importance and the complexity of each question before determining a final grade.

Some of the ideas implemented by those authors were combined to define the solution for the problem, as described in the next section.

3. Problem solution

As described in section 2, an evaluation resulting only in a final grade can be unfair if not considering the many specializations of a specific sector. Moreover, such method intends to evaluate qualitative aspects but, in fact, the final result values the quantitative aspect.
In this context, this article proposes an evaluation method based on fuzzy sets, available in the FBSIMU simulator, used at the EESC\USP for teaching the FOUNDATION Fieldbus™ protocol.
It is proposed divides the students' evaluation in three distinct industrial automation areas: FOUNDATION Fieldbus™ industrial protocol concepts (FFP); control strategy configuration (CSC); and industrial plant simulation (IPS).
The proposed fuzzy system consists of three inputs and one output as showed in the Figure 1. Inputs are the automation areas and the output is related to the final student evaluation.

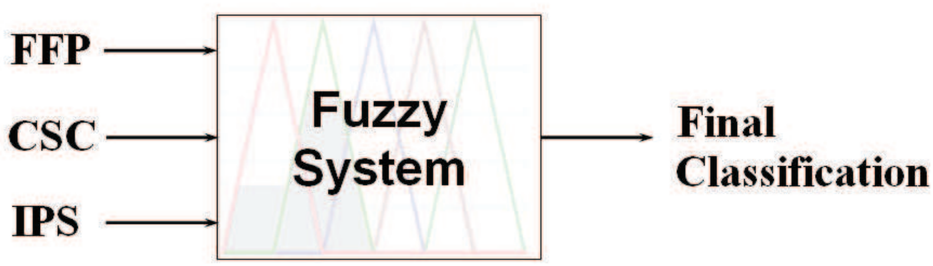

Fig. 1. Proposed Fuzzy System

The general view of the proposed methodology follows these steps: (1) apply a list of questions with items to evaluate the students; (2) calculate the grade from the evaluation for each of the three areas based on Table 1; (3) classify the student as Insufficient, Average or Excellent in the three areas, based on the grades given in step 2; (4) assign the final result to the student based on the result from step 3 and the fuzzy rules from Table 2 ("Fail", "Pass with Many Restrictions", "Pass with Few Restrictions" and "Pass"). The next section will detail the steps described above.

4. Methodology applied for the evaluation

The evaluation methodology will be exposed in three steps. The first step (sub-section 4.1) is calculating the student grade in each area considered in this research. After that (sub-section 4.2), the student classification in each area, using fuzzy theory, will be explained. To finish the process, the sub-section 4.3 explains the method to obtain final classification of a given student.

4.1 Calculating the grade

Each question in the evaluation may required from the student specific knowledge in more than one of the three areas considered in this research (FFP, CSC, and IPS) and, therefore, each area will have a specific weight for each question. For example, one question shows some FOUNDATION Fieldbus™ control strategies for a specific process. To answer this question, the student must know the FOUNDATION Fieldbus™ protocol theory and, moreover, the details on how to create a control strategy. The Table 1 shows the weight of each question in each area. Considered the information related to question one. For this question, the area FFP has weight of 0.90. The area CSC has weight 0.95. The question weight for the area IPS is zero.

Question number	Area	Weight
Q1	FFP	0.50
	CSC	0.50
	IPS	0.00
Q2	FFP	0.20
	CSC	0.20
	IPS	0.60
Q3	FFP	0.30
	CSC	0.10
	IPS	0.60
Q4	FFP	0.20
	CSC	0.45
	IPS	0.35
Q5	FFP	0.75
	CSC	0.15
	IPS	0.10
Q6	FFP	0.25
	CSC	0.55
	IPS	0.20
Q7	FFP	0.10
	CSC	0.10
	IPS	0.80
Q8	FFP	0.10
	CSC	0.80
	IPS	0.10
Q9	FFP	0.35
	CSC	0.15
	IPS	0.50
Q10	FFP	0.00
	CSC	0.10
	IPS	0.90

Table 1. Weight for each question.

