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Web based Computerized Testing System for Distance Education

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This paper proposes a design of Web based Computerized Testing System(WCTS) for distance education. The system is consistently designed to unify the functions of CATC(Computer Assisted Test Construction), CBT(Computer Based Testing) and CADA(Computer Assisted Data Analysis). The unique features of this system are addressed in the CATC and the CADA as follows: 1.The CATC assists teachers' shared use of item database, a cooperative construction of a distance test by teachers of different schools, and an interactive construction of a test. 2. The CATC has a test score distribution prediction function using past item statistics data in Item Data-Base. These functions show to the teachers the predicted score distribution during they are constructing a test. These functions are expected to assist the teachers' collaborative test construction. 3. The CADA assists an automated process of data input through test execution, marking , analysis and immediate feed-backs to the teachers ,students, and the system. Especially, it is an unique feature to analyze the newly gathered data like the number of times which an student changed his/her answer to an item. Furthermore, this paper demonstrates some performances of this system for evaluating distance education between Japan and Thailand.

Key words : Distance education, Web System, Computer Based Testing, e-testing, e-learning

1. INTRODUCTION

Practical use of the Computer based Testing (CBT) has been progressing for a few decades. The interests of CBTs studies are largely divided into the following two; 1) the CBT using test theories and 2) the CBT based on multi-media technologies. In 1), Computerized Adaptive Testing System using IRT (Item Response Theory) has been in practical use with the advance of the studies of the Item Response Theory. (See, for example, Bejar (1988), Wainer, H (1999) ,and so on.)

The test item selection algorithm using the IRT has been expanded to test construction system. (see, for example, Lineden,E.J.V.D and Veidkamp, B.P.(2002))

In 2), the CBTs based on the multi-media technologies have been developed for the assessment of the ability, which has never been evaluated, as like ability for communication, and so on. (See, for example, Van Der Linden. W. J.(1999), Roever,C.(2001), Douglas Quinney, (2001)).Furthermore, Nagaoka ((1996)and (2000) proposed an unified system using the test theories and the multi-media technologies.

On the other hands, distance education has become a popular education method over the last few years. The main idea of this paper is to utilize these CBT technologies to evaluation in the distance education by expanding the CBTs to the Web based Computerized Test System (WCTS). Similarly, some WCTSs have already been developed. For example, Nakayama, H. and Matsuda, T. (1999) developed a WCTS for classroom management. In addition, some researchers have expanded computerized adaptive test system based on the test theory to web based testing system (for example, see, Ueno.M. (1998), TYNg,Vincent and Chan, S.C.F (2003), Zaytseva,N and Prokofieva, N.O. (2003))

Especially, ETS(Educational Testing Service) has put their Web based adaptive testing system in commercial business(see, for example, Wagner ,M.(2003)). One of remarkable things in this system is the auto-marking function for essay form items (Burstein, J. Kukich, K., and Wolff,S. Lu.C. (1998)).

Although these systems have some excellent features or some advantages, they are not designed for usual distance education situations.

For example, in these systems, users can not construct a test, and only bender stuffs are permitted to construct a test. In addition, these test systems need huge numbers of items for

validation of the constructed test. In this sense, the system which teachers can construct a test by themselves is desirable. Moreover, distance education is often performed with collaboration between teachers who stay in respectively different places.

From these view points, this paper proposes a design of Web based Computerized Testing System (WCTS) for distance education. The system design is consistent to unify the function CATC (Computer Assisted Test Construction), CBT (Computer Based Testing) and CADA (Computer Assisted Data Analysis).

The unique features of this system are addressed in the CATC and the CADA as follows:

1. The CATC assists teachers' shared use of item database, a cooperative construction of a distance test by teachers of different schools, and an interactive construction of a test.
2. The CATC has a test score distribution prediction function using past item statistics data in Item Data-Base. These functions show to the teachers the predicted score distribution during they are constructing a test. These functions are expected to assist the teachers' collaborative test construction.
3. The CADA assists an automated process of data input through test execution, marking , analysis and immediate feed-backs to the teachers, students, and the system. Especially, it is an unique feature to analyze the newly gathered data like the number of times which an student changed his/her answer to an item.

Furthermore, this paper demonstrates some performances of this system for evaluating distance education between Japan and Thailand.

2. SYSTEM

The proposed WCTS has the following modules ; 1) Item Data-Base(IDB), 2)CATC (Computer Assisted Test Construction), 3) CBT (Computer Based Testing) 4)CAM(Computer Assisted Marking) and 5)CADA(Computer Assisted Data Analysis) as shown in Figure. 1. Each module is developed using Java and Microsoft SQL database, and then it is available through WWW Web. This system is designed for distance education and shared use of teachers in different places. The details of modules are introduced as follows:

