Adaptive Navigation for Learners in Hypermedia is Scaffolded Navigation

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Abstract. Adaptive navigation support can be of great help in large hypermedia systems supporting learners as well as users searching for specific information. A wide variety of adaptive mechanisms have been implemented in existing adaptive hypermedia systems that provide better and better suggestions to the user what hyperlinks to follow. We suggest that adaptive navigation support should *scaffold* a learner in an educational hypermedia system to select the appropriate links. We show that this implies that selecting a link is an educationally relevant activity that should not always be reduced to a trivial task by powerful adaptive mechanisms. It follows that learners require sometimes different kinds of adaptive navigation support than users looking for information. Finally, we will suggest how to extend current mechanisms to provide scaffolded navigation support to learners.

1 Introduction

With the advent of the World-Wide Web, hypermedia systems have become a widely used and dominating way of providing information and educational content to users. Hypermedia has been recognized as having great potential in providing content to learners because relationships between concepts can be made explicit with hyperlinks, and the same material can be organized along different dimensions presenting the material to be learned from different views [1]. The non-linear nature of hypertext environments offers opportunities as well as certain difficulties for learning, thus making the design of such systems both complex and challenging. The flexible nature of hypertext makes it necessary for designers to provide learners with some kind of navigational support. Researchers believe that learning from hypertext puts a greater cognitive load on learners [2]. Readers have to acquire specific strategies such as knowing where they are, deciding where to go next and building a cognitive representation of the network structure, in order to cope with the specific constraints of a non-linear presentation. Hyperlinks allow each individual learner to traverse and explore the content in a way that fits his or her interests and learning goals at any particular time. In a hypertext system, the reader is actively engaged in creating both meaning and structure.

The reader constantly makes decisions about where to go next. However, this added flexibility, compared to books which are often read in a more or less linear fashion, can also cause problems seriously impacting the pedagogical benefits of a hypermedia system. It is quite easy for the learner to lose orientation and therefore not knowing how the current page fits into the big picture and what hyperlinked path to follow.

Adaptive hypermedia attempts to solve these problems by individualizing the presentation of the content for each user and by providing personalized navigation support. The goal of both approaches, personalized presentation and navigation, is to reduce the cognitive load for the user. Learners with different goals and knowledge may be interested in different information or prefer examples from different domains. They also may want navigate along different paths depending on their goals and prior knowledge. This is especially important in educational systems to make sure the learner sees those content relevant to his or her learning goals. Furthermore, adaptive navigation can help prevent users from getting lost in large systems.

Adaptive hypermedia systems (AHS) approach these problems with adaptive presentation of the information and adaptive navigation. Adaptive presentation mechanisms decide how the information is delivered most appropriately to the user considering factors like user expertise, media preferences, learning goals, interests, and so forth stored in a user model [3]. The user model is learned by the AHS over time using various information sources like questionnaires, quizzes, navigation behavior of the user, and others. The basic idea of adaptive navigation is to constrain the options of where to go next to a smaller set of relevant choices making sure the user will end up at a hypermedia page that is appropriate to his or her task.

Examples of navigation support are the "next" or "continue" links which are, according to the AHS, the best and possibly only choice [4], sorted lists of links where earlier links are better choices [5], annotated links reflecting some important status like 'the user is ready to follow it or not' or 'it leads to redundant or irrelevant material' [6], or link hiding where only those links are made accessible that the system considers relevant to the user [7].

Each of these mechanisms is based on a user model which is a description of the user's preferences, knowledge, skills, characteristics, learning goals, etc. and a pedagogical model that suggests what the user should visit under what circumstances [8]. Too often, the pedagogical model is rather implicit and built into the adaptive algorithm [9]. Much of the current research focusses on providing better user models and better algorithms for providing appropriate navigation support by ordering the content according to some scheme.

In this paper, we would like to revisit the assumption that the better suggestions we can give to the user, the better the system serves its purpose. Of course, on the one hand, it is obvious that the better the adaptive mechanisms are, the better the system is. On the other hand, it is not obvious that more accurate advice is indeed better for a user—or, more specifically, a learner—under all circumstances.

