A RESTUDY THEORY BASED ON RELATED UNITS AND A PRODUCTION OF THE SYSTEM.

by

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ABSTRACT

A restudy theory is introduced, which is a kind of educational methodolosy for effective control of the order of problem presentation. It is created from the idea that, if we can control the cross relations between problems and units such as chapters and paragraphs, the automatic selection of the appropriate problems must be capable accordings to the restudy step of the student.

When teachers intend to do absolute evaluation concerning the amount of restudy, this theory is very useful. The curriculum using the CAI system based on this theory besides the normal lecture is considered to be very effective especially for the student who could not get enough understanding about the given textbook.

We show an example of application of this theory, a kind of CAI system using a personal computer.

I. INTRODUCTION

Recently, research of Computer Assisted Instruction System based on Artificial Intelligence(CAI. AI) and of CAI based on Knowledge Engineering(CAI. KE) are becoming prosperous. In fact, some special programs of them are developed and applied in special field [1], [2], [3]. And this kind of research is considered to be very significant in the sense that restriction for the way of answer is released. But, unluckily, for the present, the research for AI and KE are not so much advanced to be applicable to so high-level CAI system as human teacher, and probably, even in the future that CAI.AI and CAI.KE are greatly advanced, the flexibility of instruction will still be superior in the case of human teacher than that in the case of CAI. Then, in other word, we cannot think of the instruction without human teacher. So, important is how appropriately CAI's are used in the course of education by teachers themselves.

In fact, from about 10 years ago, we, authors started to introduce some CAI systems in some curriculum courses, most of them are produced by us, using the course generator also developed by our own[4], [5], [6].

Since then, we have studied the educational effectivity of the CAI's, when they are applied to our students.

In the course of this investigation, we came to conclusion as follows.

1) The drill style instructions merely based on simple answer matching methodology is

very superficial for university students, then the students are apt to abandon to do it in short time, in spite that the students have enjoyed the CAI system in the beginning, because of the application of novel educational methodology. Then it is very difficult to let to keep them enjoyable condition so long time. This is one reason to be required the interface of human teacher.

2) In general, the course schedules or how to decide the problem presentation order becomes more complicate, and becomes to be needed a lot of bothersome energy for production of the course, in accordance with that the scale of CAI system becomes larger.

3) Evaluation of studying is mostly apt to be forcussed on the results of how correctly the students solved the given problem. And in most cases, the evaluation does not take into account the student's own factors such as ability, effort and so on.

So, considering these three items above, we propose here a new methodology of course schedules and evaluation method of studying, i.e., RESTUDY THEORY;and show here a production of the system using a very popular personal computer.

II. RESTUDY THEORY

The original idea of this theory was born by thinking of the relation between exercise problems and units of the textbook, where, a unit means a paragraph in most cases, or a item in some cases, then a chapter consists of a group of units. It is considered that any problem has mostly some relations with several units, then, for solving the problem perfectly, it is required a wide variety of knowledge concerning the related units. Fig. 1 shows the concept of the relation between units and problems.

Furthermore, if we have a table which consists of the names or the numbers to each of the problems, then we can easily infer the capability to decide the presentation order of problems by fairly simple computation, and to reduce the bothersome energy caused by the complexity of course design, then, we show the theory based on this idea bellow.

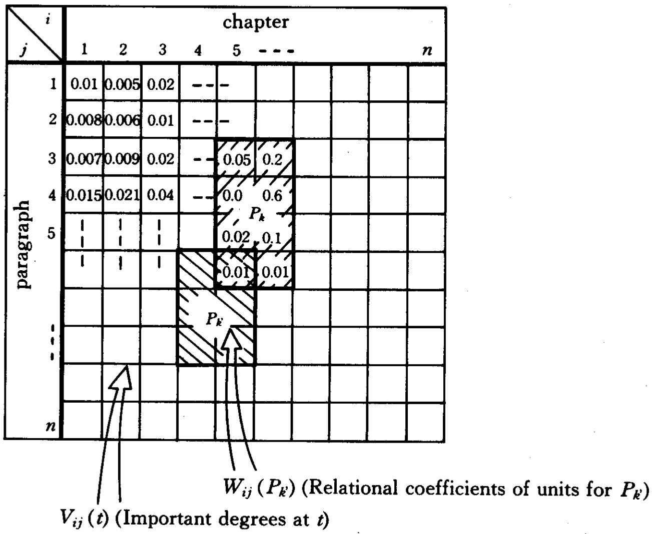

Fig.1. Concept of the relation between units and problems.