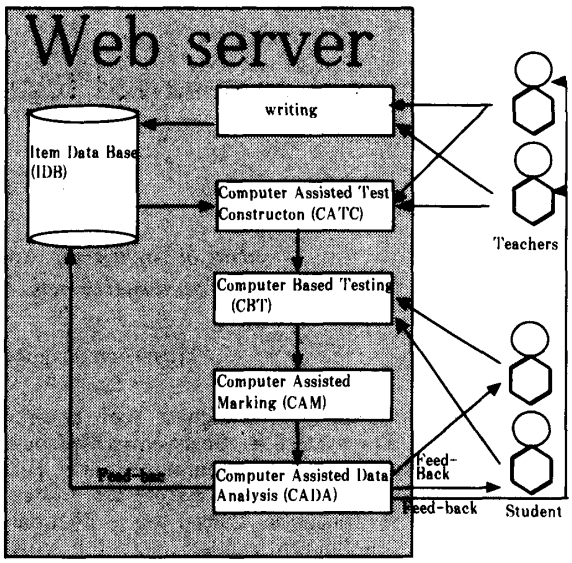

Fig. 1. Outline of the system

```
// IDB (Correct answer、explanation、
problem、option)
var units = new Array(
 ("b"," see Fig.1 and Fig.2", " Access Divide
among different income groups is clearly
observed in", "Fixed telephone line access",
"Mobile phone access", "All three media
mentioned above"),
```

Fig. 2. The structure of the item data-base

2.1. *Item Data Base (IDB)*

The IDB is a test item Data-Base which the system refers. The IDB is made by the teachers according to the format shown in Figure. 2.

The file includes the correct answers of the items, the explanations of the items, the contents of the items, and the options. There is another Data-Base in the IDB. This includes the following newly gathered statistical information for each item.

- The probabilities of correct answer for each item and the probabilities of selecting alternative in a multiple choice test item
- The average and variance of response times for each item
- The average and variance number of times which the student changes his answer

The system utilizes this information to construct and present a test. Now, there are 240 items in this IDB which is made by twelve teachers.

2.2. *Computer Assisted Test Construction (CATC)*

This system assists a distance test construction. This module is one of the unique features of the proposed system.

A teacher can construct a test through internet,

or teachers of different schools can cooperate to construct a test through internet.

First, a teacher accesses the Web and put his name and passwords, and then the menu page is presented. Next, he or she selects the button corresponding to CATC, and he or she select items to construct a test, then the system presents the predictive test score for the constructed test using historical item data shown in Figure. 3. The predictive score distribution can be obtained by the data which have been stored in the CADA.

As shown in Figure. 3, the shown information is given as follows:

A. The probability of correct answer for each item

A set of the probabilities of correct answers for m items $\Theta = \{\theta_i\}, (i = 1, \cdots, m)$ is estimated using historical data and are presented by CATC. θ_i as a Bayesian estimation based upon the Binomial distribution (see, for example, Ueno2000) can be estimated as follows:

$$\theta_i = \frac{n_i + a'}{n + a'}, \quad (i = 1, \cdots, m)$$

where

m ; the number of items of the test

n_i ; The number of students who provide correct answer

n ; The number of students

a' ; The value of the hyper parameter

In addition, here, we set $a' = 1$. Because the value of the hyper parameter a' is 1 when we assume that the prior distribution is uniform.

When the teachers decide to improve or change test items in the constructed test, this information will help their decision about which items need to be replaced.

B. Predictive score distribution

The system presents the predictive score distribution of a current constructed test in order to visualize the current status of the constructed test. It is expected that some teachers in distance places collaborate to construct the test by seeing the predictive score distribution.

In this research, we employ the mixture model of several binomial distributions as a predictive score distribution model.

Let $x, (0, \cdots, m)$ be a score random variable for the test with m items, and then the predictive score distribution is defined by

$$p(x \mid \Theta) = \sum_{i=1}^{m} \left[p(M_i) p(x \mid m_i, \theta_i) \right]$$

$$= \sum_{i=1}^{m} \left[p(M_i) \binom{n}{x} \theta_i^{m} (1 - \theta_i)^{(m-x)} \right]$$

where $m_i (1, \cdots, m)$ means the i-th model. Here, we consider that the predictive score distribution is a mixture of the models $\{M_i\}, (i = 1, \cdots, m)$ (the binomial distributions) which have, respectively,

