Fuzzy Approach of Learning Evaluation Model in Intelligent E-Learning Systems

Sung Hyun Weon[1)†]

Abstract

Recently, web-based E-learning systems have entered the spotlight by providing new learning environments that break down spatial and temporal limitations. The key to building the web-based E-learning system is in determining how to effectively use the system and to evaluate the degree of learning achieved by the students that use it. In traditional off-line learning systems, we can evaluate students by counting how many questions, designed to evaluate their learning achievement, he or she answers correctly within a predetermined time limit. But this method would make individualized learning, a strong point of E-learning systems, impossible because these systems provide same learning strategy to all students even though they achieve a different level of learning. Therefore, in this paper, I will find any relationships between given test answers using fuzzy implication theory, I call these fuzzy correlations, and then generate evaluation results that are reflected in those relationships. I will compare the differences between this evaluation method and a traditional evaluation method where a student takes a test to evaluate his or her learning achievement after some learning period. Finally, I will discuss how we can use these results in individualized learning.

Keywords : Fuzzy Correlation, E-Learning, Learning Evaluation, Fuzzy Implication

지능형 가상 학습 시스템에서 학습 평가 모델의 퍼지적 접근

원성현†

요 약

최근 공간적 시간적 제약을 초월하는 새로운 학습 환경으로 웹 기반 가상 학습 시스템이 각광을 받고 있다. 웹 기반 가상 학습 시스템 개발의 핵심은 어떻게 효과적으로 시스템을 사용하고 그 시스템을 사용한 학습자의 학습 성취도를 평가하도록 할 것인가를 결정하는 것이다. 전통적인 오프라인 학습 시스템에서는 학습자의 학습 성취도 평가를 위해 설계된 평가 문항을 학습자가 제한된 시간 내에 얼마나 많이 맞추었는지 헤아림으로써 학습자를 평가할 수 있다. 그러나 이 방법은 이들 시스템이 학습 성취도에서 차이를 보이는 모든 학습자에게 같은 학습 전략을 제공하기 때문에 가상 학습 시스템의 최대 강점이라고 할 수 있는 개별 학습을 불가능하게 한다. 따라서, 본 논문에서는 퍼지 함축 이론을 이용하여 주어진 테스트 문항에 대한 응답 간의 관계를 찾고 이 관계를 퍼지 공관계라고 부르기로 한다. 그리고 이 관계를 반영한 평가 결과를 생성한다. 일정한 학습이 경과된 후 학습자의 학습 성취도를 평가하기 위해 시험에 응시했을 때, 본 논문에서 제안하는 방법과 전통적인 평가 방법 간에 존재하는 차이점을 비교한다. 마지막으로, 이 연구 결과를 개별화 학습에 어떻게 활용할 것인지에 대해 논의한다.

키워드 : 퍼지 공관계, 가상 학습, 학습 평가, 퍼지 함축

1. Introduction

The rapid progress of information technologies has led to that technology being actively applied to all social fields. Through its effect on the field of education, the web-based E-learning system, a new educational environment, was developed. In web-based

† 종신회원: 부산가톨릭대학교 컴퓨터정보공학부 교수(교신저자)
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E-learning systems, teachers provide the digital learning materials, students learn over the Internet, and the system provides a user interface that presents a multimedia environment. These systems can evaluate students' learning achievement by various methods that general off-line learning systems can not [6, 8].

Computer aided instruction (CAI) using CD-ROM titles was used in learning environments before web-based E-learning systems became widely accepted. However, CAI using CD-ROM titles was not noticeably more efficient than traditional classroom centered learning environments because the teachers had to be physically close to the computer and student [4]. On the other hand, web-based E-learning systems have entered the spotlight by providing new learning environments that break down spatial and temporal limitations [2, 8].