A. Notation

(1) (i, j): unit(i, j) which generally means chapter i and paragraph j.

(2) $V_{ij}(0)$: important degree for unit(i, j) at initial restudy step(before the beginning of restudy)for unit(i, j), where, $0 \leqq V_{ij} \leqq 1$, for all $i, j = 1, 2, \cdots, n$.
We consider unit(n, n) as the maximum unit number, and in the case that the textbook in consideration as CAI system has no chapter or paragraph corresponding unit(i, j), $V_{ij}(0) = 0$ is set.
In general, it is considered that these initial degrees are changeable in accordance with the abilities of the students, but to estimate the initial abilities of them with no examination is very difficult. So, usually $V_{ij}(0) = 1$ is set for all unit(i, j)'s which really exists in the textbook.

(3) $V_{ij}(t)$: important degree at t (at the very end of t'th restudy step)for unit(i, j), where, $0 \leqq V_{ij} \leqq 1$, for all $i, j = 1, 2, \cdots, n$. It is considered that each of the degrees decreases step by step as the restudying is proceeded, and the tendency is similar to general characteristics for human acquisition of knowledge.

(4) P_k: name of problem contained in the set of problems $\{P_k\}$, $k = 1, 2, \cdots, l$, where l is the total number of the problems.

(5) $P_k(t)$: the problem P_k in the set, practiced during t'th restudy step.

(6) $W_{ij}(P_k)$: relational coefficient of P_k to unit(i, j),
where, $\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(P_K) = 1$, $0 \leqq W_{ij} \leqq 1$, $\sum_{K=1}^{l} W_{ij}(P_K) \geqq 1$.
In general, most of the problems have some relations to several units, and it is natural to recognize the existence of this kind of relational coefficients. These values are assigned by teachers in charge at the time of problem production, and supposed to be constant, e.g., the most simple way to decide these coefficients is to assign 1 or 0 in accordance with weather the relation exist or not.

(7) $\theta(P_k)$: Point of P_k evaluated on the basis of perfect mark 1 for the answer of the student, then, $0 \leqq \theta(P_K) \leqq 1$, $k = 1, 2, \cdots, l$

(8) $R_{ij}(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)})$: understanding degree for the unit(i, j) after the student restudied the problems $(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)})$ at t (during t' th restudy step)

(9) $R_{ij}(t, m)$: abriviation of $R_{ij}(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)})$

(10) $S_{ij}(t)$: amount of study at t for unit(i, j)

(11) $S_{ij}(1 \sim t)$: total amount of study from initial to at t for unit(i, j)

(12) $R_G(\cdot)$: understanding degree for the group of unit G

(13) $S_G(\cdot)$: amount of study for G

(14) $W_G(\cdot)$: relational coefficient for G

(15) $V_G(\cdot)$: important degree for G

(16) $V_{G.equ}(O, t)$: important degree for G from initial to at t

B. Theory

Let's consider the situation that a certain student has attended the lecture along with a textbook concerning a subject, and that he enters to study again the subject in order to acquire better understanding by using the CAI system explained later.

Furthermore, let's suppose that all initial values of important degrees $V_{ij}(0)(i, j = 1, 2 \cdots, n)$ for each student are given as a table by the teacher in charge, considering the ability of the student, of course, if the teacher cannot estimate the ability of the student, the default values can be used, i.e., $V_{ij}(0)=1$ for all $i, j=1, 2\cdots, n$.

At first when the student sits on the front of the display terminal of the CAI system, he must assign the unit numbers(chapters or paragraphs) that he want to restudy, and then he can proceed the practice by selecting and solving the problems. That is, the system presents three problems appropriate to the student, and the presentation is repeated m times during one restudy step. So the student must select m problems from $3m$ problems presented,and must solve them during one restudy step. Here, we can think of two styles for solving the problems, i.e., one is that CAI system itself can analyze the answers and the mark is also inputted directly by the system, and the other is that the answers are marked by the teacher's hand in the case that the answers are hand-written by normal human language and so much complicate to understand by machine. But this theory takes no care of such styles, and can accept both of the styles as long as the marked data is inputted. So, important for this theory is how to present the appropriate problems at each presentation time based on "importance degree table"(see TABLE Ⅲ) and "relational coefficient table"(see TABLE Ⅰ), and is how to evaluate the several parameters for the student after the end of one restudy step.

