Interactive History with Learning Affordance for Knowledge Construction in Web-based Learning

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Abstract: The main problem addressed in this paper is how to help learners construct knowledge in exploring existing hypermedia/hypertext based learning resources on the Web. Our approach to this problem is to provide a learning tool, which affords knowledge construction activities involving reflection on the exploration process. In this paper, we describe an interactive history that encourages learners to annotate their exploration history with the reasons why they have explored, which reasons have a great influence on knowledge construction in hyperspace. It also generates a knowledge map from the annotated exploration history, which map spatially represents the semantic relationships among the Web pages explored by the learners. This paper also describes an evaluation with the interactive history system. The results indicate that the system affords rethinking exploration process.
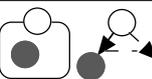
Introduction

An increasing number of hypermedia/hypertext based resources for learning/education has been available on the Web. These web-based learning resources generally provide learners with hyperspace where they can explore the Web pages by following the links among the pages to learn the domain concepts/knowledge in a self-directed way (Nielsen, 1990, Kashihara, Ujii, and Toyoda, 1999). The exploration often involves integrating the contents of some pages that have been explored to construct their knowledge (Thuering, Hannemann, and Haake, 1995). These knowledge construction activities would enhance learning (Jonassen, 1999, Chan et al., 1993). However, learners often fail in knowledge construction since what and why they have explored so far become hazy as the exploration progresses. To what extent the learning has been carried out also becomes unclear (Thuering, Hannemann, and Haake, 1995). Knowledge construction in hyperspace consequently requires reflecting on exploration process that learners have carried out (Kashihara, Ujii, and Toyoda, 1999).

The main issue addressed in this paper is how to support the reflection for knowledge construction in hyperspace. Current work on educational hypermedia/hypertext systems has provided spatial/concept maps as representative reflection aids (Brusilovsky, 1996). The suitability of these aids is founded on semantic relationships among domain concepts/knowledge embedded in the learning resource. However, these can not be always available to existing web-based learning resources since it is hard to identify semantic relationships among the Web pages without analyzing the contents of the learning resources.

Another approach to proper reflection support is to provide a learning tool, which affords reflection activities for knowledge construction (Laurillard et al., 2000). We call such feature of the tool *learning affordance*. The word *affordance* is borrowed from the psychology of perception (Gibson, 1979). The concept of *learning affordance* can be viewed as a basis for evaluating the suitability of learning tools. Web browsers such as Microsoft Internet Explorer and Netscape Navigator, for example, are regarded as web-based learning tool for popular use. Do they have proper learning affordance for knowledge construction in web-based learning? The web browsers provide learners with back buttons and browsing history. Although these facilities afford revisiting the Web pages that have been visited (Tauscher and Greenberg, 1997), they would not always create activities of knowledge construction such as integrating the contents of some pages explored. The browsing history also provides no information of why they have explored, which information plays a crucial role in knowledge construction (Kashihara, Ujii, and Toyoda, 1999), and does not allow them to sufficiently rethink knowledge that they have constructed so far. We can consequently say that the web browsers are not very suitable for knowledge construction in hyperspace.

Table 1: Exploration Goals and Visual Representation.

Exploration Goals	Visual Representation	
Supplement	Inclusion	⊙
Elaborate	Set or Part-of tree	
Compare	Bidirection arrow	○◄─►●
Justify	Vertical arrow	
Rethink	Node superposition	
Apply	Arrow	⊙─►●

○ Starting page ● Terminal page

Designing a more suitable tool needs a careful consideration of exploration process and of what kind of activity should be supported by the tool. Following this idea, we have proposed an interactive history for learning with existing web-based learning resources (Kashihara, Hasegawa, and Toyoda, 2000). In this paper, we describe the interactive history system and its evaluation. The results of the evaluation indicate that the interactive history system affords rethinking exploration process particularly in more complicated hyperspace.

Before demonstrating the interactive history, let us first consider exploration process in hyperspace to discuss what kind of knowledge construction activity should be supported.

Exploration in Web-based Learning Resource

Learners generally start exploring hyperspace with a learning goal. The movement between the various pages is often driven by a local goal called exploration goal to search for the page that fulfills it. Such exploration goal is also regarded as a sub goal of the learning goal. We refer to the process of fulfilling an exploration goal as primary exploration process, which is represented as a link from the starting page where the exploration goal arises to the terminal page where it is fulfilled. The whole exploration process can be modeled as a number of primary exploration processes.

