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ABSTRACT

The authors developed a Web-based Adaptive Educational System (Web-based AES) named ITMS (Individualized Teaching Material System). ITMS adaptively integrates knowledge on the distributed Web pages and generates individualized teaching material that has various contents. ITMS also presumes the learners' knowledge levels from the states of their knowledge reference instead of from tests or questionnaires. This paper describes the framework of adaptive knowledge integration and the method of presumption, and provides an overview of the ITMS system architecture. The current ITMS has two apparent problems to be solved. One is to prune knowledge that is unnecessary for the learners. The other is to manage the knowledge distributed in many servers. The authors are conducting experiments to evaluate ITMS and planning improvement on the basis of this evaluation. The framework is currently being applied to exploratory learning in the vast Web space. (Contains 10 references.) (AEF)

ITMS: Individualized Teaching Material System

-Adaptive Integration of Web Pages Distributed in Some Servers-

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Abstract: Web-based Adaptive Educational System (Web-based AES) has actively been developed. However, it is doubtful whether the system is useful to learners, since the system mainly deals with Web pages fixed in one server. Web-based AES should deal with various Web pages distributed in some servers in order to fulfill the learners' diversity. We developed a Web-based AES named ITMS (Individualized Teaching Material System). ITMS adaptively integrates knowledge on the distributed Web pages and generates individualized teaching material that has various contents. ITMS also presumes the learners' knowledge levels from the states of their knowledge reference instead of tests or questionnaires. This paper describes the framework of adaptive knowledge integration, the method of the presumption, and the overview of ITMS.

Introduction

In the past Adaptive Educational System (AES) was developed as a stand-alone system. Web-based AES has recently come to be developed by the rapid increase of the Web (Brusilovsky 2000). Nowadays Web pages are expected to be teaching material for life-long learning. This expectation will strongly increase the development of Web-based AES. However, it is doubtful whether the current Web-based AES is useful to learners. This is because the Web-based AES mainly deals with Web pages fixed in one server regardless of the learners' diversity, namely it does not provide the learners with useful contents created by various authors all of the world. If learners only utilize search engines, they will be able to receive piles of various Web pages. However, the piles consequently will bother them, which is what is called disorientation (getting lost) and information overload. This indicates that the accuracy and the usability of search engines are not enough for educational usage. There are a few Web-based AESs partially deal with the distributed Web pages. For example, AHA adapts hyperlinks that connect with the distributed Web pages to learners' knowledge levels (De Bra & Calvi 1998). However, these systems do not seem to solve the disorientation and the information overload on the distributed Web pages, not restricting the learners' movement among the distributed Web pages completely.

Our research goal is to adaptively provide learners with useful teaching material created by various authors and furthermore is to avoid the disorientation and the information overload in the teaching material. We developed a Web-based AES named ITMS (Individualized Teaching Material System). ITMS adaptively integrates knowledge on Web pages distributed in some servers and generates individualized teaching material that has various contents. An adaptive aspect of ITMS is to inform the learners of knowledge they should/must refer to on the basis of their knowledge levels. ITMS additionally avoid the disorientation and the information overload by contriving knowledge presentation. Here, there is a problem how ITMS assesses the learners' knowledge levels. AES needs to assess the levels frequently for proper adaptation. However, frequent tests/questionnaires will cause the learners loads. We are trying to presume the levels from the states of the learners' knowledge reference.

Framework of Adaptive Knowledge Integration

Educational Web pages need to contain a lot of the related knowledge, taking into consideration diverse kinds of learners' readiness. Especially prerequisite knowledge is essential in order to prevent novice learners from having a learning impasse caused by the contents of Web pages. However, it is hard for authors to create these Web pages by themselves. Even if they can do it, the Web pages will not have the contents organized with various viewpoints.

Hence we propose the framework that adaptively integrates a lot of the related knowledge and generates individualized teaching material. This knowledge, needless to say, is created by various authors and can be stored in distributed servers. We developed ITMS according to this framework.

Knowledge Creation

The authors create knowledge for integrating in the following order.

(i) They create educational Web pages.
(ii) They divide the Web pages into small fragments (For example, fragments on a certain formula in mathematics are "the formula", "the explanations", "the demonstration", and "the exercises").
(iii) They make an index of each fragment using HTML comments designated by ITMS (The fragments do not have semantic attributes).

The fragments can contain fragments created by various authors inside them, namely various kinds of knowledge can be structured hierarchically. The authors only describe the pointers (URLs) to the distributed Web pages containing the indexed fragments in order to structure the fragments. ITMS provides the authors with creating large-scale teaching material easily.

Integration Method

ITMS generates individualized teaching material in the following order.

(i) It receives the request of a Web page from a learner.
(ii) It analyzes the hierarchical knowledge structure through the pointers, regarding the requested page as the root.
(iii) It acquires sequentially the knowledge on the distributed Web pages on the basis of the analyzed structure.
(iv) It integrates the acquired knowledge into the requested page.

