# Development of a Mutually Usable Computer Adaptive Testing Tools Using LTI

Takashi NISHIMURA[*1], Haruki UENO[*2], Hiroshi KOMATSUGAWA[*1] and Hiroto YAMAKAWA[*2]

[*1] Graduate School of Science and Engineering, Chitose Institute of Science and Technology, Japan

[*2] Faculty of Science and Technology, Chitose Institute of Science and Technology, Japan

e-mail: m2220190@photon.chitose.ac.jp

This study aimed to develop a mutually usable Computer Adaptive Testing (CAT) system for higher education based on the specification of Learning Tools Interoperability (LTI). First, we proposed four system design plans that are required to mutually use and provide CAT tools for our university and other universities. Next, we chose one of the plans that involved re-making features and developed a new CAT tool within LTI according to the plan. As a result, our CAT tool achieves interoperability but raised concerns about code duplication and maintenance costs.
Key words: CAT, LTI, LMS

## 1. INTRODUCTION

In general education within higher education curriculum, it is expected that by learners progressing through optimized learning based on Computer Adaptive Testing (CAT) results, their learning outcomes will improve. However, implementing a CAT system suitable for general education presents several problems, which include the creation of numerous appropriately leveled questions and the design of optimized question algorithms derived from diverse learning logs. Therefore, the desired CAT system for general education should be unrestricted to individual institutions but usable across multiple institutions.

CIST-Solomon is a Learning Management System (LMS) developed and used by Chitose Institute of Science and Technology. CIST-Solomon contains many learning contents for general education (such as informatics, mathematics, and English), and they are labeled with difficulty levels. In a previous study, CAT features were developed to estimate the comprehension of the learners using the learning contents [1]. However, CAT features are not integrated into other systems. To solve implementation problems of the CAT system, we should be making the CAT feature available to other institutions will enable multiple institutions to use it.

This study aims to realize a CAT system that can be mutually usable by multiple institutions. In this study, we attempt to reimplement the CAT feature of our previously developed CIST-Solomon (as a legacy system) for the specification of Learning Tools Interoperability (LTI). LTI tool specification facilitates educational system integration. LTI tools can be deployed as plugins on LMS, enabling systems to overcome interoperability barriers like user authentication and learning log sharing. To compare and study what system design plan is suitable for realizing a mutually usable CAT tool. Then, the design will be evaluated by developing an LTI tool system.

## 2. PROPOSAL OF SYSTEM DESIGN PLAN

When developing a new CAT tool based on the legacy system, it is imperative to design the system to consider quality for users existing LMS (ex, Moodle) at other universities and the cost for the system provider. In this study, we have three viewpoints, which are barriers to quality and cost for usability in learning activity, ease of sharing learning logs, and maintainability in system providing. Furthermore, we aim to overcome these barriers by considering system design for implementation. Table I shows the type of barriers. The following is a description of the four types of system design plans and how well they achieve barriers.

**Table I Barriers to mutual use**

| Barrier | Viewpoint | Example |
|---|---|---|
| A | Usability in learning activity | Users perform learning activities without switch between systems for authentication, authorization, and use of features. |
| B | Ease of sharing learning logs | Systems perform sharing laerning logs and users access it without having to switch between systems. |
| C | Maintainability in system providing | Sysmtem provider perform provides CAT service and contents without use duplicated implementation and/or operation cost. |

Design 1 in Figure 1 shows how our university's system operation has stayed the same, and other universities implemented and operated a new other CIST-Solomon for the use of the CAT feature. Barrier A is not achieved because it cannot be said to be easy to use because users from other universities use multiple LMS, and users themselves have to switch authentication, authorization, and use of the CAT feature depending on the situation. Barrier B is not achieved because the new CIST-Solomon in other universities has not been integrated into existing LMS, such as by incorporating it into other systems or by sharing learning logs. Barrier C is not achieved because other universities also operate CIST-Solomon as a duplicate system, which increases the maintenance cost for other universities and our university as the system provider.

