2006-1916: FUZZY RULES IN ASSESSING STUDENT LEARNING OUTCOMES

Faouzi Bouslama, Zayed University

Faouzi received a PhD in Electronics Engineering from Shizuoka University, Japan, in 1992. From 1992-1994, he was a researcher at Toshiba Co., Tokyo. From 1994-2000, he was Associate Professor of Information Systems, Hiroshima City University, Japan. He joined Zayed University, UAE, in August 2000. Currently, he is a Professor of Information Systems, Zayed University, UAE. His research interests include Neuro-fuzzy modeling and control, Signal processing, and IS curriculum design and development.

Azzedine Lansari, Zayed University

Azzedine received a PhD in Biomedical Engineering from North Carolina State University in 1992. From 1992-1998, he was a senior researcher at MANTECH, NC. He joined Zayed University in August 1998. Currently he is an assistant professor of Information systems. His research interests include systems modeling, educational technology and curriculum design in Information Systems. His teaching interests include instructional technology and statistical modeling.

Akram Al-Rawi, Zayed University

Akram is a Professor of CIS at Zayed University, UAE. He has worked at several academic institutions of which the last two were the University of Missouri-Columbia and Columbia College, MO. His teaching interests in-clude programming languages, logic design, and computer architecture. His research interests include computer simulation, web-caching architecture, and curriculum design. He holds certifications in A+, Network+, Sun Certi-fied Java Programmer, ICDL, i-Net+ and CCNA Intro.

Fuzzy Rules in Assessing Student Learning Outcomes

Abstract

In this paper, it is shown how fuzzy rules can be used as a modeling and evaluation tool for the achievement of the learning outcomes in information systems (IS) courses. In an outcome-based educational model (OBE), all courses in an IS college are required to clearly demonstrate the experiences that students can gain upon achieving a learning outcome. Consequently, master course syllabi describing the integration of the desired learning outcomes into IS courses are developed. The IS college provides a map between passing a given course and achieving a particular learning outcome at a certain level. Four different levels of achievements are identified: Beginning, Developmental, Achieved and Exemplary. Though, the map shows a clear relationship between courses and learning outcomes, it is not easy to define the boundaries between these four achievement levels or to combine all of the achievement results into one final assessment. In this case, the use of fuzzy logic is suitable to represent the complexities and vagueness in modeling the students learning outcomes achievements. Fuzzy membership functions are developed to model the achievement levels and define their overlaps and Fuzzy rules are generated to model the relationship between course grade (input) and the expected achievement level of learning outcomes (output). The aggregation of all learning outcome achievement levels for a sequence of courses that a student has to take provides an approximate indication of the experiences learned. Moreover, an overall analysis of all students' performances can identify the inherent strengths and weaknesses in the outcome-based educational model. Furthermore, theses results can be used by faculty members to assess the effectiveness of the integration of the learning outcomes into their courses.

1. Introduction

Academic institutions, when moving to an outcome-based education, try to ensure that all students acquire appropriate skills to be effective and productive in the workplace. At Zayed University (ZU), an all female laptop university in the United Arab Emirates (UAE), the education model is based on Learning Outcomes (LOs). The Outcomes-Based Education (OBE) model at ZU is framed by two different sets of LOs[1]. One set is course embedded, the MAjor Learning Outcomes (MALOs), and another one is a set of higher intellectual outcomes called the ZU Learning Outcomes (ZULOs). To fulfill their ZULO and MALOS requirements, students compile evidence of their achievement in electronic portfolios (ePortfolios), which are then later assessed by faculty members. The LOs are observable demonstrations of student learning that occur after a significant set of learning experiences. Typically, these demonstrations or performances reflect what students know, what they can actually do with what they know, and their confidence and motivation in demonstrating what they know.

Although the OBE[2,3] is a very promising approach which answers the needs for students to have skills that can make them competitive once they join the workforce, there are a number of issues that need to be carefully addressed for the OBE to be successful and to have efficient implementation. Issues such as the evaluation and the assessment of the student's work, the efficient selection of activities that lead to achieving a given LO, and the courses design are critical to the success of the approach. Any academic model needs to be constantly assessed and refined to best address those issues. For this purpose, an analysis tool can be devised to track and monitor the performance of the OBE model is needed.