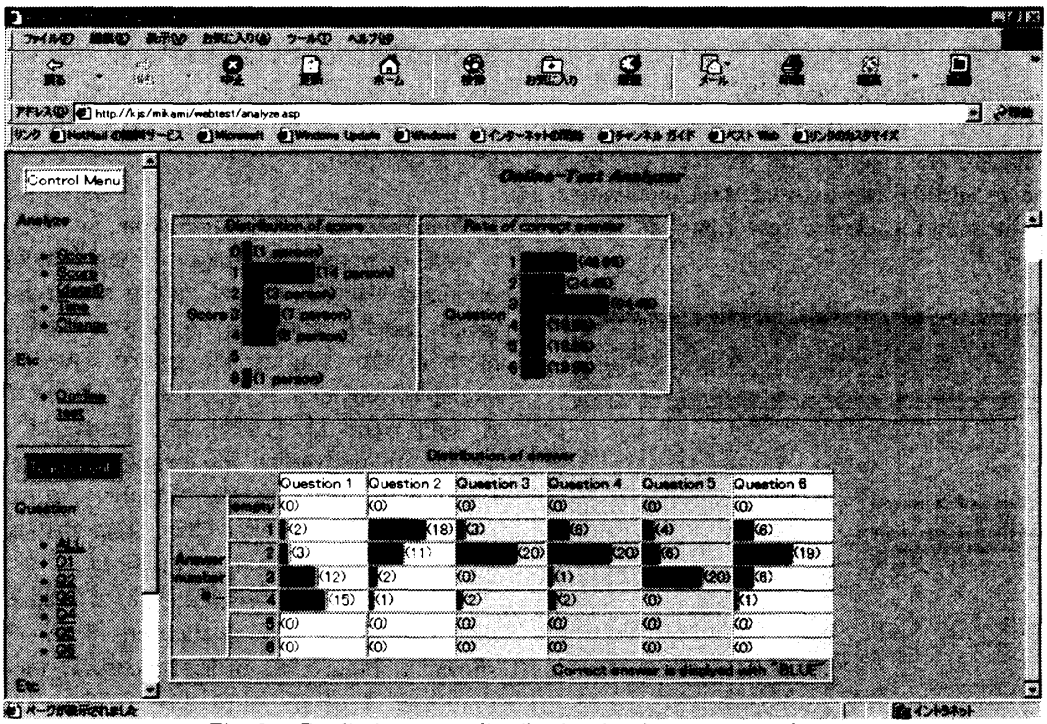

Fig. 3. Predictive score distribution for the constructed test

the probabilities parameters $\{\theta_i\},(i=1,\cdots,m)$. However, now, we have no knowledge about $\{M_i\},(i=1,\cdots,m)$, then we set the following uniform prior distribution

$$p(M_i)=\frac{1}{m}$$

The predictive number of students n_x in each score x is given using the following generated n random numbers.

$$n_x \xleftarrow{random} p(x\mid\Theta))$$

Thus, the system shows the distribution of n_x as a predictive score distribution. This predictive distribution is called "plug-in distribution "(For example, Aitchson, j. 1975).
By seeing this distribution information, the teachers can recognize the degree of difficulty of the constructed test.

C. The response probabilities for alternatives

The system also presents the response probabilities for alternatives in multiple choice items using historical test data. This information will also help the teachers' their decision about what item needs to be replaced, when they decide to improve or change test items in the constructed test by seeing the predictive score distribution.

Thus, the teachers, who participate in the distance education, can interactively construct a test using these functions.

2.3. Computer Based Testing (CBT)

The CBT assists executing the constructed test in 2.2. The students access the server, and they put his name and passwords, and then the system presents the multiple choice test items as shown in Figure. 4.

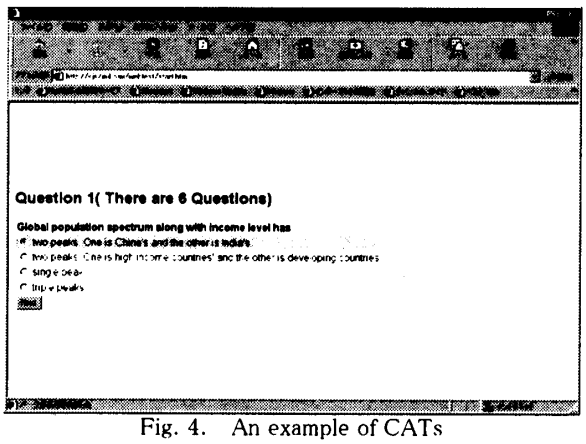

Fig. 4. An example of CATs

2.4. Computer Assisted Marking(CAM) and Computer Assisted Data Analysis(CADA)

The system shows the analyzed results to the students to some feedbacks as shown in Figure. 5. The feedbacks includes each student's score, his level, and explanation of his answers. The one of advantages of CAM is that the student can get his/her results and feedbacks as soon as he or she completed the test. Furthermore, the system shows the feed back to the teachers as follows:

A. Test data matrix

This feed-back is a basic test data matrix shown in Figure. 6. The column indicates the students' IDs, and the row indicates students' test scores and the correct answers and the students' answers. This feedback is designed to be easy that the teachers can copy to the spreadsheet soft wares , for example, Microsoft Excel, and so on.

B. Test score distributions

This feedback provides us the test score distributions, and the probabilities of correct answers to the items, corresponding to the executed test by the teachers. An example of the feedbacks is shown in Figure. 7.

Especially, the unique feature of this module is that the feedbacks are corresponding to distance education between several classes. In usual distance education, several classes participate in the class. In this case, the teacher of each class is interested in his/her own classes' feed-backs. This system presents the feedbacks to classify the students' class. The feedbacks for the two classes and the unified feedbacks are shown in Figure. 7. In this case, we can see that the 1st class provides less score than 2nd class.

C. Item response time distribution

Item response time data is one of unique data obtained from CBT, and some researchers have given much effort to develop a new analysis methods for this newly gained data, (see for example, Nagaoka, K. and Wu A, (1989) , Nagaoka, K. and Ueno M. (1991), and Ueno, M. (1992)). These studies utilize the property that response time data reflects the number of cognitive processes of the item. Thus, item response time data is effective for item evaluations.

