A Structure of Personalized e-Learning System Using On/Off-line Mixed Estimations Based on Multiple-Choice Items

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ABSTRACT

In this paper, we present a structure of personalized e-Learning system to study for a test formalized by uniform multiple-choice using on/off-line mixed estimations as is the case of Driver's License Test in Korea. Using the system a candidate can study toward the license through the Internet (and/or mobile instruments) within the personalized concept based on IRT(item response theory). The system accurately estimates user's ability parameter and dynamically offers optimal evaluation problems and learning contents according to the estimated ability so that the user can take possession of the license in shorter time. In order to establish the personalized e-Learning concepts, we build up 3 databases and 2 agents in this system. Content DB maintains learning contents for studying toward the license as the shape of objects separated by concept-unit. Item-bank DB manages items with their parameters such as difficulties, discriminations, and guessing factors, which are firmly related to the learning contents in Content DB through the concept of object parameters. User profile DB maintains users' status information, item responses, and ability parameters. With these DB formations, Interface agent processes user ID, password, status information, and various queries generated by learners. In addition, it hooks up user's item response with Selection & Feedback agent. On the other hand, Selection & Feedback agent offers problems and content objects according to the corresponding user's ability parameter, and re-estimates the ability parameter to activate dynamic personalized learning situation and so forth.

Keywords: *personalized e-Learning, on/off-line mixed estimation, IRT(item response theory), user ability parameter, item parameters.*

1. INTRODUCTION

Customized or Personalized learning has been one of the most important goals in educations either online or offline learning sites. Therefore many researches have proposed various concepts of 'personalization' or 'customization' in our education's world. Especially the concepts of personalized e-Learning which dynamically offers appropriate learning objects on the ground of the learner's characteristics were recently proposed in some literatures[1]. On the other hand, there are many kinds of qualifying examinations such as written exam of driver's license or estate agent license etc. in our recent complicated society. Most of these examinations are formalized by multiple-choice problems with 4 or 5 alternatives. People trying to get such license usually study using books or learn from specialists in some public or private academies. In recent years, however, it became usually known that online study through the Internet maybe more effective than these offline studies mentioned above, especially for the younger age called 'Netizen'.

In this paper we propose a structure of personalized e-Learning system using on/off-line estimations for any qualifying test formalized by uniform multiple-choice. But our stress may be focused on Driver's License Test which has regular form of multiple-choice with 5 alternatives. User can study toward the license through the Web(and/or mobile instruments) within the personalized concept based on IRT(item response theory) using the system. IRT is a convenient tool to estimate user's ability and offer optimal problems and learning contents according to the estimated ability so that the user can approach the goal of the license in a shorter time[2],[3]. Especially driver's license test is an indispensable social qualifying exam as far as there exists cars on the street of our modern society, therefore the e-Learning system of the license can be easily expected to be industrialized continuously for the time being[4]. As shown easily in our complex society, conventional learning methods using offline books or private academies can exhaust too much cost and time to get the license, and the effectiveness of this offline learning is gradually lower and lower evaluated.

The rest of the paper is organized as follows; Section 2 describes the system structure and learning procedure proposed in this paper. We deal with content design for e-Learning, system architecture for personalization and operations for preparing deriver's license test. Section 3 presents the industrial application areas for the system designed in this paper. Finally

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Section 4 gives our concluding remarks and describes the future studies.

2. SYSTEM AND CONTENT STRUCTURE

We propose a personalized e-Learning system based on IRT that dynamically estimates learner's ability parameter and offer the optimal problems and content objects to the learner according to the estimated ability parameter so that he/she can easily arrived at qualifying goal. In order to achieve the objectives mentioned previously, we design a framework of our e-Learning system as shown in Fig. 1.

2.1. System Architecture

The personalized e-Learning system for a kind of qualifying test formalized by multiple-choice consists of 3 databases and 2 agents. In addition Bilog-MG Estimator(160) and Public/Private Academies(170) are attached in offlined manner depicted by dotted line in Fig. 1. Databases are Content DB(110), Problem Bank DB(120), and User Profile DB(130). We also introduce two kinds of program modules such as Interface Agent('IF agent': 140) and Selection & Feedback Agent('SF agent': 150). In Fig. 1, these blocks are connected together according to their functions and operating sequences.