In this paper, it is shown how fuzzy rules[4] can be used as an evaluation and assessment tool for the achievement of the learning outcomes in courses. In fact, all courses in a college are required to clearly show the experiences that students draw upon achieving an LO. For this purpose, a master course syllabus[5] is developed which addresses the integration of desired learning outcomes into particular courses. Moreover, four different levels of achievements, Beginning, Developmental, Achieved and Exemplary, are used to represent the expected achievement of each LO in each course. It is not easy to define the boundaries between these four levels or to combine all of the achievement results into one. Here, fuzzy membership functions are used to model the achievement levels and define their overlaps. Fuzzy rules showing the relationships between courses and their ZULOs and MALOs maps can be developed. The use of fuzzy logic in the inference process is suitable to represent the complexities and vagueness in modeling the students LOs achievements. The aggregation of the achievements in all the courses that a student has to take can give an approximate indication of the skills learned by each student. Moreover, an overall map of all students' performances identifies the strengths and weaknesses in the OBE model and can provide advice on how the student should use their remaining learning experiences to consolidate and improve their portfolios.

The rest of the paper is organized as follows: Section 2 introduces the outcomes-based education model at Zayed University and provides definitions of the high-level ZULOs and the major related MALOs. Section 3 shows the mapping of the ZULOs in major courses at the College of Information systems. Section 4 shows the fuzz membership functions and the fuzzy rules for the courses-LOs system and how the fuzzy logic is suitable to represent the complexities and vagueness in modeling the students learning outcomes achievements. Section 5 gives the aggregation of the achievements in all the courses that a student has to take and show how the fuzzy system can give an approximate indication of the skills learned by each student. Section 6 is the conclusion.

2. Review of outcomes-based education and learning outcomes

In academia, there is a belief that the traditional input educational system needs improvement to adequately prepare students for challenging life and work experiences. Consequently, academic institutions are modifying the way to measure the effectiveness of learning and education. There is an emphasis on outcomes-based education (OBE). OBE is a method of teaching that focuses on learning outcomes and what students can actually do after they are taught instead of traditional inputs such as course credits earned. Learning outcomes need to be clear, observable demonstrations of student learning that occur after a significant set of learning experiences. Learning outcomes are demonstrations that reflect what students know; what students can actually do with what they know; and the confidence and motivation of students in demonstrating what they know[6,7]. Hence, all curricular and teaching decisions in an OBE model are made based on how to facilitate the desired outcome. This leads to a planning process that is different from the traditional educational planning. The desired outcome is first identified and the curriculum is created to support the intended outcome.

2.1. ZULOs at Zayed University

Zayed University (ZU), an academic institution in the United Arab Emirates (UAE), adopted an OBE academic model. The university was established to ensure that female national students acquire quality education and skills required for success in modern information driven society. The academic program model at ZU was developed to address challenges that face a rapidly changing society such as the UAE. The ZU academic program model includes learning outcomes embedded at all levels of the curricula. ZU identified five learning outcomes which are essential to assure students' future success. They are:

- Critical Thinking and Reasoning (**CTR**): Graduates will be able to use information, reasoning, and creative processes to achieve goals and make responsible decisions.
- Global Awareness (**GA**): Graduates will be able to relate to communities beyond the local, perceive and react to differences from an informed and reasoned point of view, and be critically aware of implications and benefits of cultural interactions.
- Information Literacy and Communication (**ILC**): Students who graduate will be able to recognize information needs, access and evaluate appropriate information to answer those needs, and communicate effectively to a variety of audiences in English and Arabic.
- Information Technology (**IT**): Graduates will be able to use information technology to solve problems and communicate in an ethical way. They will also be critically aware of the impact of information technology on the individual and society.
- Teamwork and Leadership (**TL**): Graduates will be able to work efficiently and effectively in a group and will be able to assume leadership roles and responsibilities in a variety of life situations and accept accountability for the results.

Students must document accomplishments of these outcomes in their portfolios[5] in order to complete their degree programs. Moreover, each college at ZU identified a set of major-related learning outcomes (MALOs) and integrated those outcomes in all major courses. For example, the College of Information Systems (CIS) at ZU has established five major leaning outcomes which form the basis for curriculum analysis and student assessment. They are: Problem identification and analysis (**PIA**), Problem solving (**PS**), Internet technologies and applications (**ITA**), Systems principles and practices (**SYS**), and Technical communication (**TC**). The focus of this study will be on the assessment of the ZULOs in CIS courses. A similar assessment can be done for the MALOs.

