Design of Individualizing Learning Framework with Fuzzy Expert System and Variable Learning Route Model: A Case Study of UML

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Abstract: - In this paper, we discuss how a fuzzy expert system is utilized in education. We present a conceptual framework for designing individualizing learning materials using a fuzzy expert system and a variable learning route model. The framework can help teachers to design their customized teaching materials for individual students based on the academic achievements of the students. In the framework, we first use pre-assessment to evaluate the students' academic achievements. The fuzzy expert system is then used to select suitable learning material for the students according to their academic achievements. The variable learning route model serves to determine the adaptive learning paths for the students based on the results of the fuzzy expert system. We introduce the concepts of the learning model with a simulative example. Unified Modeling Language (UML) is utilized in this paper to describe the structures and behaviors of the proposed framework. Discussion and concluding remarks are finally provided at the end of this paper.

Key-words: Fuzzy expert system, Variable route model, Individual learning, Adaptive learning, UML, OOAD, System analysis and design.

1. Introduction

Mark Twain mentioned that a tool in your hand is only a hammer but every thing in the world will be the nails". Similarly, if teacher has only one teaching method or one type of teaching material, the students in the classroom will be taught in the same way. The teacher is unable to use suitable teaching methods and customized teaching materials for individual students with different academic achievements. Two kinds of learning methodologies are utilized during conducting learning activities: passive methodology and active (or adaptive) methodology. In passive methodology, all learners are taught using the same series of learning materials. The advantage of the passive learning is simple and easy to design learning materials and to conduct learning activities. But it can not satisfy the special needs for individual students with different backgrounds and academic achievements. The adaptive learning improves the disadvantage of the passive learning by providing customized learning materials for individual students based on their special needs. Recently due to the rapid changes and developments in social structure, teachers face a situation that the students in a class are from culture backgrounds with different different academic achievements. If the teachers use a single teaching material to teach these divergent students, the learning performance for them will be significantly reduced. Adaptive learning with customized learning materials will be the solution to solve such problems. In adaptive learning, students are taught with the learning materials which are suitable for them. To do this we first need to assess the academic achievements and learning capabilities for individual students. The selections of learning for individual student are then based on the result of the assessment.

There are four main learning models in learning theory including simple linear model, refined linear model, branched model, and variable route models [1,2]. The proposed framework adopts the variable route model. The four learning models will be further explained later in Section 2.

In this paper, we present a conceptual framework for designing individualizing learning materials using a fuzzy expert system and a variable learning route model. The framework can help teachers to design their customized teaching materials for individual students based on the students' academic achievements. We also introduce the learning theories and explain how a fuzzy expert system is applied in adaptive learning with a simulative example. Unified Modeling Language (UML) is utilized in this paper to describe the structures and behaviors of the proposed framework. Discussion and concluding remarks are finally provided at the end of this paper.

2. Background

2.1 The theory of learning model

The learning models are very importance to learners and instructors. In the theory of learning models, four learning models are adopted during conducting learning activities including the simple linear model, the refined linear model, the branched model, and the variable learning route model [1,2]. We briefly describe them as follows [1,2]:

(1) Simple linear model: This model consists of a sequence of learning modules. Learners should follow the pre-defined learning sequence to conduct their learning activities, module after module. Learners are advised to master the learning material of the current module before the go to the next module.

(2) Refined linear model: The model basically extends the simple linear model by adding a series of optional units to enhance the learning performance.

(3) Branched model: The model contains two learning paths: core path and optional path. If a learner can not master the learning materials on the core path, he can use the optional path to get familiar with the learning objective designed for the modules on the core path.

(4) Variable route mode: The model is a network-structured learning map. It emphasizes that learning can master learning objective using different learning paths (or called alterative). It is not necessary for learners to following a single linear learning sequence. The diagram of the learning routes for the variable learning model is shown in Figure 1 [1,2] (displayed at the end of this paper for better article organization).