This paper is not about what can and cannot be done. It is about how adaptive navigation should be designed for specific users, especially for learners. We do not need to propose new mechanisms—many good ones already exist. However, we want to make explicit that efficiently getting to the right page should often not be the overriding goal of adaptive navigation support for learners.

Consider the following hypothetical AHS. Let's assume that the user model and adaptive mechanisms are so good that the system can almost always provide exactly one link to the page that is best for the user to visit next. In an information-seeking task, this is of course great because the user will find immediately what he was looking for, possibly without ever thinking about what he was looking for at all. But is this also a good system for a learner? We will come back to this question at the end of this paper.

2 Adaptive Navigation

Throughout this paper, we will consider two types of tasks—learning and information seeking–that cover a large class of activities AHS are used for. A learner who uses an AHS to learn about a certain concept executes a learning task. It is the system's goal to make sure that the learner will understand well enough the concept and all the necessary prerequisite concepts. On the other hand, if the user is only interested in finding the relevant information, then we consider the task to be supported by the AHS an information-seeking task. Many systems support both types of tasks, however, it is not necessarily the case that both types of tasks should get the same adaptive navigation support.

Next, we will review existing adaptive hypermedia mechanisms. Then we will discuss what navigation support information-seeking and learning tasks require. We will argue that the objectively best suggestions the adaptive mechanism can provide are not necessarily the ones from which learners benefit the most.

2.1 Adaptive Mechanisms

Adaptive navigation deals with the problem of the user having to select a link among the many possibilities. Often, there are too many possibilities and it is very difficult for the user to choose an appropriate link. Adaptive navigation reduces the number of choices using various mechanims. Some of the most frequently used ones are link ordering, link hiding, link annotation and the use of the "next" link [10]. All these mechanisms constrain how and from how many links the user can choose to go to the next page in the hypermedia system.

The most restrictive mechanism is the "next" or "continue" link that the AHS recommends as leading to the most relevant next page. This allows the user to turn to the next page as easily as in a book, i.e., there is no need to think about where to go next. If this were the only link provided, the hypermedia system would be reduced to an individual, though completely linear structure, indeed even more linear than a textbook. However, in combination with other mechanisms, as for instance in InterBook [11], the "next" link can be useful.

The previous idea can be somewhat relaxed and instead of suggesting just one link, an ordered list of links can be provided where the first link is the most relevant for the user, according to the system, and the last one the least relevant. This approach provides some choice to the user, but in return, requires him or her to make a conscious decision which link to choose. However, Guzdial found evidence in WebCAMILE, a web-based collaboration system, that users tend to choose the first item in a list simply because it is the first item in the list [12]. In this case, and no real decision has to be made. Thus, the sorted list may not be that qualitatively different to "next" link approach.

Another widely used approach is link hiding where links that should not be followed are simply hidden, e.g., on a WWW page by presenting the link text as simple text [13]. This approach has the advantage that it does not impose an external ordering on the links, yet the binary approach—a link is either hidden or visible—does not allow for great expressiveness. Therefore, this approach was extended resulting in annotated links, another way to support learners.

Annotated links are hyperlinks that are further tagged with some information that can be taken advantage of by the user to decide whether to follow it or not. For instance, the tag can provide further information about the difficulty of or relevance of the information on the page the link leads to [6]. This allows the user to make a more informed decision about which link to follow and it does require less trial-and-error behavior.

All these adaptive mechanisms constrain the number of choices for the learner. The less choice, the easier the decision will be for the user. The annotated-link approach, however, does not just reduce the set of choices but provides further information to the user supporting the decision making process to choose a good next hypermedia page, i.e., a page relevant to the current goals.

2.2 Navigation Support for Information Seekers and Learners

Now, which one of those mechanisms is the best? This question needs to be answered from two directions. First, empirical evidence needs to be collected and second, the tasks the adaptive navigation is supposed to support need to be analyzed to understand what kind of support they require. This paper focuses on the latter of the two issues where we look at the tasks of learning and of finding information.

