A CAI System to Identify Each Weak Part of a Student : A Proposal of a new Student Model and an new Instruction Program

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***Abstract*—** Recently, it is required to develop a Web-Based-CAI system to be able to learn efficiently due to the spread of Internet. However, since the order of giving a chain of decision frame does not change, without relation to whether a student of the CAI system can solve a given problem or not, he/she has also to learn the parts in his/her element. Therefore, he/she cannot learn efficiently. Therefore, the authors propose a new instruction program and a new student model that improved the existent overlay model. The new model is easy to create the teaching materials, and it is able to grasp where the student's weak parts in detail are. This paper clarifies by concrete examples how this system grasps where are the student's weak parts by using what kind of student model and what kind of instruction program. The authors show the proposed student model and the proposed instruction program are effective through an experiment.

***Keywords*—** Identifying weak part, Enhanced-Overlay-Model, Student Model, Intrinsic Program, Branching Instruction Program, Web-Based CAI

I. Introduction

Recently due to the widespread usage of the Internet, expectations to the CAI system operating under web environment are on the rise. This is because by constructing a CAI system on the web, no matter what the time, physical disturbance is, whoever, whenever, and wherever, anyone can use the CAI system; at the same time offer the same teaching-materials to the students that use the system.

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Taking this state in consideration, research and development of AI system, Web Based CAI (Computer Assisted Instruction) system operating under the web environment is evident. However, not all but almost commercially used CAI system presents the same teaching-materials whether the answer of the student is correct or incorrect (thus student) and it is not a satisfactory learning efficiency system since it learns what the student has already comprehended. To solve this issue, we have to adopt a Branching [1]-[3] Instruction Program that has a teaching- materials frame that changes what will be presented next, when the answer of the student is correct or incorrect.

The present study promotes the idea of Branching Instruction Program with a system that keeps on branching the teaching materials frame by seeking the weak part of the student, and by the system itself, identifying what the weak part of the student is, we aim to construct a system such that student only needs to learn his/her weak parts. To construct such system, the system needs to comprehend the student's comprehension situation, more specifically; the system needs to comprehend where the student actually comprehends and where he/she dose not. For this reason, we will use the Student Model as a barometer. However, if we adopt the Overlay-Model as a Student Model, teaching material will be easier compared to other Student Models, but there is an issue of unsuitability in delicate processing of the student's comprehension situation. Additionally, if we adopt a Student Model other then the Overlay-Model, it might suit the delicate processing of comprehending the student's comprehension situation, but an issue of teaching material being difficult arises. To solve this issue, we propose a new Student Model (Enhanced-Overlay-Model) that has expanded the existing Overlay-Model. This enables the easiness of the teaching materials and at the same time lets the system comprehends the student's comprehension situation (where his/her weak parts are.)

This paper shows you with specific actual examples how the system works in Student Models and the Instruction Programs to identify the student's weak part, and will prove the effectiveness of the proposed Student Model and Instruction

Program through experiments. However, CAI system based on Branching Program has not been constructed hardly in spite of its great learning efficiency. The reason behind this is the structure of the control program (called the learning control program) that controls the presentation of the teaching materials frame. This needs to be innovated, otherwise you need to change the control program when adding, deleting, or changing the presentation order. Lastly, we will present the format of this paper.

II. Learning control Instruction Program

A. Student Instruction Program and the Branching Instruction Program

As Fig.1 shows, the Instruction Program is generally classified into two types. One, the Instruction Program used in B.F.Skinner's Teaching Machine [4][5] with a characteristic that whether the answer of the student is correct or not, the teaching materials frame presented next is always the same. Student Instruction Program completely blunts the student's comprehension situation; therefore the student has to learn the already comprehended, this clearly shows bad learning efficiency. By contrast, to solve this inadequacy, N.A.Crowder [6] has propounded an Instruction Program where the next presented teaching materials frame dynamically changes according to the student's correct/incorrect answer to a given question. Branching Instruction Program is the first Instruction Program that considers the student's comprehension situation and is highly appreciated because of that point.

The present study promotes the idea of Branching Instruction Program with a system that keeps on branching the teaching materials frame by seeking the weak part of the student, and by the system itself, identifying what the weak part of the student is, we aim to construct a system such that student only needs to learn his/her weak parts.

But we don't intend to study the structure of the learning control program that it is not necessary to change the structure when screens of teaching-materials were added, and/or deleted, and/or display sequences of teaching-materials were changed. Because even if Branching Instruction Program can detect student's flaws in student understands, the instruction program to remedy of the flows cannot be realized only with Branching Program. In order to realize such a CAI system, which detects and remedies student's flaws in student's understanding, the Student Model and the Instruction Program based on the Student Model are necessary. We aim at building of CAI System, which has Instruction Program that identify and remedy student's flaws from a point of view of understanding.