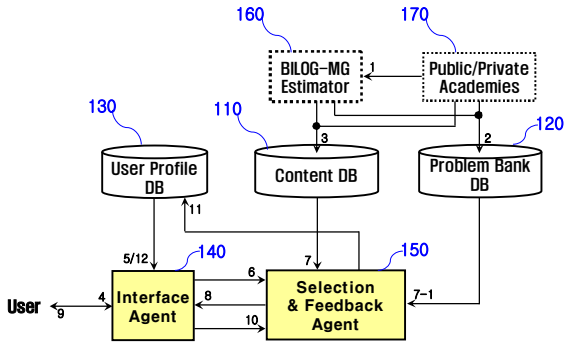

Fig. 1. Block Diagram of the Personalized e-Learning System Structure

Content DB(110) maintains learning content objects in the form of conceptual-unit as described in [5] or [6]. The content object stored in this DB possesses each peculiar lesson-ID that is connected to the unit-IDs of the qualifying test. In addition, all the problems in Problem Bank have their inherent IDs just same as that of content objects so that we can select and offer the optimal problems and learning content object for the examinee through 'incorrect answer analysis' from his/her item responses.

Problem Bank DB(120) maintains items used in the qualifying test for the real licensing written exam. They can be offered by the authority of the license or public/private academies. Also we can obtain the items from various textbooks. The items stored in this DB have their own 'difficulties', 'discriminations', and 'guessing parameters' estimated by Bilog-MG as well as their inherent IDs just same as that of content objects. The items parameters might be periodically re-estimated by offline estimator such as Bilog-MG.

Moreover there are 3 distinct 'evaluation problems' in this DB. A Mock Exam consists of 50 items like the real qualifying test, an Occasional Exam has 20 or 30 items, and a Quiz has 10 items. They are assigned to the user by selection of SF agent according to the examinee's ability parameter. After user responses to the items offered, the answers from the user will be feedback to re-estimate the ability parameter and cumulated to be used for offline tracing of item parameters by the offline estimator.

User Profile DB(130) contains learner status, accounting information, item response vector, user ability parameter, and performing information about learning content. Throughout the interactions with IF agent, it transmit the recent learner's ability parameter, and then SF agent selects the optimal learning content objects and displays to the user.

Interface Agent(140) realizes HCI(human computer interface) that transmits learner ID, password, status information, and various queries. Moreover it displays content objects and items to learner and relays examinee's response to the system.

Selection & Feedback Agent(150) performs parameter estimations and updates, selections of learning Nodes, and their offering. The key points in the process of personalized e-Learning are dynamic estimations of parameters and dynamic selections of the optimal content and test item. At the end of every test, SF agent re-estimates the examinee's ability parameter so that we can select the optimal item available that has the nearest 'difficulty' parameter measured from the ability parameter. Although there are various methods to measure the distances from learner's 'ability' to item's 'difficulty', we use the mean-square error criterion.

Bilog-MG Estimator(160) is a package program which estimates item parameters for all items in the Problem Bank DB(120). Each item has its own 'difficulty', 'discrimination', and 'guessing parameter' because we utilize the 3-parameter Logistic Model in IRT for our personalized e-Learning system.

For the first time of the system operation, we should estimate item parameters using the abundant item-responses that have been made for a long time by various examinees of the qualifying test in offline manner. In succession, estimated item parameters are stored in the Problem Bank DB(120) with the corresponding items.

Once the system starts operations, more and more item-responses will be accumulated. We can make item parameters to be re-estimated using the online responses once in a fixed period, for example 6 months. The re-estimated item parameters will be used to renew the Problem Bank DB(120). Although there are several kinds of offline estimators realizing IRT concepts, we select Bilog-MG that is one of the most popular package programs in this era[7].

2.2. Content Design

Content stored in Content DB should be broken into segments to be used independently so that we can achieve the personalized e-Learning scheme proposed in this paper. The content segments are equivalent to the conceptual-unit object described in [5] or [6], and they have the same concept as SCO(sharable content object) in the SCORM standard [8].

