A Conceptual Model based Distance Learning System for Computer Literacy

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Abstract

In distance learning for computer literacy, a student's skill is dependent on personal experience. In such cases, it is important to determine the student's understanding. In order to determine the level of understanding, it is necessary to clarify the hidden relationships among the concepts involved in a problem. We think it is possible to determine the understanding correctly by subdividing concepts and by subdividing problems. In this paper, we propose the following method; first we divide a problem conceptually into some questions; next we ask those questions of students step by step; finally we build a conceptual model of the problem using the rate of correct answers.

1. Introduction

Recently, many researchers have studied e-Learning, which supports education using IT and increases educational chances for children. In e-learning, distance learning is especially important because it can deliver educational content to massive numbers of students through the Internet. In this way, distance learning increases educational opportunities to the maximum.

In order to realize distance learning, syllabus databases, the course registration system, courseware that manages educational content and educational content itself is needed. We have developed a syllabus database[1] and a course registration system[2] that cooperates with the syllabus database, in order to construct an education support system. This course registration system supports i-mode, which is an Internet access service for cellular phones developed in Japan by NTT. In addition, it can recommend a suitable course for each student by considering their educational history and personality[3][4]. We then developed a course lottery system[5], which selects students when they choose a course in which the number of students is limited. In this way, we have developed several systems, but mainly a course registration system.

IT drives the automation of education. However, its effect depends on whether or not students understand. Automation decreases the cost of education and also increases educational opportunities. However, it is not meaningful if none of students understand anything.

In general, the earlier misunderstandings are found, the easier they are to correct. Also, what a student misunderstands is dependent on each student. So, a student who misunderstands can ask questions in order to understand. However, in distance learning, it is difficult for a teacher to answer these questions because there are too many students so there are few chances to correct students' misunderstandings. In order to correct students' misunderstandings early, what she misunderstands should be found, so that the teacher can then correct it appropriately. An examination is useful for finding misunderstandings. However, although an examination can find out who misunderstands, it is difficult to find out exactly what is misunderstood.

In this paper, we propose an learning system which supports finding out what a student misunderstands. This system uses a user model in order to find the user's misunderstandings. It also generates new questions for correcting misunderstandings. We apply this system to computer literacy education for freshman at the University. In distance learning for computer literacy, we have to assume that each student has a different preliminary knowledge of computers. In such a case, it is important to identify students' misunderstandings.

In order to do this, it is necessary to clarify the dependency among concepts hidden in a quiz. For that purpose, we subdivide the concepts in the quiz. In our method, the learning system generates some quizzes subdivided conceptually, it analyzes the results, and refines the conceptual model on the basis of the rate of incorrect responses. If a student takes an examination then the conceptual model is updated. The teacher analyzes the model and adds new quizzes to it. The student takes the examination again so that she corrects misunderstandings. If this process is repeated, the conceptual model can be refined. As a result, even if another student takes the revised examination, it can still provide her with suitable quizzes.

The remainder of this paper is organized as follows. Section 2 describes the related work. Section 3 describes the conceptual model of the quizzes. Section 4 describes the system overview and implementation. Finally, we conclude.

2. Related Work

Recently, many researchers have been studying distance learning. We have developed a syllabus database[1] and a course registration system[2] which co-operates with the syllabus database, in order to construct an education support system. This course registration system supports i-mode, which is an Internet access service for cellular phones developed, in Japan, by NTT. In addition, it can recommend a course suited to each student by considering their educational history and personality[3][4]. Subsequently, we have developed a course lottery system[5], which selects students when they choose a course for which the number of students is limited. In this way, we have developed several systems, but mainly a course registration system. However, these have none of the all-important educational content.

CAI is a conventional method based on IT that automates education. In CAI, many students are supported because a machine responds to all of the interactions. This feature is important for e-Learning. However, a student can soon become familiar with its response pattern because of its simplicity. So, a student becomes tired. In this way, in CAI, it is difficult to maintain student motivation. Even if AI techniques are used, it is difficult to realize interactions that satisfy all users. So, we need a system that supports interactions between students and teachers because a student wants to communicate with a teacher but not with a machine.

In order to use conventional information systems, users have to learn the system model and commands. On the other hand, user-model based information-systems can infer a user's intention, and the user can operate it naturally[6]. A user model is a database and/or repository that stores the user's characteristics. A learning system based on a user model analyzes the user's understanding so that it can generate quizzes suited to each user. For an example, a system employs Bayesian network as a user model[7]. In such a system, quizzes are selected on the basis of the user's understanding and suitable hints are selected.

In a sense, every distance learning program needs a user model in order to model remote users. A user model is useful for checking whether or not the user understands, but is not useful for checking why the user misunderstands.