B. The CAI System which we aim at

Some Student Models, which identify and remedy Bugs (such as wrong understanding, wrong usage knowledge and deficient understanding) as student's flaw from point of view of understanding have been proposed and discussed. However, we embrace student's weak part as student's flaw. In other words, we aim at implementing CAI System, which identify

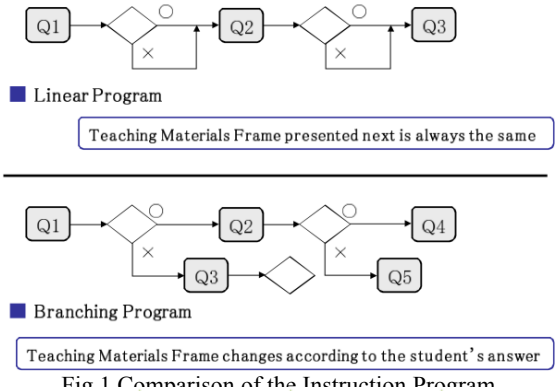

Fig.1 Comparison of the Instruction Program

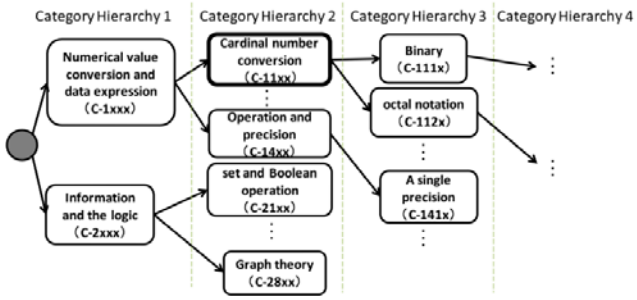

Fig.2 Example of the field to learn hierarchical classification according to the whole-part relationship

and remedy Student's weak parts. To define Student's Weak Part, we bring in notion of category, which shows the classification that a learning object, which the student should learn (It is equivalent to the learning subject) was classified into hierarchically based on the containment relationship. In addition, the category is described always in the tree structure.

We target only the course that knowledge of learning object is classified into hierarchically based on the containment relationship as tree structure. Fig.2 shows the example that course "information processing technology" is classified into hierarchically based on the containment relationship. The category of "the numerical value change and the data representation" in the category hierarchy 1 is classified into the category such as "radix conversion" and "operation and precision" in the category hierarchy 2 based on the containment relationship. In addition, the category of "the radix conversion" in the category hierarchy 2 is classified into the category such as "binary numeral" and "octal number" in the category hierarchy 3.

We define the student weak part as follows. We suppose that the certain course is classified based on inclusion relations hierarchically. When five questions which belong to certain category "***C***" are delivered to student collectively in one frame (Called Decision Frame) and are answered incorrectly, we define the minimum category "***C***" which includes those questions as the student's weak part. For example, when five questions, which belong to category "radix conversion" of the category hierarchy 2 in Fig.2, are delivered and answered incorrectly, the "radix conversion" is student weak part. Such a category is called "a weak category".

III. Student Model

A. What is a Student Model?

A Student Model is [7][8] a barometer for the system to comprehend the student's comprehension situation. In details, the Student Model is a barometer that clarifies "which parts the student is uncomprehending" and "which and how they did not comprehend." This is the content of learning aimed by the teaching material creators. The reason behind this is because, when the parts that students are uncomprehending become clear, an Instruction Program that concentrates on the part that they did not comprehend can be built. When the student wrongly comprehends, the Instruction Program that can remediate that part can be built. At the same time, teaching materials frame is an ingredient to build the Instruction Program.

1) Overlay-Model [7]-[10]

The characteristic of the Overlay-Model is that you only need to put a flag to the articles that the student has comprehended, so the Student Model is easily constructed; therefore, the teaching materials are easier. However, this model enables the modeling of the student's wrong knowledge despite the fact that it can model the lack of knowledge in a student. As just described, the Overlay-Model simplifies the Student Model for easier creation of the student model, but is not suitable for comprehending the student's comprehension situation (where is the student's weak part)

To be more precise, like TABLE I or TABLE II, preliminarily and neatly define learnings in corresponding relationships between questions and learnings. Based on the corresponding relationship, when the student's answer is correct, evaluate it as comprehended, and by placing a check-mark(□), it regulates which learnings are comprehended. Though at this time, when you try to handle several questions in one learning like TABLE I, since the granularity of the learnings is uneven, when you try to even the granularity of the question, the number of questions to once learning will be uneven.

For this reason, a rule is necessary per learnings as to how many correct answers are needed out of how many questions to assume comprehension, and a function is necessary to define the correspondent relationship between the learnings and questions per learnings, so depending on the structure of the learning control program, you have to rewrite it according to the course material. Meanwhile, if you state the corresponding relationship of learnings and questions in one to one basis like TABLE II, the necessary rule per learnings as to how many correct answers are needed out of how many questions to assume comprehension will vanish, so the need to rewrite the control program of learnings per teaching materials vanishes as well. Consequently, many of the commercialized system state the correspondence relationship between learnings and questions on one to one basis like TABLE II.

The characteristic of the Overlay-Model is that you only need to put a flag(□) to the articles that the student has comprehended, so the Student Model is easily constructed; therefore, the teaching-materials are easier. However, this enables the modeling of the student's wrong knowledge despite the fact that it can model the lack of knowledge in a student. For example, TABLE II shows that the student cannot comprehend learnings L-002, but you cannot tell where and why they made a mistake. As just described, the overlay-Model simplifies the Student Model for easier creation of the student model, but is not suitable for comprehending the student's comprehension situation.

TABLE I
EXAMPLE OF ONE TO N BASED OVERLAY MODEL

Fin/ Unfin	Learnings	Correct/ Incorrec	Question Number
✔	L−001	○	D−001
		×	D−002
		○	D−003
✔	L−002	○	D−004
		○	D−005
		×	D−006
		○	D−007
		×	D−008

TABLE II
EXAMPLE OF ONE TO ONE BASED OVERLAY MODEL

Fin/ Unfin	Learnings	Correct/ Incorrec	Question Number
✔	L−001	○	D−001
	L−002	×	D−002
✔	L−003	○	D−003

2) Bug model[7][8]

The Bug Model expresses the bug situation that the student has where Overlay-Model could not, and it enables to comprehend the bug situation with precise details. However, taking the view of model construction, the bug model is an expression by combinations of preliminarily analyzed student bug, therefore preparation procedure is enormous and the teaching materials creator's overload issue arises. Consequently, the Bug Model precisely comprehends the bug situation that the student has, but then again the teaching material creations that accommodate the model will be very troublesome. This is why the commercial CAI system hardly adopts it

Therefore, we don't adopt the strategy that the CAI system grasps and corrects the bugs of the student minutely by expressing the bugs. We adopt the strategy that the CAI system grasps the weak part of the student for the lack of knowledge of the student minutely to let the student study the weak part intensively.