The following are the four major components of CAI with CD-ROM titles as specified by G. Kearsley, the domain expertise module, the student model module, the tutoring module, and the interface module. All of these components have structured sub-functions. Among the sub-functions, the evaluation function in the domain expertise module has special importance because a proper evaluation is needed to set an appropriate student-centered strategy in fostering the best learning environment [4]. H. Huang argued that a web-based environment is equivalent to CAI [2]. M. Roccetti presented another 4 components of E-learning system, but they are not really different from Kearsley's 4 components [9].

The key to building a web-based E-learning system is determining how to effectively use the system to evaluate the degree of learning achieved by the students that use it. In traditional off-line learning systems, we can evaluate students by counting how many questions, designed to evaluate their learning achievement, he or she answers correctly within a predetermined time limit. But this method would make individualized learning, a strong point of E-learning systems, impossible because these systems provide same learning strategy to all students even though they achieve a different level of learning. Therefore, in this paper, I will find any relationships between given test answers using fuzzy implication theory. I call these fuzzy correlations, and then generate evaluation results that are reflected in those relationships. I will compare the differences between this evaluation method and a traditional evaluation method where a student takes a test to evaluate his or her learning achievement after some learning period. Finally, I will discuss how we can use these results in individualized learning.

2. Previous Studies

2.1 E-Learning Systems

There has been much research on E-learning systems in the field of education.

A. Davidovic presented SEATS, a structural example-based adaptive tutoring system. He insisted that their system can produce an effect on the rate and extent of learning that is significantly greater than when the features are used alone or when both are absent [1]. M. Khalifa compared two different types of web learning environments: distributed passive learning (DPL) environments and distributed interactive learning (DIL) environments. In his research, he found that the DIL environment was superior to the DPL environment in terms of both the learning process and the learning outcome [5]. H. Huang designed a learning environment for electronic instruments and developed it using the Java language. The system is used to teach students how to use oscilloscopes, function generators, and logic analyzers. He argued that this system could very effectively be used for distance learning [2]. G. Hwang suggested a test sheet generating algorithm in his paper. He formulated a multiple criteria test-sheet-generating problem and then proposed a dynamic programming approach to cope with the problem [3]. It is clear that there has been a focus on web-based cyber learning systems. Teachers and students are currently using such systems over the Internet to both teach and learn. In these systems, the most important research issue is how to evaluate the learning achievement of students. In my opinion, there are several kinds of evaluations: diagnostic tests, quiz tests, chapter tests, and final tests. A diagnostic test is a test that evaluates the student's present status before learning, a quiz test is a test that evaluates the students' learning status on learning process, a chapter test is a test that evaluates the student's present status after finishing a chapter, and a final test is a test that evaluate the status of students after finishing all the steps of a scheduled course.

Most research on web-based E-learning systems have attached importance to system development. In line with that focus, the central controversy is how can make the digital learning contents or can connect teachers and students conveniently, etc. But the most important difference between E-learning systems and traditional learning environments or CD-ROM title based CAI is how to evaluate students intelligently. Unfortunately, these has been little work concerning this matter [10].

2.2 Fuzzy Set Theory in Learning Systems

Fuzzy set theory is the mathematical theory proposed by L. A. Zadeh in 1965. It is widely used as a methodology that can handle vagueness. Fuzzy theory is good for modeling the activity of the human brain and for applying to ambiguous situations such as decision making, prediction, diagnosis, etc [11].

The key components of fuzzy theory are fuzzy membership functions, fuzzy membership grades and fuzzy implications. A fuzzy set is a set where all the elements of the set have real values in the range [0, 1] that correspond to their degree of belonging to the set. This is different from the traditional concept of a set where all elements of the set have value 1 as their degree of belonging to the set. Generally, a fuzzy set is expressed as a group of ordered pairs, where each pair has an element and a fuzzy membership grade. The degree of belonging to the set is the fuzzy membership grade. The fuzzy membership grade uses the notation μ and puts the element at the back of μ. The fuzzy membership function is the function that returns the fuzzy membership grade which is a value in the range [0, 1]. A fuzzy implication is the relationship between fuzzy set A and fuzzy set B. We express the fuzzy implication, a two dimensional matrix, as $A \rightarrow B$. There are various methods to get the value.

