

# Evaluating Adaptive Navigation Support

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## ABSTRACT

From the few evaluations of adaptive navigation systems that have been performed, we see an emerging pattern where depending upon the domain, only certain types of adaptive navigation strategies work. The results indicate that adaptations should leave the interface somewhat predictable, it should not force users to interpret advanced annotations, and finally, the adaptation should not change the structure of the information space.

Furthermore, evaluations of adaptive navigation support systems fail to recognise some of the more important aspects of why certain systems provide better support than others do. These studies typically measure task completion time, or how well the structure of the space is remembered. While these are among the important measurements that should be taken, other features, such as how much anxiety the system induces in users, how pleasant it is to navigate, or how much users actually learn of the information contained in the space, might be more crucial measurements.

## Keywords

Adaptive, navigation, evaluation, hypermedia

## INTRODUCTION

“Lost in hyperspace” is a feeling that is familiar to almost anyone using a computer. After a few actions, we do not know where we are, how we got there, or what our original goal was. *Adaptive navigation systems* has been proposed as a means to aid users in finding their way through information spaces. Several systems have been designed that adapts the navigation to users’ knowledge (Brusilovsky and Pesin, 1994, Brusilovsky, Schwartz, and Weber, 1996, Kobsa et al., 1994, Boyle and Encarnacion, 1994), to users’ preferences and goals (Kaplan et al., 1993), to users’ tasks (Höök et al. 1996), or to users’ spatial ability (Benyon and Murray, 1993). The hope is that if user characteristics are considered the cognitive workload can be reduced, or users’ learning of the content may be improved, etc.

The question we want to pose here is exactly when those systems do in fact reduce workload/improve learning/etc.? Can we find criteria that will give us better insight into how adaptive navigation should be designed to best assist users?

In order to investigate these issues further, we shall first review studies made on adaptive navigation support systems, and then outline some criteria by which these system should have been evaluated. Let us start by defining the concepts ‘navigation’ and ‘information space’.

## Navigation and Information Space

We use the metaphor ‘navigating an information space’, but what do we mean by ‘navigation’ and ‘information space’? In Benyon and Höök (1997) navigation is defined as both the more traditional *wayfinding* activities (when the destination is known), as well as *exploration* and *object identification*. According to Downs and Stea (1973) wayfinding in the real world can be broken down into a four step process:

- orienting oneself in the environment,
- choosing the correct route,
- monitoring this route, and

- recognising that the destination has been reached.

In an exploration activity, people are not trying to get anywhere, they are not trying to find their way. Instead they are just interested to have a look around. So in exploration, the second step on Downs and Stea's four step process is relaxed. Recognising that the destination has been reached must be interpreted as "having found out enough about the space to feel content".

When identifying objects, the user is not interested in the location of objects, nor is the user interested in finding a path or reaching a goal. Although object identification is somewhat akin to exploration, the purpose of the activity is different. While exploration focuses on understanding the contents of an environment and how the things are related, object identification is instead concerned with finding categories and clusters of objects spread across environments, with finding interesting configurations of objects and finding out information about the objects.

From this wide definition of navigation, it is obvious that the destination is something that is often negotiable and is altered as the user moves around. This is the challenge for designers of tools for navigation: they should support users in not only finding the destination, but actually improve the quality of their goal so that they find more information than requested, or perhaps rethink their goal and find another destination than the one they originally were aiming for. This should be done without failing to aid the pure wayfinding process.

We interpret the concept *information space* in a very wide sense, including real world spaces, augmented worlds, as well as virtual worlds. Real world spaces are often overlaid with man-made information such as street signs, symbols, or just paths that result from many people walking or using certain objects. Augmented worlds are, for example, museums with interactive information devices, route guidance systems in the car, or mobile phone systems connected to the Internet. Finally, virtual worlds include anything from your file system, databases, etc. to immersive 3D virtual environments. What comes to mind first when discussing information spaces, are hypermedia spaces, in particular the WWW (World Wide Web). Most systems and evaluations we describe below are adaptive *hypermedia* systems, but we would like to make clear that adaptive navigation can also be concerned with the interface to a database system, the organisation of menus in a direct-manipulation interface, or a hierarchical file system.