This system also visualizes item response time distributions for the evaluation of the items as shown in Figure. 8. From Figure. 8, we can see that item 4 needs more time compared with the other items. Following the previous studies, it is

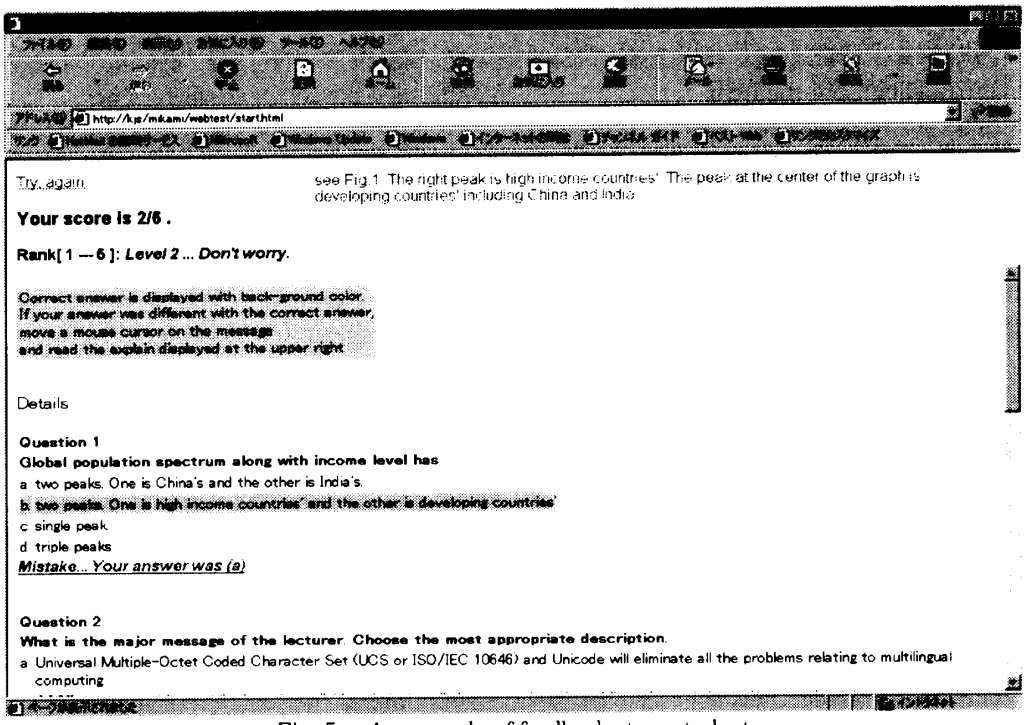

Fig. 5. An example of feedbacks to a student

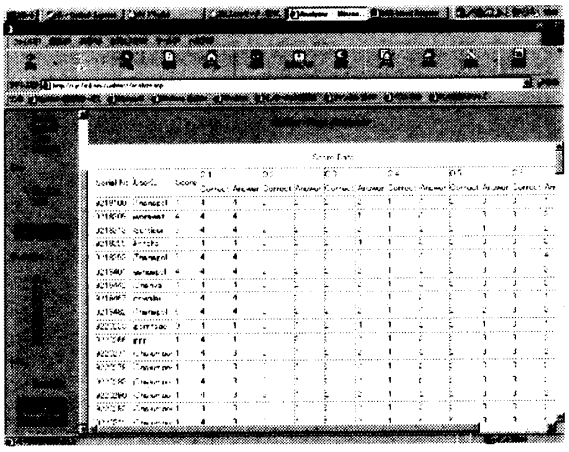

Fig. 6. Test data matrix

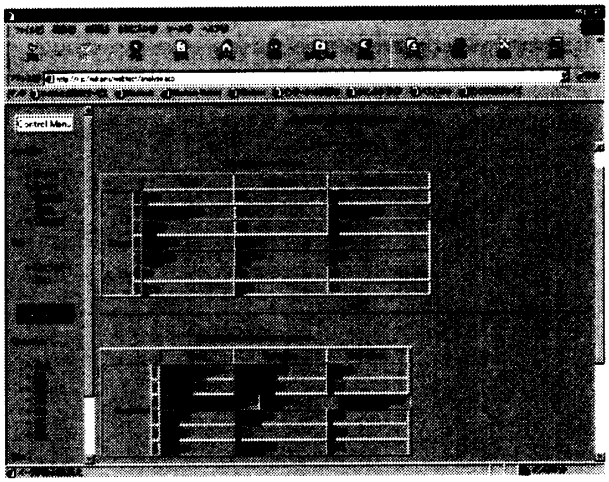

Fig. 7. Test score distribution and correct Probability for each item for several classes

interpreted that item 4 needs deep consideration or item 4 is more difficult than the other items in the sense of cognitive processes.

D. The numbers of answer-changing times

One of unique features of the CADA in this paper is the information about the numbers of changing answers times. Although the previous researches concerned with CBT or E-learning have rarely discussed about the numbers of changing answers times, there are some researches in psychology society (For example, Rele P.J. and Briggs L.J. (1952), Bath J.A. (1972), Foote R. and Belinsky C. (1972), Pressley M. and Ghatala E.S. (1988), Pressley M., Ghatala E.S, Woloshyn V. and Pirie J. (1990), and Geiger M.A. (1991)).