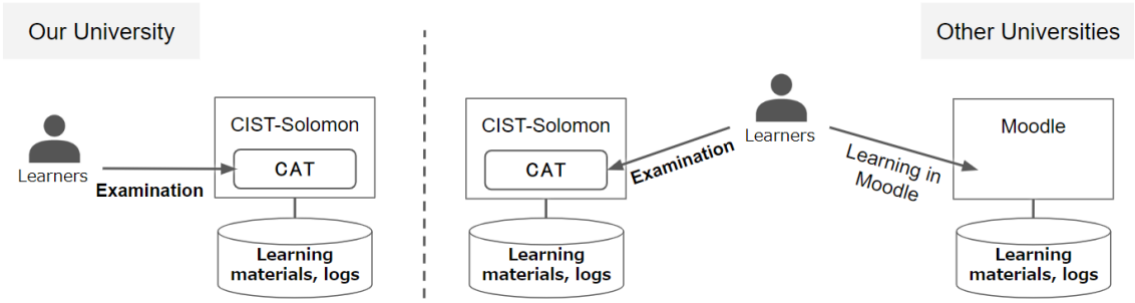


**Figure 1 Design 1**

Design 2 in Figure 2 shows how our university's system operation has stayed the same, and other university users directly use the CAT feature in our university's CIST-Solomon, too. Barriers A and B are not achieved because they have the same problem as design 1. However, Barrier C is achieved because the only CAT used by all users is our university's CIST-Solomon, and the easier maintenance of the CAT feature than Desing1 as the system provider.

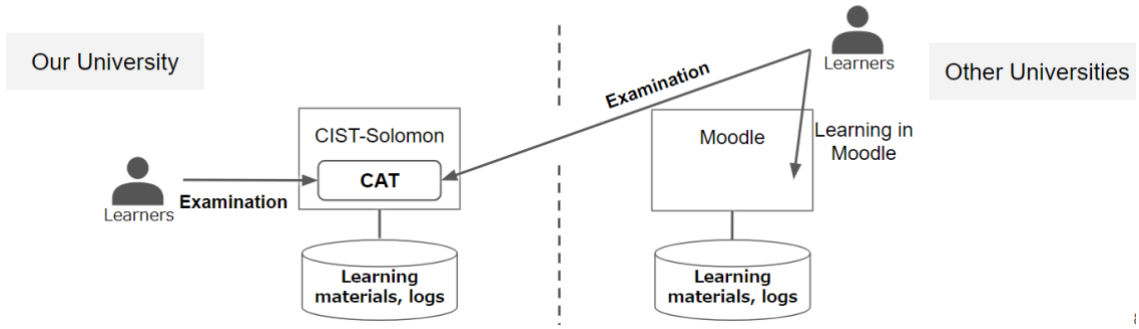


**Figure 2 Design 2**

Design 3 in Figure 3 shows how out university developed a new CAT tool other than CIST-Solomon, and other universities use it. Barrier A is achieved because the CAT tool is provided as an LTI tool, and other university users can use the CAT feature without switching between systems for authentication authorization in the existing LMS feature as if integrated. Barrier B is also achieved because the CAT tool as an LTI tool is able to share learning logs, and users access those without switch systems. It indicates that the introduction of LTI enables interoperability between systems, so that data on teaching materials and learning history can be managed without dispersion between CAT tool and LMS. However, Barrier C is

not achieved because both CIST-Solomon and the CAT tool have the same CAT feature as a duplicate system. So, providing such a design creates the problem of incurring double maintenance costs for the system provider.