### **ADAPTIVE NAVIGATION SYSTEMS**

An adaptive system will try to infer an understanding of some user characteristics based on users' actions with the system. Based on this inferred understanding, the so-called *user model*, it will then adapt its behaviour to improve the interaction with the user. Many different aspects of user characteristics can be inferred. In adaptive hypermedia, the *user's knowledge*, for example, is used as a basis for educational hypermedia (Brusilovsky and Pesin, 1994, Kay and Kummerfeld, 1995). The *user's familiarity with the structure of the hyperspace* is another factor that can help us limit the search for information. Vassileva (1994) uses this distinction in her adaptive navigation techniques. The *user's goal or task* is mostly used to support navigation between nodes in the hypermedia structure (Vassileva, 1994; Kaplan et al. 1993), but can also be used to decide what to show within a node (Höök et al., 1996).

As far as we know, there are no adaptive hypermedia systems that attempt to adapt to users' cognitive abilities, style, or personality traits (except in the sense that users' learning is a cognitive ability). We believe that this is a fruitful direction of research since there are strong connections between cognitive abilities and ability to make use of hypermedia systems (Dahlbäck et al. 1996). Benyon and his colleagues (1993) made use of the fact that spatial ability together with experience of computers was related to how many errors users performed with certain database interfaces. Their system was adapted through selecting different interface for different groups of users.

### **Content Adaptation and Navigation Adaptation**

Basically, there are two features of the hypermedia that can be affected by the adaptivity: the *content* of a page and the *navigation* between nodes<sup>1</sup>. According to Brusilovsky, we can distinguish five methods for content adaptation:

- *additional explanations* can be used for a special category of users
- *explanation variants* are used to present information in various ways depending on the user's knowledge of the subject
- *prerequisite explanations* and *comparative explanations* change the information presented about a concept depending on the user's knowledge of other related concepts
- *sorting* means that the information pieces about a concept that are most relevant to a particular user are placed in front

Brusilovsky furthermore identifies four different adaptive techniques that affects the navigation between nodes:

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<sup>1</sup> Even if this pattern is most apparent in hypermedia systems, many other applications can be analysed in similar terms. For example, navigation in a direct-manipulation interface can be viewed as navigation between states (nodes), and adaptation can either be done on how to traverse the states or on the content of each state.

- in *direct guidance* the system decides which is the next “best” node for the user to visit according to the user’s goal
- in *adaptive ordering* links - on a particular page – are sorted according to the user model – the closer to the top of the list, the more relevant
- in *hiding* parts of the navigation space are hidden or restricted by removing links to non-relevant pages
- *adaptive annotation* means that we augment the links with some form of comments which can tell users more about the current state of the nodes behind the annotated links (text or visual cues)

## EVALUATIONS OF ADAPTIVE NAVIGATION SYSTEMS

There are few studies of adaptive systems in general and even fewer of adaptive navigation in hypermedia systems. When first interpreting the few studies of adaptive hypermedia systems around, it can be assumed that they are, in general, quite efficient in reaching their goals. In the second of two studies of HYPERFLEX, (Kaplan et al., 1993), it was shown that the adaptive system could sometime decrease users’ search time by 40%. In the study by Boyle and Encarnacion on MetaDoc, (1994), it was shown that after using the adaptive system users solved a set of reading comprehension tasks in significantly less time, and they also had significantly more correct answers. Unfortunately, other studies give a more complex view.

Edward Carter, (1996), pre-structured a hyperspace in several different ways reflecting the domain content. During the experiment, the system would switch structure when the subject turned to a new question that would be more easily solved with the other structure. Users disliked this system, and they performed worse in terms of information seeking time, time spent on each node, remembrance of the hyperspace structure after the experiment, etc. Carter speculates that this may be due to the fact that a commonly used strategy when users get lost in a hyperspace is to return to a “landmark” node from where they know how to proceed. If the structure is changed, they may not be able to get back to their landmark, thereby losing their bearings.

InterBook (Brusilovsky and Schwartz, 1997), ISIS-Tutor (Brusilovsky and Pesin 1994), and ELM-ART (Weber et al., 1996) are three educational hypermedia systems where the navigation between nodes is adapted through annotating the links. In InterBook, for example, depending upon users’ assumed knowledge of the domain, certain links are deemed as already known by the user (coloured in green), ready to be learnt (yellow), or too difficult (red). All three systems have been studied in order to determine their efficiency (Brusilovsky and Pesin, 1994, Brusilovsky and Pesin, forthcoming, Weber and Specht, 1997, Eklund et al., 1998). These studies show that the adaptive navigation support will indeed aid users in traversing the space efficiently, avoiding nodes already visited or known to the user, but they fail to provide that learning is increased.

