APPLICATION OF FUZZY INFERENCE SYSTEM (FIS) TO CRITERION-REFERENCED ASSESSMENT WITH A CASE STUDY

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ABSTRACT

In this paper, the use of fuzzy inference system in criterion-referenced assessment was investigated. The aim of criterion-referenced assessment (CRA) was to report student achievement with reference to their objective reference points. To ease the assessment as in common practice, scores were given to each item or task. In this paper, we focus on CRA that utilizes rubric. Rubric is an essential scoring tool for subjectivity assessment. Scores on different assessments tasks are added together and then projected or aggregated, usually linearly. Component score maybe weighted before being added to reflect their relative importance of each task. With regards to Fuzzy Inference System (FIS), it can be viewed as a method where a multiple-input model can be constructed in an easy manner, via a set of fuzzy rule base. In this paper, we present a novel FIS-based CRA model that provides an aggregated score as a measure of overall achievement where subjectivity is involved. Our proposed model allows relationship between the aggregated score and to score given to each single task or item to be modelled in an easy manner. It can be viewed as an alternative method how the score given to each single task or item can be aggregated, and an aggregated score is produced. The use of our model is investigated with a real case study relating student project assessment.

KEYWORDS

Criterion-referenced assessment, Fuzzy rule base model, Case study

INTRODUCTION

In this article, assessment is defined as the process of forming judgement about quality and extent of students' achievement or performance, and therefore by inference that a judgement about a learning has taken place. Judgement is formed usually based on information obtained by requiring students to attempt specified tasks and submit their work for an appraisal of its quality. The term scoring refers to the process of representing students' achievement by numbers or symbols.

However, from literature, it has been pointed out that scoring usually refers to items and tasks rather than to overall achievement Sadler (2005) and Joughin (2008). To ease the assessment as in common practice, score is given to each item or task. As pointed out in Sadler (2005), scores on different assessments tasks are added together and then projected, usually in a linearly. Or score maybe weighted before being added to reflect their relative importance of each task.

With regard to criterion-referenced assessment (CRA), ideally, students' grade should be determined by comparing their achievements with a set of clearly stated criteria for learning outcomes and standards for particular levels of performance. The aim of CRA is to report students' achievement to their objective reference points. It can be a simple pass-fail grading schema, a series of key criteria rather than as a single grade or percentage (Sadler, 2005; Burton, 2007). There is a possibility for all students within a particular group to get very high or very low grades depending on the individuals' performances against the established criteria and standards.

Fuzzy Inference System (FIS) can be viewed as a method where a multiple-input model can be constructed in an easy manner (Jang et al., 1997; Lin and Lee, 1995). FIS has demonstrated its ability in a variety of problem domains, e.g., control, modelling, and classification problems. One of the key factors of its success is the ability to incorporate human/expert knowledge where information is described by vague and imprecise statements. Besides, the behaviour of an FIS is also expressed in a language that is easily interpreted by humans.

The use of fuzzy set related techniques in education assessment model is not new. Biswas (1995) presented a fuzzy set related method to evaluate students' answer scripts. This work was then further enhanced by Chen and Lee (1999). Next, Ma and Zhou (2000) presented a fuzzy set related method to assess student-centred learning whereas Cin and Baba (2008) presented the use of FIS in English proficiency assessment.

In this paper, we presented a novel FIS-based CRA model that utilizes rubric as scoring tool where subjectivity is involved. FIS is used as an alternative to simple addition or weighted addition for several reasons. (1) Criteria in rubric maybe qualitative rather than quantitative. For example, score of 4 in a rubric does not mean two times better than score of 2. (2) Various combination of the scores associated to each task may generate the same aggregated score, but the performance of the students may be different. (3) Relative importance of each task may be different, depend on the learning outcome. FIS can be used as an alternative approach to model or to customize the relationship between the score of each task and aggregated score.

The idea of replacing simple addition or weighted addition with more complicated algorithm is not new (Sadler, 2005). Sadler (2005) pointed out that aggregation of scores may be done by some designed algorithm. The proposed FIS-based CRA can be viewed as an alternative method to perform the aggregation process.

In this paper, we investigated the use of our FIS-based CRA model with a case study. Our developed model allows student's project to be assessed.

THE PROPOSED FUZZY INFERENCE SYSTEM BASED CRITERION ASSESSMENT MODEL

Figure 1 depicts our proposed FIS-based CRA procedure. The procedure is linked with the definitions of learning objective and learning outcomes. From the definitions, test items or tasks are designed. To ease explanation, we explained our procedure with a case study on students' laboratory project assessment.

From the defined test items or tasks, assessment criteria are further defined. In this paper, students' projects were assessed based on three tasks, i.e., electronic circuitry design, electronic circuitry development, and presentation. Tables 1, 2 and 3 demonstrated the scoring rubrics used for the three tasks respectively (Mertler, 2001). Note that holistic rubric was used. In this paper, criteria associated to each task were represented as a fuzzy membership function.