Having the weight value for each area and for each question, we then calculate the grade of a specific student for a particular area using Formula (1).

$$\text{Grade}\,(\text{Area}) = \frac{V1 * PQ1(\text{Area}) + V2 * PQ2(\text{Area}) + \ldots + Vn * PQn\,(\text{Area})}{PQ1(\text{Area}) + PQ2(\text{Area}) + \ldots + PQn(\text{Area})} \quad (1)$$

In Formula (1), the field "Area" represents FFP, CSC or IPS. The value of the variable Vn is "1" for the right answers and "0" for the wrong answers. Finally, PQ1, PQ2 … PQn, represent the weight that a particular area has over a specific question (Table 1). To better understand Formula (1), suppose that a student got the questions 1, 2 and 3 right, but the others, in a total of ten questions, were wrong. So, the value Vn for these correct answers is "1" and for the wrong answers is "0". The weigh values in the area FFP for the three "correct" questions would be 0.5, 0.3 and 0.2. Therefore, the calculation would be:

$$\text{Grade}(\text{FFT}) = = \frac{1 * 0{,}5 + 1 * 0{,}2 + 1 * 0{,}3}{0{,}5 + 0{,}2 + 0{,}3 + 0.2 + 0.75 + 0.25 + 0.10 + 0.10 + 0.35 + 0.00} = 0.363$$

4.2 Classifying the student

The next step in this work is classifying the student according to the three proposed control and automation areas. At this point, a fuzzy system is used to classify the student based on the grade obtained in the step described in sub-section 4.1.

Figure 2, 3 and 4 shows the fuzzy pertinence function of each research area (FFP, CSC and IPS). The universe of discourse is the numeric value of the grade (from 0.0 to 1.0) in one of the three areas discussed in this article.

It is important to notice that each area has different pertinence functions. This difference is related to the contribution level of each area for the students'. For example, a student who has a good knowledge in FOUNDATION industrial Fieldbus™ concepts (FFP) and an average knowledge in the industrial area plant simulation (IPS) than other student with a little knowledge in FFP area and an excellent knowledge in IPS area. Comparing figure 2 with figure 4, it is evident that the pertinence function IN (Insufficient) of the FFP area has the universe of discourse from 0.0 to 0.6 whereas in the IPS area the same function has the universe of discourse from 0.0 to 0.3. This means that the minimum grade required to the student to be considered an Average student in the FFP area is bigger than the grade required to the same student to be considered an Average student in the IPS area. This occurs because the IPS area to the students' formation.