McKenzie defines six characters of the instructional scaffolding for curriculum design. They are indicated as follows [3,4]:

(1) Clear direction to reduce the learners' confusion;

(2) Clarifies purpose for the reason and importance of the learning.

(3) Keeping learning on the learning task, not wandering off of the path, which is the designated task;

(4) Clarifying expectations using assessment and feedback with showing excellent examples.

(5) Guiding learners with learning resource, providing them learning alternatives; reducing learners' confusion, frustration, and time.

(6) Providing multiple learning paths to decrease the learners' feelings of uncertainty, surprise, and disappointment.

The variable learning route model provides a

sufficient freedom of selecting learning materials. In addition, it fits the McKenzie six characters of the instructional scaffolding. In this study we use the variable learning model in our framework. This paper covers the issues of e-learning by using fuzzy expert system. Some other topics on the e-learning can be found in [5-7].

2.2 The Fuzzy Expert System

In 1965, Zadeh first presented the concept of fuzzy logic to solve the uncertainty problems. Basically fuzzy logic imitates verbal expression and thinking process of human beings. The fuzzy expert system technique is one of successful fuzzy logic applications used in solving real-world problems in many fields. It is based on fuzzy inference using fuzzy if-then rules. Traditional crisp sets use two values (0 and 1) to indicate the belonging relationship between an element and a set. There is no gradual transition from 0 to 1 (or from 1 to 0) in a crisp set. Fuzzy logic, on the other hand, uses membership functions to represent the gradual changes from 0 to 1 (or 1 to 0). In a membership function, matching degree (μ) is the measurement to represent how a particular element belongs to a fuzzy set.

Mainly, two types of membership functions are used in fuzzy logic: trapezoidal and triangular membership functions. The trapezoidal membership function is represented by four parameters: a, b, c and d, as shown in the following equations [8]:

$$trapezoid (x:a,b,c,d) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x < b \\ 1 & b \le x < c \\ (d-x)/(d-c) & c \le x < d \\ 0 & x \ge d \end{cases}$$
(1)

A triangular membership functions is the special case of a trapezoidal function where b is equal to c. Fig. 2 shows a triangular l membership function for a fuzzy set of "*The car speed is moderate*". In the figure, a = 50, b = 60, c = 60, and d = 70. The matching degree for the speed of 55 km/hour is 0.4. It is import to note that in a triangular member function it is not necessary for a triangular membership function to be horizontally symmetric.

Normally, a fuzzy expert system contains three parts: an inference engine, a rule base and user interfaces. The user interfaces allow users to define membership functions, compose fuzzy rules, enter inputs, and display outputs. The fuzzy rule base is a place to store the fuzzy rules. The inference engine generates fuzzy outputs from the fuzzy rules ignited by the inputs. A fuzzy rule includes two parts: an IF part (called antecedent) and a THEN part (called consequent or conclusion). The following example shows a fuzzy rule for controlling an air-conditioning system.

IF the temperate is high (antecedent part) *THEN* the cooling level is strong (consequent part).

The inference engine generates fuzzy conclusions. However, in real-word problems, we need to use crisp values to make decisions in expert systems or make some necessary adjustments in control system. The defuzzification process is then applied to get crisp values from the fuzzy conclusions.

There are two popular defuzzification methods, the Mean of Maximum (MOM) method and the Center of Area (COA) method [8]. In this study, we use COA defuzzification method to get crisp values from fuzzy conclusions. The computational details on the COA method will be described latter in this paper.

The procedure of building a fuzzy expert system is summarized as follows [8]:

1. Define problems and fuzzy expressions using membership functions.

2. Compose fuzzy rules.

3. Inputs crispy values and transfer them to fuzzy values (matching degree) using appropriate membership functions.

4. Conduct fuzzy inference and get fuzzy

5. (Optional) Employ defuzzification procedure, if necessary.