In Weber and Specht’s (1997) evaluation of ELM-ART II adaptive link annotation is compared to an adaptive NEXT button technique. Two measurements are taken: how many exercise pages are visited, and how many navigational steps subjects used to solve the tasks. Regarding the first measurement, it is shown that the NEXT button is of use to novices with no previous experience of hypermedia nor of the material to be learnt, while adaptive link annotation is of use to more experienced users. Regarding the second measurement (number of navigational steps), no positive effects of the adaptive annotation can be shown, in fact, subjects perform worse with the adaptive annotation. With the NEXT button, they take slightly fewer steps. Unfortunately, this study did not measure whether users learnt more with the adaptive conditions.

In studies by Brusilovsky and Pesin (1995, 1997) on the ISIS-Tutor, it was found that the adaptive system reduced the number of steps, the number of concept repetitions, and the number of task repetitions<sup>2</sup>. Two conditions were studied, adaptive annotations and adaptive hiding. The authors conclude, “a significant difference between annotation and hiding techniques of navigation support was not found, however there is an evidence that unrestricted freedom of navigation is important for the user”. Comprehension time was not affected by the adaptive conditions, and the authors say that:

Adaptive navigation support can hardly improve the quality of learning and the comprehension time, but it can reduce the number of visited nodes – thus further reducing the overall learning time.

So in both the study by Weber and Specht and the study by Brusilovsky and Pesin, the adaptive navigation support has some positive effects on the traversal of the hyperspace. But, obviously, what should be measured for an educational hypermedia system is how much more students learnt with the adaptive system, as opposed to a non-adaptive variant. Something that is not done in these two studies.

In a study by Eklund and colleagues, (1998b) on InterBook it was found that when using the adaptive system subjects did not improve their learning, rather they actually seemed to learn less when using the adaptive system. However, further investigation revealed some interesting results. The more the subjects used the recommended links the more they improved their learning. The subjects that did not use the adaptive feature or used it little, did not improve their learning. Eklund and colleagues also found that the most widely used navigational aid was the non-adaptive “continue” button. Combining these two findings may imply that in order for an adaptive system to work it must be easy to use, such as, an adaptive “continue” button, and the adaptive feature must be used continuously throughout the system – i.e. trust in the systems adaptations.

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<sup>2</sup> Tasks and concepts are presented in separate pages in this hyperspace.

So, in summary, studies of all the three educational hypermedia systems with adaptive navigation (InterBook, ELM-ART II, Isis-Tutor), show that even though they may reduce number of visited nodes, they do not promote learning – thus failing to reach their main goal. Eklund and Brusilovsky (1998a) also show that there are few empirical studies in favour for adaptive annotation. Together with Carter’s findings, should we conclude that adaptive navigation fails?

We mentioned above that Boyle and Encarnacion’s study of MetaDoc did show that learning was improved by the adaptive parts of the system. In the light of the studies we have just seen, this may seem strange. As it turns out, Boyle and Encarnacion do not adapt the navigation between nodes, but the information within a node. The information space structure is thus stable and does not change, and each node will contain a description of the same concept each time it is visited – what is changed is *how* the concept is described. Boyle and Encarnacion have taken care to make sure the different explanations obey the same pattern of description, see for example, figure 1. As we can see in the figure, stability of presentation in the two conditions (novice and expert) in MetaDoc is maintained as much as possible. The node structure is the same when a user learns more and the only thing that changes are the explanations of the different concepts (e.g. kernel and shell).

In the HYPERFLEX system designed and evaluated by Kaplan and colleagues, users are actively restructuring a space themselves. Users main task in this space is not exploration but wayfinding. The space will be used over and over by users, and only when they have reused the space and adapted it to their needs often enough will it provide the users with some mileage for his/her tasks.