Exploration goal, represented as verb, signifies how to develop or improve the domain concepts and knowledge learned at the starting page. We currently classify exploration goals as shown in Table 1, which are not investigated exhaustively.

An exploration goal arising from visiting a page is not always fulfilled in the immediately following page. In such case, learners need to retain the goal until they find the appropriate terminal page/s. While searching for the fulfillment of the retained goal, it is possible for other exploration goals to arise. The need to retain several exploration goals concurrently makes the knowledge construction more difficult to achieve.

Executing a primary exploration process, learners also make a semantic relationship among the domain concepts and knowledge in the starting and terminal pages (Tauscher and Greenberg, 1997). The semantic relationship is shaped according to the exploration goal. Each exploration goal provides its own way to make relationship between the starting and terminal pages (Kashihara, Hasegawa, and Toyoda, 2000). Integrating several primary exploration processes, learners construct their knowledge structure.

The above consideration of exploration process in hyperspace indicates that it is necessary to rethink primary exploration processes and their integration for succeeding in knowledge construction.

Interactive History
Overview

In order to encourage learners to rethink primary exploration processes that they have executed during exploration, the interactive history provides an exploration history annotated with primary exploration processes. It

also provides a knowledge map, which visually represents relationships among the primary exploration processes, to help the learners to rethink knowledge structure that has been constructed.

The interactive history system first enables learners to annotate an exploration history, which includes Web pages sequenced in order of time they have visited, with primary exploration processes. In order to help learners note down primary exploration processes during exploration, the system provides them with a list of exploration goals, and requires them to select one from the list when an exploration goal arises. The learners are also asked when they find the terminal pages. The interactive history system annotates the exploration history with the information noted down. The annotated exploration history enables the learners to retain their primary exploration processes.

The learners are also enabled to directly manipulate the annotated exploration history to modify/delete the primary exploration processes and to add new primary exploration processes after exploring hyperspace. Such direct manipulation enables them to reorganize their exploration process.

The interactive history system second transforms each primary exploration process, which is extracted from the annotated exploration history, into a visual representation by means of a visualization scheme that describes the correspondence of an exploration goal to a visual representation. It then combines each visual representation to generate a knowledge map. The knowledge map does not obviously represent the contents included in the explored pages, which may be summarized by the page titles. However, this summarized information would be substantially fruitful for learners to reflect on what they have learned.

Annotated Exploration History

In the interactive history system, learners can use a user interface as shown in Figure 1. They can also explore a hyperdocument on a WWW server with one learning goal in the left window. When they want to set up an exploration goal in visiting a page, they are required to mouse-click the corresponding page in the *Annotated Exploration History* window. The *Exploration Goal Input* window then appears as shown in Figure 1. The learners can select one corresponding to the goal from the exploration goal list in the window. The page visited currently is also recorded as the starting page of the exploration goal. After inputting the exploration goal, the *Exploration Goal Input* window disappears.

When the learners find a terminal page of the exploration goal, they are required to mouse-click the exploration goal in the *Annotated Exploration History* window. The *Exploration Goal Input* window then appears. They can input the terminal page by dragging the title of the terminal page and pasting into the terminal page section in the *Exploration Goal Input* window. They can also add the object of the verb describing the exploration goal. It means what to develop/improve in the current page whereas the exploration goal specifies how to develop/improve.

Figure 1 gives an example where a learner explores a hyperdocument on a WWW server with the learning goal of understanding the occurrence of earthquake. The annotated exploration history shows the sequence of the pages visited and primary exploration processes that have arisen. For example, he/she visited the page *Animation of the Mechanism* in order to rethink the description in the page *The Mechanism of Occurrence of Earthquake*. He/she then visited the page *Seismic Wave* since he/she did not know the meaning of the term used in the previous page.

The system also provides another support for helping learners store part of the contents of the page visited currently with Cut&Paste function although they may not always need this support. In hyperdocuments on WWW, in addition, the title tags of the pages do not always represent the contents of the pages. If the learners want to change the page titles, they can input new titles in the *Exploration Goal Input* window, which new titles should represent the contents the learners explored in the pages. The pasted information and the changed page titles are also used in the annotated exploration history.