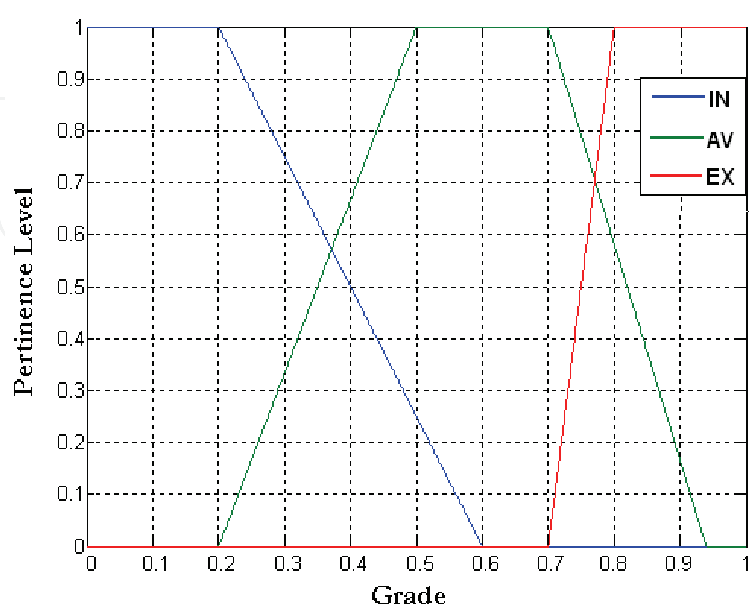

Fig. 2. Pertinence function for the student's final grades in a FFP area

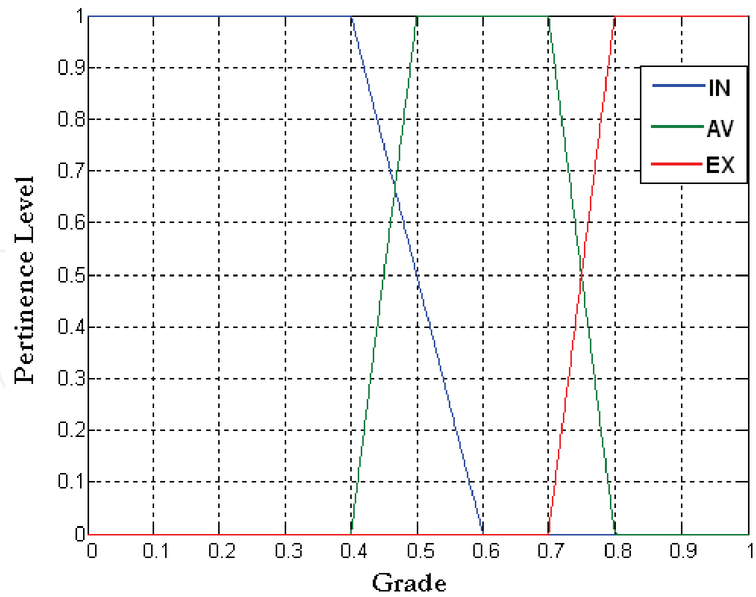

Fig. 3. Pertinence function for the student's final grades in a CSC area

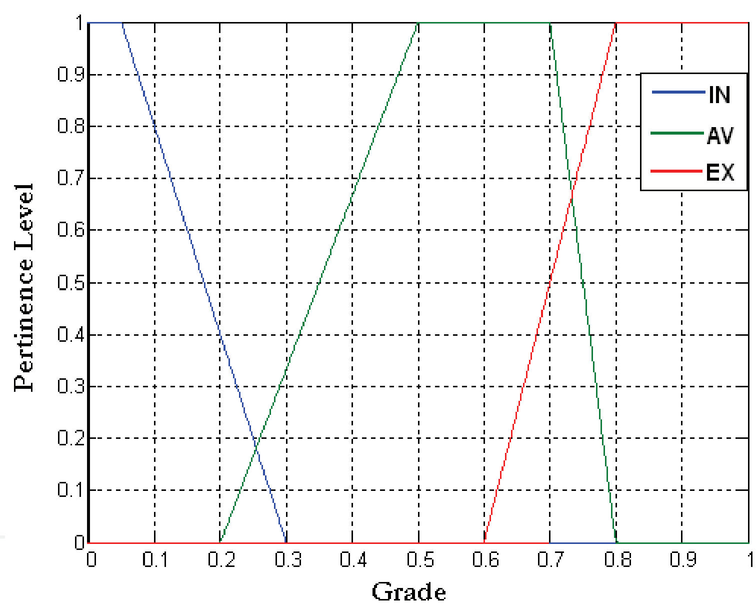

Fig. 4. Pertinence function for the student's final grades in an IPS area

Summarizing, it is very significant to analyse the importance of each area in the proposed methodology and depending on this importance level, the pertinence functions should be adjusted.

These figures also show that the output of this set will be the student's classification: Insufficient (IN), Average (AV) and Excellent (EX). Comparing the previous example where the student's grade in the area FFP is 0.36 to the pertinence function in Figure 2, the student's classification is AV with pertinence level 0.54 and IN with pertinence level 0.58.

This classification is calculated for the three evaluation areas. After obtaining the student's classification in the three areas, it is necessary to finalize the evaluation procedure and assign the general classification for the student. This step is described in the next sub-section.

4.3 Assigning the final classification to the student

The fuzzy system is used for the student's final classification. The inputs for this fuzzy system are the student's classification in each of the three areas (sub-section 4.2) and the output will be: Fail (FA), Pass with Many Restrictions (MR), Pass with Few Restrictions (FR) or Pass (PA). Figure 5 shows the pertinence function that represents this last set.
To determine whether the student will Fail (FA), Pass with Many Restrictions (MR), Pass with Few Restrictions (FR) or Pass (PA), it is necessary to find the rules active (Table 2) .