#### **General System Structure (expert)**

The AIX Operating System has three parts:

- The AIX Virtual Resource Manager (VRM)
- The AIX Operating System kernel
- The shell

#### **General System Structure (novice)**

The AIX Operating System (a group of programs that act as interface between the user and computer) has three parts:

- The AIX Virtual Resource Manager (VRM), a set of programs that manages the resources of the computer (main storage, disk storage, display stations, and printers)
- The AIX Operating System kernel, a set of program that send instructions to the VRM. It is a set of programs that control, using the VRM, the system hardware (the physical components of the system)
- A shell is often called an interface or a command interpreter. It is the part of the operating system that allows access to the kernel

**Figure 1.** Expert and novice explanations in MetaDoc

Still, in both the MetaDoc and HYPERFLEX studies is not completely clear that they have measured the right aspect with respect to their users’ tasks, when they measure time spent finding information.

Stability of presentation seems to be a crucial factor in the success of many adaptive systems. In a study by us (Höök, 1998), we showed that our system, that adapted the content of a node, did help users to find the most relevant information in a large on-line documentation system. It also reduced the number of actions. Even more importantly, users preferred the adaptive system to the non-adaptive variant. Our system also maintains a stable interface. What is adapted within the node is which headers are ‘opened’ and which are ‘closed’. An opened header is one where the text under the header is shown, while a closed only shows the name of that section. By clicking on the header, the user can force a header to be closed/opened. The order of headers within a node is never restructured. What is perhaps more interesting with our study is that we measured how much *relevant* information users found with/without the adaptive system. In our particular domain, this was the crucial test of the system, not whether users could find any vaguely related information *faster* with the adaptive system, but whether the information that the adaptive system picked for them was the relevant information. If the system had adapted the navigation between pages, this may not at all have contributed to finding the most relevant information.

Meyer (1994) and Debevc and colleagues (1996) show the same results. In both systems care is taken to make the adaptivity somewhat stable and predictable. In both studies of these two systems, users’ perform better and also like the adaptive system.

What is not clear in any of the studies mentioned above, is how well the system can adapt to the user? In the educational system examples, the system is supposed to keep track of the user’s knowledge. But how much can be known about the user’s knowledge from which links they click on? Unless we can be sure that the adaptations are “correct”, these systems will be of no use. As pointed out by Judy Kay (1994) (“Lies, damned lies, and stereotypes”) adaptations are always more or less stereotypical, and will therefore only be approximations of the individual users’ characteristics. It is one of the crucial prob-

lems for the whole adaptive systems field to show that they can in fact predict user behaviour/knowledge/abilities more or less correctly. But those kinds of tests should be done separate from testing the usefulness of the adaptive behaviour as such, see for example, Opperman (1994).

### **Inferred design recommendations**

From the few studies mentioned above we cannot claim that adaptive navigation in hypermedia is always bad, or that it is only efficient in reducing the number of nodes visited. The results may of course be due to a bad design, bad adaptations, or the fact that users are quite unused to these kinds of interfaces. Once we have standardised ways by which adaptive navigation works, users may learn how to best utilise them. This is a matter of building a user interface culture known by users throughout the world. For example, on the WWW links are coloured differently if the user has visited them. This very simple annotation strategy probably becomes useful to a large user population after a longer time of use. Also since this behaviour is consistent throughout the web no matter which site is visited, it can become part of users strategies in general for keeping track of where they are and where they have been. (Remember through that this adaptation is not an example of proper user modelling as nothing is inferred by the user – the adaptation is mainly a reflection of user actions.)

So, further studies are needed in order to single out exactly what makes an adaptive design useful, both in the short term and in the long term. Interface design culture should not be underestimated when it comes to understanding why certain interfaces work while others do not (even when they are carefully designed!). Once we make certain adaptations into standard behaviour of many different information spaces, users will learn how they work and may well find ways of getting the most benefit out of them.

But what tentatively may be concluded from the studies mentioned above is that adaptations should:

- leave the interface somewhat predictable so that users do not feel lost (as in Carter's experiment),
- it should not force users to interpret advanced annotations, thus distracting them from their main tasks, and,
- finally, the adaptive navigation support should not *change* the structure of the space (as in the adaptive hiding example or in Carter's example).