2.2. CIS courses and learning outcomes

The College of Information Systems (CIS) at Zayed University seeks to produce graduates having current and comprehensive education in information systems (IS). The college coursework provides opportunities for students to develop competency and document achievement in the ZULOs. In fact, all CIS courses are required to clearly show the experiences that students draw upon achieving a learning outcome. For this purpose, a master course syllabus is developed which addresses the integration of desired learning outcomes into particular courses. Moreover, four different levels of achievements, Beginning (BEG), Developmental (DEV), Achieved (ACH) and Exemplary (EXM), are used to represent the expected achievement of each learning outcome in each course. Table 1 shows some selected CIS courses and the ZULOs achievement levels in those courses.

Table 1. Information systems courses and Learning Outcomes

Selected CIS Courses and Learning Outcomes					
ZU Learning Outcomes(ZULOs)					
	CTR	**GA**	**ILC**	**IT**	**TL**
Course #					
CIS 101			BEG	BEG	
CIS 215	BEG				
CIS 240	DEV				
CIS 304		BEG			
CIS 305		DEV	DEV		
CIS 320				DEV	
CIS 340				DEV	BEG
CIS 350				ACH	DEV

Note:

CTR= Critical Thinking and Reasoning
GA= Global Awareness
ILC= Information Literacy and Communication
IT= Information Technology
TL= Teamwork/Leadership

The achievement of the CIS students in the ZULOs is usually assessed through a current procedure which involves major advisors and course instructors[5]. Though it is relatively easy to assess an LO achievement in one particular CIS course, it is not easy to define the boundaries between these four levels or to combine all of the achievement results into one.

3. Assessment by fuzzy rules

In this section, it is shown how fuzzy rules[4] can be used as an evaluation and assessment tool for the achievement of the learning outcomes in courses. The use of fuzzy is suitable to represent the complexities and vagueness in modeling the students learning outcomes achievements. The inputs to the fuzzy inference engine are the selected CIS courses of Table 1 and the outputs are the five ZULOs. Figure 2 shows the block diagram of the fuzzy model. All simulations are conducted using the fuzzy logic toolbox in MATLAB software package.

Fig. 2. Fuzzy logic assessment system of the ZULOs

3.1. Fuzzification of CIS courses and ZULOs input-output spaces

The first step in implementing the fuzzy logic processor is to decide on the fuzzification of the input space consisting of all CIS courses. The input interval representing the achieved grade for each CIS course is represented by four linguistic variables[4] as shown in Figure 3. Grades in the interval [60, 100] are only used as there is no achievement of ZULOs in case a student fails a course which means a grade less than 60. Four trapezoidal and triangular membership functions D, C, B, and A are used for each course.

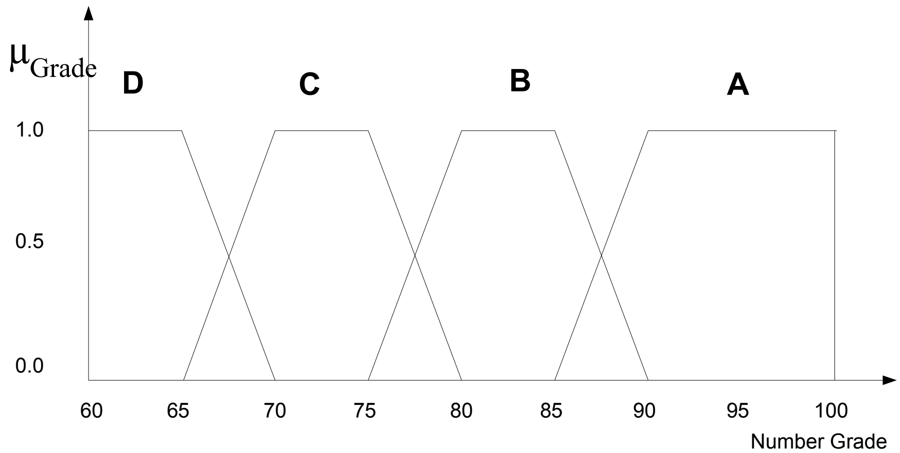

Fig. 3. Fuzzy membership functions for CIS courses inputs

Fuzzy membership functions are used to approximately model the expected four achievement levels of the ZULOs and define their overlaps as shown in Figure 4. The four achievement levels, which are Beginning (BEG), Developmental (DEV), Achieved (ACH), and Exemplary (EXM) for each ZULO, are categorical variables which are effectively represented by linguistic fuzzy variables.