B. Enhanced-Overlay-Model

We aim at implementing CAI System, which identify and remedy Student's weak parts. To do that, Student Model is necessary. There is Bug's Model as the student model, which is already suggested to. However, Bug's Model is an expression

by combinations of preliminarily analyzed student bug, therefore preparation procedure is enormous and the teaching-material creator's overload issue arises. We embrace student's weak part as student's flaw. We expand the Overlay Model to Student Model, which can identify the weak category of the student that couldn't do it with the overlay model. Such a model is the following Enhanced Overlay Model.

1) Classification of learning object into hierarchically based on the containment relationship

The questions asked to the student refer inevitably to some the field to learn. For example, the question "Ask for the two's complement of 01011100 binary digit" refers to the (complement representation) field. Because of this, limit it to the field to learn that hierarchical can classify based on the relations between the whole and the part, and discuss it by this thesis. Theoretically speaking, the number of category hierarchies can be many, but hierarchal-number needed for the teaching material's (teaching course) assortment intended for learning will differ. For example, when the (numerical inversion and data representation) is referred to as a whole, it can be hierarchically classified into finely the field to learns showed in Fig.2.

By the way, it is common that one question refers to several categories in each hierarchy. For example, question "display decimal number -5 in 8 BIT, binary digit, and answer with hexadecimal the result of 3BIT arithmetic shift to the right. But, show the negative number in two's complement" refers to these three categories; "radix conversion", "complement representation" and "arithmetic shift." The learner model that we suggest it to accept that one question belongs to plural categories.

The correspondence relationship between the category number and category name is defined by preparing a category table such as TABLE III for every learner. Like the Overlay Model, we record the category that the student finished learning by adding a checkmark to the item finished with learning.

We allot the category number to a category in a form to show in Fig.3. Fig.3 shows an example of category number C-132xx ... The digit number of numbers after C- is the same as the greatest category hierarchy number of the teaching materials. In this example, digits after the upper three figures are x. This shows that the category that this category number shows is a category of the category hierarchy 3. This number become C-13xxxxx... when the first third place digit is replaced by x. This category number shows a category of category hierarchy 2 and shows that category C-132xxx ... is a category included by this category. This form makes it easy to grasp the classification of the category based on the containment relationship by watching a category number.

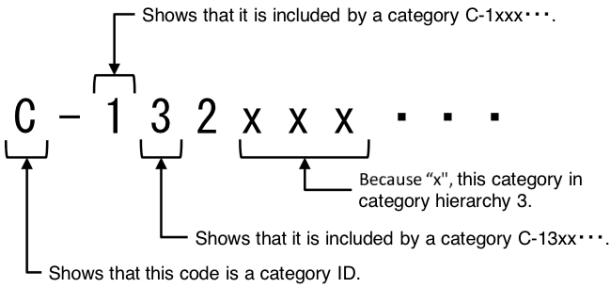

Fig.3 Category ID format

2) Constraint about the learning order

TABLE III
ORDER-CONSTRAINED (THE FIELD TO LEARN OF) CATEGORY LIST TABLE

Number of Learnings	Questions Possible	Category Number	Category Name	Flow-constrained category		
				Compre hended	Priority Caegory	Follow-on Category
1	✓	C-1000	Numerical Inversion and Data Representation			C-2000
						C-3000
0	✓	C-2000	Information and Logic	✓	C-1000	C-3000
0		C-3000	Mathematical Application	✓	C-1000	
					C-2000	

TABLE IV
MANAGEMENT TABLE STATUS OF EACH THE ANSWER OF THE STUDENTS

Display Numbe	Questio n ID	Correct/ Incorrect	Focused Hierarch	Affiliated Category		
				Hierarchy1	Hierarchy2	Hierarchy3
F-003	D-001	X	1	C-1xxx	C-12xx C-13xx	C-121x C-131x C-132x
F-003	D-002	O	1	C-1xxx	C-13xx	C-133x
F-003	D-003	X	1	C-1xxx	C-11xx	C-112x C-113x
F-003	D-004	O	1	C-1xxx	C-13xx C-14xx	C-133x C-142x
F-003	D-005	X	1	C-1xxx	C-13xx	C-133x C-134x

In addition learning order rules like; "only after you comprehended division, you can comprehend fraction, so you have to learn division before fraction" exists between the fields to learn. We call it the Learning ordering constraints.

Only the teaching material which the category to satisfy ordering constraints has can be indicated to the student. However, it becomes much cost is equal to necessity that ordering constraints between the categories that the depth of the hierarchy is different is defined. Because, it is necessary to read for consistency of the constraints such as a circular reference. If an author of teaching materials must define ordering constraints in lower hierarchy the hierarchy 1, his / her burden is increased. Therefore, we define ordering constraints about the category of the hierarchy 1 alone whose category hierarchy is the shallowest.

So, extract all the flow-constraint that exist between the fields to learns, and define them all using the Category List Table shown in TABLE III. For example, category in TABLE III shows that you cannot learn C-3xxx "Mathematical Application" before learning C-1xxx "numerical inversion and data representation" and C-2xxx "Information and Logic."