Using the information inputted from the learners, the system generates the annotated exploration history as shown in Figure 1 so that the primary exploration processes can be viewed clearly. In the annotated history, each page has the page title. The starting page of each goal is linked with the corresponding terminal page/s. There may be some primary exploration processes without terminal pages since they have not been found yet. The learners can look at the annotated exploration history on their demand during exploration. They can also click the pages in the history to review the content information, which they have inputted with Cut&Paste function.

Directly manipulating the annotated exploration history, learners can reconstruct their exploration process. Each manipulation is done by means of mouse-clicking/dragging parts of the primary exploration processes. There are three basic manipulations: deleting and changing exploration goals/links between starting and terminal pages, and adding new primary exploration process.
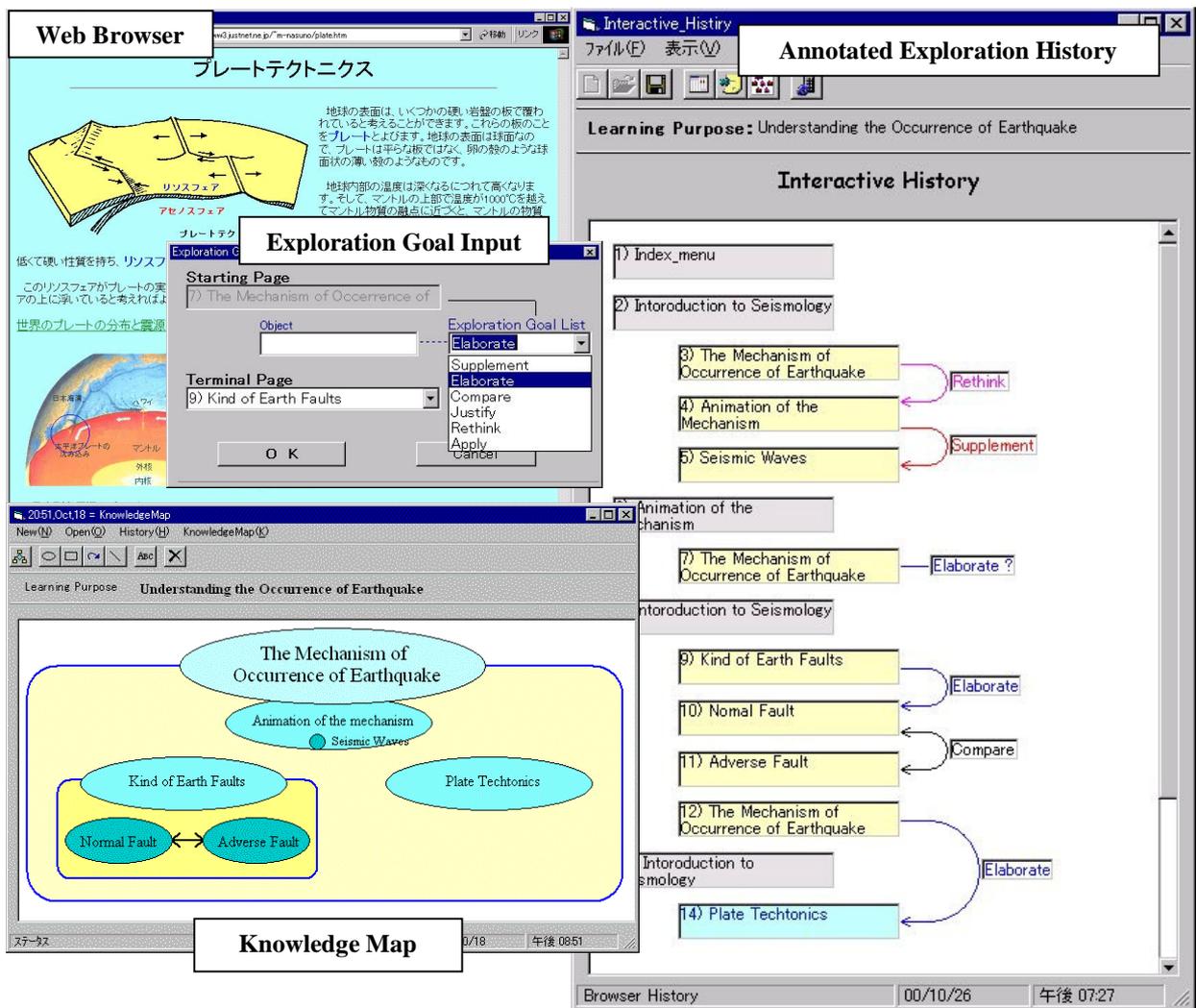
Figure 1: User Interface of Interactive History.