So, the following rules are adopted for picking up the appropriate three problems at r'th presentation time:

1) the first one is of which the product of the important degree by the relational coefficient is largest in the assigned group of units G. Then the problem picked up during t'th restudy step satisfies the value,
   max $[V_{ij}(t)W_{ij}(P_r^{(t)}) \mid i, j \in G, P_r^{(t)} \in \{P_1, P_2, \cdots, P_l\}]$
2) the second one is picked up by the nearest value of the mean,
   nearest. mean $[V(t)W_{ij}(P_r^{(t)}) \mid i, j \in G, i, j \in G, P_r^{(t)} \in \{P_1, P_2, \cdots, P_l\}]$
3) The third one is picked up by the minimum value, min $[V(t)W_{ij}(P_r^{(t)}) \mid i, j \in G, i, j \in G, P_r^{(t)} \in \{P_1, P_2, \cdots, P_l\}]$.
   By the way, we can infer in general that the more is the number of related units for a problem, the more complicate becomes the problem and the more knowledge or ability is required for solving the problem perfectly.

Then, we can say the above classification by the followings,

1) the first problem is of basic level
2) the second one is of medium level
3) the third one is of appllication level.

The student can select any one among three by the will of himself. This selection way to proceed the practice is one of the outstanding feature of the system, because, people have nature to feel something to be mentally stressed under the condition of strict schedule in general, then this kind of redundant system whose problem selection is left to the student'own will is considered to be very preferable.

Now, let's enter the practice mode, and suppose that the student practices the problems($P_{k1}, P_{k2}, \cdots, P_{km}$), and reports all of the answers to the teacher in charge(or in some case, by the CAI system directly) by using the way assigned, as the result, he is given the points marked as $\theta(P_{k_1}), \theta(P_{k_2}), \cdots, \theta(P_{k_m})$. Where, if we consider these points are marked on the basis of perfect mark 1, each points of these can be allowed to be the value of understanding for the problem. Note that the teacher(or CAI system)can mark the reported answer to be 0 point, if it does not come up to the standard mark(SM) which is assigned previously by the teacher, e.g., $SM=0.6$. Consequently, the value of understanding degree with respect to the unit(i, j) contributed by understanding the problem, $R_{ij}(P_k)$ is considered to be the product of $\theta(P_k)$ by the rerational coefficient of P_k to unit(i, j), $W_{ij}(P_k)$, i.e.,

$$R_{ij}(P_k)=\theta(P_k)W_{ij}(P_k), \tag{1}$$

where, $0 \leqq R_{ij} \leqq 1$ for all i and j,

$$\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(P_K) = 1 \tag{2}$$

$$\sum_{K=1}^{l} W_{ij}(P_K) \geqq 1. \tag{3}$$

It is natural to define the value of R_{ij} in the range from 0 to 1, considering the meaning of degree, then the special case of $R_{ij} = 1$ means the case that the relation of P_k is restricted in only one unit and the student gives the perfect answer. Eq. (2) means that sum of all relational coefficients for P_k with respect to unit is 1. And Eq. (3) means that sum of all relational coefficients for a fixed unit(i, j) with respect to problem must exceed 1, because, if $\sum_{K=1}^{l} W_{ij}(P_K) < 1$ then the understanding degree of unit(i, j) can never reach perfect understanding notwrithstanding any effort. Consequently, in general, in the case that m problems $\{P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)}\}$ in the first restudy step are selected to solve, the understanding degree for the unit(i, j) after the m problems practiced is given by

$$R_{ij}(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)}) = U\left(\sum_{r=1}^{m} R_{ij}(P_r^{(t)})\right), \tag{4}$$

Where, $1 \leqq m \leqq l$ (total number of problems),

$$U(X) = \begin{cases} 1 : X > 1 \\ X : 0 \leqq X < 1. \end{cases} \tag{5}$$

Eq. (4) means that the understanding for unit$(i, j)$is regarded as perfection, if the summention value of understanding degrees resulted from the practice for m problems exceeds 1. In this sense, the value of understanding degrees is surpressed under 1, and defined like as above by using a unit function.