An information seeker is a person who is interested in quickly and easily finding relevant information. Adaptive hypermedia can be extremely helpful if the user model is accurate. In this case it can make sure that the user is never confronted with irrelevant information and thus, the search space that the user has to explore to find the information can be made quite small. The more accurate the user model, the more powerful the adaptive algorithms and the more constraining the mechanisms, the better the system will support the user. This is consistent with many AHS's approaches.

The case where the user is a learner is more complicated, but extremely important because many AHS target learners. Of course, many educational systems must also support information-seeking tasks. A learner not only needs to understand concepts and principles but also has to place the new knowledge in context, often requiring prerequisites that will enable her to understand the current concepts. This definition can be extended such that it is not necessarily the user's goal to learn but whoever made the learner use the hypermedia system.

Supporting a learning task requires the learner to focus much more on the process of acquiring the necessary knowledge and skills than just on finding a certain location in the hypermedia system. The learning task, especially the examples and practice exercises, should be as authentic as possible, i.e., relevant to the learner's interests. In addition to the concept to be learned, the learner also needs to be provided with all the prerequisite knowledge that she has not learned yet. Furthermore, the order in which these different concepts, examples and exercises are visited is dependent on the employed teaching methodology, which in turn may be dependent on the learner's history and the material to be learned. Although the learning process should not be dragged out forever, minimization of time is not as important as when looking for information. Furthermore, the learner needs to be challenged, yet nor frustrated by the difficulty of the material. Of course, this will cause some decent cognitive load for the learner without which learning could not occur. This does not imply that AHS need to be designed to make them difficult to use. However, the learner must be encouraged to make non-trivial decisions and reflect, for instance on what he or she is learning, how this ties into previous knowledge, and why it is useful for accomplishing the actual learning goal. In other words, adaptive navigation for learners should be viewed as scaffolded navigation.

2.3 Scaffolded Navigation

Scaffolding in the context of learning has originally been defined by as an "adult controlling those elements of the task that are essentially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence" [14]. Scaffolding has been linked to the work of soviet psychologist Lev Vygotsky, although he never used the term scaffolding. According to Vygotsky, a novice learns with an expert, and learning occurs within the novice's Zone of Proximal Development (ZPD). ZPD is defined as the "distance between the child's actual developmental level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance and in collaboration with more capable peers" [15]. Enabling the learner to bridge this gap between the actual and the potential depends on the resources or the kind of support that is provided. Instruction in the ZPD can therefore be viewed as taking the form of providing assistance or scaffolding, enabling a child or a novice to solve a problem, carry out a task or achieve a goal "which would be beyond his unassisted efforts" [14].

Adaptive navigation can be viewed as a method to provide scaffolding to a learner navigating through a large hypermedia system. Scaffolding in this context then implies the following among other things [16, 17].

- The learner must be aware of and interested in the goal of the learning activity.
- Continuous assessment of the learner needs to be used to calibrate the support.
- Scaffolding fades away over time and the learner must take control of the task.
- The learner needs to be actively involved in the learning process.

We will now discuss each of these characteristics with respect to adaptive navigation support in adaptive hypermedia systems.

The learner must be aware of and interested in the goal of the learning activity. The learner needs to have a choice of selecting links that deal with more authentic problems. For instance, it is important that the user selects the example that he or she is more familiar with, if there is more than one example illustrating the same point. An AHS can accomplish this by providing all the examples illustrating the same point and the user can choose, or, if the user model contains information about the preferences, it can simply provide the one example it knows the learner is interested in. The latter solution is more efficient whereas the former requires and allows the learner to make a decision. It is important that the learner has to make a decision if there is a potential educational benefit in doing so.

Continuous assessment of the learner needs to be used to calibrate the support. The difficulty of the decision which link to select needs to be adapted to the learner so that it is in the ZPD. In other words, providing a set of possibly annotated links needs to be viewed as posing a problem to the learner that the learner should be able to solve, yet it must not be too simple to be pointless activity. This implies that making it as simple to the learner as possible to select a correct next page should not be the goal. It is important for a learner to figure out what knowledge, information sources, case studies, etc. are relevant. For instance, in Problem-Based Learning, finding out what the relevant knowledge to learn is, is at the heart of this learning methodology [18, 19].