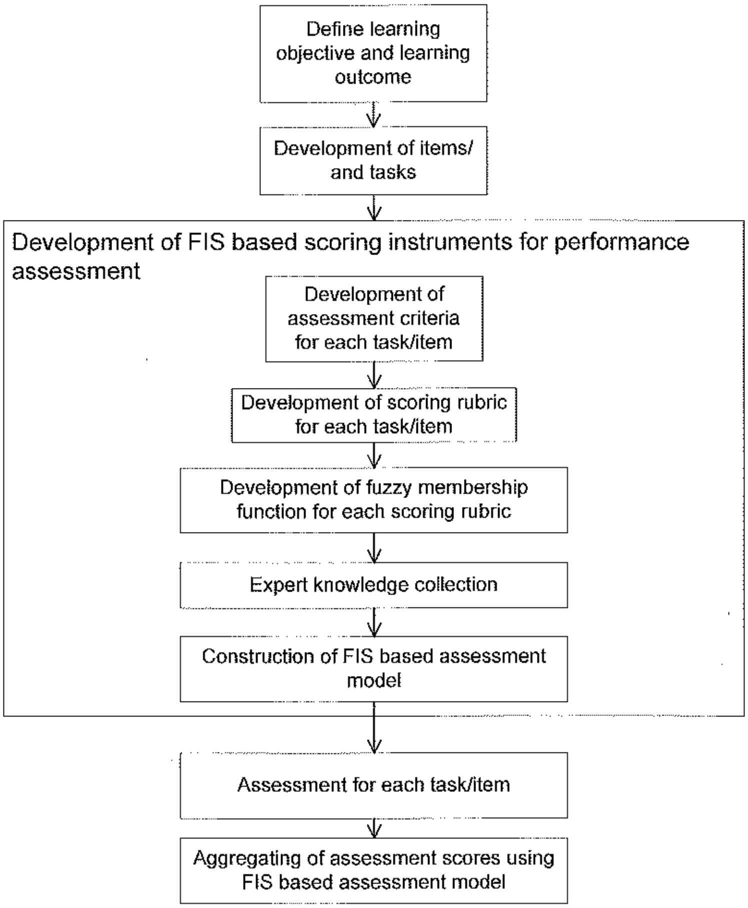

Figure 1. Criterion-referenced assessment procedure using fuzzy inference system (FIS)

Table 1. Scoring Rubric for electronic circuitry design

Score	Linguistic Terms	Criteria
10	Excellent	The circuit is complex (≥ 10 necessary ICs). Able to apply knowledge in circuit design. Able to simulate and clearly explain the operation of designed circuit.
9~8	Very good	The circuit is moderate (7~9 necessary ICs). Able to apply most of the learned knowledge. Able to simulate and clearly explain the operation of the circuit.
7~6	Good	The circuit is moderate (5~6 necessary ICs). Some unnecessary components are included. Able to apply most of the learned knowledge. Able to simulate the circuit and briefly explain circuit operation.
5~3	Satisfactory	The circuit is simple (3~4 necessary ICs). Some unnecessary components are included. Apply moderate of the learned knowledge. Simulate only parts of circuit and briefly explain the circuit operation.
2~1	Unsatisfactory	The circuit is simple (1~2 necessary ICs). Some components are not included and unnecessary components are added. Only apply some of the learned knowledge. Unable to simulate and explain the operation of designed circuit.

Table 2. Scoring Rubric for electronic circuitry development

Score	Linguistic Terms	Criteria
10~9	Excellent	PCB: Demonstrated excellent soldering technique (No cold solder joints, no bridge joints and all components leads were soldered to the pad). Circuit fully operated as expected. Project board: All components, jumpers and cables are well-arranged and tidy. Circuit fully operated as expected.
8~7	Very good	PCB: Demonstrated good soldering technique (Some cold solder and bridge joints, some components leads were not soldered to the pad). Circuit operated as expected. Project board: Most components, jumpers and cables are not so tidy. Circuit operated as expected.
6~5	Good	PCB: Demonstrated good solder technique. (Some cold solder and bridge joints, some components lead were not soldered to the pad). A part of circuit is malfunctioning. Project board: The components are well-arranged but jumpers and cables are messy. Part of the circuit is malfunctioning.
4~3	Satisfactory	PCB: Demonstrated poor solder technique (Many cold solder and bridge joints and many components leads were not soldered to the pad). Major part of the circuit is malfunctioning. Project board: The arrangement of components, jumpers and cables are messy. Major part of the circuit is malfunctioning.
2~1	Unsatisfactory	PCB: Demonstrated poor soldering technique. (Many cold solder and bridge joints and many components leads were not soldered to the pad). The circuit totally not functions. Project board: The arrangement of components, jumpers and cables are very messy. The circuit totally not functions.

