Modeling Learners as Individuals and as Groups

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Abstract. Adaptive navigation support normally attempts to make selecting a relevant hyperlink as easy as possible. However, in educational applications, this may have negative learning effects since selecting a link is sometimes an important educational problem for the student to solve. To provide appropriate scaffolding to students, it is necessary to understand how they navigate in hypermedia sites. By grouping students with similar conceptual (mis)understanding we were able to uncover a small set of characteristic navigation patterns, and to demonstrate that students with similar conceptual understanding have similar navigation patterns.

1 Introduction

One of the main application areas of adaptive hypermedia is educational technology. First, adaptive hypermedia can be used to individualize learning material for each student. Second, an adaptive hypermedia system can adapt itself to the evolving understanding of individual students. And third, it can help keep the student from getting lost in the vast hyperspace by implicitly or explicitly recommending certain well-selected links to follow.

In this paper, we focus on adaptive navigation support. Navigation support normally tries to simplify selecting a relevant link by reducing the complexity of deciding which page to visit next. This can be accomplished, for instance, by reducing the number of possible links to chose from. The most extreme case is the situation where only one “next” link is provided which is determined by the adaptive system to lead to the “best” page according to some internal pedagogical model and the user model of the learner.

However, as we have argued elsewhere [1], in an educational hypermedia system, quite often, selecting a link has to be considered an educationally important problem for the learner to solve. Thus, the learner ought to be scaffolded by the adaptive system to make the right choice, i.e., just making it as easy as possible for the learner to make the right choice is sometimes the wrong approach. Learning to select the appropriate link is a method that should be learned by the student while solving a specific problem leading not only to domain-specific understanding, but also to learning how to solve problems.

Thus, understanding how they navigate is just as important as knowing how they ought to do it. Only providing a normative model that drives the students towards the right pattern would be inconsistent with scaffolding since it is important for the scaffolder, the adaptive hypermedia system in this case, to assess the student's understanding and then providing the appropriate support. The incorrect behavior and its meaning needs to be recognized by the system to provide the proper guidance [2].

We studied the students' navigation patterns by developing group models based on the individual learners' user models. In the remainder of this paper, we will provide details of these models used to find (sub)groups of students with similar conceptual understanding.

2 Modeling Groups of Individuals

This work was based on earlier results that showed that learners' navigation patterns are characteristic of the learner's conceptual understanding of the domain described by the hypermedia system [3]. The hypermedia system used in this research is called CoMPASS, which displays each concept on a separate page and allows the user to navigate the concepts using textual hyperlinks as well as a clickable concept map.

We built simple models for the learners only based on their navigation behavior, i.e., which concepts the learners visited and in what order. It is clear that visiting a page does by no means imply that the user has studied the material or even understood. Nevertheless, the results of a classroom study showed that the navigation patterns of the students clearly indicates what the students have learned and at what depth [3].

The user model used in the mentioned study will be described next. Then, a group model will be introduced that was used to understand whether there are common patterns among students with similar conceptual understanding.

2.1 Modeling Individuals

The main goal of the user model is to capture the conceptual understanding of a student. To support our approach to group modeling described below, the user model needs to use a relatively simple representation so that the structural similarity between pairs of user models can be measured.

As mentioned earlier, the only data used to characterize a learner's navigation behavior is the order in which the concepts were visited in CoMPASS. This information is represented in a transition matrix D, where each entry D_{ij} represents how many times the user has traversed the link from page (or concept) i to page j. The transition matrix can be visualized by a directed graph where the nodes are the pages and the links are annotated by the number of traversals. Then, a modified Pathfinder Network Scaling (PFNet) procedure is applied to matrix D computing an approximate representation of the conceptual model of the user [4].

PFNets were developed to find relevant relations in data which described the proximity between concepts. Generally, all concepts are somehow related to all others, however, only the relevant relations should be retained. PFNet takes the transition matrix representing the navigation pattern of a user and removes redundant or even counterintuitive links resulting in a matrix W representing the student's conceptual model. A link from i to j is removed, if there is some indirect path from i to j via some other pages, if all the entries in D along this indirect path are at least as large as D_{ij}. Thus, the output matrix W of the Pathfinder procedure is exactly the same as the input D except for the removed links which are set to zero (no transition).

2.2 Similarity of Individual Learners

We are interested in groups of learners that have a similar conceptual understanding. Since PFNets capture the conceptual understanding of learners, students with similar PFNets are assigned to the same group. There are many graph similarity measures that can be applied to PFNets and often these measures are quite application-domain specific.[3] Since for our application, the relation between concepts is relevant, measures that capture the structural similarity of graphs are of interest. Several measures were considered, however, they all led to similar results so that a simple measure was chosen that has already been used to measure the similarity of PFNets [5].

Both graphs, i.e., PFNets, contain the same concepts. A concept is represented similarly in both graphs if it is connected to the same concepts in its respective graph. If they are connected to rather different concepts, they are structurally quite dissimilar.

More specifically, let C_X be the set of links going from some concept C in PFNet X to other concepts in X. C_Y is defined analogously for concept C in PFNet Y. Then the structural similarity of the X and Y with respect to C is the quotient of how many links the two networks have in common divided by the total number of links, i.e., $|C_X \cap C_Y|/|C_X \cup C_Y|$. Finally, the similarity of the two networks is computed as the average of the structural similarity of each concept in the networks.

2.3 Modeling Groups

A group of individuals is modeled almost the same way as individuals as follows. First, the transition matrices for all the group members are added and the PFNet procedure is applied to this new matrix. Thus, also group models are represented by PFNets.

Clustering algorithms are normally used to assign elements that are "close" to each other to the same group. In our case, the elements are the Pathfinder

[3] See http://www.dbs.informatik.uni-muenchen.de/~seidl/graphs/ for an idea of the richness and complexity of this area.

networks representing the students and the "distance" is measured by the similarity measure introduced above. Intuitively, the more similar two networks are, the closer they are. The K-Means clustering algorithm [6] was selected because of its simplicity and adequate results. Like many other greedy algorithms, k-means does not always find the optimal solution. However, the results we obtained were satisfactory.

After k-means has found a partition, the clusters can be analyzed by looking at each cluster member individually and by looking at the clusters' centroid, i.e., the group's conceptual model.

We applied the PFNet clustering method in a classroom study [3]. With the clustering algorithm we found that different students with similar understanding did indeed show similar navigation patterns. Most students showed one of three characteristic navigation patterns or some a combination thereof.

3 Conclusions

The clustered PFNet representation was developed as a means to understand how (and whether) students' navigation behavior correlates with a certain conceptual understanding of the material.

Although the models for the individuals and for the groups are extremely simple, they have led to a better understanding of the close relationship between navigation and conceptual understanding. Although just visiting pages does in general not lead to learning, the fact that the learner has selected a certain link reflects his relational knowledge of the domain. We found that students with similar conceptual understanding of the material to be learned also showed similar navigation patterns. Furthermore, only a small set of characteristically different navigation patterns was found [3].

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