The results, which is concerned with the CBTs, of these researches are summarized up as follows (Ueno, M. (1992)):

- The number of times a student change his/her answer is an index reflecting self-confidence for his /her own knowledge.
- The number of times a student change his/her answer in a multiple choice item is an index reflecting delusiveness of the choice alternatives. This index reflects how

much the alternatives in the multiple choice item work well. That is, this index also concerns difficulty of the item.

Considering these results, this system presents the distribution of students' changing answer times as an index of the delusion which the item has. An example is shown in Figure. 9. This example shows that the modes in statistics of the number of times students change their answers equals 1 for any of the six items.

3. APPLICATION TO INTERNATIONAL DISTANCE EDUCATION

3.1. Outline of actual distance education

In order to demonstrate some performance of this system, this section will discuss about application to the distance education between Japan and Thailand.

The distance education was completed using the TV conference system between Thamassat University in Thailand and Nagaoka University of Technology in Japan, on 17th.March, 2001. Two ISDN lines were employed in this practice. For this month, the five distance lectures were performed between two universities.

The subject, which the teachers used this system, is " International Industry Politics" . The instruction style is that a teacher in Japan and a teacher in Thailand cooperate to instruct to the students in Thamassat University. Thirty two students in Thamassat University participated in this class. A distance lecture situation is shown in Figure. 10.

After the lecture from Japan to Thailand, the Web based test was executed as shown in Figure. 11. As soon as the test was completed, various feed-backs related in the section 2.4. were shown from the system. The test was constructed by cooperation of the teacher in Japan and Thailand using this system. The CATC presented the predictive test score distribution using the past data which was stored in data base. In this case, the teachers previously inputted their own test items, which they have executed in past lecture, with needed statistical data into the DB. In addition, the test had been constructed by two

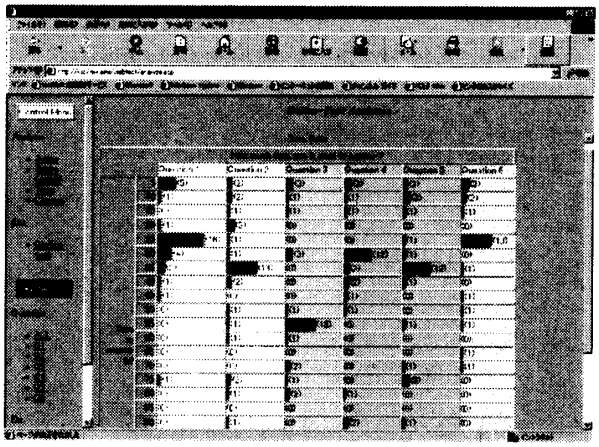

Fig. 8. Item response time distributions

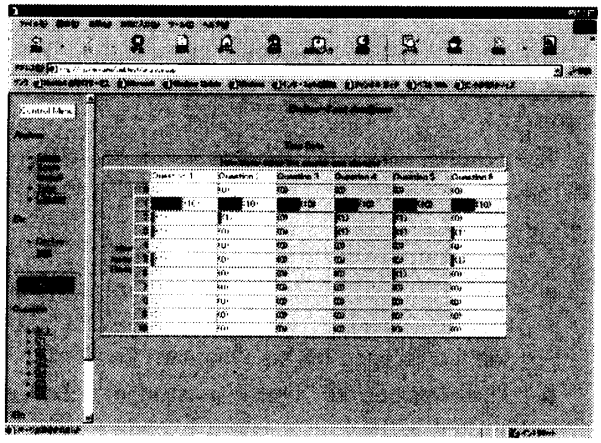

Fig. 9. The distribution of students' changing answer times

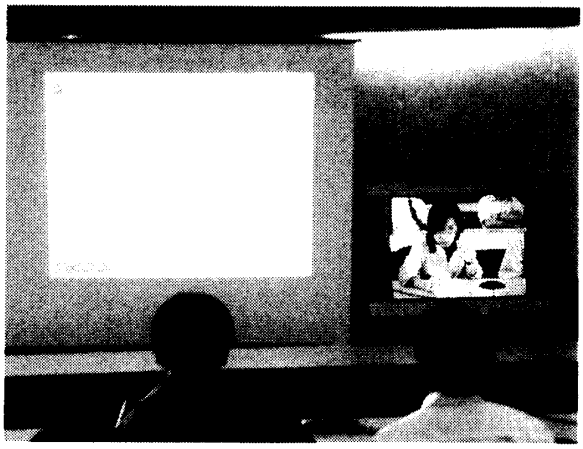

Fig. 10. The distance lecture from Japan to Thailand

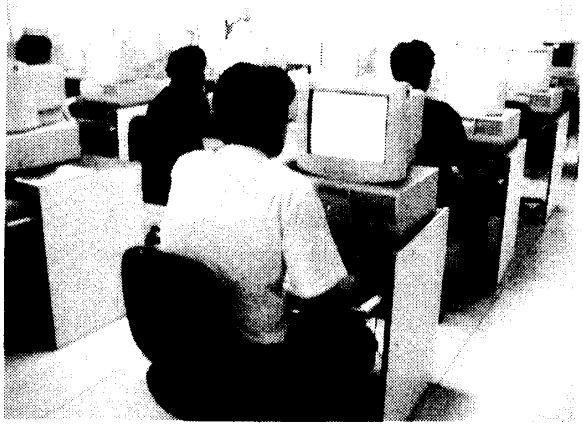

Fig. 11. A situation of Web based Test in Thailand

teachers for a few days. They cooperated to select the test items from the data- base in this system through the internet in different countries. The predictive distribution shown in Figure. 3 related in the section 2.2. was constructed in this practice.

