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A Proposal of a CAI System for Remedial Education

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Abstract. Giving a lecture to a number of students by a teacher is an efficient way to convey knowledge in short period of time, but this traditional method has a disadvantage that the level of understanding for each student would vary[1]. For this reason, we are proposing an individual learning system using a CAI system in order for students to study intensively for the specific subjects that they are weak at. The existing CAI systems, however, have no concept of the different areas of study in Student Models[2][3] so that students may have to study subjects that they have already understood enough. Therefore, these conventional system are time consuming and not efficient. Our goal here is to build a CAI system for the remedial education which forces students to only focus on their weak parts by automatically identifying the weak parts of students. This paper is written for the purpose of explaining about Instruction Programs of the CAI system to clarify how it identifies the weak parts of study by using concrete examples. We will also prove the effectiveness of the proposed Instruction Programs with experiments.

Keywords: Identifying weak parts of study, Student Models, the drill & practice mode of CAI

1. Introduction

In recent years, the widespread usage of the Internet has been expected to be a study support system based on Website. This study support system is not affected by time or geographical restriction and available for everyone once the system is constructed on the Website. However, a general CAI system has no concept of different areas of study in Student Model, and students may have to study the areas where they have already understood enough. Therefore, we can safely say that this system has room for improvement in providing an ideal learning method. In order to solve this problem, we need to create a system that automatically identifies the comprehension level of each student to figure out which part of study is not sufficient as well as to adapt Instruction Programs so that students learn intensively to overcome their weak parts.

In this paper, we will focus on students' weak parts as a target field. Our goal here is to build a CAI system for the remedial education which forces students to only focus on their weak parts by automatically identifying the weak parts of students. This paper shows you how the system works in Student Models and the Instruction Programs to identify the student's weak parts by using concrete examples, and will prove the effectiveness of the proposed Student Models and Instruction Programs through experiments.

2. How to Create the Ideal CAI System

To define a student's weak part, we introduce the notion of category classification on learning objects to identify weak parts where students need to study intensively. The target fields on each student are classified in hierarchically based on the containment relationship as shown in Figure 1. Our immediate goal here is to pass Fundamental Information Technology Engineer Examination by using the new CAI system, and the information-processing technology has been selected as the target learning object. In the selected field of study, we will determine the area where a student is weak at in terms of understanding. By doing so, we will

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try to build a new CAI system which allows students to only focus on specific areas of study. We also set a definition for the areas where students are weak at.

"A student is given a group of questions belonging to the category C. If all the answers the student produced are incorrect, the lowest level of the category among the different levels of the category hierarchy which contains all the questions that the student answered incorrectly is defined as a part where the student is weak at."

In addition, this category is defined as a category which the student is weak at. Some students have multiple categories which they are weak at.

The target users of this system are considered to have already studied all the categories and possess some degree of knowledge. Otherwise, when a student without any knowledge about the categories uses the new CAI system, the system will judge that all the categories are weak for the student. This makes the new CAI system even worse than general CAI systems in terms of efficiency.

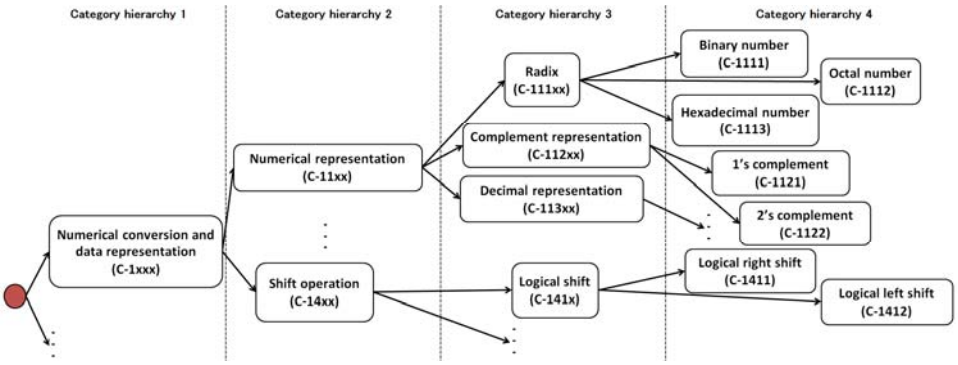

Figure 1. An example of the category hierarchy based on the containment relationship of the target study areas

Each student has his or her own weak categories. For this reason, the results of the test would be different for each student. We also need to manage the progresses made by the students in order to judge whether they have comprehended a specific group of questions coming from a category or not. Table 1 is prepared for managing the comprehension status of each student on each question in order to identify their weak parts of their study area.

Table 2 is also used to define the relationship between category names and category numbers in order to manage the progress made by students. Check the box if the learning has been completed on each section, and record information about the number of times a student finished learning on the category.