Of course, all systems should be evaluated with respect to the purpose of the system, the domain, and an understanding of the intended user population. From a domain and task analysis we may see if adaptation of navigation is at all feasible. For example, in a large domain that users seldom revisit and where there is no need for the user to learn the structure of the space, adaptive guidance might be very useful. Also, in a domain where the structure is of (nearly) no importance, as for example, in a collection of movies or food recipes, where any organisation can work, adaptation as a means of structuring the space according to preferences may work really well (see e.g. Shardanand and Maes, 1995)

Finally, in a domain to which users frequently return perhaps even daily, and where it is very important that they can create shortcuts through the space, adaptations based on interactions with the users might be useful. This was shown in the system created and evaluated by Kaplan and his colleagues, (1993). The system associated weights with the links between nodes. These weights were partly set initially depending upon the relation between the topics in the nodes, as well as the relation between topics and users' goals. The users could also affect the weights themselves. The system presented a list of nodes, organised as a prioritised list that users could manipulate through dragging items higher up or lower down in the list. Users' thereby become active participants in reorganising the hyperspace.

In general, allowing users to understand (at some level) and/or influence the adaptations of the system is important (Höök et al. 1996, Höök, 1996, Cook and Kay, 1994).

### **Underlying problems**

Going back to the definition of wayfinding in terms of the four steps from Downs and Stea, we find some clues to the underlying explanations to why certain adaptations will only be of limited use and may have to be combined with other methods. It seems as if the main problem with most existing adaptive navigational systems are not what they do, but rather what they not do. Considering wayfinding as described above, it is safe to say that current systems usually address the problem of choosing the correct route. The four adaptation techniques presented by Brusilovsky: direct guidance, adaptive ordering, hiding, and adaptive annotation, all try to – in one way or the other – minimise the number of steps that a user has to take to reach a specific goal in a hypermedia system, that is, the systems focus on finding the most effective (shortest) path through the information space. However, a good adaptive hypermedia system needs to support the other steps in wayfinding as well: orienting oneself in the environment, monitoring the route, and recognising when the destination has been reached.

Firstly, the user's ability to orient herself in the hypermedia system is often reduced by the current adaptive navigation techniques, especially adaptive ordering and hiding. These techniques alter the information space either by rearranging the links or by hiding certain links from the user. The faster a user gets to know the whole of the hypermedia system, the easier it is for her to locate herself in it, thus, increasing or decreasing the space by hiding links may delay this process. Instead of choosing the shortest path through the information space, one possibility is to adapt to the most logical and easy to remember path through the system, something which may increase the user's ability to remember the structure of the space. A strategy often employed by users is to identify one node as a "landmark" node. Whenever users are lost, they "walk back" to the landmark and reorient themselves from there. If the space is adapted, this strategy will be destroyed.

Second, a space that is dynamic (changing) can reduce the ability for a user to monitor her given route. If the information space changes from time to time, for instance using hiding techniques, it will take a longer time for a user to get to know and understand the space, and thus, make it harder to monitor a route.

Lastly, adaptive navigation systems as described above, does not recognise that users may need help in reformulating their goal(s)/destination. On the contrary, the four techniques discussed above try to see to it that a user sticks to a given route. As indicated by our definition of navigation into wayfinding, exploration and identification of objects, users may not even have a particular destination in mind. In learning situations, it may in fact be important that users wander around in the space, revisiting certain concepts, turning to other information sources, such as text books, exercises, other students, etc. and then returning to the space. In general, in exploration situations measuring time spent will tell us nothing at all about whether users like the space and want to spend time in it!

## **EVALUATION CRITERIA**

From the studies discussed above, it also seems crucial to discuss how to measure the success of a navigational tool – what to measure in a study, and which method to employ.

### **Measurements**

In the studies of adaptive navigation support systems above, in general, only certain measurements were taken, such as:

- number of visited nodes
- task completion time
- how well a user remembers the structure of the information space

What do these measure in terms of successful navigation in hypermedia systems? Again, it is obvious that the first and second criteria are measures of shortest paths through a hypermedia system, but is that to say that the navigation was successful? We believe that visited links and task completion time are not good measures of successful navigation, or rather, they only show one aspect of navigation. Remembering the structure of a hyperspace can only be interesting if it is related to the structure of the domain and thus should be remembered. Alternatively, if the system is used often, and the user has to remember it in order to find relevant information. Remembering an arbitrary information space organisation just for the sake of it, seems a waste of time and energy.