Now, in number of learnings in TABLE III represents the student's learned, comprehended, or to count that. There are two ways to use the number of learnings. One, use it to provide balance between the numbers of the comprehended categories. Another, it is risky to think that you corrected one refer category question out of the whole hierarchy, so, let the hierarchy answer a few questions from the refer category to think it has comprehended. How many numbers are needed for the standard learning number? I want to answer this after

operating this system and with considerable experience.

3) Management of each the answer of the students

Weak part differs within the student. To identify the weak part per student, prepare a table that administrates the answer situation per question like TABLE II. TABLE IV is configured with teaching materials frame number F-003 with five questions D-016, D-017, D-018, D-019, D-020, and shows which the field to learn they refer to in each hierarchy and each question. For example, question D-018 is C-1xxx when viewed in hierarchy 1, C-11xx in hierarchy 2, C-112x, and C-113x in hierarchy 3 and shows which the field to learn (category) they refer to.

In TABLE IV, the focused hierarchy field is stated as one. This means "attention on field hierarchy 1." So, view field hierarchy 1 and find that there are five categories ID C-1xxx aliened. This states that, under the hypothesis that the student's weak part is C-1xxx, five questions submitted are all with C-1xxx as affiliated category at hierarchy 1. Then, look at the correct, incorrect information field. Question ID D-008 and D-010 is X when others are all O, so this student answered incorrectly on D-008 and D-010 only, and correct on other three questions.

The Student Model configured in TABLE III and TABLE IV is called "Enhanced-Overlay-Model" at present study

IV. Strategic Knowledge to Identify the Weak Part, and Adopting Instruction Programs

A. Strategic Knowledge to identify the weak part

Fig.4 shows the system overall processing flow illustrated as a flow-chart. The system presents the Decision Frame first, to identify the student's weak part. By doing so, when the weak part is identified, the Text Frame of knowledge intended for learning is presented by remediation of incorrect knowledge, making up for lacking knowledge. The system presents the Test Frame after several Decision Frames are presented. On the other hand, a normal CAI system presents the Decision Frame after several Text Frames has been presented. In that sense, please note that not only the presentation order compared to the normal CAI system is reversed, but whichever frame is used mainly is reversed as well.

To identify the student's weak part (category), we used the four following strategic knowledge in the system.

[S1] For several questions that refer to the same category, when the same student answers incorrect for all, there is a possibility that that category is the weak part. Contrarily, the category is not a weak part if the student answers correctly in all the questions.

[S2] For several questions that refer to the same category, the same student answers correctly and incorrectly; there is a possibility of a weak part and a weak field existing in a subordinate position in the incorrectly answered question located in the presently focused category

[S3] When the same student answers incorrect on a question; there is a possibility of a common weak part (category) hidden beneath referring category-refer category based product set.

[S4] The same student answers incorrect on a question; when the refer category based product set becomes an empty set in the hierarchy (simply, a common weak part could no be found in the incorrectly answered questions) if you do sum of sets operation to the same category that you have done product set operation earlier, there is a possibility of a weak part category that configures the result.

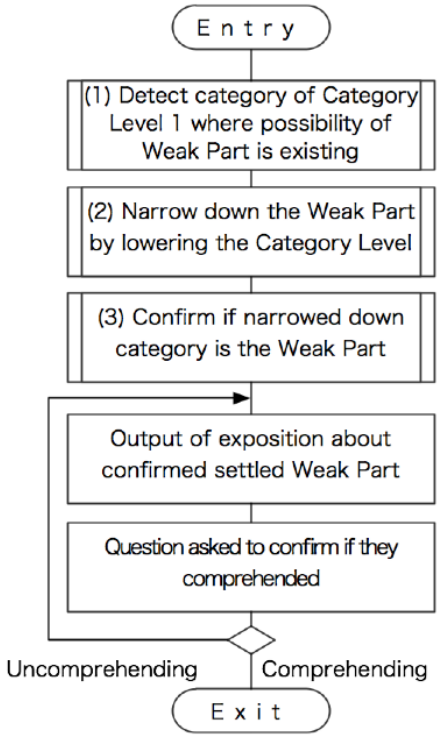

Fig.4 Process flow of the whole system

B. Identifying weak category of the student on Hierarchy 1.

Here, we detect the category hierarchy 1 that has a possibility of having a weak part in a subordinate position using the procedures below.

1. Choose one question from each category that can be questioned from TABLE I and let each question be minor-question. The system generates and asks questions (groups of minor questions) that are chosen. In this paper, "category that can be questioned" means category with check mark in Question Possible in TABLE I and category hierarchy is one.
2. Student answers every minor question.
3. At this time, if the student answers correctly in every minor question, you cannot detect the student's weak part from this question (groups of minor questions), so go back to 1. to let the system generate other questions to be asked. As for categories of the question of the correct answer, 1 increasing "learning number of time" in TABLE I and give a check mark to the following category's "Questions Possible". If the student incorrectly answers a question in the minor question, this student's weak part is in

subordinate category in category hierarchy 1, so move onto 4.

4. Choose one the field to learn from top of the category ID in the field to learn of category hierarchy 1 that the student answered incorrectly and select 5 questions from the category ID to be asked.
5. When the student answers incorrectly in all the five questions, assume that hypothesis is attested (weak part identified) and move on to the Instruction Program where remediation of the weak part occurs.
6. If the answer correct/incorrect is mixed, assume that weak part cannot be identified in the field to learn of category hierarchy 1, and refine the hypothesis by lowering the category hierarchy about all the questions that the student answered as incorrect.
7. If the student answers all five questions correctly, the system judges weak part was not identified within category hierarchy 1.And prepare new five questions with a category ID (on hierarchy 2) to be obtained by lowering one level category hierarchy that questions chosen in 4. belongs to.