We can find the example of applying artificial intelligence as like fuzzy theory for evaluating learning achievement in Law's paper [7]. Law asserted the method that decides the evaluation grade by fuzzy number, but it required an excessively complex mathematic procedure. Also, it could not integrate the various fuzzy environments. Weon and his colleagues defined fuzzy membership functions for difficulty, complexity, and importance of made questions and they proposed the method that gets the results to them [10]. But this method could not apply the result of the previous step to the result of the next step.

If we apply fuzzy theory to the evaluation of learning achievement for students, we can get the fuzzy membership grade from the degree of correctness. Instead of getting whether or not a question was answered correctly, we want to get the degree of correctness, absolutely correct, almost correct, somewhat correct, and so forth. Also, we can get evaluation result of next test step reflecting previous step as fuzzy implication of the fuzzy set of result previous test step and next step. In case of quiz test, it is very important that reflect the result of learning contents previous step to next step because they have very tight relations, but, there is no research about this [10].

3. Learning Evaluation Model using Fuzzy Correlation

3.1 General Procedure of Evaluation

In the test procedure for evaluating learning achievement, there often are several kinds of evaluations, diagnostic tests, quiz tests, chapter tests, and final tests. A diagnostic test is a test that evaluates the student's present status before learning, a quiz test is a test that evaluates the students' learning status on learning process, a chapter test is a test that evaluates the student's present status after finishing a chapter, and a final test is a test that evaluates the status of students after finishing all the steps of a scheduled course.

A student who wants to study using the E-learning system first accesses the learning contents and studies them. The student then takes a quiz test and a chapter test at the appropriate times in the learning process. Then the system gathers the responses of the student and generates evaluation results. Also, the system analyzes the evaluation results and determines the next appropriate learning level for the student. Finally the system presents the next learning contents to the student. This process is repeated.

3.2 Basic Procedure

I assume that there are n chapters in one unit the student is to learn and the student must take a chapter test after covering a chapter. Then we can express the learning domain of each chapter as Eq. (1) where the total learning domain is T [10].

$T = \{T_1, T_2, \cdots, T_n\}$ ---------------- Eq.(1)
(where, T_i (i = 1, 2, , n) is the subset of total learning domain T)

I will evaluate to get the degree of learning achievement to total question domain T and each of its subset T_i.

Also, I assume that P, following group of questions for a chapter test, is made. P_1 is the set of first step questions for the chapter test when we consider P as total domain for evaluating. Therefore, a chapter test is completed to evaluate domain P through P_1 to P_n.

$P = \{P_1, P_2, \cdots, P_n\}$ ----------------- Eq.(2)
$P_1 = \{P_{11}, P_{12}, \cdots, P_{1m}\}$ -------------- Eq.(3)
$P_2 = \{P_{21}, P_{22}, \cdots, P_{2m}\}$ --------------- Eq.(4)
⋮
$P_n = \{P_{n1}, P_{n2}, \cdots, P_{nm}\}$ --------------- Eq.(5)

On the other hand, I assume that evaluation result R produced by a chapter test is a set that has n elements as shown below.

$R = \{R_1, R_2, \cdots, R_n\}$ ----------------- Eq.(6)

(where, R_i (i = 1, 2, , n) is test result of each step by chapter test.)

Then, we can define the result of chapter test R_i as the following fuzzy set.

$R_i = \{(P_{i1}, \mu P_{i1}), (P_{i2}, \mu P_{i2}), \cdots, (P_{im}, \mu P_{im})\}$ --------Eq.(7)

(where, μP_{ij}(j = 1, 2, ⋯, m) is fuzzy membership grade of student's response accuracy to question P_{ij})

The method that transforms the R_i, that is generated by a chapter test, to a fuzzy set is as follows.