3.2. *Evaluation of Predictive Distribution*

In this section, the predictive distribution function shown in Figure. 3 is evaluated. The Figure. 12 shows the predictive distribution of test score obtained from the CATC and the real distribution of the test score obtained from the CADA. In the case that the test score is two, the difference between the predicted score and the real score is large, but large difference can not be found for the other scores. In addition, the chi squared test shows the fitting between the predictive score frequencies and the real frequencies with $\alpha = 0.1 (\chi^2 = 10.785)$. Here, the frequency of the predictive score 5 is zero, then this data is treated as a missing data. However, it should be noted that there are some data of which frequency is less than five in this data, this does not satisfy the condition of the chi squared test, in the strict sense. In this sense, we have to gather more data to provide valid evaluation of this prediction function.

3.3. *Examples of item evaluation from various viewpoints*

This section demonstrates some examples of item evaluation using correct answer probabilities, response time data, and changing answers times, in order to show some advantages of evaluation from various viewpoints.

Figure. 13 shows the probabilities of correct answers for the items, Figure. 14 shows the modes of response time distributions for the items, and Figure. 15 shows the averages of changing answers times for the items.

From Figure. 13, we can see that items 4, 5, and 6 are same difficulty items in the sense of correct answer probabilities. However, we can see that item

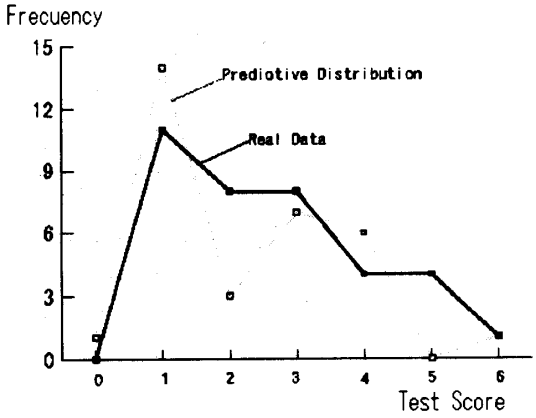

Fig. 12. The predictive distribution and real test score distribution

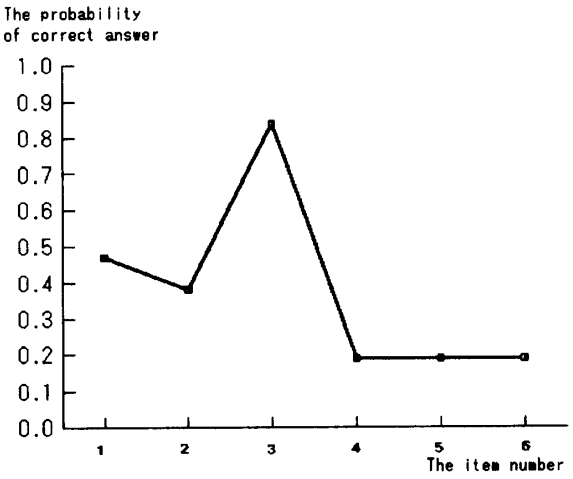

Fig. 13. The probabilities of correct answers

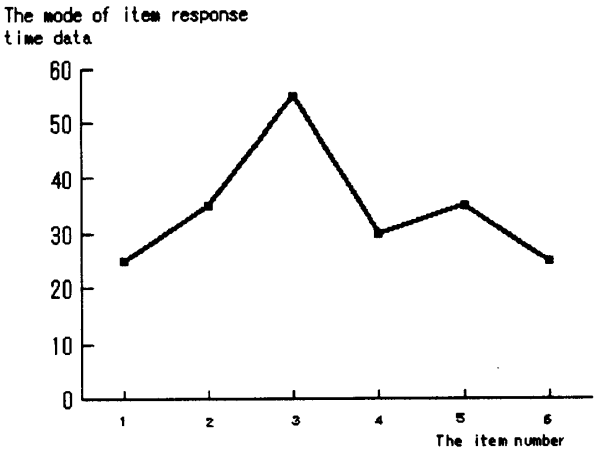

Fig. 14. The modes of response time distributions

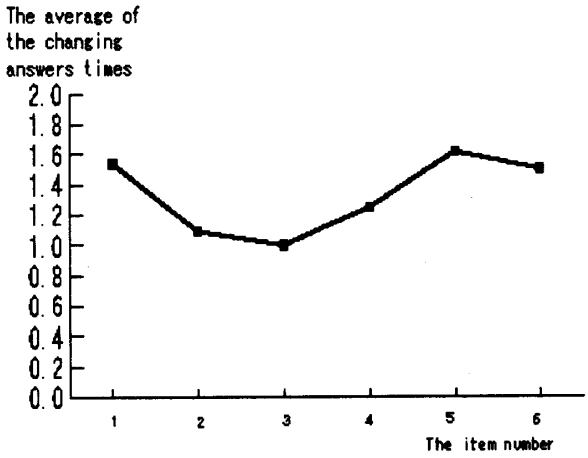

Fig. 15. The averages of changing answers times

5 is the most difficult item in the sense of response time data from Figure. 14. Similarly, Figure. 15 also shows that item 5 is the most difficult in the sense of the averages of changing answers times. Therefore, it is interpreted that item 5 needs deeper consideration than item 4 and 6.