Table 1. Status management table on each question

Screen number	Question number	Correct or incorrect	Focused hierarchy	Category belonging to		
				Hierarchy 1	Hierarchy 2	Hierarchy 3
F-001	D-001	×	1	C-1xxx	C-12xx C-13xx	C-121x C-131x C-132x
F-001	D-002	○	1	C-1xxx	C-13xx	C-133x
F-001	D-003	×	1	C-1xxx	C-11xx	C-112x C-113x
F-001	D-004	○	1	C-1xxx	C-13xx C-14xx	C-133x C-142x
F-001	D-005	○	1	C-1xxx	C-13xx	C-133x C-134x

Table 2. Category management table

Completed	The number of times completed study	Enable to test	Category number	Category name	Category with order restriction		
					Comprehended	Preceding category	Subsequent Category
✓	1	✓	C-1xxx	Numerical conversion and data representation			C-2xxx C-3xxx
	0		C-11xx	Numerical representation			
✓	1		C-12xx	Non-numerical representation	✓		
✓	1		C-13xx	Arithmetic and accuracy	✓		

2.2 Difficulty of the questions

The questions presented from CAI system will be checked if these questions are appropriate to use in CAI system. To ensure that these questions are suited to be used in the CAI system, a paper format exam will be conducted to a group of students who will actually use the CAI system later or similar group of such students. After choosing the appropriate questions to be used in the CAI system, the difficulty of these questions are defined as numbers calculated by multiplying 100 to each question's error rate. Then, some sets of questions are prepared. The questions in each set should be carefully chosen to minimize the difference of difficulty between sets in the same category. It is important to minimize the difference of difficulty between the sets of questions in order to make the CAI system reliable, so that whenever the system is used it provides consistent results for its judgment. For the identification of weak categories, we use a set of questions with low level of difficulty. The low level of difficulty here indicates questions which has the difficulty number 50 or less. The system presents a set of questions which difficulty numbers are 50 or less first, and if all the answers the student produced are incorrect, the category which contains all the questions that the student answered incorrectly is defined as a weak category for the student.

2.3 Strategic knowledge for identifying a weak category

The search method we adopted provides one question belonging to category hierarchy 1 at a time in order to identify a weak category possibly included in subordinate position of category hierarchy 1. Then, if a testee fails to answer even one question in the test, we assume that the category where the failed question is included or under its subordinate position of the category as a weak category and make it as a starting point for searching for a weak category.

Once we set a starting point, we give the testee a certain number of questions belonging to the category, and narrow down choices of categories to pin down a weak category by analyzing the answers produced from the testee. When giving a testee a certain number of question chosen from a category, the results of the test are divided into following three cases, [S1], [S2] and [S3].

[S1] All the answers are incorrect. In this case, the strategic knowledge regards this category as a weak category.

[S2] All the answers are correct. In this case, the strategic knowledge regards this category as a not weak category but a category which a testee may have comprehended. Therefore, this case is considered to be failed in searching a weak category.

[S3] Some answers are correct and others are not. In this case, the current category is still too broad to figure out a weak category. We need to go deeper to consider a more specific category hierarchy. When going one category hierarchy down from the starting point, set the categories included questions which the testee chose incorrect answers as B1, B2,•••, Bm, and set the categories included questions which the testee chose correct answers as G1, G2,•••, Gm. Then the strategic knowledge of [S3] can be expressed as follows. It is possible to say that the testee's weak category maybe included in categories of B1, B2, •••, Bm or in subordinate categories of these categories. Furthermore, categories of G1, G2, •••, Gm and subordinate categories of these categories may not include any weak categories. In case of [S3], the top level of a category which may be a weak category for the testee can be expressed by using the arithmetic mean of set theory "∪" which means "OR" in mathematical field. With "∪", the category is shown as $B1 \cup B2 \cup \bullet\bullet\bullet \cup Bm - G1 \cup G2 \cup \bullet\bullet\bullet \cup Gn$. Therefore, the strategic knowledge of [S3-1] and [S3-2] can be delivered from the strategic knowledge of [S3].

[S3-1] When $B1 \cup B2 \cup \cdots \cup Bm - G1 \cup G2 \cup \cdots \cup Gn$ is not an empty set, if $B1 \cup B2 \cup \cdots \cup Bm - G1 \cup G2 \cup \cdots \cup Gn = \{ C1, C2, \cdots, Cp \}$, weak categories may exist in subordinate categories under each of C1, C2, ···Cp.

[S3-2] When $\{ B1 \cup B2 \cup \cdots \cup Bm \} \cap \{ G1 \cup G2 \cup \cdots \cup Gn \}$ is not an empty set, if $\{ B1 \cup B2 \cup \cdots \cup Bm \} \cap \{ G1 \cup G2 \cup \cdots \cup Gn \} = \{ D1, D2, \cdots, Dq \}$, weak categories and categories that are not may co-exist in subordinate categories under each of D1, D2, ···Dp. Therefore, we need to analyze for each of D1, D2, ···, Dq by going one category hierarchy down from the starting point.