Students must answer the questions within the time allowed. That means we don't permit unlimited time for question answering. Students can get the scores in test under the time considered the difficulty and complexity by teachers. And it is different when the student spends a short time answering a question for making the answer and a long time answering a question. We use the following Eq. (8) that was defined by Weon and Kim [10].

$$R_i = \bigcup_{i=1}^{n} \{P_i, \sum_{j=1}^{m}(\mu P_{ij} \times \mu T_{ij})\} \text{ ----------- Eq.(8)}$$

(where, μP_{ij} is membership grade that jth sub question of ith question is correct or not (correct : 1, incorrect : 0), Σ is algebraic sum, ∪ is set, × is algebraic product, μT_{ij} is membership grade of time that is needed when solving the question P_{ij}.)

μT_{ij} is also computed by inverse sigmoid function in Eq. (9). This function is originated from sigmoid function in reference [12].

$$T_{ij} = \begin{cases} 1 & : v \leqq \alpha \\ 1-2(\frac{v-\gamma}{\gamma-\alpha})^2 & : \alpha < v < \beta \\ 2(\frac{v-\alpha}{\gamma-\alpha})^2 & : \beta \leqq v < \gamma \\ 0 & : v \geqq \gamma \end{cases} \text{ --------- Eq.(9)}$$

(where, v is question solving time for P_{ij}, α is permitted lower limit time and γ is permitted upper limit time for question solving, $\beta = \frac{\alpha+\gamma}{2}$.)

3.3 Fuzzy Correlation

Let's consider the following implication statement.

「IF pressure is high THEN volume is small」

The membership function of fuzzy set A, big pressure, can be interpreted as some function. The membership function of fuzzy set B, volume is small, can be interpreted as another function. In this case, we represent fuzzy implication A and B as A→B. This indicates what is the value of B under condition A.

We can get various values for A→B because many researchers already have defined functions for getting values for A→B. However, we present a new definition for its value and call it a fuzzy correlation.

$R_i \rightarrow R_j$ is the fuzzy correlation of evaluation result R_i to Pi and R_j to P_j (j = i - 1) is as follows.

$$R'_j = R_i \rightarrow R_j = \begin{cases} P_{jk}^2 & : if P_{ik} > P_{jk} \\ P_{ik} or P_{jk} & : if P_{ik} = P_{jk} \\ \sqrt{P_{jk}} & : if P_{ik} < P_{jk} \end{cases} \text{ ----------- Eq.(10)}$$

(where, k is 1, 2, ⋯, m.)

R_i will be the condition and R_j will be the conclusion part. Therefore, R_i is result of past chapter test and R_j is the result of present chapter test. Then, we can strengthen the result of evaluation if learning achievement on past step is low, but next step is high. In case of opposite, we can make weaken. And it has no change if there are same result of evaluation. R_i and R_j are one dimensional vectors, but $R_i \rightarrow R_j$ is a two dimensional matrix. So, the number of elements is m^2. Also, we can get evaluation result of next step regarding evaluation result of past step (R_i) by dividing the sum of all element as m^2.

4. Experimentations

4.1 Experimental Environments

I gave 25 mathematics questions to 4th grade Korean elementary school students to validate proposed model. The questions included the 4 basic operations : addition, subtraction, multiplication, and division. The first 5 were for addition, and the next 5 were for subtraction. Similarly, the next 5 were for multiplication and the following 5 were for division. The final 5 questions were a mix of the 4 basic operations. All questions were made by 4th grade elementary school teachers. Also, there were limit time for answering the questions. They were gained from the fastest answer and the slowest answer that they are submitted by top 10% rankers who took the test.