ITMS adopts hierarchical stretch-text as a method of knowledge presentation in order to facilitate the learners' knowledge reference. Hierarchical stretch-text, which contains knowledge hierarchically inside it, is expanded and collapsed by the learners' preference. When the learners need to refer to knowledge inside it, they click the title of the knowledge (the trigger of the stretch-text) and the knowledge is expanded beside the title. It is indicated that stretch-text (hierarchical stretch-text) is effective in the decrease of getting lost and information overload (Boyle & Encarnacion 1994)(Höök et al. 1996)(Murray et al. 2000). Although conventional stretch-text mainly deals with text data, hierarchical stretch-text in ITMS deals with various data such as images, movies and Java applet.

Adaptation

ITMS adapts the contents of the individualized teaching material to the learners' knowledge levels by embedding visual annotation (Brusilovsky 1995) and knowledge hierarchy alteration. The two methods, which inform the learners of knowledge they should/must refer to, not only prevent the decline of their knowledge levels but also are useful in presuming the levels.

Taking into consideration the fine-grained knowledge for integrating, we simply classify the knowledge levels as follows: "understanding", "unstable understanding", and "no understanding". The next section describes the presuming method. Table 1 shows the relation between the knowledge level and the adaptation. Figure 1 shows the overview of the adaptive knowledge integration.

Knowledge Level	Adaptation
understanding	A circular blue icon, which means knowledge that a learner does not have to refer to, is embedded beside the title of the knowledge.
unstable understanding	A circular yellow icon, which means knowledge that a learner should refer to, is embedded beside the title of the knowledge.
no understanding	Knowledge, which a learner must refer to, is transferred to the top layer of a new Web page and a circular red icon is embedded beside the title of the knowledge. Additionally, a star-shaped red icon, which means the transfer of the knowledge, is embedded in the original location of the knowledge.

Table 1. The relation between the knowledge level and the adaptation

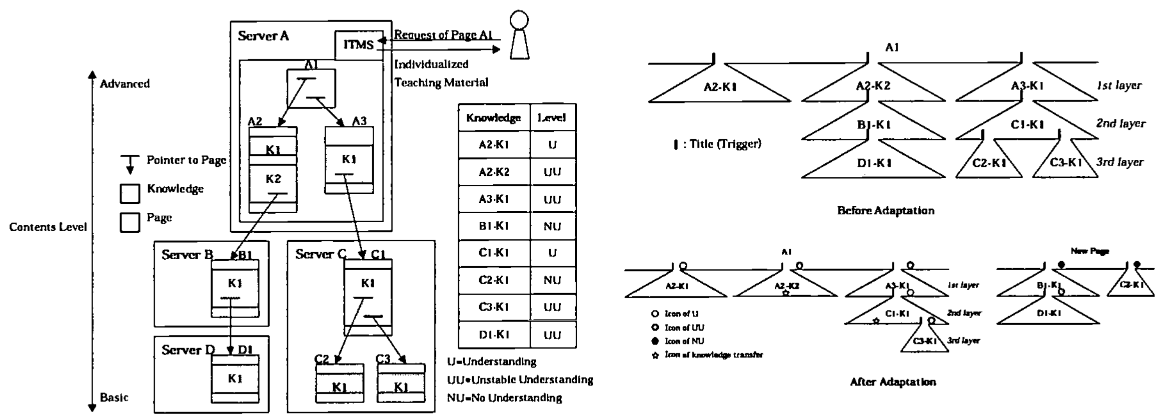

Figure 1. The overview of the adaptive knowledge integration

Method for Presuming Learners' Knowledge Levels

Fundamental Idea

Tests and questionnaires are methods for assessing learners' knowledge levels correctly. Frequent tests/questionnaires are necessary for AES to assess their latest knowledge levels, whereas the frequent test/questionnaires will cause the learners loads.

ITMS needs to assess their latest knowledge levels in order to provide proper adaptation. Accordingly it utilizes the states of their knowledge reference as elements for presuming the levels. Activities of their knowledge reference do not cause them loads basically, based on their intention.

Related Works

It is indicated that data on learners' activities in hypermedia is so insufficient that AES should not independently use the data to presume their knowledge levels (Brusilovsky 1996). Especially data from a Web browser such as browsing history may be unreliable.

There are some AESs that presume their knowledge levels from such activities (Hohl et al. 1996) (Wu et al. 2000). These systems, which mainly utilize data on the activities and data on knowledge structure of a domain (domain model) for the presumption, do not take into consideration the decline of the levels, namely it is difficult for these systems to assess their latest knowledge levels. Although some of these systems allow the learners to modify their own levels (user model), their modifications are not always correct and might be loads.