Well, it is easily understood that the understanding degree of the student for unit(i, j) is increased from 0 to $R_{ij}(1, m)$(the abriviation of $R_{ij}(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)})$, afterwards $R_{ij}(t, m)$is used in place of $R_{ij}(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)})$ for convenience)by the practices for these problems, then the remained understanding degree without understanding becomes $1 - R_{ij}(1, m)$. Consequently, the important degree at 1 (just after the end of the first restudy step)for unit(i, j) is given by.

$$V_{ij}(1) = V_{ij}(0)(1 - R_{ij}(1, m)). \tag{6}$$

Then, in general, the important degree for unit(i, j) at t is induced from Eqs. (1), (4) and (6) as following way,

$$V_{ij}(t) = V_{ij}(t-1)\{1 - R_{ij}(t, m)\} \tag{7}$$

$$= V_{ij}(0) \prod_{S=1}^{t} \{1 - R_{ij}(s, m)\} \tag{8}$$

$$= V_{ij}(0) \prod_{S=1}^{t} \left[1 - U\left\{\sum_{r=1}^{m} \theta(P_r^{(S)}) W_{ij}(P_r^{(S)})\right\}\right]. \tag{9}$$

on the other hand, if we introduce a new variable $S_{ij}(t)$, We can rewrite Eq. (7) in the following form,

$$V_{ij}(t) = V_{ij}(t-1) - S_{ij}(t) : \text{for any unit } (i, j), \tag{10}$$

where,

$$S_{ij}(t) = V_{ij}(t-1) R_{ij}(t, m), \tag{11}$$

Note that the Eq. (11) contains a very interesting meaning. The reason is that, if we consider the general properties concerning the relation between the amount of study and the ability of the student in place of the important degree, the following two general rules can be recognized intuitively.

1) in the case that the given problem is fairly easy for the ability of the student(in other words, the important degrees of several units related to the problem are fairly low), the problem will be solved correctly without so much effort or without so large amount of study, and the resultant understanding degrees of the related units to the problem will be increased.

But on the other hand,

2) in the case that the given problem is fairly difficult(the important values are fairly high), the problem will not be solved correctly as long as the effort or the amount of study is made as same as in the above case, and the resultant understanding degrees related to the problem will not be increased.

Then, it can be said that Eq. (11) shows the inverse proportional rule between the important degree and the understanding degree with respect to the amount of study. Then afterwards, $S_{ij}(t)$ is denoted as "amount of study at t for unit(i, j)".

Consequently, the total amount of study for unit(i, j) from initial to at t is given as,

$$S_{ij}(1\sim t)=\sum_{l=1}^{t} S_{ij}(\ell), \tag{12}$$

$$=\sum_{l=1}^{t} V(\ell-1)R_{ij}(\ell, m) \tag{13}$$

On the other hand, from Eq. (10), $S_{ij}(1\sim t)$ is also rewritten as in another form,

$$S_{ij}(1\sim t)=\sum_{l=1}^{t}\{V_{ij}(\ell-1)-V_{ij}(\ell)\}, \tag{14}$$

$$=V_{ij}(0)-V_{ij}(t). \tag{15}$$

In the next part, let's consider the expansion of these equations to for a group of units such as a chapter. The understanding degree for a group of units contributed by understanding the problem P_k can be easily defined without curiousity, thinking of the similarity to Eq. (1), i.e.,

$$R_G(P_K)=\theta(P_K)W_G(P_K) \tag{16}$$

$$W_G(P_K)=\frac{1}{N_G}\sum_{(i,j)\in G} W_{ij}(P_K) \tag{17}$$

where, G: set of units, $\{(i, j), (i, j), \cdots, (i, j)\}$

N_G: number of units contained in G

W_G: relational coefficients of P_k to the set.

Therefore, in general for the multiple problems at t, the following equations,

$$R_G(t, m)=R_G(P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)})=U\left\{\sum_{r=1}^{m} R_G(P_r^{(t)})\right\} \tag{18}$$

are hold. Thus, similarly to the way of introduction for Eqs.(6)~(15), we can obtain the expanded equations as follows,

$$V_G(t)=V_G(t-1)(1-R_G(t, m)) \tag{19}$$

$$=V_G(t-1)-S_G(t), \tag{20}$$

$$S_G(t)=V_G(t-1)R_G(t, m), \tag{21}$$

$$V_G(t)=\frac{1}{N_G}\sum_{(i,j)\in G} V_{ij}(t) \tag{22}$$

Where, $V_G(t)$ is the important degree for the group, and $S_G(t)$ is the amount of restudy at t. Then the total amount of restudy is written as,

$$S_G(1\sim t)=\sum_{l=1}^{t} S_G(\ell), \tag{23}$$

$$= \sum_{l=1}^{t} V_G(\ell-1)R_G(\ell, m), \tag{24}$$

$$= V_G(0) - V_G(t). \tag{25}$$

On the other hand, suppose that the student do not forget the knowledge obtained in the course of previous t restudy steps, the understanding degree obtained by solving the mt problems,