The questions and limit time were examined by another 5 elementary school teachers. The reviewers had no comment about the degree of difficulty of the problems, but they indicated that the limit time was too short. I decided to go on with the experiment because the purpose of this research is not to get good test results but to get the features of the proposed model and to review the differences between this method and any other method.

Total 100 subjects were taken the test, but I selected just three students for analysis. <Table 1> shows the questions in the test.

<Table 1> 25 Questions for Test

Question No.	1	2	3	4	5
1	3+5+7	13+5+7	13+15+7	130+5+7	130+105+7
2	8-3-5	18-3-5	18-13-5	180-13-5	18-13-51
3	3X5X7	13X5X7	13X15X7	130X5X7	130X105X7
4	16÷4÷2	160÷16÷2	48÷3÷4	5÷(12÷6)	84÷3÷2
5	8-5X12÷4	3+20÷5-10	17-64÷16	15÷3X7+9	7X28X32÷2

(where, the row and column numbers(1, 2, 3, 4, 5) are question numbers to the test, such as P_{11}, P_{12}.)

<Table 2> is a time table that allowed for each question solving.

I used a start and stop button to measure the time that was required for question solving. Students had to click the button when they started to solve a problem and click again when they finished solving the question. I ignored some error in the aspect of time that occurred during experimentation.

<Table 2> Time Allowed for Each Question Solving

Unit : Sec, [lower limit, upper limit]

Question No.	1	2	3	4	5
1	[1,4]	[1,4]	[1,4]	[1,4]	[1,4]
2	[1,6]	[1,6]	[1,6]	[1,6]	[1,6]
3	[3,10]	[3,10]	[3,10]	[3,15]	[3,25]
4	[5,15]	[5,15]	[10,15]	[10,15]	[10,15]
5	[10,25]	[10,25]	[10,25]	[10,25]	[20,30]

<Table 3> # 3 Student's Response Results

Unit : Sec

Question	1		2		3		4		5	
No.	O/X	T	O/X	T	O/X	T	O/X	T	O/X	T
1	O	2	O	3	O	2	O	1	O	4
2	O	2	O	4	O	5	O	4	O	6
3	O	7	O	7	O	13	O	15	O	15
4	O	11	O	7	O	12	X	12	X	13
5	X	16	X	16	O	18	X	22	O	22

(where, O/X means that answer is correct or not. If it is correct, we mark "O", but it is not, we mark "X" . T means the time that is used for question answering.)

<Table 4> #7 Student's Response Results

Unit : Sec

Question	1		2		3		4		5	
No.	O/X	T	O/X	T	O/X	T	O/X	T	O/X	T
1	O	2	O	3	O	2	O	1	O	4
2	O	2	O	4	O	5	O	4	O	6
3	O	7	O	9	O	13	O	15	O	15
4	O	11	O	7	O	8	O	15	X	13
5	O	21	O	16	O	18	X	21	O	24

<Table 5> # 20 Student's Response Results

Unit : Sec

Question No.	1		2		3		4		5	
	O/X	T	O/X	T	O/X	T	O/X	T	O/X	T
1	O	3	O	2	O	4	O	3	O	2
2	O	4	O	3	O	6	O	4	O	6
3	O	6	X	7	O	9	O	12	X	29
4	X	12	O	10	O	12	X	12	O	23
5	O	16	O	17	O	18	O	20	X	34

<Table 3>~<Table 5> show the responses of 3 students to the given questions <Table 1>.

4. 2 Experimentations

Now, I showed the simulation results of the proposed model using the data in the previous tables : <Table 1>, <Table 2>, <Table 5>. First, I calculated the response accuracy of a student (Student # 20) using Eq. (8) and Eq. (9). <Table 6> shows the results.

<Table 6> Response Accuracy for Student # 20

Question No.	1	2	3	4	5
1	0.222	0.778	0	0.222	0.778
2	0.32	0.68	0	0.32	0
3	0.63	0	0.041	0.125	0
4	0	0.5	0.68	0	0
5	0.68	0.56	0.44	0.22	0

Then, R_1, the results of chapter test to P_1 are as follows.