Table 3. Scoring Rubric for project presentation

Score	Linguistic Terms	Criteria
10	Excellent	Information is presented in logical and interesting sequence. Full knowledge is demonstrated by answering questions with explanations and elaborations. Graphics explained and reinforced screen text and presentation. Used clear voice and correct, precise pronunciation of terms.
9~8	Very good	Information is presented in logical sequence. Eased with expected answers to all questions, but fails to elaborate. Graphics relate to text and presentation. Voice is clear. Pronounced most words correctly. Most audience members can hear presentation.
7~6	Good	Information is presented in logical sequence. Answers all simple questions, but fails to elaborate. Graphics relate to text and presentation. Voice is low; audience members have difficulty hearing presentation. Pronounced most words correctly.
5~3	Satisfactory	Jump around, difficult to follow presentation. Uncomfortable with information and is able to answer only simple questions. Used graphics that rarely support text and presentation. Voice is low. Pronounces terms incorrectly.
2~1	Unsatisfactory	Presentation cannot be understood because there is no sequence of information. Do not have grasp of information, cannot answer questions about subject. Used superfluous graphics or no graphics. Speak unclear, incorrectly pronounces terms, and speaks too quietly for audience in the back of class to hear.

Figures 2, 3 and 4 depict a plot of fuzzy membership function for electronic circuitry design electronic circuitry development, and presentation. For example, score 8 to 9 in electronic circuitry design refers to criteria *"The circuit is moderate (7~9 necessary ICs). Able to apply most of the learned knowledge. Able to simulate and clearly explain the operation of the circuit."* It can be represented as a membership function with label *"very good"* in Figure 2.

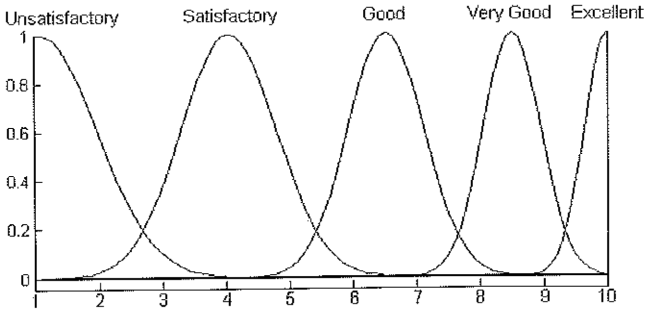

Figure 2. Membership functions for electronic circuitry design

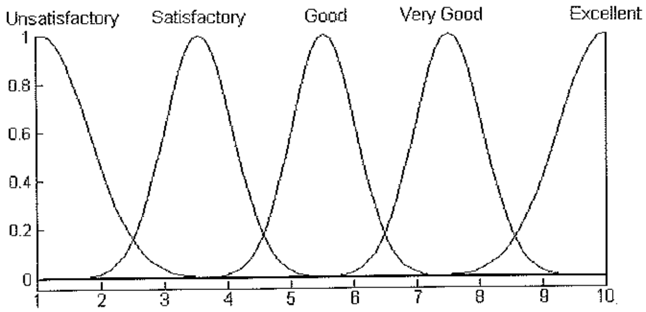

Figure 3. Membership functions for electronic circuitry development

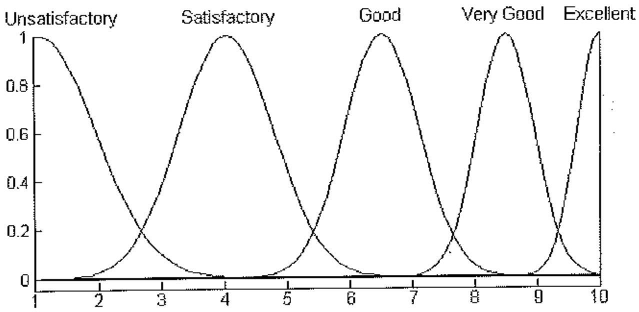

Figure 4. Membership functions for presentation

With a FIS, relationship between the three tasks and the aggregated score could be represented with a set of If-Then rules. The aggregated score; varied from 1 to 100, was represented by seven fuzzy membership functions, i.e., "Excellent", "Very good", "Good", "Fair", "Weak", "Very weak" and "Unsatisfactory", respectively. There was a total of 125 (5 (System design) × 5 (System building) × 5 (Presentation)) rules. For example, Rule 1, and Rule 2 showed a part of the rules collected.

