In the context of exploring educational hypermedia on the World Wide Web, this paper presents a history visualization that helps learners reorganize explored contents to find what Web sites they should visit next. Learning-by-exploration is discussed as it relates to educational hypermedia, including the "Get Lost in Hyperspace" problem, learning support approaches, and current work on hypermedia exploration aids. A history visualization tool (HiVis) is presented. The HiVis user interface and three types of visualization that are not currently implemented in standard Web browsers are described: (1) time sequential representation with contextual information; (2) structural representation; and (3) superposition on an overview diagram. A preliminary evaluation of HiVis is summarized; results indicate that the history visualization is informative for learners. Figures present the HiVis interface, a time sequential representation, structural representation, and superposition representation. Contains 11 references. (Author/AEF)
A History Visualization for Learning-by-Exploration in Hypermedia on WWW

Akihiro Kashihara, Yoshitomo Satake, and Jun'ichi Toyoda
The Institute of Scientific and Industrial Research, Osaka University, JAPAN
E-mail: kasihara@ai.sanken.osaka-u.ac.jp

Abstract: Educational hypermedia provide learners with hyperspace where they can explore with a learning purpose in a self-directed and constructive way. As the exploration progresses, however, what and why they explored so far often become unclear. They cannot finally find what to explore next. In order to resolve this situation, it is necessary to reflect on to what extent they learned and what is insufficient for achieving a learning purpose. This also requires them to think back to their history and to reorganize the contents they explored. In the context of exploring educational hypermedia provided on WWW, this paper presents a history visualization which helps learners reorganize the explored contents to find what they should visit next. This paper also describes a history visualization tool called HiVis, and its preliminary evaluation. The results indicate that the history visualization is informative for learners.

1. Introduction

In the last few years, there have been increasingly provided various types of hypermedia on WWW, which are designed from an educational point of view, or which are worth learning. Learning with such educational hypermedia has become more and more important [Brusilovsky 1997].

Educational hypermedia generally provide hyperspace where learners can explore in a self-directed, self-regulated, and constructive way [Kashihara et al. 1997]. In exploring with a learning purpose, however, what and why the learners explored so far often become unclear as the exploration progresses. They can not finally find what to explore next for achieving the learning purpose. This is a well-known problem in hypermedia called "get lost in hyperspace" problem [Nielsen 1990; Conklin 1988].

Current work on hypermedia systems provides several navigational aids [Brusilovsky 1996], which present users with the candidates they should explore next. These aids can help learners who know what to explore next, and who do not know where it is. However, the navigational aids are not so fruitful for learners who do not know what to explore next since they cannot understand why they should follow one of the candidates. In order to resolve the "get lost in hyperspace" situation, it is indispensable to reflect on to what extent the learners learned and what is insufficient for achieving a learning purpose. This also needs to think back to their history in the hyperspace to reorganize the contents they explored.

In current hypermedia systems, an exploration history is often visualized so that learners can pay attention to it. However, it is done in a straightforward way. More informative visualization requires greater consideration of what to and how to visualize in regard to learners' history, which is the main issue addressed in this paper.

In the context of exploring hypermedia on WWW with one learning purpose, this paper proposes a history visualization, and presents a history visualization tool called HiVis (History Visualization). HiVis monitors the learners' exploration activities to make history, which includes the hypermedia nodes (WWW documents) and links they visited. The history is visualized on their demand so that the learners' exploration cannot be restricted as much as possible. HiVis provides three types of visualization which are not currently implemented in standard WWW browsers such as Netscape Navigator or Microsoft Internet Explorer. This paper also describes a
preliminary evaluation of HiVis with four subjects. The results indicate that the history visualization is informative for learners.