Learners are not always required to input the above information whenever they visit pages. Nevertheless, inputting the information during exploration may be troublesome for learners. On the other hand, it enables the learners to make their exploration more constructive. The annotation, in addition, requires a meta-cognitive skill that is indispensable for managing knowledge construction process in existing web-based learning resources. The interactive history system could distract learners, who do not have it, from their learning tasks in hyperspace. We believe, however, it is educationally important to train the learners to improve the meta-cognitive skill so that they can learn in a constructive way. The interactive history can be viewed as a potential tool for this training.

Knowledge Map

In order to make the knowledge map understandable, we have adopted a visualization scheme shown in Table 1. This table shows the correspondence of an exploration goal to a visual representation of the relationship between the starting and terminal pages. For example, an exploration goal to *Elaborate* is transformed into a set that visualizes the starting page as a total set and the terminal page as the subset. Following such correspondence, the system generates a knowledge map by combining visual representation of each primary exploration process in the annotated exploration history. The knowledge map generation is executed on learners' demand before/after manipulating the annotated exploration history.

Figure 1 shows an example of the knowledge map that is generated from the annotated exploration history shown in Figure 1. Viewing this map, the learner can reflect on the relationships among the primary exploration processes. For example, he/she can recall that he/she elaborated *The Mechanism of Occurrence of Earthquake* by exploring *Kind of Earth Faults*, and that he/she furthermore elaborated it by comparing *Normal Fault* and *Adverse Fault*.

Before using the interactive history system, in addition, learners need to know how to interpret the visual representation used for the knowledge mapping. In order to explain it, the interactive history system demonstrates few examples of annotated exploration history and knowledge map before starting the actual learning support.

Preliminary Evaluation
Experiment

In order to evaluate the interactive history system, we have had a preliminary experiment. The main goal of this experiment was to analyze the utility of the system and to ascertain if the interactive history affords rethinking exploration process compared to learning without the system. We also prepared two web-based learning resources as shown in Table 2, which had comparatively simple and complicated hyperspace. Table 2 describes the number of pages, and the number of links per page, which was calculated except for navigation links such as Next, Back, and Top. These can be viewed as the indicators of the complexity of hyperspace each learning resource provides. The learning resource 2 accordingly had a more complicated hyperspace. Subjects were thirteen graduate and undergraduate students in science and technology.

We set four conditions, which were (1) learning in the learning resource 1 with the system (Simple-With), (2) learning in the learning resource 1 without the system (Simple-Without), (3) learning in the learning resource 2 with the system (Complicated-With), and (4) learning in the learning resource 2 without the system (Complicated-Without). Subjects were provided with Internet Explorer as WWW browser under each condition. In this experiment, each subject learned one learning resource with the system, and learned the other without the system. In other words, he/she was assigned two conditions, which were Simple-With and Complicated-Without (or Simple-Without and Complicated-With).

Before learning, subjects were given a learning goal for each learning resource. Under Simple-With or Complicated-With, they were also given the explanation about how to use the interactive history system, and were asked to try it in a sample learning resource whose hyperspace is simple. They were then asked to explore hyperspace with or without the system to accomplish the learning goal. The time of learning in each condition was limited to thirty minutes.

In this experiment, the utility of the system was analyzed with the dispersion of pages visited, the number of revisit per page (Tauscher and Greenberg, 1997), the number of primary exploration processes executed, and the number of revisiting pages that were included in the primary exploration processes. Comparing the averages of them under Simple-With and Simple-Without or under Complicated-With and Complicated-Without, we evaluated the utility of the interactive history system.

Results and Discussion

Table 3 summarizes the analysis of the utility. The average number of revisit per page on Complicated-With was larger than that on Complicated-Without although there was a slightly difference between Simple-With and Simple-Without. The average dispersion of pages visited on Complicated-With was lower that that on Complicated-Without although there was a slightly difference between Simple-With and Simple-Without. These results indicate that the interactive history system makes learners' exploration more intensive in a more complicated hyperspace.