Method

We hypothesize that learners autonomously refer to knowledge if they do not understand the knowledge. Accordingly, this hypothesis indicates that the states of their knowledge reference are strongly related to their knowledge levels. Specific hypotheses are as follows:

(a) Learners do not refer to knowledge they understand.
(b) Learners refer to knowledge they do not understand.
(c) Learners understand knowledge just after referring to the knowledge.
(d) As the time passes, learners' knowledge levels decline.

On the basis of the above hypotheses, ITMS assesses the level of the knowledge that the learners can directly refer to at "understanding" regardless of the sates of the reference. In other words, the level of the stretch-text that the learners can directly expand is assessed at "understanding". Hence it is important how ITMS presumes the level of the knowledge that the learners cannot directly refer to, namely hidden knowledge. To take an example in "Before Adaptation" in Figure1, ITMS assesses all the level of A2-K1, A2-K2 and A3-K1 at "understanding" and cannot assess the level of the others in the case that a learner refers to A1, since it is unknown whether the learner is aware of the others.

ITMS presumes the level of the hidden knowledge from the frequency of sequential presence of the hidden knowledge. In the case that the frequency reaches thresholds that are related to the knowledge levels, ITMS adapts the knowledge presentation in order to make the learners be aware of the hidden knowledge. The knowledge hierarchy alteration presents the hidden knowledge that was presumed to be in "no understanding" on the front Web browser as a new Web page. By this alteration, the learners will surely be aware of the hidden knowledge of importance and ITMS assesses their latest knowledge levels. Table 2 shows the relation between the knowledge level and the threshold.

Knowledge Level	Threshold (Initial value)
understanding	--
unstable understanding	2
no understanding	5

Table 2. The relation between the knowledge level and the threshold

ITMS modifies the thresholds from hypothesis (a) and (b) and realizes fine-grained adaptation. The rules for modifying the thresholds are shown below.

```
if (Level of Knowledge X == "unstable understanding"){
       if (Learners referred to Knowledge X){
              Threshold of "unstable understanding" of Knowledge X --   (>2)
       }
       elseif (Learners did not refer to Knowledge X){
              Threshold of "unstable understanding" of Knowledge X ++
       }
}
elseif (Level of Knowledge X == "no understanding"){
       if (Learners referred to Knowledge X){
              Threshold of "no understanding" of Knowledge X --   (>5)
       }
       elseif (Learners did not refer to Knowledge X){
              Threshold of "no understanding" of Knowledge X ++
       }
}
```

ITMS

System Architecture

ITMS may be popularized from the reason of a client/server system with simple architecture, which does not need additional devices such as a proxy server. The authors can easily do setup of ITMS. All the learners have to do is prepare a Web browser interprets Dynamic HTML and JavaScript. Figure 2 shows the architecture of ITMS. ITMS, which is implemented using Perl, consists of the following modules and databases.

Data Receiving Module (DRM): This module receives all of the data from the learners (login name, page request and the states of knowledge reference).
Knowledge Level Presumption Module (KLPM): This module presumes their knowledge levels from the data of their knowledge reference and the thresholds.
Knowledge Integration Module (KIM): This module adaptively integrates the related knowledge and generates individualized teaching material. It additionally attaches JavaScript that observes the states of their knowledge reference to the individualized teaching material.
Knowledge Reference DB (KRDB): This database has the data of the states of their knowledge reference.
Knowledge Level DB (KLDB): This database has the data of their knowledge levels (the thresholds of each knowledge).
Knowledge Metadata DB (KMDB): This database has the metadata (index and location) on the integrating knowledge.
Teaching Material DB (TMDB): This database has educational Web pages containing the integrating knowledge.