2. Learning-by-Exploration

2.1 "Get Lost in Hyperspace" Problem

Educational hypermedia provide learners with a hyperspace where they can explore in a self-directed and self-regulated way. In the hyperspace, learners can learn the hypermedia material with a learning purpose in a constructive way. As the work on cognitive science pointed out, the mental efforts involved in the exploration contributes to enhancing learning [Carroll et al. 1985]. However, the constructive learning by exploration is not so easy [Kashihara et al. 1997]. As the exploration progresses, what and why learners explored so far often become unclear. At last, the learners cannot find what to explore next for achieving the learning purpose. This is called a "get lost in hyperspace" problem.

2.2 Learning Support

Resolving the "get lost in hyperspace" problem requires learners to reflect on to what extent they learned so far. This also requires them to reorganize the contents they explored. One approach to this problem is to present the learners with the candidates to be explored next [Brusilovsky 1996]. This allows them to focus on reorganizing the explored contents. However, such a navigational aid would not work effectively unless the learners have their consciousness of reorganizing what they explored. In addition, it reduces the opportunities for them to explore other places in the hyperspace, reducing mental efforts to be involved in the exploration and the intrinsic effectiveness of learning-by-exploration [Zeiliger et al. 1997; Kashihara et al. 1997].

The other approach is to give learners some support on their demand so that exploration activities cannot be restricted as much as possible [Zeiliger et al. 1997]. This means to encourage the learners to make suitable mental efforts in exploring [Carroll et al. 1985; Kashihara, Hirashima, and Toyoda 1995]. Following this approach, we propose a history visualization which helps learners reorganize their exploration history, and find what to explore next in hyperspace. The history visualization should fulfill the following requirements.

Reorganizing history first requires learners to reproduce the thought processes during their exploration in hyperspace. It also requires them to rethink the history from several viewpoints. Second, finding what to explore next requires learners to recognize to what extent they accomplished a learning purpose. The history should be accordingly visualized so that such reproduction, rethinking, and recognition can be facilitated.

2.3 Related Work

Current work on hypermedia systems has provided a number of exploration aids. The representative aid related to history visualization is graphical overview diagrams. Graphical overview diagrams display hypermedia nodes and links [Domel 1994; Mukherjea and Foley 1995]. They can be also views of already visited subspace. They are generally generated and displayed before learners start exploring. The diagrams allow learners to directly access the hypermedia nodes by clicking on the corresponding nodes in the diagrams. These diagrams can inform the learners where they are, where they have already visited, and where they have not visited. However, there are some problems as follows.

The original network structures that hypermedia have are usually very complicated. They are accordingly filtered so that they can be understandable for learners. The filtered network structures result in overview diagrams [Mukherjea, Foley, and Hudson 1995]. Exploring with such diagrams is more restricted compared to exploring the
original hypermedia. In addition, overview diagram generators on WWW usually attach URLs of WWW documents or title tags in the HTML files to nodes in overview diagrams [Mukherjea and Foley 1995; Domel 1994]. Learners may consequently have difficulty in recalling the contents of the visited nodes.

3. HiVis

In this section, we discuss what kinds of history visualization are necessary, and demonstrate HiVis.

![Figure 1: Interface of HiVis](image_url)

3.1 Interface

Before discussing the history visualization, let us present the user interface of HiVis in Figure 1. In Figure 1, a learner visits the homepage of hypermedia material "Recycling of drink containers." Exploring WWW documents with one learning purpose in the left window, the learner can look at his/her history in the right window when necessary. The interface monitors the nodes (WWW documents) and links he/she explored to make a history including the contextual information.
3.2 History Visualization

3.2.1 Time Sequential representation

In order to encourage learners to reproduce the thought processes during their exploration, HiVis visualizes the contextual information of what, how long, and why they visited so far.

As shown in Figure 2, HiVis sequences the nodes in order of time a learner visited. Each node is labeled the descriptor of the anchor he/she selected for exploring it in the previous nodes. During exploring the hypermedia, the learner is requested to describe the reason why he/she visits the next node whenever he/she pushes the anchor. Some examples of the reasons are (1) to go back to the previous node, (2) to look at the detailed explanation, (3) to receive an answer to question, (4) to look into related items, etc. HiVis tags the reasons between nodes in the time sequential representation as shown in Figure 2. HiVis also displays how long the learner visited each node. This may allow him/her to confirm which node is more important according to the length of time they visited.