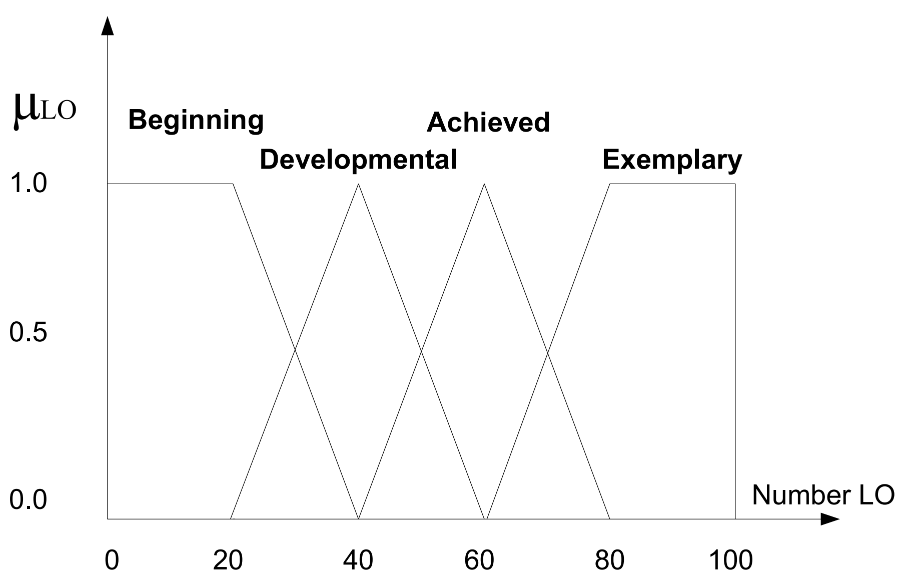

Fig. 4. Fuzzy membership functions for ZULOs outputs.

3.2. Generation of fuzzy rules

Fuzzy rules showing the relationships between courses and their learning outcomes maps are then developed. The fuzzy rules are based on the ZULOs integration of Table 1. The basic structure of the fuzzy rules is as follows:

> *If CIS101 is {C, D, B, or A} AND CIS215 is {C, D, B, or A} AND … then CTR is {BEG, DEV, ACH, or EXM} AND GA is {BEG, DEV, ACH, or EXM} AND …*

For simplicity, 20 fuzzy rules are used in the fuzzy rule base. Figure 5-a shows the generation of these fuzzy rules in the rule generator windows of the fuzzy logic toolbox. These rules, shown in more detail in Figure 5-b, are combined using the Mamdani Min-Max-Center of Gravity inference and defuzzification method[8]. All the contributions of each course to the achievements of the ZULOs are aggregated using the fuzzy inference engine.