The problem model is a set of dependencies among the many concepts required to solve a problem. A student has to understand them all correctly, although this understanding is not always clear. Therefore, the problem model needs to be refined by applying experience to it.

There is a dependency relationship between concepts. For example, if for concepts A and B, B depends on A, then understanding A is required for understanding B. In this case, we show its dependency by the expression $A \rightarrow B$. There are few educational systems that use problem models. In almost all distance-learning systems, the problem model exists only in the student's brain. The system does not know it. A teacher needs to infer what a student misunderstands, but, there are no suitable tools for this purpose.

3. A Conceptual Model of Binary Numbers

In this paper, we consider the conceptual model and problem model for binary numbers because this problem is important for freshman in computer science courses. In addition, we assume that students have already learned about binary numbers in the classroom.

3.1 An Initial Model

We show an initial conceptual model in Table 1. In this table, ID is the identifier for the quiz, The quiz is a description, and Pred. are the predecessors of the quiz in the problem model. There are nine categories of quizzes: counting, converting decimal numbers to binary numbers, converting binary numbers to decimal numbers, adding, subtracting, multiplying, dividing, complement, and subtracting by adding the complement.

In the quiz for counting binary number, the student must return the next number for a given binary number. In this quiz, we check whether or not the student understands the difference between decimal numbers and binary numbers. In Quiz A, a given number is counted with no carrying. Therefore, the resultant binary number ends with a zero. The student can answer this quiz if s/he understands the concept $0+1 \rightarrow 1$. Next, Quiz B counts with 1-bit carrying. At this time, the examination system selects as a questions a binary number matched to the regular expression $[01]^*01$. The student has to understand $1+1 \rightarrow 10$. Next, Quiz C counts up binary numbers that consist of all 1s, such as $11+1 \rightarrow 100$, $111+1 \rightarrow 1000$ and so on for the student to understand more than 1-bit carrying. This rule can be represented as the regular expression $1^a+1 \rightarrow 10^a$. Finally, Quiz D counts binary numbers, including a 0 between the 1's. This rule can be represented as the regular expression $[10]^a01^b+1 \rightarrow [10]^a 10^b$. In Quiz D, we check whether or not the student understands that carrying stops on 0.

Next, the student works through exercises to convert a decimal number to a binary number. First, the system shows an example, and then the student tries to convert each decimal digit to a binary number (Quiz E). Next, the student converts a decimal digit to a binary number without an example (Quiz F). It is easy for the student to learn this because only ten patterns exist. Furthermore, if the student remembers some base numbers, then she can find the correct number by counting. Next, the student converts a decimal number equal to 2^n to a binary number (Quiz G). It is represented as the regular expression 10^n. Finally, the student converts a two-digit decimal number to a binary number (Quiz H). We check whether she understands that any decimal number can be represented by the summation of 2^n.

Next, the student carries out exercises in converting a binary number to a decimal number. First, the system shows an example, and then the student tries to convert the binary number to a decimal digit (Quiz I). Next, the student converts a binary number to a decimal digit without an example (Quiz J). These quizzes can be answered easily by the student who carries out exercises to convert decimal numbers to binary numbers. Even if the student has not completed the exercises, if she understands the principle, she can solve the problems. Here, we aim for them to understand the principle. Next, the student converts a binary number 2^n to a decimal number (Quiz K). Finally, the student converts a binary number to a two digit decimal number (Quiz L).

Next, the student carries out exercises to add a binary number to another binary number. First, in Quiz M, she performs exercises to add without carrying, for example, 1010+0100=1110. In such a case, two binary numbers a and b have the relationship a+b=a EOR b. Next, she adds with a 1-bit carry (Quiz N). She can solve this if she understands how to count up the carried part in a binary number. Finally, she performs exercises in adding any binary number to any other binary number (Quiz O).

Next, the student carries out exercises in subtracting a binary number from another binary number. First, in Quiz P, she performs exercises in subtracting without borrowing, e.g. 1101-1001=0100. In such cases, three binary numbers a, b and c (a-b=c) have the relationship b EOR c = a. Next, she subtracts with 1-bit borrowing (Quiz Q), e.g. 1101-1010=0011, excluding the following case of more than two borrowings 1101-0110, 1001-0011. Finally, she performs exercises in subtracting any binary number from any binary number with more than two borrowings (Quiz R), assuming that the result is not negative. This is because negative binary numbers are represented as complements.

Next, the student performs exercises in multiplying a binary number by another binary number. Multiplying is a combination of shifting and adding. First, the system gives a hint (Quiz S), and then the student carries out exercises without hints (Quiz T).

Next, the student performs exercises in dividing a binary number by another binary number. Dividing is a combination of shifting and subtracting. She performs exercises in dividing without any hints (Quiz U). Note that negative binary numbers are not used. Generally, dividing is a higher-level concept than subtracting but in dividing, the result of subtracting is not negative. Therefore, a complement is not needed. So, in this sense, dividing is simpler than subtracting negative binary numbers.