Scaffolding fades away over time and the learner must take control of the task. A very important part of scaffolding is that it fades away as the learner learns to select the proper next page. A user model that takes the learner's behavior into account can take care of this part automatically. Since the basic idea of adaptive navigation is to constrain the learner's options, it implies that the constraints need to be relaxed as the learner gains more expertise. Of course, these constraints must not be relaxed to violate usability guidelines.

The learner needs to be actively involved in the learning process. This implies that the learner should not be spoon-fed with the correct choices, but should be actively involved in the decision process of where to go next. This adds yet another strong argument against over-constraining the choices for the user. The learner should not just passively follow the lead of the system but should make the decisions, or should at least, over time assume control.

Several important observations can be made. First, fading scaffolding maps quite well to the adaptive nature of AHS. Second, selecting a link should be regarded as a problem to be solved if the decision is educationally relevant. And third, reducing the difficulty of selecting the right link as much as possible is not always the right thing to do. Actually, it is important that the learner is allowed to make mistakes for two reasons: it provides him- or herself some valuable feedback and the AHS can use it to improve the user model based on the learner's apparent misconception.

The central observation is that selecting a link is sometimes an educationally relevant task that needs to be scaffolded. Therefore, making it as easy as possible is not adequate in such a situation. Selecting the link needs to require the learner to reflect upon what is important to learn or read about next. How will this information at the other end of the hyperlink help with respect to the learning goals? We therefore suggest that the link-selection task needs to be put into a context that supports the learner to make the right decision.

We suggest that the context consists of prompts and questions that are adaptively selected together with the set of links. Assume, the learner is working on a problem where she has to figure out when an object hits the ground when dropped from a certain height. Now, should we provide just links related to velocity and acceleration or also links to mass? An AHS will recommend against going to the pages about mass as they are irrelevant for this problem. However, we provide both sets of links plus the contextual prompt "Does a heavy item fall faster than a light one?". Of course, the question needs to be phrased so that the learner can answer it, i.e., it must be at the right level with respect to the ZPD.

3 Conclusions

We have made the argument that adaptive navigation for learners in hypermedia is scaffolded navigation. We have provided a largely theoretical argument whose implications are backed up by the empirically well-established educational value of scaffolding [20, 21].

Adaptive hypermedia systems use adaptive navigation mechanisms to support the users to find their way around in large hypermedia systems. They make sure that the users find the relevant information and that learners are exposed to all the relevant concepts to understand a certain goal concept. However, it is important to keep in mind that a learner is not just interested in efficiently getting to the page describing the goal concept. The learner needs work hard to understand all the prerequisite knowledge and learn these concepts in some pedagogically appropriate order. Reducing the information seeker's cognitive load is great, however, doing the same for the learner is not always beneficial to him or her. This implies that the use of too much navigation support can be detrimental to the learner because it frees him or her up from thinking [22].

We therefore recommend that adaptive navigation support be separated into two categories. The first category deals with navigation simply to get to a certain location in the system as quickly and easily as possible, i.e., this is navigation for navigation's sake. The second category deals with educationally related decision problems where the learner needs to decide what information source, what concept, what method, and so on, would be more relevant for the current task at hand. In this case, the learner needs to be scaffolded so that he or she learns to make the right decisions, i.e., chooses the relevant information sources, tools, etc. We accomplish this annotating the adaptively selected links with appropriate prompts and questions scaffolding the learner to make a good choice.

Let's revisit the hypothetical system suggested earlier. We assumed that the user model and adaptive mechanisms are so good that the system can almost always provide exactly one link to the page that is best for the user to visit next. This is potentially a great system for an information seeker. However, if the system is supposed to support learners, then this hypothetical system boils down to an individualized book that requires to be read in exactly one order. This way we lose most of the educational advantages of hypermedia. Furthermore, the learner is not required at all to reflect on why she is reading what she is reading, she has no opportunity to make mistakes and recognize them as useful feedback. In other words, a system that is optimal in some "adaptive sense" is surely not that useful for a learner anymore.

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