$\{P_1^{(1)}, P_2^{(1)}, \cdots, P_m^{(1)}, \cdots, P_1^{(t)}, P_2^{(t)}, \cdots, P_m^{(t)}\}$ in continuation must be coincide to the sum of t understanding degrees as long as it does not exceed 1. i.e.,

$$R_G(1 \sim t, mt) = U\left(\sum_{l=1}^{t} R_G(\ell, m)\right). \tag{26}$$

Now, if we introduce a new parameter $V_{G \cdot equ}(0, t)$ for the sake of convenience to conbine $S_G(1 \sim t)$ and $R_G(1 \sim t, mt)$ as of equivalent important degree as Eqs. (11) and (21), $S(1 \sim t)$ can be rewitten as the following form,

$$S_G(1 \sim t) = V_{G.equ}(0, t)R_G(1 \sim t, mt), \tag{27}$$

consequently,

$$V_{G.equ}(0, t) = S_G(1 \sim t) / R_G(1 \sim t, mt), \tag{28}$$

$$\sum_{l=1}^{t} V_G(\ell-1)R_G(\ell, m) / U\left(\sum_{l=1}^{t} R_G(\ell, m)\right). \tag{29}$$

Note that the valuable $V_{G \cdot equ}(0, t)$ becomes a convenient parameter to see the studying effectivity of the student until at t.

This reason is that, the valuable $V_{G \cdot equ}(0, t)$ is always positive in the range of 0 to 1, and tends to the maximum value 1 as t increases, because, both of the denominator U $(\sum R_G)$ and the numerator $\sum V_G R_G$ tends to 1 as t increases. Then it can be easily noticed that the valuable $V_{G \cdot equ}(0, t)$ has absolutely a minimum value at some restudy step te(see Fig. 2), and at this time te, the effectivity becomes maximum,

In other words, the effectivity $V_{G \cdot equ}(0, t)$ which means the amount of study for perfect understanding at time t decreases as t increases until at t_e, on the contrary, the understanding degree increases as t increases, and reaches almost near to 1 at time t_e, i.e., although if the student want to get perfect understanding after the time t_e, a little more amount of study is required. But almost all of properties concerning his studying is extracted until the time te. Then it is natural to use the vector $\{S_G(1 \sim t_e), R_G(1 \sim t_e, mt_e), V_G(t_e), t_e\}$ as one point evaluation measure of each student.

This measure is considered to be much more significant than that of usual method in the sense that it extracts absolute four properties of the student.

An example of utilization of these parameters is shown in Fig. 3 which gives an appropriate comment to the teacher in charge that it is better to classify the students in the next lecture, otherwise it is better for the next lecture to take the four patterns of students into account, and so on.

III. AN EXAMPLE OF RESTUDY BY A STUDENT

TABLE I shows an example of Problem-Relational coefficients Table(PRT), in which the data are decided by us using the problems in the book [7]. The book is now a textbook of our students for the curriculum as "introductive education of computer language".

TABLE II shows an example of how a student practiced selecting the problems in each restudy step. In each restudy step t, 3 problems $(P_1^{(t)}, P_2^{(t)}, P_3^{(t)})$ are selected, and the answers are reported to the teacher in charge(one of us) at the end of each step. And the evaluated points $\{\theta(P_1^{(t)}), \theta(P_2^{(t)}), \theta(P_3^{(t)})\}$ are inputted into the restudy system produced by us. The relational coefficients shown in TABLE Ⅱ are bounded to the group of units G= {(2 , 1), (2 , 2), (2 , 3)} for the objective of group evaluation.

TABLE Ⅲ shows the resultant data of important degree of the student at $t = 2$. We can notice that almost all of the values in small number of chapters are becoming less than 1 , but others in large number of chapters are still remained as 1 , which means non-practiced.