The hierarchical structure of the content consists of 'chapter', 'large section', 'medium section', and 'small section' etc starting from the name of the subject(or license name) as usual. But we invite the concept of learning object to represent the smallest unit at which we can assign unit-ID. This concept of object will be the same as SCO distributed horizontally in a minimum section. In addition a smallest section consists of several learning objects and items so that we can relate them by assigning the same section number. If an examinee takes a wrong answer about any item SCO, the personalized e-Learning system might offer corresponding learning content object using the same section number assigned at the wrong-answer note of the item SCO.

All item SCOs in a section have their inherent item parameters, and they are re-estimated every period by the off-line estimator mentioned above. A learning content object SCO has its own number of section that is the same for directly related item SCO or the same number of section. In this method, we can construct an efficient personalized e-Learning scheme with dynamic estimation processes by making content SCOs to possess their own section number and directly related item SCOs. Although some recent systems assign 'difficulty' parameters to the content object SCOs using the 'difficulty' parameters of their corresponding item SCOs in order to build up fixed connections between contents and items in the process of personalized e-Learning[9], we just link contents to items by the IDs of their section because this strategy should be sufficient to connect the contents with their corresponding items using the wrong-answer note for surveyed items

3. LEARNING OPERATIONS FOR PREPARING A LICENSE TEST

In this section, we explain the learning procedure for preparing a license test formalized by multiple-choice with fixed alternative using the system architecture given in Fig.1. All the processes for a round of learning totally consist of an 'off-line operation' and an 'on-line operation'. The numbers assigned in Fig.1 direct the sequence of a round of learning. Moreover, a learner can select one course from three possible alternatives, 'Personalized Course', 'Beginner Course', and 'Mock Test Course'.

3.1. Off-line Operation

Off-line operation is a kind of preprocessing for on-line operation, which includes content authoring as well as estimations of item parameters, DB construction, and periodical re-estimations of item parameters. We estimate the initial item parameters from various examinee's item-responses accumulated and we initialize the Problem Bank DB(120). In addition, we can re-estimate the item parameters using item-responses obtained from on-line operations for a long period. These parameters will be utilized to renew the Problem Bank DB(120) and to maintain the total system.

1. We estimate the item parameters such as 'Difficulty', 'Discrimination', and 'Guessing' from various examinee's item-responses using the off-line estimator named Bilog-MG.
2. We store all items and their parameters in the Problem Bank DB(120). Each item essentially possesses its 'Difficulty', 'Discrimination', and 'Guessing' parameters based on the 3-parameter Logistic model of IRT. Moreover, all the items have their IDs indicating their embedded sections so that SF Agent(150) can select content object SCOs with the same ID from the Content DB(110) using the wrong-answer note.
3. We store all content objects with IDs indicating their embedded sections in the Content DB(110). All the content objects are stored in the form of conceptual-unit which can be extracted by their IDs connected to IDs of corresponding items in the Problem Bank DB(120).

3.2. On-line Operation

After Problem Bank DB(120), Content DB(110), and User Profile DB(130) are prepared and initialized through the processes discussed above, the two agents will be operating together to make the system to be on-line situation.

4. Login and course selection; Learner enters the system using his ID and password via IF agent(140). New user has to register his personal status information before login. After login, user can select a favorite course among 3 available courses such that 'Personalized Course', 'Beginner Course', and 'Mock Test Course'.

3.2.1. When 'Personalized Course' is selected ;

5. (with the step 6) Transferring Learner's Ability Parameter; The system identifies user and transmits his ability parameter from the User Profile DB to the SF agent via the IF agent. The ability parameter of a new user without any profile information will be given by '0'. This step initializes SF and IF agent to operate for the procedures of personalized e-Learning course.
6. (attached t0 the step 5)
7. Selections of content object or items; SF agent selects the optimal learning content object from Content DB(110) according to the wrong-answer note which is recently extracted by the learner. (7-1) In addition, SF agent also selects items from Problem Bank DB(120) according to the learner's ability given by the step 5 and 6 presented above.