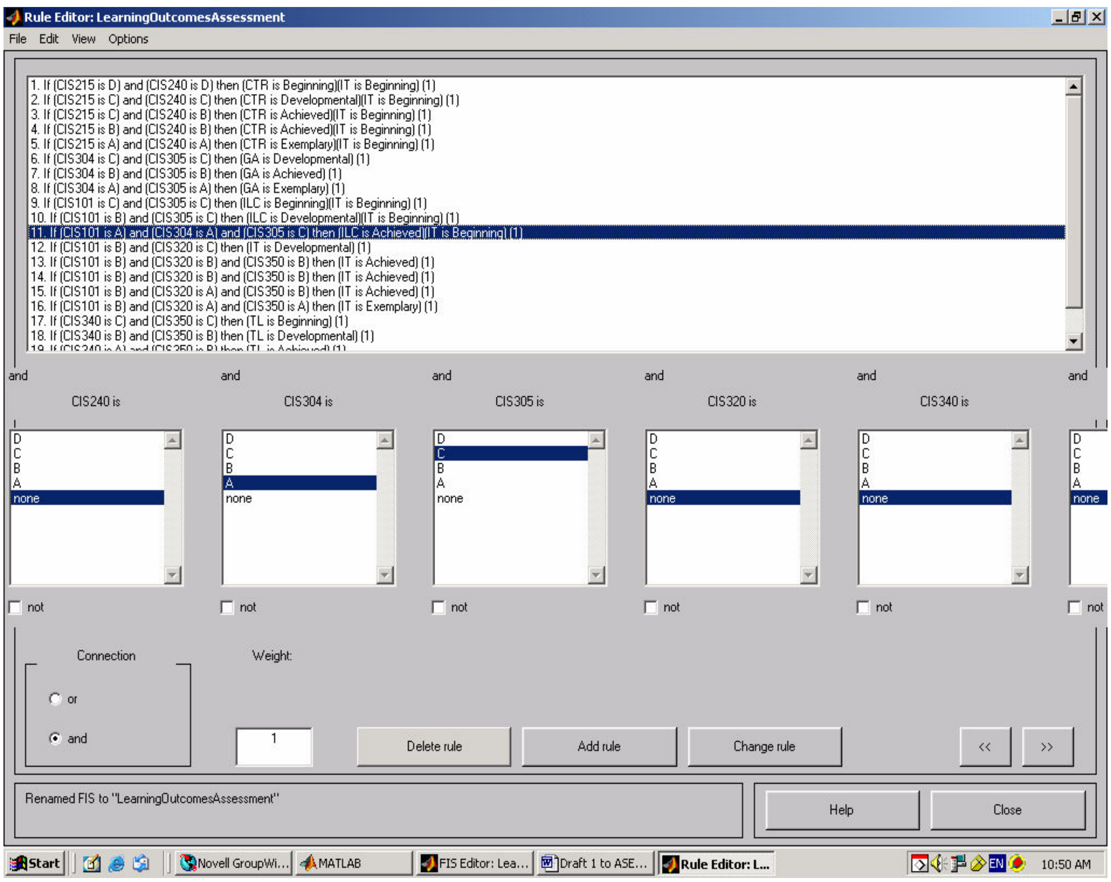

Fig. 5-a Fuzzy rule base generation screen.