TABLE Ⅳ shows the computed data by using the tables Ⅰ, Ⅱ and Ⅲ, These data are computed internally by the restudy system. The variation of the important parameters in TABLE Ⅳ are drawn in the Fig. 2 in accordance with restudy step t. As mentioned before, we can notice that the minimum value of $V_{G.equ}$ exists at $t= 4$ (then $t_e = 4$), after the time t_e, the effectivity of restudy becomes worse. This property is , in some sense, very similar to the intuitive feeling of human, such that the perfect job generally needs large amount of energy in the ending part than that in all of the other parts. So we can extract the values of a vector $(S_G, R_G, V_G, t_e) = (0.731, 0.994, 0.269, 4)$ as an very significant evaluation measure of the student.

Fig. 3 shows an example of $S_G(1 \sim t_e)$—$R_G(1 \sim t_e, 3t_e)$ characterristics of a classroom which consists of 20 students. The values of students are scattered in several locations on S_G —R_G plane indicated by the student number i. The figure shows that all of the students have individual nature for restudy. Then, if we think of the total effectivity for education of the classroom, it can be said that this kind of figure presents very significant information to classify the students in accordance with 4 partitions, e.g., the students contained in the partition (B) are in general regarded as the students who make a lot of efforts and obtain high level points as the result of their efforts, but the students in (D) may be regarded as the students who can not get easily the rewards inspite of their efforts, and so on.

TABLE Ⅰ

An Example for Problems-Relational Coefficients Table of a Student.
Note that all of the blanks means 0. 0 and $\Sigma W_{ij} = 1$

Problems	Chap.	Relational Coefficients of paragraphs in chap. i									
P_k	i	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}	W_{i6}	W_{i7}	W_{i8}	W_{i9}	W_{i10}
P_1	1	0.4	0.3	0.2	0.1						
P_2	1	0.1	0.3	0.3	0.2	0.1					
P_3	1		0.1	0.1	0.2	0.3					
	2	0.2	0.1								
P_4	1	0.3	0.3	0.3	0.1						
P_5	1				0.2	0.2					
	2	0.3	0.2	0.1							
⋮ P_n											

TABLE Ⅱ

An Example Table of a Student for the Problems Selected in Each Restudy Step t and the Relational Coefficients in the Groop of Units, $G = \{(2, 1), (2, 2), (2, 3)\}$

No. of prob. s		Selected prob. s	Relational coefficients				Marked points
t	$P_r^{(t)}$	P_k	W_{21}	W_{22}	W_{23}	W_G	$\theta(P_k)$
1	$P_1^{(1)}$	P_4	0.3	0.2	0.1	0.200	1.00
	$P_2^{(1)}$	P_5	0.2	0.2	0.3	0.233	0.90
	$P_3^{(1)}$	P_7	0.1	0.2	0.2	0.167	0.90
2	$P_1^{(2)}$	P_6	0.2	0.2	0.1	0.167	0.80
	$P_2^{(2)}$	P_{10}	0.0	0.0	0.1	0.033	0.70
	$P_3^{(2)}$	P_8	0.0	0.1	0.1	0.033	0.80
3	$P_1^{(3)}$	P_9	0.0	0.0	0.2	0.067	0.90
	$P_2^{(3)}$	P_{11}	0.0	0.0	0.0	0.0	0.80
	$P_3^{(3)}$	P_{13}	0.0	0.1	0.1	0.067	0.60
4	$P_1^{(4)}$	P_{12}	0.0	0.0	0.1	0.032	0.80
	$P_2^{(4)}$	P_{14}	0.0	0.2	0.2	0.133	0.75
	$P_3^{(4)}$	P_{15}	0.1	0.0	0.1	0.067	0.65
5	$P_1^{(5)}$	P_3	0.1	0.0	0.0	0.033	0.85
	$P_2^{(5)}$	P_{16}	0.0	0.0	0.1	0.033	0.70
	$P_3^{(5)}$	P_{17}	0.0	0.0	0.2	0.067	0.95

TABLE Ⅲ

An Example of Important Degree Table of a Student at $t=2$

	i	chapter									
j		1	2	3	4	5	6	7	8	9	10
paragrah	1	0.02	0.21	0.79	1	1	1	1	1	0	0
	2	0.01	0.28	0.91	1	1	1	1	1	0	0
	3	0.11	0.59	0.81	0.94	1	1	0	0	0	0
	4	0.03	0.53	0.95	0.97	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0