		IPS Classification		
		IN	**AV**	**EX**
Classification FFP/CSC	**IN/IN**	FA	MR	MR
	IN/AV	MR	FR	FR
	IN/EX	MR	FR	FR
	AV/IN	MR	FR	FR
	AV/AV	FR	FR	PA
	AV/EX	FR	PA	PA
	EX/IN	MR	FR	FR
	EX/AV	FR	PA	PA
	EX/EX	FR	PA	PA

Table 2. Summary of the fuzzy rules.

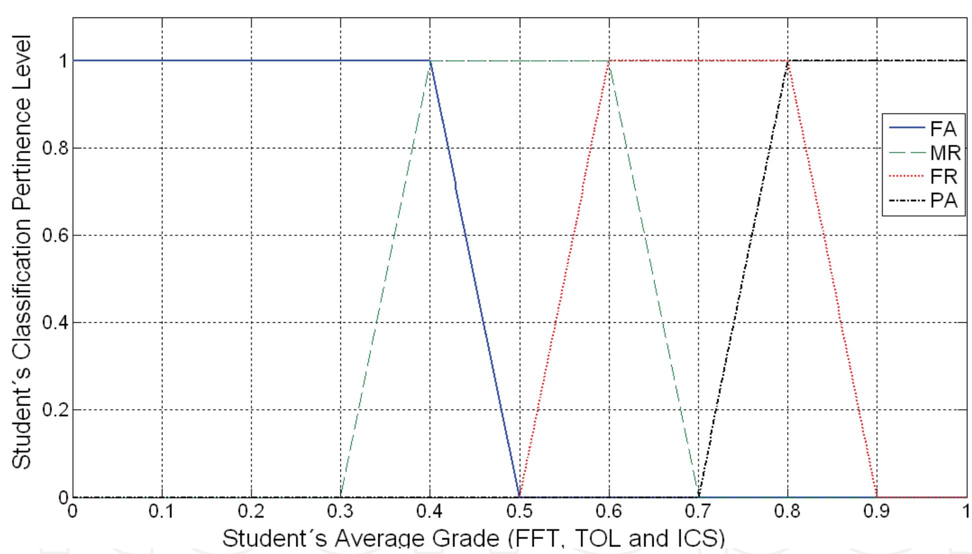

Fig. 5. Pertinence function for the student's general classification: Fail (FA), Pass with Many Restrictions (MR), Pass with Few Restrictions (FR) and Pass (PA).

The generalized *Modus-Ponens* inference process was used in the Fuzzy calculations, in addition to the *Max-Min* composition operator, the *Mandani* implication operator, and the *Maximum* operator for aggregation of the three fuzzy system inputs. The defuzzification of the output "final classification" used the *Center of Area* technique in this work because the resulting values were more appropriate when compared to the other evaluated techniques (*Mean of Maximum* and *First of Maximum*).
The goal of this system is providing a different way to classify the student. Instead of assigning a final grade and simply consider that the student was approved or not in the

evaluation, it is possible to create a report with specific information, whether the student is very good in FFP, insufficient in CSC and insufficient in IPS, for example.
The rules indicated in Table 2 are used for classifying the student. The fuzzy rules are similar to:

If (FFP is Insufficient) and (CSC is Insufficient) and (IPS is Excellent) then the student will Pass with Many Restrictions.

Consider the following example of an output from the evaluation system: "*The classification of the student Luis Carlos Silva is Pass with Few Restrictions, because he had an Average performance in FOUNDATION Fieldbus™ industrial protocol theory, an Insufficient performance in tuning and optimization of industrial process control loops, and an Excellent performance in identifying control strategies in industrial processes.*"

5. Results

The results were obtained from real questions used for evaluating the students at the EESC/USP. Three situations were considered:

- Student gets questions 1, 3, 5, 6 and 8 correct;
- Student gets questions 1, 4, 7, 8 and 9 correct;
- Student gets questions 2, 4 and 9 correct;

It is necessary to obtain the values PQn to apply Formula (1), where n is the number of the question (from 1 to 10).
Each of the following sub-items reports the results from the cases considered above.