The strategic knowledge [S3-2] is the knowledge about subordinate categories of [S3-1]. Hence, [S3-2] will be applied after applying the strategic knowledge of [S3-1]. The examples for applying [S3] are shown as follows:

Table 3. Answering status management table on each question

Question number	Correct or incorrect	Focused hierarchy	Category belonging to			
			Hierarchy 1	Hierarchy 2	Hierarchy 3	Hierarchy 4
D-006	○	1	C-1xxx	C-13xx	C-131x C-132x	C-1313 C-1323
D-007	○	1	C-1xxx	C-12xx	C-122x	C-1221 C-1223
D-008	×	1	C-1xxx	C-11xx C-13xx	C-112x C-133x	C-1121 C-1331 C-1332
D-009	○	1	C-1xxx	C-12xx	C-121x C-122x	C-1214 C-1222
D-010	×	1	C-1xxx	C-11xx C-13xx	C-111x C-132x	C-1112 C-1321

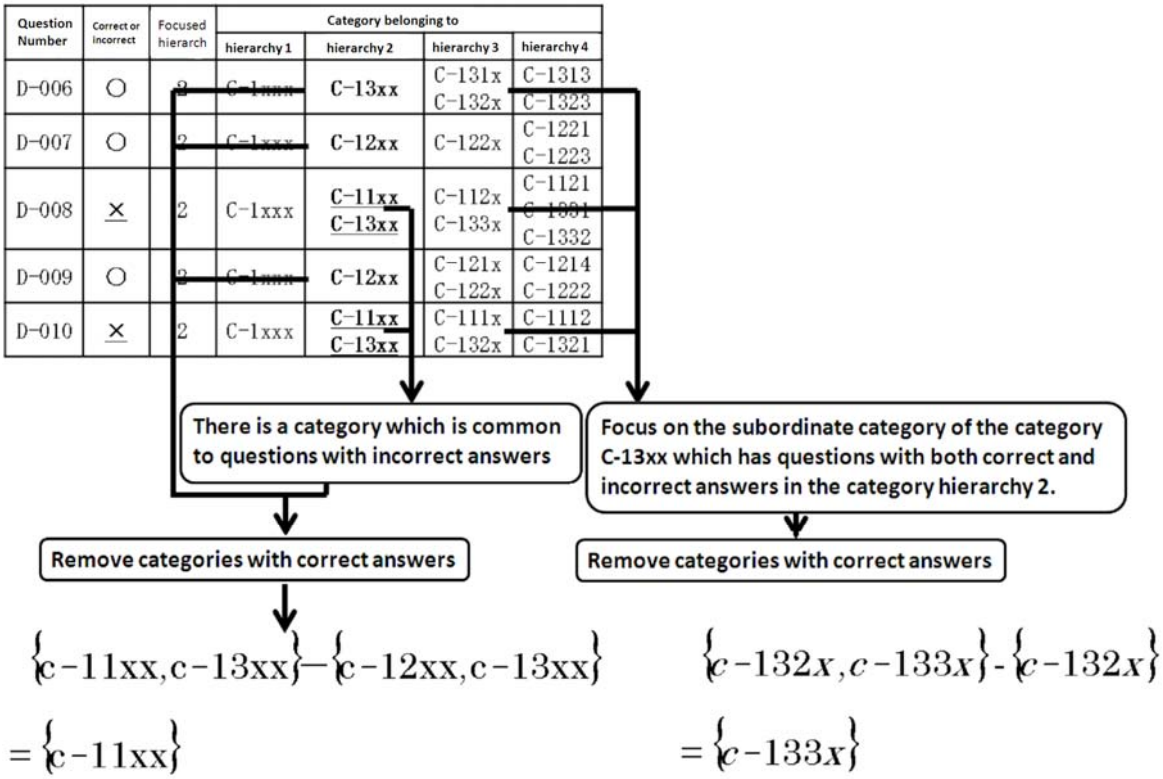

Figure 2. Example of delivering a hypothesis category

Table 3 shows the situation where a set of questions (five questions in this example) was given to a testee under the hypothesis that a weak category for the testee exists in the category C-1xxx. The answers produced by the testee contain both correct and incorrect answers. If we apply the strategic knowledge of [S3] to this situation, we can assume that both weak and not weak categories for the testee exist in the subordinate category of the category C-1xxx where the testee produced an incorrect answer. Therefore, the strategic knowledge [S3-1] is applied to this situation in order to figure out the testee's weak category by going one category hierarchy down from the starting point. The union of sets of categories for the category hierarchy 2 where the questions which the testee produced incorrect answers belong to is {C-11xx, C-13xx}. On the other hand, the union of sets of categories for the category hierarchy 2 where the questions which the testee produced correct answers belong to is {C-12xx, C-13xx}. From both unions of sets above, difference set of { C-11xx, C-13xx } − { C-12xx, C-13xx } = { C-11xx } can be delivered. Therefore, { C-11xx } can be chosen as a candidate of the weak part. After completing the search for the subordinate categories under C-11xx, the strategic knowledge [S3-2] can be applied to deliver { C-11xx, C-13xx } ∩ { C-12xx, C-13xx } ={ C-13xx }.