Next, let take item 3 as another example of item evaluation. Item 3 has the longest response time average in all items, nevertheless it is the easiest item. On the other hand, from Figure. 15, we can see that it shows the least average time of changing answers in all items. This means that item 3 can be solved by repeating very easy consideration processes. The students take long time to solve this item, but they are confident to derive their answers.

As shown in this example, the various data which is presented from the CADA, we can deeply recognize the item characters from various viewpoints. And it is expected that these evaluations are effective for improvements of the items.

4. EVALUATION BY QUESTIONAIRES

The questionnaires investigations were provided to the students as soon as the test was completed in order to evaluate the web based computerized testing system. The contents of the questionnaires are shown as follows:

① Did you feel any problems about the Web based computerized test system including man-machine interface?
1. Strongly agree 2. Agree 3. Faire 4. Deny 5. Strongly deny

② How did you feel about the Web based test compared with paper tests?
1. Very Poor, 2. Poor 3. So so 4. Excellent 5. Very Excellent

③ How did you feel about the instantaneous feed-back from the system?
1. Very Poor, 2. Poor 3. So so 4. Excellent 5. Very Excellent

④ Do you think that computerized testing style effects to your test score?
1. Strongly agree 2. Agree 3. Faire 4. Deny 5. Strongly deny

⑤ How did you feel about the Web based computerized test system totally?
1. Very Poor, 2. Poor 3. So so 4. Excellent 5. Very Excellent

The results are shown in Figure. 17, 18, 19, 20, and 21, respectively.

The Figure. 17 shows the results for the item 1.