We further analyzed the utility of the interactive history system on Simple-With and Complicated-With. Table 4 shows the average number of primary exploration processes executed, the average number of starting and terminal pages, and the average number of revisiting pages that are included in the primary exploration processes. The average numbers of starting and terminal pages on Simple-With and Complicated-With corresponded to about half of the average numbers of pages visited as shown in Table 3 (54.8% on Simple-With and 51.0% on Complicated-With). In other words, half of the visited pages were related to the primary exploration processes. The average numbers of revisiting the starting and terminal pages on Simple-With and Complicated-With accounted for 74.5 % and 79.9 % of the whole revisits shown in Table 3. These ratios were very high. These results indicate that the interactive history system can afford rethinking each of primary exploration processes and their relationships.

Table 2: Learning Resources.

	Learning Resource 1	Learning Resource 2
Number of Pages	73	158
Number of Links per Page	1.2	2.3

Domain of learning resource1: Mechanism of earthquake
Domain of learning resource2: Life in Sea

Table 3: Utility Analysis.

	Total Number of Pages Visited (a)	Number of Pages Visited (b)	Dispersion (b/a)	Revisit (a-b)	Revisit per Page ((a-b)/b)
Simple-With	70.6	23.9	0.34	46.7	1.95
Simple-Without	69.8	22.7	0.32	47.1	2.07
Complicated-With	71.6	25.3	0.35	46.3	1.83
Complicated-Without	57.2	30.2	0.53	27.0	0.89

Table 4: Analysis of Revisit on Primary Exploration Processes.

	Number ofPrimary Exploration Processes	Number of Starting and Terminal Pages	Revisit
Simple-With	11.2	13.1(54.8%)	34.8 (74.5%)
Complicated-With	11.6	12.9(51.0%)	37.0 (79.9%)

Conclusions

This paper has claimed that knowledge construction in hyperspace requires learners to reflect not only what but also why they have explored, and that learning tool should afford rethinking their exploration process and knowledge structure being constructed by them.

This paper has also demonstrated the interactive history with the learning affordance. The interactive history encourages learners to annotate and reorganize the exploration history to rethink their exploration processes. It also generates a knowledge map from the annotated exploration history, which allows the learners to reflect on what they have constructed during exploration. In addition, this paper has described an evaluation of the interactive history system. Although we need a detailed evaluation with more subjects, the results indicate that the system affords rethinking primary exploration processes particularly in a complicated hyperspace.

In the future, we will have a more detailed evaluation. We would also like to classify exploration goals in detail to represent learners' exploration process more precisely.

References

Brusilovsky, P. (1996). Methods and Techniques of Adaptive Hypermedia, Journal of User Modeling and User-Adapted Interaction, 6, 87-129.

Chan, T.W., Lin, C.C., Lin, S.J., and Kuo, H.C. (1993). OCTR: A Model of Learning Stages, Proc. of 6th World Conference on Artificial Intelligence in Education, 257-264.

Jonassen, D.H. (1999). Designing Constructive Learning Environments, In C.M.Reiguluth (Ed.), Instructional Design Theories and Models, 2nd Ed., Lawrence Erlbaum Associates.

Gibson, J.J. (1979). The Ecological Approach to Visual Perception. Houghton Mifflin.

Kashihara, A., Uji'i, H., and Toyoda, J. (1999). Reflection Support for Learning in Hyperspace, Educational Technology, 39, 5, 19-22.

Kashihara, A., Hasegawa, S., and Toyoda, J. (2000). An Interactive History as Reflection Support in Hyperspace, Proc. of ED-MEDIA 2000, 467-472.

Laurillard, D., Stratfold, M., Luckin, R., Plowman L., and Taylor, J. (2000). Affordances for Learning in a Non-Linear Narrative Medium, Journal of Interactive Media in Education, 2000(2) (http://www-jime.open.ac.uk/00/2).

Nielsen, J. (1990). The Art of Navigating Hypertext, CACM, 33, 3, ACM Press, 297-310.

Tauscher, L., and Greenberg, S. (1997). How people revist web pages: empirical findings and implications for the design of history systems. International Journal of Human-Computer Studies, 47, 1, 97-137.

Thuering, M., Hannemann, J., and Haake, J.M. (1995). Hypermedia and Cognition: Designing for Comprehension. CACM, 38, 8, ACM Press, 57-66.