Next, the student performs exercises in computing the complement of 2. First, the system shows an example such as -0011=1101 (Quiz V). Finally, the student computes a complement without an example (Quiz W).

Table 1. Initial Model

ID	Quiz	Pred.
Counting		
A	Counting without carrying	
B	Counting with carrying	A
C	Counting binary numbers without 0	B
D	Counting binary numbers including a single 0	B,C
Converting a decimal number to a binary number		
E	Converting a decimal digit to a binary number with an example	A,B,C,D
F	Converting a decimal digit to a binary number with no example	E
G	Converting the power of 2 to a binary number	F
H	Converting two decimal digits to a binary number	G
Converting a binary number to a decimal number		
I	Converting a binary digit to a decimal number with an example	A,B,C,D
J	Converting a decimal digit to a binary number with no example	I
K	Converting the power of 2 to a decimal number	J
L	Converting any 8 bit binary digit to a decimal number	K
Adding		
M	Adding without carrying	A
N	Adding with 1 bit carrying	B,C,D
O	Adding a binary number to another binary number	A,B,C,D
Subtracting		
P	Subtracting without borrowing	M
Q	Subtracting with 1 bit borrowing	N
R	Subtracting a binary number from another binary number (the result is not negative)	P,Q
Multiplying		
S	Multiplying with a hint	O
T	Multiplying without a hint	S
Dividing		
U	Dividing without a hint	R
Complement		
V	Complement with a hint	D
W	Complement without a hint	V
Subtracting by adding a complement		
X	Subtracting with a hint	W,O
Y	Subtracting without a hint	X

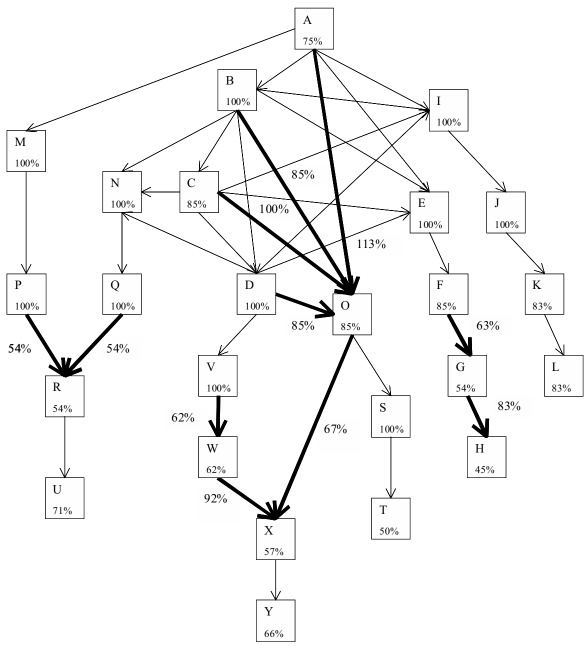

Figure 1. Evaluation result of the initial model

The last category includes subtracting where the result is negative. First, the student carries out exercises with an example shown (Quiz X). Next, she carries out exercises without an example (Quiz Y).

This initial model represents the problem model as conceptualized by the teacher. She finds what a student misunderstands by analyzing the answers that the student gives. She focuses on the quiz for which correct rate is the lowest, in order to investigate any lack of necessary concepts. She can explain it to the student in detail later.

We have developed an examination system based on the model mentioned above which six students have used. The result is shown in Figure 1. This figure illustrates the dependencies between quizzes and their rate of correct response. A rectangle represents a quiz. In each rectangle, both the quiz ID and its correct rate are shown. An arrow indicates the dependency. An arrow A→B means that a set of concepts in quiz A includes a set of concepts in quiz B. The percentage along an arrow is the correct rate of the successor to correct rate of the predecessor. The lowest value of these percentages shows the bottleneck in conceptual understanding.

3.2 Improving the Model

Here, we consider the result of an evaluation and improve the model.

We assume that to pass, the correct rate must be greater than 60% although quizzes G, H, R, T, and X have correct rates of 54%, 45%, 54%, 50%, and 57% respectively. The lowest correct rate (H) is 45% but the reason that this is low is that the correct rate of G, the predecessor of H, is low. 83% of students who passed G also passed H, but, only 63% of students who passed F, the predecessor of G, passed G. Therefore, the bottleneck is G rather than H. So, the student lacks the concepts for understanding G. (G is a quiz that converts decimal number 2^n to a binary number). So, the student does not understand the mapping of 2^n decimal number to a binary number 10^n. The correct rate also depends on the order of the quiz. In general quiz K, in which a binary number 10^n is converted to decimal number 2^n, is easier than quiz G. In fact, the correct rate of K, 83%, is higher than the correct rate of G, 63%. However, we do not have to modify the model for G because the rate of G to its predecessor is over 60%. We do not have to modify the model for H either for the same reason. In this sense, the rate of a quiz to its predecessor is more important than the correct rate. The only quiz in which the rate to the predecessor is under 60% is R, the value of which is 54%. The next is W.