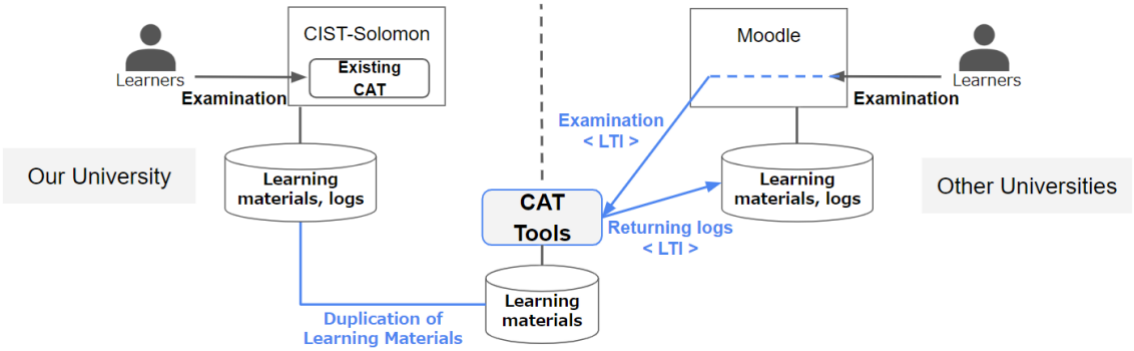


**Figure 3 Design 3**

In addition to the CAT tool in Design 3, Design 4 in Figure 4 shows how CAT can be modularized with a WEB-API to provide the CAT feature directly to CIST-Solomon. Barrier A and Barrier B are achieved in the same way as in Design 3. Barrier C is considered to be achieved because it is easy to update and maintain the system that provides CAT to our university and other universities. The interoperability of the systems prevents the dispersion of user materials and their learning logs. In addition, CAT can be provided to all universities without incurring excessive costs. Note that in Design 4, the modularization of existing CIST-Solomon's CAT feature and the cost of maintenance must be addressed.

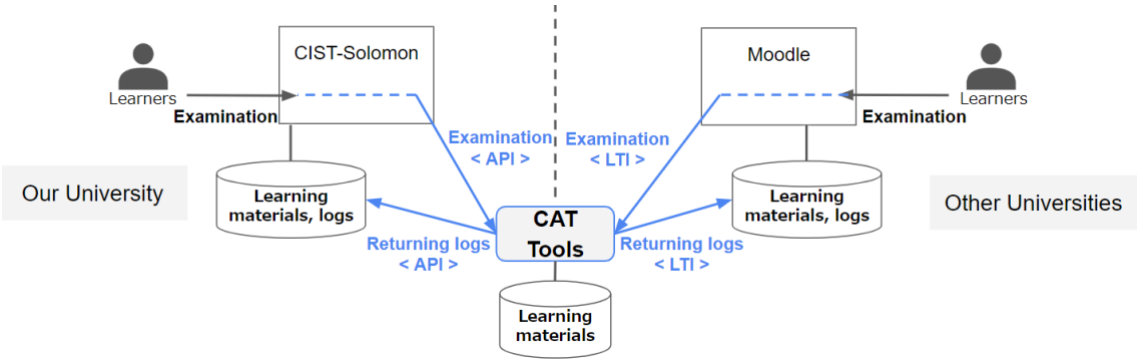


**Figure 4 Design 4**

The achievement status of the barriers for the four proposed designs is presented in Table II. Table II shows that Design 4 achieves the most Barriers. This means that Design 4 is the most desirable design for the interoperability of the CAT feature. However, in this study, the policy is to develop a system adopting Design 3 and then develop it into Design 4 in the future. The reason is the internal complexity of CIST-Solomon. CIST-Solomon, the base of CIST-Solomon, has been under development since 2007 and has various features other than CAT. Among these, the CAT feature is highly dependent on the internal implementation of CIST-Solomon. As an example, the total number of lines of Java source code for the entire CIST-Solomon system is 114,291 lines for student features and 154,830 lines for faculty features. In order to realize Design 4, it is necessary to decipher the complex and highly dependent source code from among these source codes and cut out only the source code for the CAT feature. In our study, Design 3 was adopted as a preliminary step to realize Design 4. Design 3 involves the development of a new CAT tool, which causes the source code for the CAT part to be duplicated. However it does not require any changes to CIST-Solomon and allows CAT to be provided to LMS at other universities without dependencies. In the case of development to Design 4, the new CAT tool will be organized into a WEB-API so that it can be used as a module. By modifying the system so that it can be used from CIST-Solomon as well, we can consider an implementation that can be linked to existing systems with very little internal complexity.

**Table II Achievement status**

| Barrier | Design 1 | Design 2 | Design 3 | Design 4 |
|---|---|---|---|---|
| A | ✕ | ✕ | ○ | ○ |
| B | ✕ | ✕ | ○ | ○ |
| C | ✕ | ○ | ✕ | ○ |

## 3. DEVELOPMENT OF CAT TOOLS

When users use our developed CAT tool based on Design 3, they can access the developed CAT tools via resource links on the platform. Since the request messages from the platform contain course and user information, this information is used to provide features related to CAT. The following sections describe the specific features of the system in the order of the CAT creation screen and the CAT examination screen.