C. Identifying weak category of the student on lower than Hierarchy 2.

There are three patterns in Identifying weak category of the student on lower than hierarchy 2.

1. When the question that was not answered correctly by a learner does not belong to the same category
2. When there is category that all incorrectly answered questions belong to, and all correctly answered questions don't belong to.
3. When there is category that all incorrectly answered questions and correctly answered questions belong to.

We will explain how our CAI System narrow down categories and how the System generate hypotheses that the category is the weak category of the student. In addition, we define the formula to get the set of the category, which a question belongs to, in a certain category hierarchy.

First, each question has the unique ID number, and the number which indicates which category that question belongs to in each category hierarchy When ID number of a question and category hierarchy to notice are indicated, we can know which category the question belongs to.

We define $CH(D-X,h)$ as follows. $CH(D-X,h)$ is a set of categories that a question, which ID number is *X*, belongs to in the indicated category hierarchy *h*. The reason for assuming the set, one question that there is a possibility of belonging to two or more categories in a specific category hierarchy. For example, the question of question ID "D-016" is specified set of categories ID of the category that belonged to category hierarchy 2 when writing "$CH(D-016,2)$"

1) When the question that was not answered correctly by a learner does not belong to the same category

When the question that was not answered correctly by a learner does not belong to the same category, we narrow down the Weak Part and go through the algorithm to generate the candidate as hypothesis. Refer to TABLE V for example. TABLE V is the same Table as TABLE IV, only the number section is abbreviated, and hierarchy 4 is added in the open category of the affiliated category section.

TABLE V
MANAGEMENT TABLE FOR STATUS OF ANSWERS IN EACH LEARNERS (ILLUSTRATION1)

Question ID	Correct /Incorre	Focused Hierarch	Affiliated category			
			Hierarchy	Hierarchy	Hierarchy	Hierarchy
D-006	X	1	C-1xxx	C-12xx C-13xx	C-121x C-131x C-132x	C-1211 C-1312 C-1322
D-007	O	1	C-1xxx	C-13xx	C-133x	C-1332 C-1333
D-008	X	1	C-1xxx	C-11xx	C-112x C-113x	C-1122 C-1132
D-009	O	1	C-1xxx	C-13xx	C-133x	C-1332
D-010	O	1	C-1xxx	C-13xx	C-133x C-134x	C-1334 C-1342

This is, under the hypothesis that the student's Weak part is C-1xxx, an aspect where five questions are gathered from the affiliated category C-1xxx in hierarchy 1, and the answer of the student is divided into questions that are answered correct/incorrect. At this time, apply strategic knowledge [S2] to identify the student's Weak Part, and notice that there is a possibility of an existing non-weak part and a Weak Part field, in the subordinate category C-1xxx (here as hierarchy 2) where incorrectly answered questions are focused. To identify the Weak Part of the student, decide which strategic knowledge should be applied. Focus on the refer category that the student incorrectly answered in hierarchy 2 question, and take the product set, in result;

$$\begin{aligned} &CH(D-006,2)\cup CH(D-008,2) \\ &=\{C-12xx,C-13xx\}\cup\{C-11xx\} \\ &=\phi \end{aligned} \tag{1}$$

Therefore, strategic knowledge [S4] is applied to identify the student's Weak Part. Given this factor, sum of sets operation to the same category as product set operation will result in;

$$\begin{aligned} &CH(D-006,2)\cap CH(D-008,2) \\ &=\{C-11xx,C-12xx,C-13xx\} \end{aligned} \tag{2}$$

And assume that several Weak Parts are hidden inside the assembled category in the configured hierarchy (here, as hierarchy 2.) To research if these categories contain the Weak Part, again apply strategic Knowledge [S2] to identify the student's Weak Part. For that, take the sum of sets with refer category of the same hierarchy (here as hierarchy 2) questions that the student answered correctly will be;

$$CH(D-007,2) \cup CH(D-009,2) \cup CH(D-010,2) = \{C-13xx, C-14xx\} \quad (3)$$

Subtract this sum of sets from the previous;

$$CH(D-006,2) \cup CH(D-008,2) - CH(D-007,2) \cup CH(D-009,2) \cup CH(D-010,2) = \{C-11xx, C-12xx\} \quad (4)$$

So there is a possibility of the student's Weak Part contained in the subordinate category of C-1xxx and C-12xx. More specifically, each category that configures {C-112x, C-113x, and C-121x} refers to it as the Weak Part candidate.

If;

$$CH(D-006,2) \cup CH(D-008,2) - CH(D-007,2) \cup CH(D-009,2) \cup CH(D-010,2) = \phi \quad (5)$$

Then retrieval cue for the Weak Par will be lost, so assume that retrieval for Weak Part has failed. When there is an empty set of the refer category product set in the same hierarchy of the question that the same student answered incorrectly, we narrow down the Weak Part and go through the algorithm to generate the candidate as hypothesis. The above algorithm will be called "algorithm A." For all the arguments, algorithm A can be sorted as below.

1. Take the product set of refer category in the same hierarchy where the same student answered as incorrect.
2. Take the sum of sets to the same previous category since the product set is an empty set.
3. Take the sum of sets operation to the same previous category hierarchy that product set operation has been done in the questions that the student answered correct.
4. Subtract the sum of sets provided at 2. from the sum of sets given at 3).
5. Assume each component category assembled in 4. as the weak part candidate.
6. When 4. is assemble of empty sets, assume that weak part retrieval has failed.