Although the correct rate of R's predecessor is 100%, the correct rate of R is low. This reason is that R includes more than two carryings though the predecessor of R includes only one carry. So, we insert a new quiz R' before R. In R', we show an example of computing with multiple carryings.

Next, we discuss how to improve W. The correct rate of W is over 60% but we try to compare it with the previous discussion. A complement is the most important concept in understanding binary numbers. The correct rate of X, 57%, is lower than the correct rate of W, 62%. But, the rate of X to its predecessor W is 92%. On the other hand, the rate of W to its predecessor V is 62%. Therefore, the bottleneck is W rather than X. W is a quiz that computes a complement without a hint. V is a quiz that computes a complement with a hint. We wondered why the correct rate of W is low because the correct rate of V is 100%. So, here is a lack of necessary concepts. In quiz V, we show an expression for adding 1 to a number of which all bits are negated. We thought that the student had not understood because this hint was not suitable. So, we inserted a new quiz W' before W. In W', we showed a hint that the complement is equivalent to negating all bits and adding 1. As a result, we show an improved model in Table 2.

3.3 Evaluation of the Improved Model

The same six students carried out exercises using the examination system based on the revised model. The result is shown in Figure 2.

We consider the result of the improved model by comparing with the result of the initial model. The differences between the initial model and the improved model are R' and W' inserted before R and W respectively.

Table 2. Improved Model

ID	Quiz	Pred.
Subtracting		
P	Subtracting without borrowing	M
Q	Subtracting with borrowing	N
R'	Subtracting with a hint	P,Q
R	Subtracting a binary number from another binary number (the result is not negative)	R'
Complement		
V	complement with a hint	D
W'	~x + 1	V
W	Complement without a hint	W'

First, we discuss R'. The correct rates of R' and R are 100% and 75% respectively. This is 21 points higher than the initial model and over the pass rate. Therefore, it is clear that students understand well.

Next, we discuss W'. The correct rates of W' and W are 86% and 67% respectively. This is 16 points higher than the initial model. Therefore, it is clear that the students understand well.

However, we faced new problems. Quizzes H, T, and Y have a correct rate of under 60% (50%, 46%, and 26% respectively). Although both H and T are contained in the initial model, we did not modify them. So, we checked the rate to the predecessor. The rates of G→H, S→T, and X→Y are 67%, 57%, and 53% respectively. Therefore, we excluded H. In future we should insert new quizzes before S→T and X→Y. In this way, we can refine the model by repeating the evaluation process.

4. Conclusions

In this paper, we propose a conceptual-model based distance learning-system for freshman in computer science courses learning binary numbers. In this system, quizzes are generated at random on the basis of the conceptual model. The student answers them in a natural order. The system reflects the user's understanding and gives her suitable quizzes. The system stores in a database, the ID of the quiz, the student's answers, the time when she answered, and the correctness. The system stores this information so that it can find who misunderstands and what is misunderstood. In this way, this system supports a teacher in responding to students' misunderstandings as quickly as possible. We will accumulate several case studies as future work.

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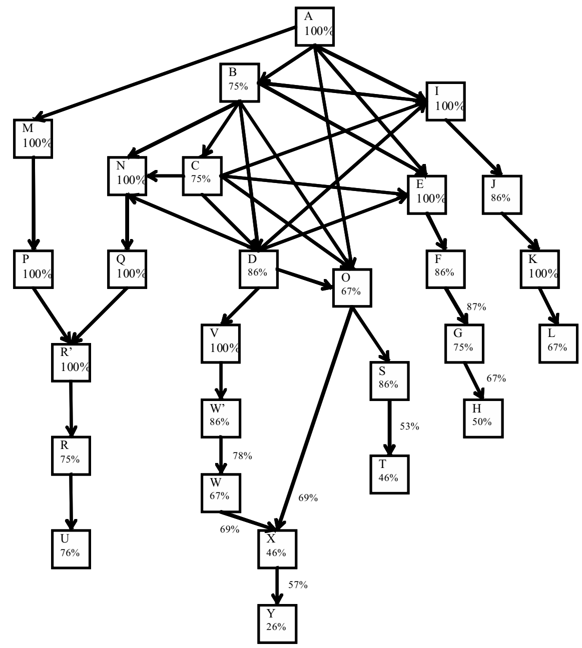

Figure 2. Evaluation of the improved model

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