2.3 The whole process of CAI system

The whole process of the system is shown in the flow chart in the figure 3.

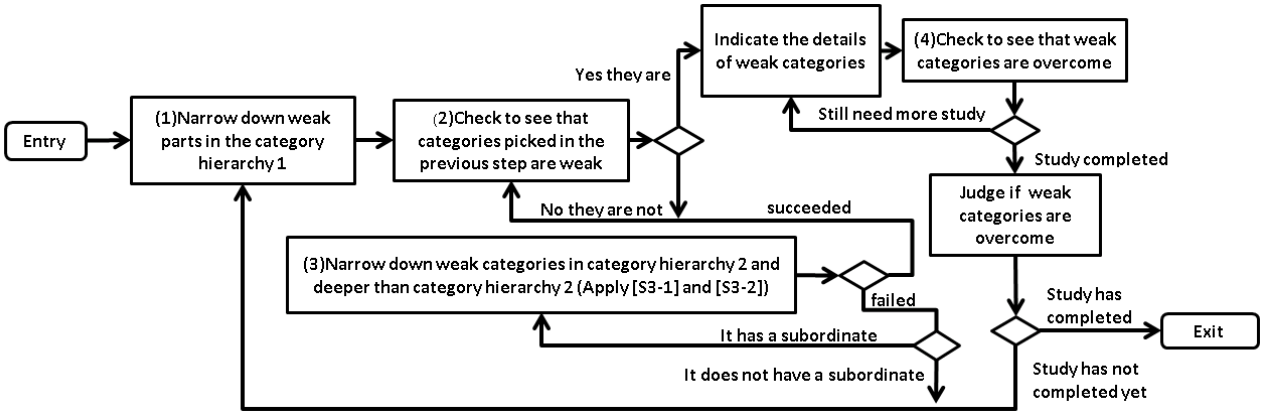

Figure 3. The whole process of CAI system

3. Assessment Experiment

We have conducted a series of experiments in order to clarify how many questions are required to identify one's weak category.

Materials for this series of experiments were divided into 63 categories by using IT CBK (Common Body of Knowledge) from "Skill Standards for IT Professionals" as a reference. 669 questions in a word description format were prepared by using the exam questions from previous Fundamental Information Technology Engineer Examination as a reference. These extracted questions from the exam were modified to reproduce some derived questions. The number of questions to bring out was set to 4 when determining a category whether it is a weak one or not in this series of experiments.

In those experiments, the system experiment was conducted with 55 first-year students belonging to the department of information engineering. Among them, one student was determined that he/she has no weak category since he/she got all the answers right. The time limit for this experiment is 60 minutes and even if the test is not finished, this experiment will be over. We conducted a preliminary experiment on 5 testees beforehand. The shortest period on time to complete was 38 minutes and the longest period of time was 158 minutes. The average length of time to finish was 96.2 minutes.

This series of experiment successfully identified weak categories of 49 testees out of 54 testees (90.07%). 5 testees (9.93%) were not able to complete the exam in time and failed in identifying their weak categories. To get as many testees as possible for the experiments, the experiments were conducted during class. Some testees failed in completing the exam in classroom time (90 minutes). The rate for successfully identifying weak categories for those who completed the exam in time was 100% including a testee without any weak category.

4. Conclusion and Future Direction

The existing CAI systems have no concept of different areas of study in the Student Model, and students may have to study the areas where they have understood enough. Therefore, we can safely say that those systems are not providing an ideal learning method. To solve this problem, we proposed to build a CAI system for the remedial education which forces students to only focus on their weak parts by defining their weak parts of study and automatically identifying the weak parts for the students. We used the concept of category on the areas of study to divide them into specific areas, and targeted areas where we can divide it into hierarchical categories based on the containment relationship to identify a category where a weak parts of study belongs to in order for CAI system to be able to identify weak parts of study for students.

To materialize the proposal above, we proposed the idea of Instruction Programs for CAI system to make the system identify weak parts of study for students. We conducted a series of experiments with Instruction Programs on 55 candidates to ensure that the system is able to identify the candidates' weak parts of study. The experiments succeeded and the Instruction Programs are proven to be effective.

5. References

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