The below algorithm will be called "algorithm A."

2) When there is category that all incorrectly answered questions belong to, and all correctly answered questions don't belong to.

When there is category that all incorrectly answered questions belong to, and all correctly answered questions don't belong to, sum of sets of the refer category in the hierarchy where product set operation has been done, and also in a case where the subtracted result from the product set is not an empty set, we narrow down the Weak Part and go through the algorithm to generate the candidate as hypothesis.

TABLE VI
MANAGEMENT TABLE FOR STATUS OF ANSWERS IN EACH LEARNERS (ILLUSTRATION2)

Question ID	Correct /Incorre	Focused Hierarch	Affiliated category			
			Hierarchy	Hierarchy	Hierarchy	Hierarchy
D-011	O	1	C-1xxx	C-13xx	C-131x C-132x	C-1313 C-1323
D-012	O	1	C-1xxx	C-12xx	C-122x	C-1221 C-1223
D-013	X	1	C-1xxx	C-11xx C-13xx	C-112x C-133x	C-1121 C-1331 C-1332
D-014	O	1	C-1xxx	C-12xx	C-121x C-122x	C-1214 C-1222
D-015	X	1	C-1xxx	C-11xx C-13xx	C-111x C-132x	C-1112 C-1321

Refer to TABLE VI for example. TABLE VI is the same Table as TABLE V, like TABLE IV, the number section is abbreviated, and hierarghy4 is added in the open category of the affiliated category section. This is, under the hypothesis that the student's Weak part is C-1xxx, an aspect where 5 questions are gathered from the affiliated category C-1xxx in hierarchy1, and the answer of the student is divided into questions that are answered correct/incorrect.

At this time, apply strategic knowledge [S2] to identify the student's Weak Part, and notice that there is a possibility of an existing non-weak part and a Weak Part field, in the subordinate category C-1xxx (here as hierarchy 2) where incorrectly answered questions are focused. To identify the Weak Part of the student, decide which strategic knowledge should be applied. Focus on the refer category that the student incorrectly answered in hierarchy 2 question, and take the product set, in result;

$$CH(D-013,2) \cap CH(D-015,2) = \{C-11xx, C-13xx\} \neq \phi \quad (6)$$

Therefore, strategic knowledge [S3] is applied to identify the student's Weak Part, and assume that there is a possibility of a common Weak Part hidden in {C-11xx, C-13xx} to research if these categories are Weak Part candidates, again apply strategic Knowledge [S2] to identify the student's Weak Part. For that, take the sum of sets of affiliated category in hierarchy 2 that were answered correctly in TABLE VI questions (here D-011, D-012, and D-014) will be;

$$CH(D-011,2) \cup CH(D-012,2) \cup CH(D-014,2) = \{C-12xx, C-13xx\} \neq \phi \quad (7)$$

Subtract this sum of sets from the product set;

$$\begin{aligned} &CH(D-013,2)\cup CH(D-015,2)\\ &-CH(D-011,2)\cup CH(D-012,2)\\ &\cup CH(D-014,2) \\ &=\{C-11xx\}\\ &\neq \phi \end{aligned} \quad (8)$$

The answer to the referred question C-11xx by this student are all incorrect, so use strategic knowledge [S1] to identify the student's Weak Part, and in case of TABLE VI, C-11xx is judged as the Weak part candidate of this student. In the question where the same student answered incorrect, referring to the same category of the same hierarchy, and when the product set is not an empty set, in the question that this student answered correctly, sum of sets of the refer category in the hierarchy where product set operation has been done, and also in a case where the subtracted result from the product set is not an empty set, we narrow down the Weak Part and go through the algorithm to generate the candidate as hypothesis. The above algorithm will be called "algorithm B."

For all the arguments, algorithm B can be sorted as below.

1. Take the product set of refer category in the same hierarchy where the same student answered as incorrect.
2. When the product set is not an empty set, take the sum of sets of refer category of the same hierarchy in the question that the same student answered correct.
3. When the operation result of (product set - sum of sets)is not an empty set, each category that configure the result of this operation, assume that it is this student's weak part candidate.

The below algorithm will be called "algorithm B."

3) When there is category that all incorrectly answered questions and correctly answered questions belong to.

When there is category that all incorrectly answered questions and correctly answered questions belong to, we narrow down the Weak Part and go through the algorithm to generate the candidate as hypothesis. Refer to TABLE VII for example. TABLE VII is the same Table as TABLE V, like TABLE IV, the number section is abbreviated, and hierarghy4 is added in the open category of the affiliated category section.

TABLE VII
MANAGEMENT TABLE FOR STATUS OF ANSWERS IN EACH LEARNERS (ILLUSTRATION3)

Question ID	Correct /Incorre	Focused Hierarch	Affiliated category			
			Hierarchy	Hierarchy	Hierarchy	Hierarchy
D-016	X	1	C-1xxx	C-11xx C-12xx	C-113x C-121x	C-1134 C-1211
D-017	X	1	C-1xxx	C-12xx C-13xx	C-121x C-132x	C-1211 C-1323
D-018	O	1	C-1xxx	C-11xx	C-111x C-112x	C-1114 C-1123
D-019	O	1	C-1xxx	C-12xx C-13xx	C-122x C-131x	C-1224 C-1311 C-1312
D-020	O	1	C-1xxx	C-13xx	C-131x	C-1311 C-1312