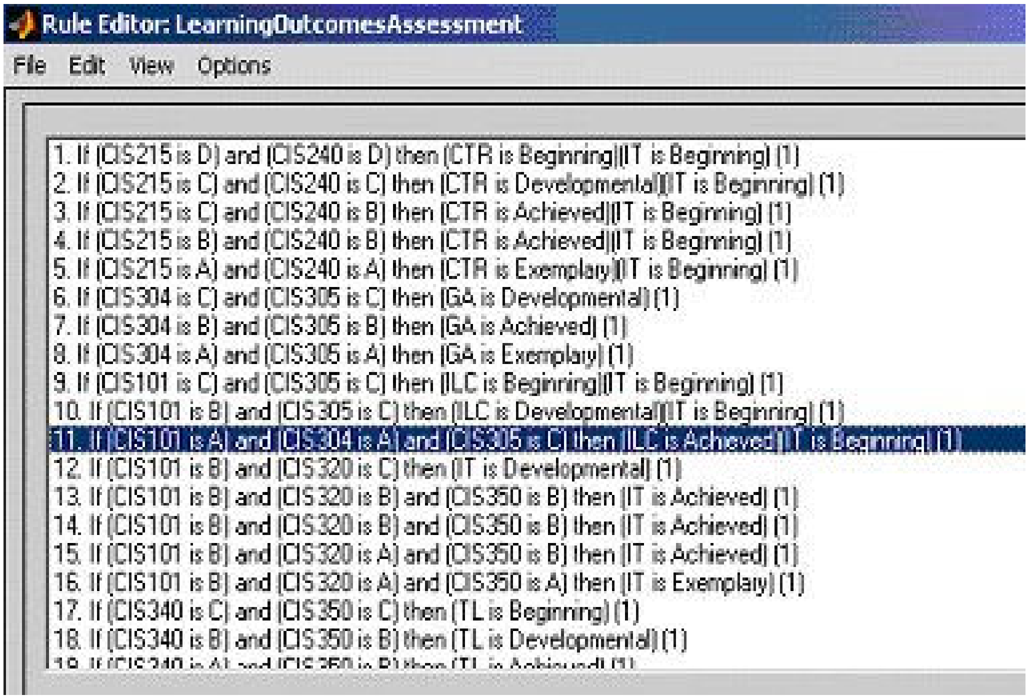

Fig. 5-b Fuzzy rules

3.3. Fuzzy inference using Min-Max-COG method

The aggregation of the achievements in all the courses that a student has to take can give an approximate indication of the skills learned by each student. Figures 6 shows an example of the assessment by fuzzy of the ZULOs achievements.

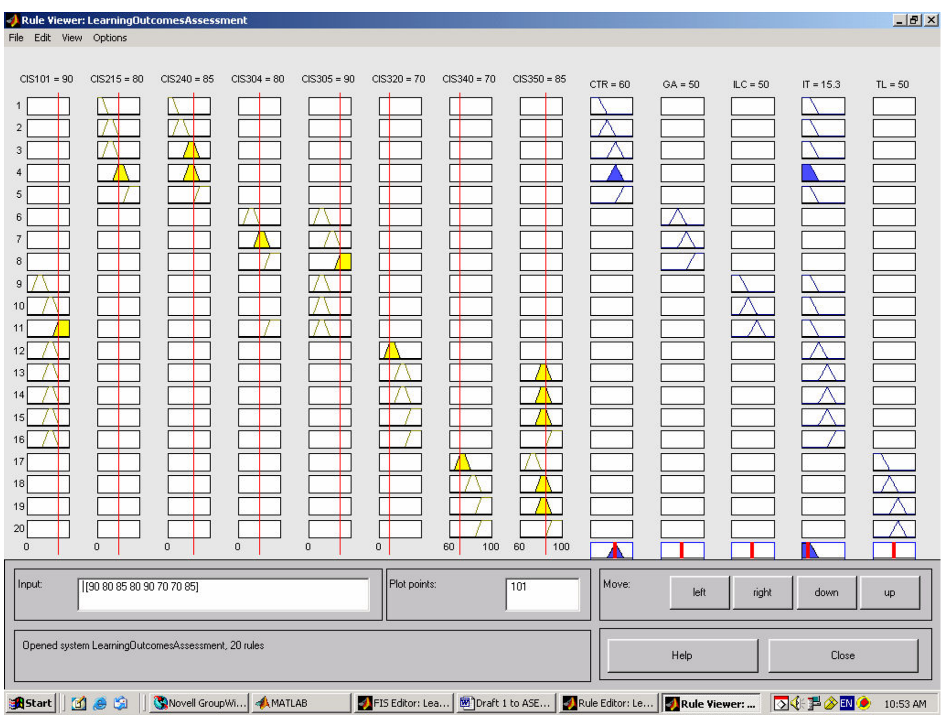

Fig. 6. Example of input grades and fuzzy outputs.

In Figure 6, the input vector grade is [90 80 85 80 90 70 70 85] represents the number grade achieve by a hypothetical above average student in the courses listed in Table 1. In this case, the student achieved: 90 in CIS 101 and CIS 305 resulting in the activation of rules 9 to 11 and subsequently, the generation of specific achievement levels for the Information Literacy and Communication ZULO. Likewise, the other inputs will activate other mapping rules leading to different achievement levels for other ZULOs. The fuzzy outputs in this example show an approximation of the overall level of achievements in the five ZULOs. Finally, a narrative report can be automatically generated and reviewed by faculty members before it is added to the final records of a student.

4. Conclusions

In this paper, it was shown how fuzzy rules can be used to model and evaluate the achievement of the learning outcomes in information systems courses. The membership functions were used to capture the complexities and vagueness in the inherent overlap between the level of achievements of learning outcomes. Fuzzy rules were generated to model the relationships between course grade and the expected achievement levels of learning outcomes. The aggregation of all learning outcome achievement levels for a sequence of courses taken by a student provided an approximate indication of the student's learning experiences. This approach can be used in analyzing the students' performances in achieving the desired learning outcomes. This model can also help faculty members and administrators identify the strengths and weaknesses of the outcome-based educational model.

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