TABLE Ⅳ

Several Parameter Values Computed from the Values in Tables Ⅰ, Ⅱ and Ⅲ

restudy step	t=0	t=1	t=2	t=3	t=4	t=5
θ ($P_1^{(t)}$)		1.0	0.8	0.9	0.8	0.85
W_G ($P_1^{(t)}$)		0.2	0.167	0.067	0.033	0.033
θ ($P_2^{(t)}$)		0.9	0.7	0.8	0.75	0.70
W_G ($P_2^{(t)}$)		0.233	0.033	0.0	0.133	0.033
θ ($P_3^{(t)}$)		0.9	0.8	0.6	0.65	0.95
W_G ($P_3^{(t)}$)		0.167	0.033	0.067	0.067	0.067
R_G (t, 3)		0.5590	0.1831	0.1005	0.1697	0.1149
R_G (1~t, 3t)		0.5590	0.7421	0.8426	0.9943	1.00
V_G (t)	1.0	0.4410	0.3603	0.3240	0.2690	0.0
S_G (t)		0.5590	0.0808	0.0362	0.0550	0.0309
S_G (1~t)		0.5590	0.6398	0.6760	0.7310	0.7620
V_G. equ (o, t)		1.0	0.8621	0.8023	0.7352	0.7620

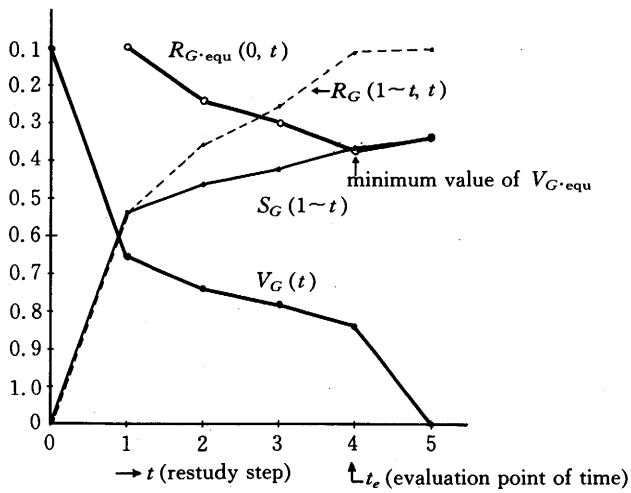

Fig.2. Variation of several important parameters with respect to restudy step, which is drawn by the data of toble Ⅳ.

One point evaluation of this student $(S_G, R_G, V_G, t_e) = (0.713, 0.994, 0.269, 4)$

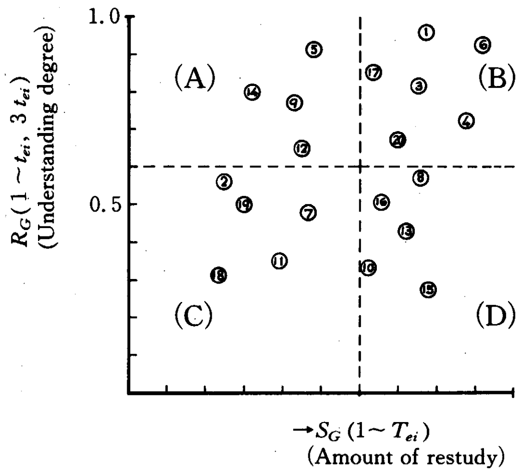

Fig.3. An example of S_G-R_G characteristics of a classroom which consists of 20 students. ⓘshows the location for No.i student, t_{ei} corresponds one point evaluation time to No.i student (A), (B), (C) and (D) show an example to classify the students into 4 groups based on the similarity of restudy properties.

Ⅳ. CONCLUSION

We have produced an example system named RESTUDY as an auto presentation system of problems based on this theory by about 2000 instructions of BASIC language, and applied it mainly to the introductive education of computer language, FORTRAN and PASCAL. The name of personal computer of which it is applied is MULTI-16 produced by Japanese computer company, Mitsubishi Electric Co., Ltd. We have an computer system for education, which is composed of a fairly large scale general computer and of 20 personal computer terminals of the machine MULTI-16. Each of the machines installed in our center contains i8086 CPU and 512 K Byte memories. Then, for the present, although we cannot give plenty of machines to our students, but we have a realisable schedule to install a lot of personal computers of the same family machine in next year. Then, it is hopeful that this software RESTUDY is applied to other kinds of curriculums besides ours. But it remains without investigation how the evaluation measure of this theory is adaptable to discribe other kinds of properties of students extracted from several curriculum course. And furthermore, it will be needed to develop several software systems based on this theory applicable to various kinds of machines.

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