3. The proposed frame work

Figure 3 (displayed at the end of the paper) shows the conceptual diagram for the proposed framework. Intended learners are first given pre-assessments to evaluate the academic achievements. The assessment results are then fed to a fuzzy expert system to perform fuzzification process translating the assessment results to fuzzy variables by appreciate membership functions. Based on the fuzzy rules ignited by the fuzzy variables, the fuzzy inference conducts fuzzy conclusion. These conclusions are then mapped to a crisp output using a defuzzification process. The recommended learning materials are finally determined by the learning material selector constructed by the variable learning route model.

The pre-assessments serve to evaluate the academic achievements for different learning subjects. The

number of subjects determines the number of fuzzy input variables for the fuzzy expert system. We explain the procedure for implementing the proposed framework using a simple example with two subjects. The procedure is described as follows:

<u>Step 1:</u> Design two pre-assessments for the two subjects.

Step 2: Generate the membership functions for the assessment scores using fuzzy expressions. In this example, we define three fuzzy input variables: low, middle, high to represent the assessment scores. Figure 4 shows the three possible membership functions to represent the assessment results for subject 1 where m and δ represent the mean and the standard deviation of the assessment scores. Table1 lists computational details for the three membership functions.

Step 3: define the fuzzy output variables to express the difficulty of learning materials. In this example, five fuzzy output variables are used to represent the difficulty of the learning materials, as shown in Figure 5.

<u>Step 4:</u> Compose fuzzy rules

The fuzzy rules for the example are demonstrated in Table 2.

<u>Step 5:</u> Conduct fuzzy inference: Normally this step is done by a computer package.

3.4 Defuzzification

We use the COA defuzzification method to get the crisp values for the examples, given by the following formula [8]

$$y = \frac{\sum_{i=1}^{n} \mu_{i} x_{i}}{\sum_{i=1}^{n} \mu_{i}}$$
(2)

where y is the desired crisp value, x_i is the value of element *i*, μ_i is the matching degree for element *i*, and *n* is the number of elements in a fuzzy set. Normally, this step is also done by computer software.

<u>Step 5:</u> Determine the learning materials. In this example, we select the best learning material from nine learning materials for the learner. The nine learning materials are ranked by difficulty with a 100-point score form the easiest (0 point) to the most difficult (100 points). Normally this can be done by interviewing domain experts. Table 3 demonstrates the nine learning materials with difficulty ranges.

4. Simulation

Assume the statistics for two pre-assessments for the two subjects are as follows:

Subject 1: m = 10, and $\sigma = 10$,

Subject 2: m = 40, and $\sigma = 20$.

Consider a learner whose pre-assessment scores for the two subjects are 50 and 65, respectively. Figure 6 shows the fuzzy mapping from a crisp value 50 to its corresponding fuzzy variables for subject 1. Figure 7 demonstrates the fuzzy mapping from a crisp value 65 to its corresponding fuzzy variables for subject 2. The ignited fuzzy rules are showed in Table 4. The matching degrees of the ignited rules are shown as follows:

- R2 : Subject1 matching degree is 0.3333 Subject2 matching degree is 0.16667
- R3 : Subject1 matching degree is 0.3333 Subject2 matching degree is 0.8333
- R5 : Subject1 matching degree is 0.6667 Subject2 matching degree is 0.16667
- R6 : Subject1 matching degree is 0.6667

Subject2 matching degree is 0.8333

Results:

According to the defuzzification result, the difficult of the learning material suggested for the learner is 37.375. By Table 3, the recommended learning material is Material 4.

5. UML Analyses

We use three UML diagrams to explain the structures and behaviors of the proposed framework including use case, class and sequence diagrams. Figure 8 shows the use case diagram of the proposed framework. Three use cases are involved in the figure including: select learning materials, set the rules for choosing materials, and take exam and get leaning materials. Figure 9 demonstrates the class diagram. There are six classes in the figure: TeacherAgent, StudentAgent, CourseManager, FuzzyBean, FuzzyRule, and Membership. Table 5 gives the detailed explanations of the class diagram. Figures 10 to 12 demonstrate the three sequence diagrams associated with the three use cases shown in Figure 8.