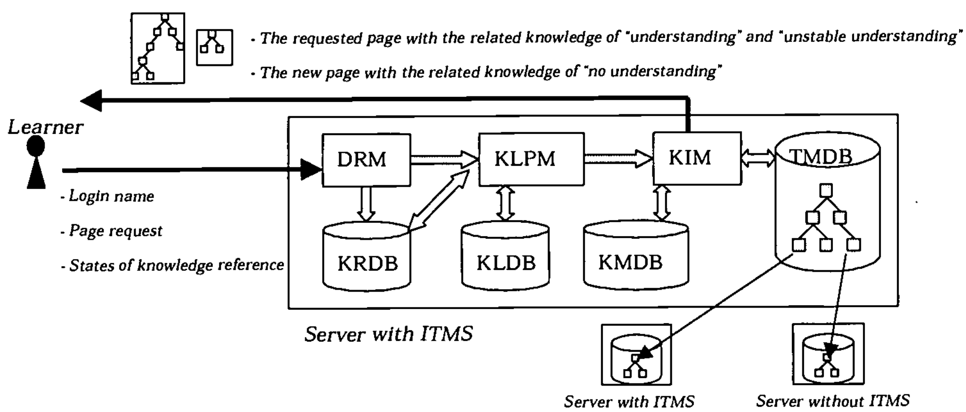

Figure 2. The architecture of ITMS

An Example of Adaptive Knowledge Integration

We created educational Web pages on CG (Computer Graphics), which contain the prerequisite knowledge of linear algebra and programming language. The prerequisite knowledge is created by two authors and is stored in two servers. Figure 3 shows a learning example in ITMS. The left Web browser shows one of the educational Web pages that a learner requested. The right Web browser shows a Web page that contains the related knowledge (the prerequisite knowledge) of "no understanding". Hierarchical stretch-text in this example has images and a Java applet. The learner acquires various kinds of knowledge of CG in accordance with the adaptation of ITMS.

Conclusion

This paper described ITMS that has the framework of adaptive knowledge integration. This framework adaptively provides learners with useful teaching material created by various authors. A key feature of ITMS is to deal with Web pages distributed in some servers for the adaptive knowledge integration. ITMS additionally presumes the learners' knowledge levels from the states of their knowledge reference in order to decrease their loads.

The current ITMS has two apparent problems to be solved. One is to prune knowledge unnecessary for the learners. As the integrating knowledge increases, overload to ITMS increases beyond doubt. The other is to manage the knowledge distributed in many servers. The solution of the former may need analyzing the learners' knowledge levels in detail. The introduction of XML for solving the latter is now under consideration.

We are evaluating ITMS by experiments and planning to improve ITMS on the basis of the evaluation. In addition, we are currently applying the framework to exploratory learning in vast Web space.

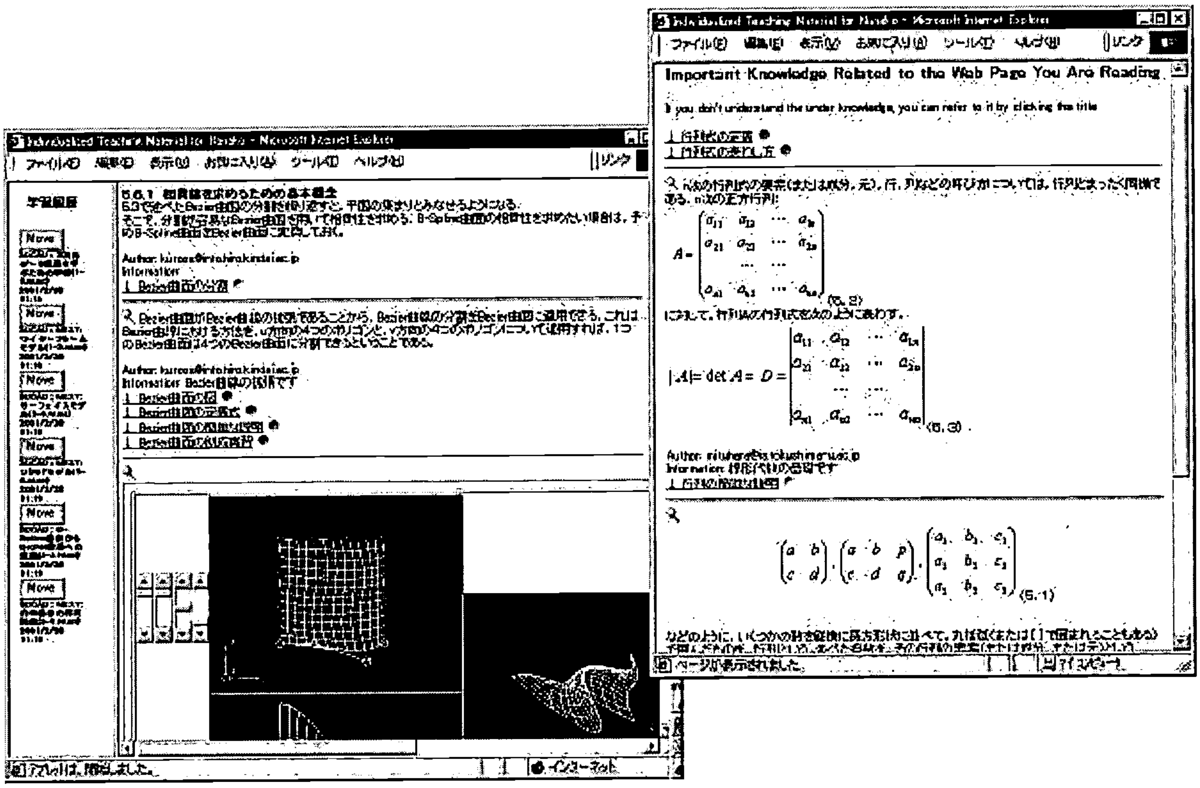

Figure 3. A learning example in ITMS

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