5.1 First case (questions 1, 3, 5, 6 and 8)

Considering that the questions 1, 3, 5, 6 and 8 are correct and applying Formula (1), the value for V1, V3, V5, V6 and V8 is 1, and the value for the other questions is 0.
Therefore, using the values shown in Table 1 as a reference, we have:

- Grade in area FFP: 0.69;
- Grade in area CSC: 0.67;
- Grade in area IPS: 0.43.

Having the values from FFP, CSC and IPS, we define the first part of the student's classification: the student is Average in FFP, CSC and IPS areas.
Using the COA method, the CRISP value is obtained. Then, the final classification is applied and the student's classification is "Pass with Few Restrictions."
Bringing together the classification by area and the general classification, the current student's classification will be: "*Pass with Few Restrictions" because the performance was Average in FOUNDATION Fieldbus™ industrial protocol theory, Average in tuning and optimization of industrial process control loops, and Average in identifying control strategies in industrial processes*.
If the traditional analysis methodology were used, the student's grade would be 5 and this student would be approved in the course, with no information regarding in which area this student has a higher or lower potential. As mentioned previously in this article, a student whose grade is 5, being evaluated in the traditional method and with no knowledge in FFP, might be hired by a company instead of another student whose grade is also 5 but with a better performance in the area FFP. Using fuzzy, it is possible to identify the student's potentialities and apply a fair evaluation process.

5.2 Second case (questions 2, 3, 4, 7, and 8)

Considering that the questions 2, 3, 4, 7, and 8 are correct and applying Formula (1), the value for V2, V3, V4, V7 and V8 is 1, and the value for the other questions 0.
Therefore, using the values shown in Table 1 as a reference, we have:

- Grade in area FFP: 0.32;
- Grade in area CSC: 0.53;
- Grade in area IPS: 0.59.

Having the values from FFP, CSC and IPS, we define the first part of the student's final classification: the student is Insufficient in area FFP and Average in area CSC and IPS areas.
The fuzzy output area is obtained after executing the algorithms described previously.
Using the COA method, the CRISP value is obtained. Then, the final classification is applied and the student's classification is "Pass".
Linking the classification by area and the general classification, the current student's classification will be: *"Pass" because the performance was Insufficient in FOUNDATION Fieldbus™ industrial protocol theory, Average in tuning and optimization of industrial process control loops, and Average in identifying control strategies in industrial processes*.
Analyzing this result, we conclude that the student, who would be approved with the traditional evaluation method, is approved with one restriction because the performance in the area FFP was Insufficient.

5.3 Third case (questions 3, 7, 9 and 10)

Considering that the questions 3, 7, 9 and 10 are correct and applying Formula (1), the value for V3, V7, V9 and V10 is 1, and the value for the other questions is 0.
Therefore, using the values shown in Table 1 as a reference, we have:

- Grade in area FFP: 0.27;
- Grade in area CSC: 0.14;
- Grade in area IPS: 0.67.

Having the values from FFP, CSC and IPS, we define the first part of the student's final classification: the student is Insufficient in area FFP, Insufficient in area CSC, and Average in area IPS.
The resulting fuzzy area is obtained after executing the algorithms described previously.
Using the COA method, the CRISP value is obtained. Then, the final classification is applied and the student's classification is "Pass with Many Restrictions".
Bringing together the classification by area and the general classification, this student's classification will be: *"Pass with Many Restrictions" because the performance was Insufficient in FOUNDATION Fieldbus™ industrial protocol theory, Insufficient in tuning and optimization of industrial process control loops, and Average in identifying control strategies in industrial processes.*
In this case, the student would not be approved in the traditional method. Using the fuzzy system described in this article, the student's classification was "Pass with Many Restrictions." The student would receive a report from the course and it would be recommended for this student to take a new learning stage based on the indicated deficiencies.