The CAT setting screen is available for the role of teacher. As shown in Figure 5, the screen displays items for setting the unit of knowledge to be tested in the CAT, the name of the CAT, and the number of times the CAT can be taken. It is also possible to check the contents of a group of questions in the unit of the examination. In order to construct a CAT, the user needs to set at least one unit of knowledge. The scope of the CAT includes all the questions at all levels of the knowledge set.


**Figure 5 Screen of CAT creation**

The CAT examination screen is available to users with student or teacher roles and allows them to take the CAT. Figure 6 shows the screen when the CAT examination is started. When the user answers a question, the next question is displayed. This process is repeated until the user finishes taking the CAT. The system collects the results of correct and incorrect answers for each question and estimates the level of questions via the maximum likelihood estimation method for displaying the next question. Figure 7 shows the screen of the results when the CAT examination is completed. The screen shows the optimal level of questions estimated through the examination as knowledge unit mastery. In addition, the screen also shows correct and incorrect answers to questions, and their model answers can also be checked.

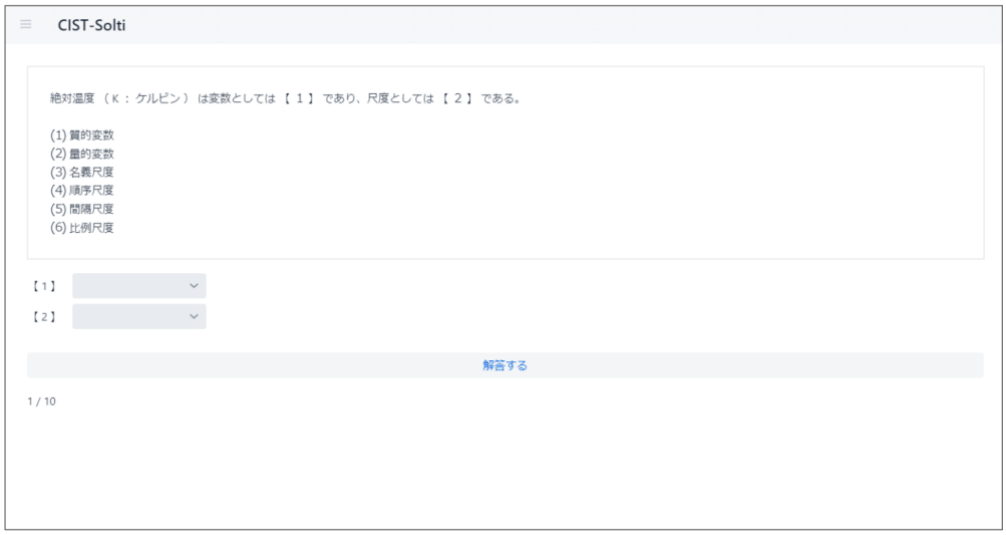


**Figure 6 Screen of CAT examination**

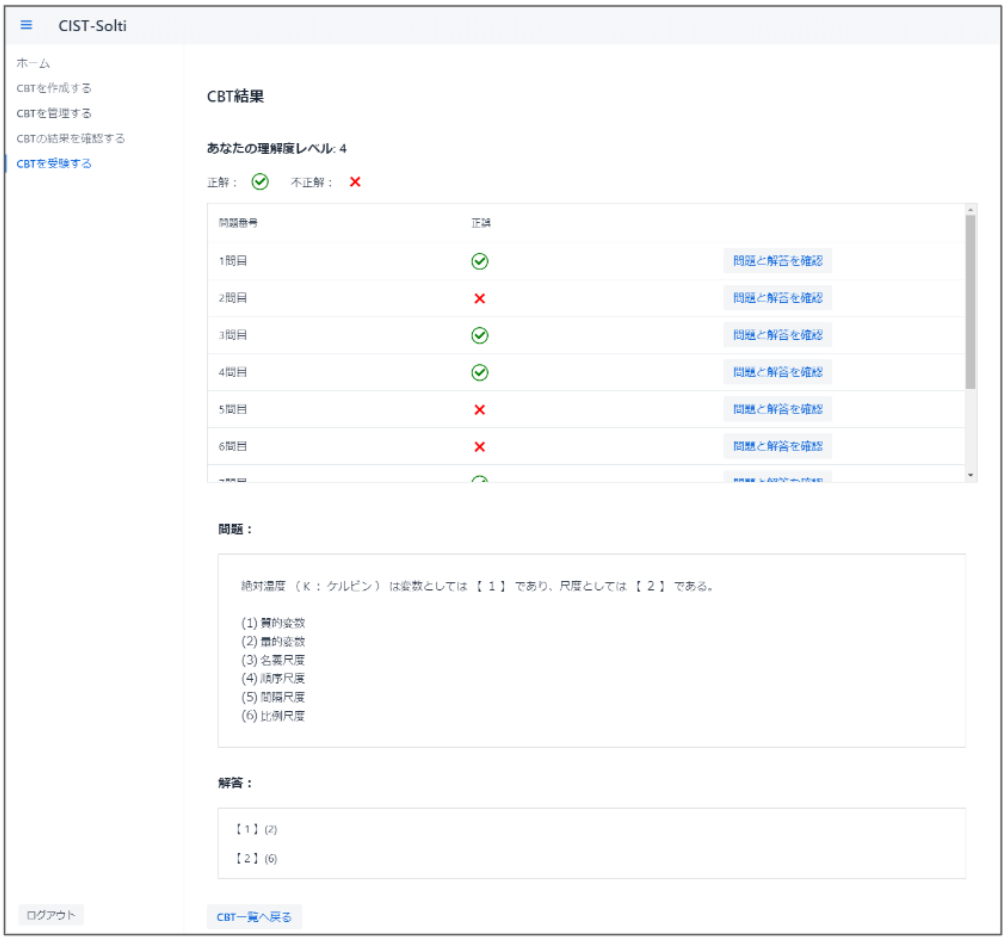


**Figure 7 Screen of CAT result**

## 4. EVALUATION

We developed a CAT tool based on Design 3 and then evaluated the duplication part of the system of CAT feature, which is inferior to Design 4. As a result, The total number of lines of Java source code for the entire CAT tool is 6,028, including 2,665 lines for student features and 3,373 lines for faculty features. The realization of the system employing Design 3 confirms that the CAT tools corresponding to the CAT feature

of CIST-Solomon have achieved Barrier A and Barrier B. However, the Java source code that provides CAT is duplicated for 2,665 lines for student features and 3,373 lines for faculty features. However, the Java source code that provides CAT is duplicated as above. As a result, it is necessary to maintain approximately 6,000 lines of Java source code, a net increase of approximately 6,000 lines due to the duplication, in the future operation and maintenance of CAT. In other words, we can see an issue with barrier C, as assumed in Design 3.