$R_1=\{(P_{11},0.222),(P_{12},0.778),(P_{13},0),(P_{14},0.222),(P_{15},0.778)\}$ ------------------------------ Eq.(11)

Eq. (12), (13), (14), (15) are the results of chapter test to P_2, P_3, P_4, P_5, by same manner.

$R_2=\{(P_{21},0.32),(P_{22},0.68),(P_{23},0),(P_{24},0.32),(P_{25},0)\}$ ------ Eq.(12)

$R_3=\{(P_{31},0.63),(P_{32},0),(P_{33},0.041),(P_{34},0.125),(P_{35},0)\}$ ------ Eq.(13)

$R_4=\{(P_{41},0),(P_{42},0.5),(P_{43},0.68),(P_{44},0),(P_{45},0)\}$ ------ Eq.(14)

$R_5=\{(P_{51},0.68),(P_{52},0.56),(P_{53},0.44),(P_{54},0.22),(P_{55},0)\}$ ------ Eq.(15)

We can get the following two dimensional matrix using Eq. (8) for the fuzzy implication $R_1 \rightarrow R_2$.

<Table 7> Values of R'_2 ($R_1 \rightarrow R_2$)

No.	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}
P_{11}	0.566	0.825	0	0.566	0
P_{12}	0.102	0.462	0	0.102	0
P_{13}	0.566	0.825	0	0.566	0
P_{14}	0.566	0.825	0	0.566	0
P_{15}	0.102	0.462	0	0.102	0

The summation of scores to P_{21} is 1.902 and the summations of scores to P_{22}, P_{23}, P_{24}, P_{25} are 3.399, 0, 1.902, 0, respectively. Therefore, evaluation result of P_2 that reflect the evaluation result of P_1 is 1.441 that is their average. The evaluation result of P_1, the result of Eq. (10), does not change because of not applying the fuzzy implication.

We can get the result of $R_2 \rightarrow R_3$, $R_3 \rightarrow R_4$, $R_4 \rightarrow R_5$ by the same manner.

<Table 8> Values of R'_3 ($R_2 \rightarrow R_3$)

No.	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}
P_{21}	0.794	0	0.002	0.016	0
P_{22}	0.397	0	0.002	0.016	0
P_{23}	0.794	0	0.202	0.354	0
P_{24}	0.794	0	0.002	0.016	0
P_{25}	0.794	0	0.202	0.354	0

The summation of scores to P_{31} is 3.573 and the summations of scores to P_{32}, P_{33}, P_{34}, P_{35} are 0, 0.41, 0.756, 0, respectively. Therefore, evaluation result of P_3 that reflect the evaluation result of P_2 is 0.948 that is their average.

<Table 9> Values of R'_4 ($R_3 \rightarrow R_4$)

No.	P_{41}	P_{42}	P_{43}	P_{44}	P_{45}
P_{31}	0	0.250	0.825	0	0
P_{32}	0	0.707	0.825	0	0
P_{33}	0	0.707	0.825	0	0
P_{34}	0	0.707	0.825	0	0
P_{35}	0	0.707	0.825	0	0

The summation of scores to P_{41} is 0 and the summations of scores to P_{42}, P_{43}, P_{44}, P_{45} are 3.078, 4.125, 0, 0, respectively. Therefore, evaluation result of P_4 that reflect the evaluation result of P_3 is 1.441 that is their average.

The summation of scores to P_{51} is 3.98 and the summations of scores to P_{52}, P_{53}, P_{54}, P_{55} are 3.306, 2.377, 1.503, 0, respectively. Therefore, evaluation result of P_5 that reflect the evaluation result of P_4 is 2.233 that is their average.