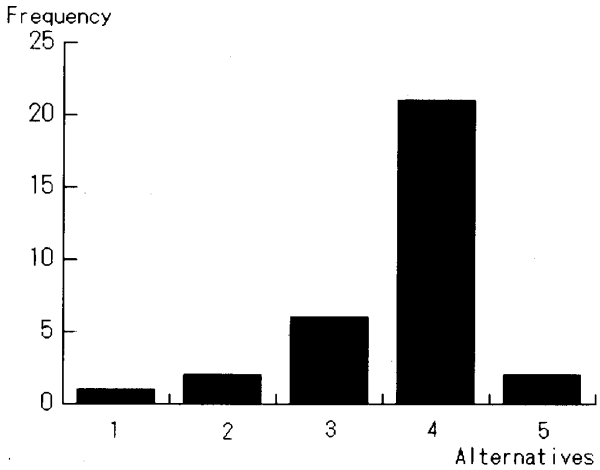

Fig. 16. The results for the questionnaire item 1

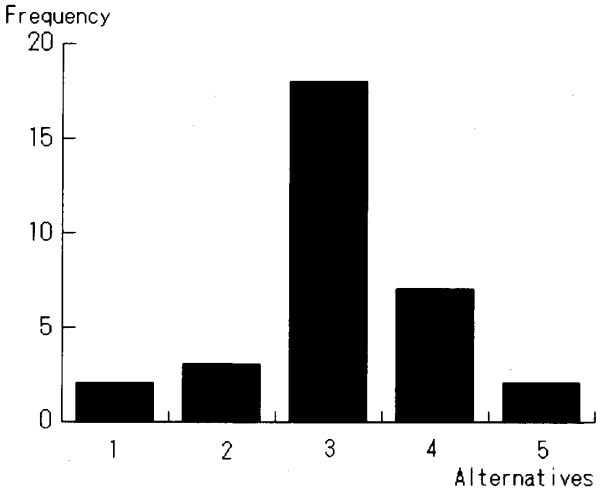

Fig. 17. The results for the questionnaire item 2

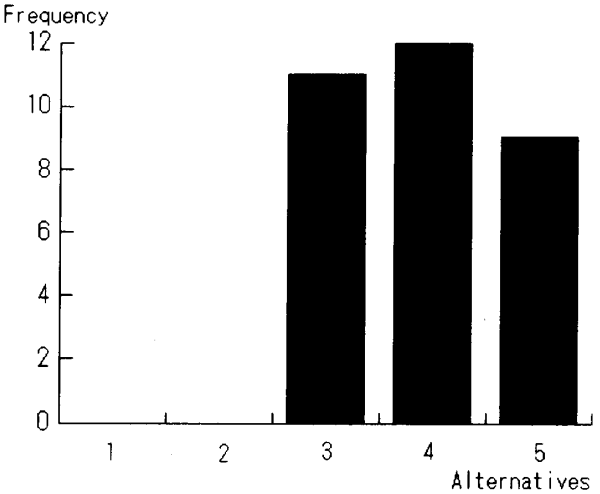

Fig. 18. The results for the questionnaire item 3

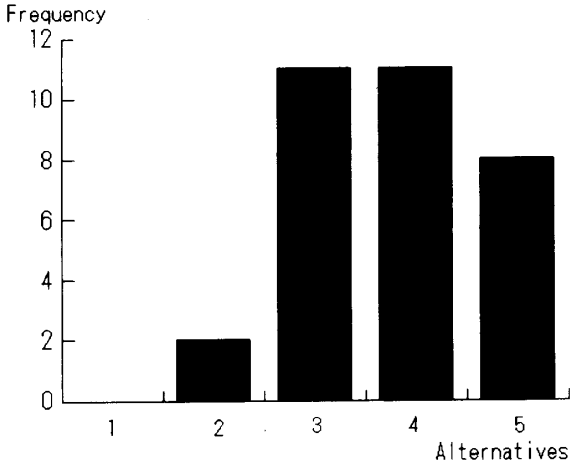

Fig 19. The results for the questionnaire item 4

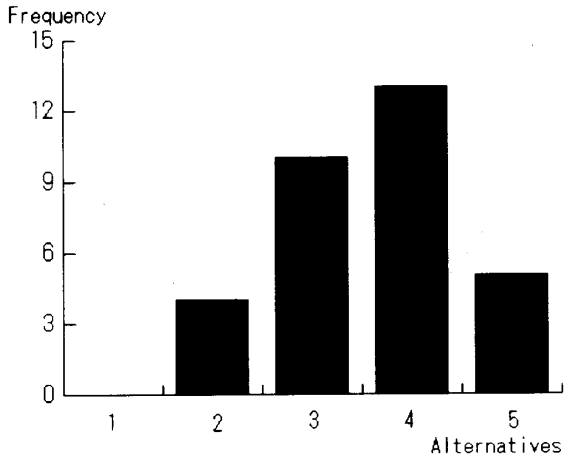

Fig. 20. The results for the questionnaire item 5

It shows that the system has good man-machine interface.

The Figure. 18 shows the results for the item 2. It does not show strong superiority to paper test style, but it shows that the students did not feel worse than paper test style at least.

The Figure. 19 shows the results for the item 3. From the results, it is known that the almost all the students appreciate the instantaneous feed-back of the test in this system.

The Figure. 20 shows the results for the item 4. It shows that almost all the students did not feel that the web based computerized test effected to their test score. However, a few people think that the test method effected to their test score, and we should investigate the reasons.

The Figure. 20 shows the results for the item 5. The item 5 asked the students about the system totally. From the results, we know that this system was appreciated by almost all the students except a few students.

Thus, it is shown that the proposed system is practical for the students to be used in actual situation from the results.

5. EVALUATION BY INTERVIEWING TEACHERS

This section discusses about an evaluation of the system by interviewing two teachers who use this system to construct a test. Their opinions are summarized up as following:

- The system is very convenient to construct a test between two teachers in different places, and there is no serious problem in the system.
- The instantaneous feed-back function is very excellent.
- Although there was no problem because the teachers were lectured enough about how to use this system or how to interpret various feed-backs, the feed-back might be too much and be difficult to interpret by themselves.
- The predictive function were also convenient. However, when there are not lots of items, the function might not effect to their decision to select items.
- It might be difficult to construct a test for new subjects. Because it needs to write new items and input them into the system. It will overload the teachers.

From these opinions, the future tasks to improve the system are considered as follows:

1. Development of an instruction system to help the teachers' comprehension about the functions of the system and data analysis methods.
2. Propelling the use of this system for teachers' usual lectures without limiting distance lectures style. It will help teachers' comprehension about system and it will make the IDB, which the teachers make a great effort to build, worthier by increasing the opportunities of using it.

6. CONCLUSIONS

This paper proposed a design of Web based Computerized Testing System (WCTS) for Distance Education. The system is consistently designed to unify the functions of CATC (Computer Assisted Test Construction), CBT (Computer Based Testing) and CADA (Computer Assisted Data Analysis).

The unique features of this system are as follows:

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2. The CATC has a test score distribution prediction function using past item statistics data in Item Data-Base. These functions show to the teachers the predicted score distribution during they are constructing a test. These functions are expected to assist the teachers' collaborative test construction.
3. The CADA assists an automated process of data input through test execution, marking , analysis and immediate feed-backs to the teachers ,students, and the system. Especially, it is an unique feature to analyze the newly gathered data like the number of times which an student changed his/her answer to an item.

Furthermore, this paper demonstrated some performances of this system for evaluating distance education between Japan and Thailand.

Moreover, from the teachers' interview, the following future tasks were pointed out:

1. Development of an instruction system to help the teachers' comprehension about the functions of the system and data analysis methods.
2. Propelling the use of this system for teachers' usual lectures without limiting distance lectures style. It will help teachers' comprehension about system and it will make the ID, which the teachers make a great effort to build, worthier by increasing the opportunities of using it.

In addition, the author could not get the test construction process data between two teachers in this practice. However, it will be a very interesting task to analyze the process of collaboration by a number of teachers, and it should be executed in near future.

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