In the introduction, we argued that navigation is a cognitively demanding activity. It increases the cognitive workload, it increases anxiety, and it puts demands on users' spatial ability, and the risk is that adaptivity can create an additional burden on users. We need to find measurements on users' anxiety level, how often they feel lost, how often they feel that they have to go back in order to find their bearings, etc. In addition to the three measurements above, we argue that four aspects of navigation need to be taken into account, in order to judge an adaptive navigational system.

- navigation should be a delightful experience that raises the users curiosity
- part of navigation is goal formulation
- measurements of a system's success must be related to users' goals/tasks/domain and not only efficiency
- adaptivity, unless carefully designed, may well introduce a certain amount of anxiety in the user

Below we discuss these aspects and ways of measuring them.

### *Goal Formulation*

In those cases where the user most often knows the destination, and the system is supposed to support wayfinding in its most traditional form, we can easily imagine study situations where we give subjects a particular task of navigating to a location. After having completed the task we can ask them their subjective feelings on how well they were supported by the tool. But as emphasised above, a large part of navigation is goal formulation: the goal or the quality of the goal should be influenced. In most educational systems the goals are implicit, i.e. there are several pre-defined goals in the form of lessons, however, in the same way that a tutor can help a student to formulate her goals, adaptive navigational systems need to be more flexible in this respect. So, we cannot put a particular destination or task in the hands of our subjects. We need to find innovative ways by which subjects can be given high-level tasks, and where we can test how much their perspective was changed (to the better) by the tool.

### *Task and Domain*

Given a realistic scenario that we want to expose subjects too, we need to decide what it is that we want to measure? Different domains and tasks demand for different types of measurements. For example, in educational hypermedia we would probably have to combine, for instance, task completion time with various measurements on how much of the domain that was actually learnt. On the other hand, in a video renting situation task completion time could be used alone, i.e. people usually want to find a good video as fast as possible, without needing to know anything about the underlying domain.

### *Anxiety*

One measurement that is often overlooked is anxiety. Even if a system adapts well users may feel out of control or disoriented, in effect, creating an element of anxiety in the user. Woods (1993) states: "flexibility, in the sense of autonomous changes by an interface mediator, creates uncertainty for the user – did something change?, why did it do that?, what will it do next?" As discussed by Picard (1997), computers need to be able to detect and act upon emotions in order to be really useful. For example, when the educational hypermedia detects anxiety in the user it could change its adaptations.

### *Delight*

There are other unorthodox measurements, apart from anxiety, that we need to consider. We believe that navigation should be fun, it should induce delight in the user. A system that is fun/pleasant to use will encourage learning, it will make users more willing to explore the space, thus supporting exploration and object identification. It is also our belief that if users feel that navigation is fun, the risk of feeling anxious is highly reduced. Connected to the delight aspect, navigation should (sometimes) engage users' curiosity. If they feel engaged and want to explore the space, they might not be as bothered about having to take many steps before reaching their destination (Morkes et al., 1998).

### **SUMMARY**

Through re-evaluating a set of studies of adaptive navigation systems, mainly within the adaptive hypermedia area, we have identified a number of weaknesses of the systems and the evaluations of them. It seems as if reorganisation of space, or advanced adaptations that distract users will not reach the goal of the system be it learning or some other goal.

From our analysis of the studies, we then singled out some tentative design requirements on navigational tools, in particular, for *adaptive* navigation support tools. Firstly, in the systems discussed we could see an overemphasis on wayfinding, i.e. situations where the destination is known, rather than exploration or object identification. This emphasis has led the designers to focus mainly on aiding the user to choose the correct route, rather than helping them to orient themselves, monitor the route or improving the quality of their overall activity. Secondly, if adaptive navigation is to be used, the domain has to lend itself to adaptation. It has to be a domain that users seldom visit or a domain where the structure of it is of minor importance. Otherwise, adaptation of the navigation between nodes will only mess up users' mental models of the space. Users should also be active or at least aware of the restructuring of the information space.

Finally, from our analysis, we concluded that there are some other measurements by which we believe that navigational tools should be evaluated. Those include studying how much the quality of the goal is improved, how much anxiety the tool induces in users, if their curiosity is raised, and whether the navigation is fun!

### **ACKNOWLEDGMENTS**

Thanks to John Eklund and Peter Brusilovsky for useful comments.

This review has been done as part of the PERSONA project funded by the EEC, SICS and HMI research school. Thanks to all PERSONA members for good discussions on the ideas discussed here and related topics.

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