<table>
<thead>
<tr>
<th>Node Sequence</th>
<th>Reasons</th>
<th>Node Labels</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To look at explanation.</td>
<td>Recycling Glass Containers</td>
<td>1m30s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concerning Glass Bottles</td>
<td>20s</td>
</tr>
<tr>
<td></td>
<td>To look at detailed explanation.</td>
<td>Returnable Bottle</td>
<td>45s</td>
</tr>
<tr>
<td></td>
<td>To look into how to collect bottle.</td>
<td>Beer Bottle Collection Route</td>
<td>2m45s</td>
</tr>
<tr>
<td></td>
<td>To go back.</td>
<td>Returnable Bottle</td>
<td>5s</td>
</tr>
</tbody>
</table>

Figure 2: A Time Sequential Representation
Clicking on one node in the time sequential representation, he/she can review the corresponding hypermedia node in case he/she cannot recall the contents of the node.

3.2.2 Structural representation

In order to give learners another viewpoint of thinking back to their history, HiVis superposes the history on an overview tree diagram described in 3.2.3 to display the sub-tree which comprises all visited nodes. This sub-tree allows the learners to find the structural relationships between any visited nodes, which they tend to overlook during exploring. The sub-tree may also stimulate them to group some visited nodes and their contents according to the structural relationships.

Figure 3 shows a sub-tree representation of history in which a learner explored "Recycling of drink containers." He/she can focus on reorganizing the visited contents from a structural point of view.
3.2.3 Superposition on Overview Diagram

It is not so easy for learners to know to what extent they learned so far for achieving a learning purpose. Assuming that hypermedia material includes information necessary for the purpose achievement, HiVis accordingly superposes their history on an overview diagram, and visualizes the subspace they have visited and the subspace they have not visited.

The overview diagram is represented as a tree. Although the root is usually the homepage of hypermedia material, learners can choose any WWW document as the root. The tree is generated from the root. HiVis regards nodes to which the anchors included in the root point as the child nodes. The descriptors of the anchors are attached on the child nodes. However, the anchors linking to the different servers or the ones going back to the parent nodes are omitted. HiVis continues finding child nodes until there are no anchors in the parent nodes.

Figure 4 shows a superposition representation with the history represented in Figure 3. The nodes learners have not visited are represented with a book icon which is closed; the nodes they visited, a book icon which is open. If an overview tree diagram is too large, HiVis visualizes only the neighborhood of visited nodes.

3.3 Preliminary Evaluation
We had a preliminary evaluation of HiVis with four subjects who were graduate students. The subjects were asked to explore "Recycling of drink containers" with a learning purpose that is to find the differences in recycling each drink container. After exploring for a while, they were then asked to use the history visualization facility. After that, they were asked whether the history visualization is informative, and what information they got from it. The results were as follows.

Each visualization was informative as expected for all subjects. It also gave them the expected information. In addition, we got an opinion that one subject could understand why he/she did not explore nodes from the superposition representation. This means the visual representation provides the information necessary for selecting what to explore next. Some subjects also had opinions that they could not find the order of nodes they explored in the structural representation and in the superposition representation. However, these are not negative for the history visualization since the subjects should look at the time sequential representation of the history. In this case, it seems they did not well know how to properly use three types of the history visualization.

4. Conclusions

In this paper, we have presented a history visualization for learners to resolve "get lost in hyperspace" situation in which they do not know what to explore next. This paper has also demonstrated HiVis which provides learners with three types of history visualization: time sequential representation with contextual information, structural representation, and superposition representation. The time sequential and structural representations stimulate learners to reorganize the contents they visited so far; the superposition representation, to choose what to explore next. The learners are expected to use these visual representations properly.

We also had a preliminary evaluation of HiVis. As a result, the history visualization was informative. In the future, we should have more detailed evaluation to make problems clearer, refining the history visualization provided by HiVis.

References

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