This is, under the hypothesis that the student's Weak part is C-1xxx, an aspect where 5 questions are gathered from the affiliated category C-1xxx in hierarchy1, and the answer of the student is divided into questions that are answered correct/incorrect. At this time, apply strategic knowledge [S2] to identify the student's Weak Part, and notice that there is a possibility of an existing non-weak part and a Weak Part field, in the subordinate category C-1xxx (here as hierarchy 2) where incorrectly answered questions are focused. To identify the Weak Part of the student, decide which strategic knowledge should be applied. Focus on the refer category that the student incorrectly answered in hierarchy 2 question, and take the product set, in result;

$$\begin{aligned} &CH(D-016,2)\cap CH(D-017,2)\\ &=\{C-12xx\}\\ &\neq \phi \end{aligned} \quad (9)$$

Therefore, strategic knowledge [S3] is applied to identify the student's Weak Part, and assume that there is a possibility of a common Weak Part is hidden inside {C-12xx} Next, to judge if this category can be a Weak Part candidate, again apply strategic Knowledge [S2] to identify the student's Weak Part. For that, take the sum of sets within the affiliated category of hierarchy 2; the questions (here D-018□D-019□and D-020) that the student answered correctly will be;

$$\begin{aligned} &CH(D-018,2)\cup CH(D-019,2)\\ &\cup CH(D-020,2)\\ &=\{C-11xx,C-12xx,C-13xx\} \end{aligned} \quad (10)$$

Subtract this sum of sets from the product set will be;

$$\begin{aligned} &CH(D-016,2)\cap CH(D-017,2)\\ &-CH(D-018,2)\cup CH(D-019,2)\\ &\cup CH(D-020,2)\\ &=\phi \end{aligned} \quad (11)$$

The operation result of (product set-sum of sets) is an empty

set, the same category (here C-12xx) referring to several questions, the same student at one-hand answers correct, and on other hand incorrect. So again, apply strategic knowledge [S2] to identify the Weak Part of the student, judge that there are fields with Weak Part and non-Weak Parts. Hence, look for the subordinate category in C-12xx (hierarchy 2) to find the Weak Part candidate. Therefore, looking at the Category Level 1 below question D-016 and D-017 that the student answered incorrect, they both are C-121x, that means;

$$CH(D-016,3) \cap CH(D-017,3) = \{C-121x\} \quad (12)$$

For this, to identify the Weak Part of the student, apply strategic knowledge [S3] and notice that there is a possibility of a common Weak Part (category) hidden in C-121x. Therefore, to find out if C-121x is the Weak Part of the student, apply strategic knowledge [S2] and subtract category in hierarchy 3, in question answered correct that has C-12xx will be;

$$\begin{aligned} &CH(D-016,3) \cap CH(D-017,3) \\ &-CH(D-019,3) \\ &= \{C-121x\} - \{C-122x, C-131x\} \\ &= \{C-121x\} \\ &\neq \phi \end{aligned} \quad (13)$$

The student's answers to the questions C-121x were all incorrect, so by applying strategic knowledge [S1], the Weak part candidate of this student can be judged as C-121x. In addition, example in chart (12) was;

$$\begin{aligned} &CH(D-016,3) \cap CH(D-017,3) \\ &= \{C-121x\} \\ &\neq \phi \end{aligned} \quad (14)$$

But if this was for example;

$$\begin{aligned} &CH(D-016,3) \cap CH(D-017',3) \\ &= \{C-121x\} \cap \{C-123x\} \\ &= \phi \end{aligned} \quad (15)$$

Then by applying strategic knowledge [S4], this student's Weak Part candidate would be two, C-121x and C-123x. The question where the same student answered incorrect, referring to the same category of the same hierarchy, and when the product set is not an empty set, and in the question that this student answered incorrectly, sum of sets of the refer category in the hierarchy where product set operation has been done and also in a case where the subtracted result from the product set is an empty set, we narrow down the Weak Part and go through the algorithm to generate the candidate as hypothesis. The above algorithm will be called "algorithm C." For all the arguments, algorithm C can be sorted as below.

1. In the question that the same student answered incorrect, take the product set of refer- category of the same hierarchy.
2. When the product set is not an empty set, in the question where this student was correct, take the sum of sets in the refer category in the previous same hierarchy.
3. When the result of the operation (product set-sum of sets) is the empty set, take the product set of the categories one below the category that configures the product set.

The below algorithm will be called "algorithm C."

Using these algorithms A/B/C, we generate the hypothesis of the weak part of a student. But first, if the product set of the category from the category hierarchy one below the incorrectly answered question is an empty set, apply algorithm A. If the product set is not an empty set, operate (product set - sum of sets) and in result if it is not an empty set, apply algorithm B, if it is an empty set, apply algorithm C.

TABLE VIII
MANAGEMENT TABLE FOR STATUS OF ANSWERS IN EACH STUDENTS

Question ID	Correct /Incorre	Focused Hierarch	Affiliated category			
			Hierarchy	Hierarchy	Hierarchy	Hierarchy
D-021	X	2	C-1xxx	C-11xx	C-113x	C-1131
D-022	X	2	C-1xxx	C-11xx	C-112x	C-1121
D-023	X	2	C-1xxx	C-11xx	C-111x	C-1111
D-024	X	2	C-1xxx	C-11xx C-12xx	C-111x C-122x	C-1111 C-1221
D-025	X	2	C-1xxx	C-11xx C-13xx	C-111x C-132x	C-1211 C-1322

D. Verification whether or not a weak part was identified definitely.

The procedures to confirm if derived weak part candidate (hypothesis) is truly the weak part, applies to the any of the above, so we will take C-11xx case for example and explain.