<Selection of items> We select problems with difficulty parameter nearest to the ability parameter of the learner. SF agent calculates the minimum mean-square error given below by comparing the recent ability parameter θ_n with the difficulty parameters b_i, i = 1, 2, 3, …, N, where N is the number of items in the problem.

$$\overline{E^2} = \sum_{i=1}^{N} \frac{1}{N} (\theta_n - b_i)^2, \quad i = 1,2,\cdots,N \qquad (1)$$

where θ_n means the initial ability parameter at this step, but it will be the recent ability after some rounds of the loop with re-estimations at the end of every problem. Therefore the examinee's ability parameter dynamically varies with the item parameters and the responses about the items in this scheme.

<Selection of content object> When a learner want to study using content object after his ability has been renewed by his response vector, SF agent selects and offers the corresponding content objects using his wrong-answer note. Because content objects and items possess their section IDs, we can naturally connect them using their corresponding IDs.

8. (with the step 9) Playing the selected content objects and obtaining user's responses about the items; Displays the content objects selected by SF agent to the user and waits for his responses via IF agent.
9. (attached t0 the step 8)
10. Transmits user's item responses to SF agent in order to re-estimate his ability parameter; If the present ability is θ_{old}, we re-estimate the new ability θ_{new} using the item-responses for N items offered in the step 7-1 based on 3-parameter Logistic model as follows;

$$\theta_{new} = \theta_{old} + \frac{\sum_{i=1}^{N} a_i \{U_i - P_i(\theta_{old})\}}{\sum_{i=1}^{N} a_i^{\,2} P_i(\theta_{old}) Q_i(\theta_{old})} \qquad (2)$$

where U_i is the i-th item response flag having value '0' for a correct answer or '1' for a wrong answer, and a_i is the discrimination parameter for the i-th item.

Moreover the probability of correct answer for the 3-parameter Logistic model is given by

$$P(\theta) = c + (1-c)\frac{e^{a(\theta-b)}}{1+e^{a(\theta-b)}} \qquad (3)$$

and the inverse probability of it, ie the probability of wrong-answer will be given by

$$Q(\theta) = 1 - P(\theta) \qquad (4)$$

where 'a' is the discrimination, 'b' is the difficulty, and 'c' is the guessing parameter of the item.

11. Saves new user's ability parameter re-estimated above in the User Profile DB.
12. Transferring re-estimated ability parameter; This is the same procedure as the step 5 described above. The system transmits a new ability parameter to the IF agent for the next process for our personalized e-Learning.

During the personalized e-Learning procedures are continued after user's login, the loop from Step-5 to Step-11 is repeated and the parameters are periodically re-estimated. The change of ability parameter of one examinee can be considered as realistic improvement of his ability about the subject, but the item parameters will be maintained until the next periodical renewals of off-line estimator.

3.2.2. When 'Beginner Course' is selected ;

Selection of 'Beginner Course' means that the learner does not have any experience of the system, so the system may offer some content objects to the user. SF agent selects some contents essential for a beginner, and then the beginner can proceed the step 7-1 as is the case in the 'personalized course' and so forth.

3.2.3. When 'Mock Test Course' is selected ;

A selection of 'Mock Test Course' means that the learner has quite experiences of the system or near reach to the license, so the system may offer a Mock-up test from the Problem Bank DB. After the first offering of Mock-up test, some content objects can be assigned to the user according to the item-response in the test or user's requirement. In this case, SF agent selects and offers some contents as is the case in the 'personalized course' and so forth.

4. CONCLUDING REMARKS

In this paper, we presented a new scheme of personalized e-Learning system using on/off-line mixed estimations based on the IRT for a license test formalized by multiple-choice. Personalization is realized by means of IRT-based dynamic parameter estimations. But the item parameters are fixed during the personalized e-Learning procedure until the off-line periodical re-estimation is performed. On-line re-estimations during the loop of e-Learning should be proceeded in learner's ability parameters. This scheme can be applied to any qualifying and licensing test formalized by multiple-choice with fixed alternatives.

At present we just construct the system structure and are working toward an open on-line exercise for a realistic personalized e-Learning scheme for the written exam of driver's license test in Korea. Therefore our system needs various operations for various levels of examinees. We suffer

from the lack of operation experiences by different users from all about the license world.

In the near future, we will have a experimental results about real operational experiences. We may obtain various advancing trends toward the license according to the e-Learning procedure using the system based on pictorial services of the IRT estimator Bilog-MG.

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