6. Conclusion

We presented a conceptual framework for designing individualizing learning materials using a fuzzy expert system and a variable learning route model. The framework can help teachers to design their customized teaching materials for individual students based on the academic achievements of the students. In the framework, we first use pre-assessments to evaluate the students' academic achievements. The fuzzy expert system is then used to select suitable learning material for the students according to their academic achievements. The variable learning route model serves to determine the adaptive learning paths for the students based on the results of the fuzzy expert system. We presented a simulation to furthermore explain the proposed framework. Finally, we used UML to describe the structures and behaviors of the proposed framework.

As for the future studies, we suggest implementing the framework by case study on some courses. Besides, developing an integrated environment for selecting suitable learning materials might be good contribution in practice. This can be done by using programming languages such as java, C++, Delphi, etc.

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Fuzzy variable	Matching degree μ
Low	• $x < m-1.5\sigma, \mu = 1$ • $m-1.5\sigma < x < m, \mu = 3\sigma - m + x/1.5\sigma$ • $x > m, \mu = 0$
Middle	• $x < m-1.5\sigma, x > m + 1.5\sigma, \mu = 0$ • $m-1.5\sigma < x < m, \mu = (1.5\sigma - m + x) / 1.5\sigma$ • $m < x < m+1.5\sigma, \mu = 1.5\sigma + m - x/1.5\sigma$ • $x = m, \mu = 1$
High	• $x < m, \mu = 0$ • $x > m+1.5\sigma, \mu = 1$ • $m < x < m+1.5\sigma, \mu = (x-m) / 1.5\sigma$

Table 1: Computational details for Figure 4

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Table 2: Fuzzy rules

Rule No.	Inputs (assessment score)		Difficulty of learning materials
1	low	low	very low
2	low	middle	very low
3	low	high	low
4	middle	low	low
5	middle	middle	middle
6	middle	high	high
7	high	low	middle
8	high	middle	high
9	high	high	very high

	, 6
Learning material	Difficulty
1	0~11
2	12~22
3	23~33
4	34~44
5	45~55
6	56~66
7	67~77
8	78~88
9	89~100

Table 3: The nine learning materials

with difficulty ranges.

Table 4: Ignited fuzzy rules

Trigged rules	Subject1	Subject2	Expert's experiment
2	low	middle	very low
3	low	high	low
5	middle	middle	middle
6	middle	high	high







Fig. 2: The triangular membership function of "The car speed is moderate".



Recommended learning material for the learners

Figure 3: Conceptual diagram for the proposed framework.



Figure 7: Fuzzy mapping for Subject 2

40

10

70



Figure 8: The use case diagram.



Figure 9: The class diagram.

Class	Method	Description	
	setGrade	To set a fuzzified score	
	writeExam	To write an exam	
TagaharAgant	main	The starting point of the software package	
TeacherAgent	getScore	To get the score from the exam of a student	
	assignMaterial	To assign learning material for a student	
	getExam	To get an exam from teacher	
StudentAgent	takeExam	To take an exam	
	setMembership	To set a membership function for score	
	setFuzzyRule	To set the fuzzy rule for selecting the learning material	
FuggyDoon	getMembership	To send a membership function to CourseManager	
FuzzyDean	getFuzzyRule	To send the ignited rules to CourseManager	
	trigger	To ignite fuzzy rules	
	defuzzy	To get the crisp output of the student's score	
FuzzyDulo	getMinDegree	To get the minimum matching	
FuzzyKule	getIgnitedRule	To find the ignited rules	
Mambarshin	inference	To perform clipping	
wiembersnip	getDegree	To get the matching degree	

Table5: The detailed explanations of the class diagram (selected).







Figure 11: The sequence diagram of the case of "set the rules for choosing materials".



Figure 12: The sequence diagram of the case of "take exam and get leaning materials".