To confirm whether if C-11xx is the student's Weak Par or not, prepare five questions from the referred questions to C-11xx as in TABLE VIII. If the answers of the students to these questions are all incorrect like TABLE III, by applying the strategic knowledge S1 to identify the weak part, C-11xx is taken as the weak part of this student.

If there are both correct, incorrect answered questions, to identify the weak part, apply strategic knowledge judge that the granularity is big (in the subordinate of category C-11xx focused questions answered incorrectly, there is a possibility of a Weak, non-Weak field both existing.) This situation is completely same as 4.2 (narrowing down the weak part in category hierarchy 1) so apply the same process as 4.3 (narrowing down the weak part under category hierarchy 2.)

V. EVALUATION OF ENHANCED-OVERLAY-MODEL AND INSTRUCTION PROGRAM EFFECTIVENESS

To confirm that system with combination of Sub Chapter 3.3 proposed "Enhanced-Overlay-Model" and Chapter 4 "Instruction Program" is effective, we experimented with 68 freshmen students as examinees from information and technology department, Shibaura Institute of Technology.

For this experiment, we used the past exam problems from

the basic information technology electrical engineer examination, and with computational problems as the center we chose subjects such as; radix conversion, numerical representation (complement/decimal fraction), shift operation (logic, arithmetic, rotation) and created 36 questions. We chose computational questions as the center because you have to comprehend what procedures to calculate, so there will be clarity between what is comprehended and what not. However, when the answer candidates (group of answers) are already prepared within the question type format, there will be a possibility of the examinees choosing the correct question even though they do not comprehend. Therefore, we deleted the candidates (group of answers) from the question, and changed it to fill in the blank type questions.

In this manner description-type created paper, test questions were answered by the examinees and corrected, then we observed it following the flow of weak part identifying processing as described in Chapter 4.

TABLE IX shows the number of examinees that have been identified having a weak part in the category, and having a category that is identified as their weak part in the experiment.

But the category name to the category ID in TABLE X each corresponds as below; C-11xx "radix conversion," C-112x "septinary number radix conversion," C-12xx "numerical representation," C-121x "complement representation," C-122x "decimal fraction representation, " C-13xx "shift operation," C-132x "arithmetic shift," and C-1322 "rightward arithmetic shift."

TABLE IX
ALGORITHM APPLICABLE ORDER USED TO IDENTIFY THE WEAK PART, RIGHT/WRONG.

Pattern	Algorithm applicable				Identify	Applicable Count
	No.1	No.2	No.3	No.4		
1	A	—	—	—	success	5
2	A	A	—	—	success	11
3	A	B	—	—	success	5
4	B	—	—	—	success	11
5	B	A	—	—	success	7
6	B	A	B	—	success	2
7	B	B	—	—	success	5
8	B	B	B	—	success	1
9	C	—	—	—	success	9
10	C	A	—	—	success	6
11	C	A	A	—	success	3
12	C	A	B	—	success	1
13	C	A	B	B	success	1
14	C	B	—	—	success	1
total	—	—	—	—	—	68

TABLE X
IDENTIFIED WEAK PART PER APPLICABLE COUNT

Weak Part	Applicable count (person)
C-11xx	1
C-112x	2
C-12xx	2
C-121x	4
C-122x	2
C-13xx	15
C-132x	28
C-1322	4
C-133x	3
C-11xx C-12xx	1
C-121x C-133x	1
C-132x C-133x	5
Total	68

VI. SUMMARY AND FUTURE TASKS

We focused on the issues that many commercialized CAI adopted student Programs have presently. Student Program has a characteristic of presenting the next teaching materials frame to be always the same, no matter if the answer of the student is correct / incorrect. For that, the student has to learn the already comprehended, and to parts where they fundamentally do not need, therefore this system cannot be stated as efficient. To solve this issue, we have to adopt a Branching Program that changes the next presented teaching materials frame dramatically depending on the student's correct/incorrect answer. However, CAI system based on Branching Program has not been constructed hardly in spite of its great learning efficiency. The reason behind this is the structure of the control program (called the learning control program) that controls the presentation of the teaching materials frame. This needs to be innovated, otherwise you need to change the control program when adding, deleting, or changing the presentation order.

We aimed for constructing a system that is useful and with good CAI system efficiency by promoting the idea of the Branching Instruction Program further, which the student has to learn their weak parts only. For the system to identify the weak part of a student, we adopted a concept of category, which is a sorting and a classification category in the field to learn. Based on the truth that "learning filed can be hierarchically classified according to the whole-part relationship" we approached to identify which classification category in the hierarchy of the field to learn, the student's weak part refers.

To deliver the above idea, we propose the improved existing Overlay Model, "Enhanced Overlay Model" and an Instruction Program for the system to identify the weak part of the student. In addition, by utilizing the "Enhanced Overlay Model" and the Instruction Program, we experimented with 68 student examinees to confirm the weak part of all of them to prove the effectiveness of the Program and the Model that we have proposed. The proposed Instruction Program is under the assumption that the student has imperfect background information to the intended learnings. Consequently, the Decision Frame to identify the weak part of the student is presented first, and Text Frame to make up for the lack of the student's knowledge is presented after presenting Decision Frame. The system presents the Text Frame after several Decision Frames have been presented. The system presents the Text Frame after several Decision Frames have been presented. In that sense, the presentation order compared to the usually CAI system is opposite, and not only that, but the positioning as to which frame is considered the main frame differs too. We further need to discuss the position of the Text Frame in these circumstances and situations.

In addition, CAI system based on the "Enhanced Overlay Model" and the Instruction Program suitable for practical use should follow the Instruction Program, and the Decision Frame generated by the system in each situation to come up with the necessary "Generative Course Wear."

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