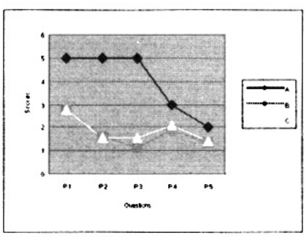
<Table 10> Values of R'_5 ($R_4 \rightarrow R_5$)

No.	P_{51}	P_{52}	P_{53}	P_{54}	P_{55}
P_{41}	0.825	0.748	0.663	0.469	0
P_{42}	0.825	0.748	0.194	0.048	0
P_{43}	0.68	0.314	0.194	0.048	0
P_{44}	0.825	0.748	0.663	0.469	0
P_{45}	0.825	0.748	0.663	0.469	0

4.3 Discussions

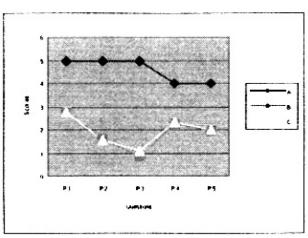
Using the results of the previous experiments, I compared the results of 3 methods : A, by traditional grading method, B, by inverse sigmoid function considered time allowed, and C, our proposed method that uses fuzzy correlation.

The following (Fig. 1)~(Fig. 3) show the results of students 3, 7 and 20. All cases show sharp differences between A and B, C. It seems to be natural results because method B and C applied strict conditions than method A.



(where, A : traditional grading method, B : inverse sigmoid function considered time allowed, C : proposed method in this paper.)

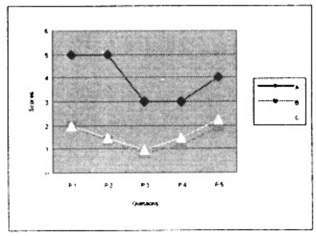
(Fig. 1) Comparison of Results for Student # 3



(Fig. 2) Comparison of Results for Student # 7

If someone wants to reduce these differences, then we can apply magnanimous conditions to <Table 2>. That means we would expand the limit time that is allowed for questions.

Differences between B and C are small. Sometimes B is greater than C and sometimes C is greater than B. These differences are apparent whether or not we applied the test results of the previous step to the present evaluation.



(Fig. 3) Comparison of Results for Student # 20

Essentially, the three graphs shown above exhibit the same pattern. That is, they all have large differences between A, B, C, while there are only small differences between B and C.

5. Conclusions

In this paper, I proposed a new learning achievement evaluation model using fuzzy correlations. I compared proposed model to both the traditional evaluation model and another evaluation model that was proposed by S. H. Weon. Proposed method reflected the progress of evaluation steps. It will make the evaluation result of present step little better when the result of present step is good while the result of previous step is bad. By contraries, it will make the evaluation result of present step little worse when the result of previous step is good. Therefore, I can make a conclusion that method B and C showed little differences as learning achievement of student.

Therefore, this new method can make dynamic evaluation results based on the result of relationships between the present step and the previous step. I could get various types of evaluation results from this model. These results will be used in individualized learning because students can advance the learning procedure at their own pace based on their different evaluation results even though they may start at the same learning level.

This method presents an engineering approach to this aspect of education. My future works will focus on determining whether or not this is the right approach by conducting surveys to validate this method with educational experts.

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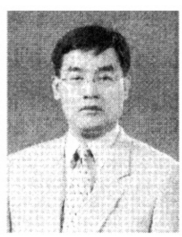
원 성 현



1990 서강대학교 전자계산학과(공학사)

1992 서강대학교 대학원 전자계산학과(공학석사)

1998 대구가톨릭대학교 대학원 전자계산학과(이학박사)

1992~2000 지산대학 전자계산과 부교수

2001~현재 부산가톨릭대학교 컴퓨터정보공학부 부교수

2003~2004 Visiting Professor, Department of Computer Science, Virginia Tech in U. S. A

관심분야 : 지능형시스템, 가상교육시스템, 디지털 라이브러리

E-Mail : shwon@cup.ac.kr