Next, 76 long-term CIST-Solomon users were asked to use the CAT tool to evaluate the usefulness of the system. After logging in to Moodle, the subjects accessed the CAT tool via the resource link and took the test to check their comprehension. Afterward, a questionnaire was collected from the participants, asking, "Were you able to open the CAT tool from Moodle?" All the participants answered "Yes" to the question. In addition, the average score for responses to the 4-point scale question "Were you able to confirm your comprehension on the results screen after an examination of the CAT?" was 3.92 (We scored the responses as follows to obtain an average score: 1. Strongly disagree, 2. Disagree, 3. Agree, 4. Strongly agree). The results of the questionnaire indicate that the CAT examination was completed without authentication or switching systems. As a result, our CAT tool provided the same CAT feature as CIST-Solomon's, and users perfumed it without switching systems from Moodle to CIST-Solomon. Thereby, Barrier A of the Design 3 assumptions was achieved. However, Barrier B could not be verified due to the development schedule, and this is an issue for the future.

## 5. CONCLUSION

The main objective of this study was to realize a CAT tool based on the LTI standard, i.e., a CAT tool with high interoperability, and a system design was conducted to new CAT tool as an LTI tool. Then, it was decided to adopt design 3 as a preliminary step to realize design 4 by carving out features from the existing system that had become complicated. Next, a CAT tool was developed in line with the system design. As a result, Barrier A and Barrier B were successfully achieved, but some issues remained due to duplication.

In the future, we will evaluate the usefulness and interoperability of the developed CAT tool. Through this evaluation, we plan to show the substitutability of the CAT tool for CIST-Solomon's CAT features and the practicality of the tool as an LTI tool.

## 6. REFERENCES

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