6. Conclusion

The evaluation system implemented in this work does not aim to disapprove the students but to orientate them during the complete learning process, indicating potentialities and deficiencies.

This method essentially analyzes the student in all aspects. Another important fact in this method is that the qualitative aspects predominate over the quantitative aspects.

A student who was not approved in the traditional method may be approved in the fuzzy method but oriented to take extra classes in specific areas of deficiency, as well as be stimulated in areas where the student has greater knowledge and capabilities. Conversely, if the student was not approved in the diffuse method (fuzzy) because of a great deficiency on the three areas of knowledge, he or she will not be approved in the traditional method either.

It is important to remember that this work can be explored to expand the rules and incorporate other inputs and outputs to the evaluation. Besides, the same methodology can be applied in different areas, others than the control area.

Many times in the traditional evaluation process, teachers use the grade as a repressing mechanism, in an authoritative manner, causing the student to be concerned about calculating the grade instead of learning. With a more detailed analysis, the student's focus may change, increasing the learning curve in the desired areas.

7. References

Mossin, E. A., Passarini, L .C., Brandão, D. (2007). Networked control systems distance learning: state of art, tendencies and a new fieldbus remote laboratory proposal. 2007 IEEE International Symposium on Industrial Electronics. Vigo, Spain.

Rosa, A., Gariba, M. J., Casagrande, J. B., Santos, C. S., Schneider, M. C. K., (1999). Superando a avaliação da aprendizagem tradicional, através da lógica de conjuntos fuzzy. Revista Scripta, Florianópolis, n. 2, p. 37-47, 1999.

Chen, M. S., Lee, C. H., (1999). New methods for students' evaluation using fuzzy. Fuzzy Sets and Systems, Ed. Elsevier North-Holland, Inc., Amsterdam. V104, issue. 2, p. 209-218, 1999.

Cheng, C. H., & Yang, K. L. (1998). Using fuzzy sets in education grading system. Journal of Chinese Fuzzy Systems Association, 4(2), 81–89.

Bai, S. M., & Chen, S. M. (2006). Automatically constructing grade membership functions for students' evaluation for fuzzy grading systems. In Proceedings of the 2006 world automation congress, Budapest, Hungary.

Chang, D. F., & Sun, C. M. (1993). Fuzzy assessment of learning performance of junior high school students. In Proceedings of the 1993 first national symposium on fuzzy theory and applications, Hsinchu, Taiwan, Republic of China (pp. 1-10).

Chiang, T. T., & Lin, C. M. (1994). Application of fuzzy theory to teaching assessment. In Proceedings of the 1994 second national conference on fuzzy theory and applications, Taipei, Taiwan, Republic of China (pp. 92–97).

Law, C. K. (1996). Using fuzzy numbers in education grading system. Fuzzy Sets and Systems, 83(3), 311–323.

Weon, S., & Kim, J. (2001). Learning achievement evaluation strategy using fuzzy membership function. In Proceedings of the 31st ASEE/IEEE frontiers in education conference, Reno, NV (Vol. 1, pp. 19–24).

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While several books are available today that address the mathematical and philosophical foundations of fuzzy logic, none, unfortunately, provides the practicing knowledge engineer, system analyst, and project manager with specific, practical information about fuzzy system modeling. Those few books that include applications and case studies concentrate almost exclusively on engineering problems: pendulum balancing, truck backeruppers, cement kilns, antilock braking systems, image pattern recognition, and digital signal processing. Yet the application of fuzzy logic to engineering problems represents only a fraction of its real potential. As a method of encoding and using human knowledge in a form that is very close to the way experts think about difficult, complex problems, fuzzy systems provide the facilities necessary to break through the computational bottlenecks associated with traditional decision support and expert systems. Additionally, fuzzy systems provide a rich and robust method of building systems that include multiple conflicting, cooperating, and collaborating experts (a capability that generally eludes not only symbolic expert system users but analysts who have turned to such related technologies as neural networks and genetic algorithms). Yet the application of fuzzy logic in the areas of decision support, medical systems, database analysis and mining has been largely ignored by both the commercial vendors of decision support products and the knowledge engineers who use them.

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