Rule 1

If System Design is **Good** and System Building is **Good** and presentation is **Unsatisfactory** then Total Score is **Weak**

Rule 2

If System Design is **Very good** and System Building is **Very good** and presentation is **Good** then Total Score is **Good**

CASE STUDY AND EXPERIMENTAL RESULTS

An experiment was conducted to evaluate the proposed FIS-based CRA model, with a case study involving second year university students' laboratory projects. For the project, students were required to use their creativity and technical skills to design and develop a digital electronic system based on the knowledge gained through the digital electronic and digital system applications subject.

Table 5 summarized the scores for each task and the aggregated score. Column "*N*" showed the label of each student's project. In columns for "ECD" (*Electronic Circuitry Design*), "ECB" (*Electronic Circuitry development*) and "PR" (Presentation), score for each activity was presented. The "Fuzzy score" column showed the total score of the lab project obtained using the FIS based assessment method. The "Expert's knowledge" column showed the linguistic term associated to each project.

Table 5. Calculated total scores using conventional method and FIS based assessment method for student's lab project

N	**Inputs score**			**FIS based assessment model**	
	ECD	ECB	PR	Fuzzy score (%)	Expert's knowledge Linguistic term
1	4	4	6	39.58	Weak
2	5	4	6	40.08	Weak
3	5	4	7	40.50	Weak
4	7	4	6	41.26	Weak
5	5	5	7	42.51	Weak
6	5	7	7	49.61	Fair
7	6	8	5	50.05	Fair
8	7	6	7	50.20	Fair
9	7	7	6	51.30	Fair
10	8	6	6	52.49	Fair
11	7	7	8	63.57	Good
12	7	9	8	74.07	Very good
13	8	8	10	80.27	Very good
14	10	8	8	93.02	Excellent
15	10	9	8	93.64	Excellent

Figure 4 depicts one of the completed projects, from Student #15. This project was given score 10 for activity *"Electronic Circuitry Design"* because it consisted more than ten integrated circuits (ICs) and student was able to simulate and clearly explain the operation of designed system. The student was given a score of 9 for activity *"Electronic Circuitry development"* as the system worked well, and all electronic components were installed on the project board correctly. All the components, ICs and jumpers were well-arranged on the project board. The circuit was fully operated as expected. The student was also awarded with a score of 8 for *"presentation"*.

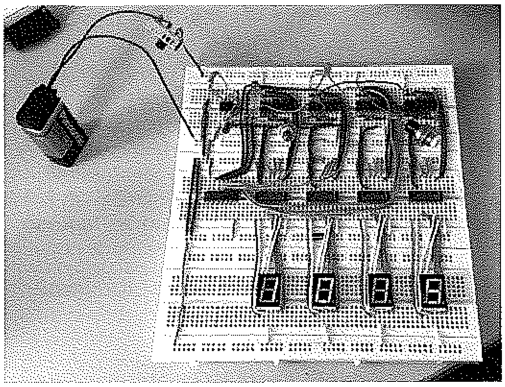

Figure 4. Digital system built by student #15

From our experiment, the FIS based education assessment model is able to aggregate a final score in accordance to expert knowledge.

Figure 5 depicts the surface plots for system design and system building versus total score at presentation score = 8, for FIS based assessment model. Figure 6 depicts the surface plots for system design and presentation versus total score at system building score = 6. From the surface plot, the non-linear relationship between the aggregated score and scores given to each tasks can be modelled.

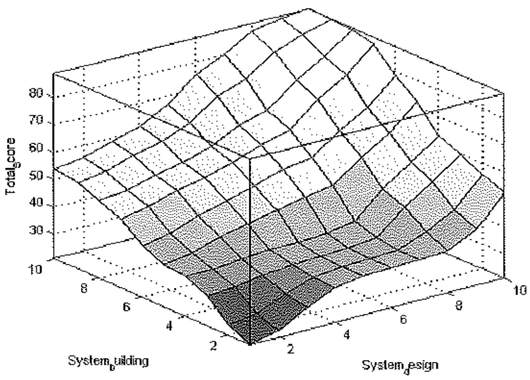

Figure 5. Surface plot of ECD and ECB vs total score at PR = 8

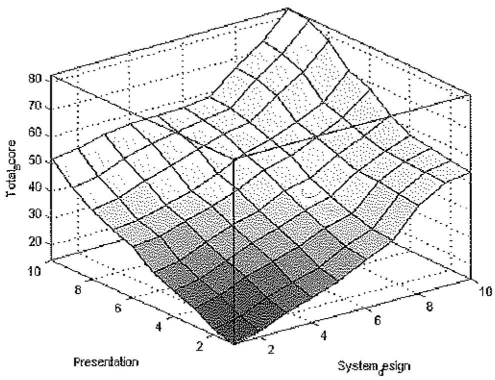

Figure 6. Surface plot of ECD and PR vs total score at ECB = 6

SUMMARY

A Fuzzy Inference System based criterion-referenced assessment model is presented and evaluated with case study. It could be viewed as an alternative method to aggregate the score from given task. Our experiment shows a promising result.

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