Methods for adaptivity in intelligent web-based learning systems

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***Abstract*—There are two main methods for implementing adaptivity in intelligent web-based learning systems: adaptive presentation (or content-level adaptation) and adaptive navigation support (or link-level adaptation). In the systems that use an adaptive presentation method, the content of an adaptive hypermedia page is generated or assembled from pieces according to the user's background and knowledge state. In such the page, narrowed and detailed deep information (in forms of multimedia or text) is provided for advanced users, while broader and less deep additional explanation is provided for novices. Adaptive navigation support is a method of helping users to find their paths of learning in hypermedia systems by adapting the way of presenting links to goals, knowledge, and preferences of individual users. It consists of all methods of altering visible links to support hyperspace navigation. Some technologies were distinguished from the points of view according to the way they adapt presentation of links: direct guidance, link sorting, link hiding, link annotation, link generation, and map adaptation. Based on recent research and applications, this simple taxonomy is developed further.**

I. Introduction

Advances in the Web technology can provide a number of learning experiences that go beyond that possible in the traditional classroom environment such as facilitation of variety of learning activities including small group discussion and collaborative projects and a forum for expression of different beliefs and attitudes. It is argued also that such learning experiences are considered as important factors to facilitate knowledge construction.

The flexibility of hypermedia system of well-designed learning environments often reflects the interrelatedness and ill-defined or unstructured characteristics of knowledge domains. Such environments could provide rich contextual structures for the acquisition of advanced knowledge [1], [2]. However, research into flexibility of hypermedia systems as an information delivery agent has documented the existence of four problems associated with the use of hypermedia: disorientation, cognitive overload, discontinuous flow, and content readiness [3]. Disorientation refers to users not knowing where they are, where they have been, or how to get where they want to go in the hypermedia space. Cognitive overload refers to users being overwhelmed or confused by options available to them in multi-path, multi-tool environments such as hypermedia documents. Discontinuous flow is divided into two issues: narrative flow and conceptual flow. Narrative flow refers to didactical or dialogical flow of the text itself. Conceptual flow refers to the flow of ideas or concepts. Content readiness refers to how the content is tailored so that the user is neither bored nor overwhelmed. Complexity of non-linear structures of hypermedia also causes inconvenience to users as often the existing navigational tools of hypermedia systems are not powerful enough to provide orientation [4].

Adaptivity is one way to increase the functionality of hypermedia and may be able to solve the problems associated with the use of multimedia. Adaptive hypermedia is a possible remedy to the negative effects of the traditional 'one-size-fits-all' approach of many hypermedia systems [5]. Adaptive educational hypermedia or intelligent learning systems are capable of recognizing specific user characteristics such as need, interest, knowledge, and preferred learning styles and respond accordingly [6]. In adaptive or intelligent systems, the systems responses are performed by tailoring learning strategies and learning materials to meet an individual learner.

II. Methods for Implementing Adaptivity

In web-based systems, adaptivity is mainly implemented in two ways according to the types of adaptation provided: adaptive presentation (or content-level adaptation) and adaptive navigation support (or link-level adaptation)[4], [5], [7].

In the systems that use an adaptive presentation method, the content of an adaptive hypermedia page is generated or assembled from pieces according to the users' interest, background and knowledge state. In such the page, narrowed and detailed deep information (in forms of *multimedia* or *text*) is provided for advanced users, while broader and less deep additional explanation is provided for novices. Hence, adaptive presentation method was subdivided into *multimedia* and *text presentation* technologies [5], [8].

The process of adapting content to specific user needs can be thought of as two main sub processes. The first sub process, which we will refer to as content adaptation, involves understanding what content can be most relevant to the current users' state, and how this content should be organized. The second sub process, which is referred to as content presentation involves deciding how to most effectively present the selected content to the user [9]. Fig. 1 shows the

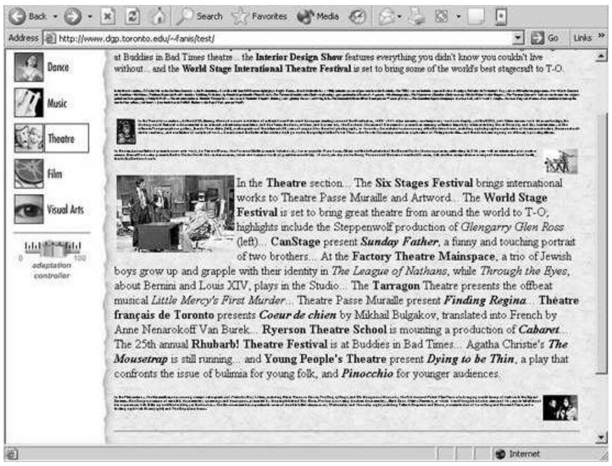

Fig. 1. Scaling-Based Adaptation [9]

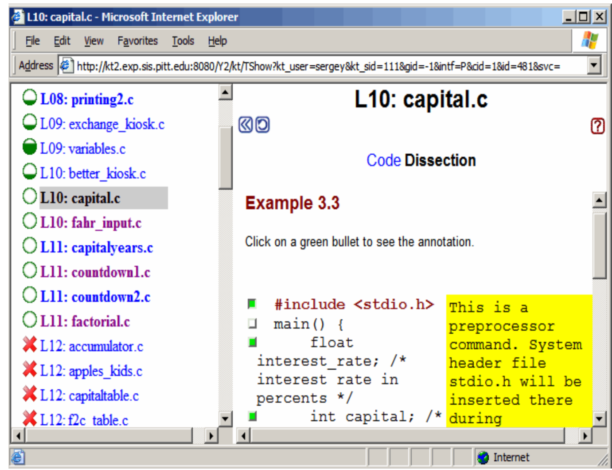

Fig. 2. Adaptive Link Annotation Technique [14]

application of *scaling-based adaptation* technique, increasing or decreasing font sizes (text presentation), as the function of user's degree of interest to the fragments of a content. Here the user's focus of interest is assessed to be theatre, thus paragraphs with different degree of relation with this topic are presented in different font sizes.

Adaptive navigation support is a method of helping users to find their paths of learning in hypermedia systems by adapting the way of presenting links to goals, knowledge, and preferences of individual users. It consists of all methods of altering visible links to support hyperspace navigation. Adaptive navigation support was subdivided into *direct guidance, link sorting, link hiding*, and *link annotation*. Some applications on those techniques are described briefly as follows.

Direct guidance can be applied in any system which can decide what is the next "best" node for the user to visit according to the user's goal and other parameters represented in the user model. ELM-ART [10] is an example of an adaptive system implemented on the Web that uses this technique. ELM-ART generates an additional dynamic link (called "next") connected to the next most relevant node to visit. Direct guidance has been criticised for being "too directive" as it provides almost no support for users who would like make their own choice rather than follow the system's suggestion.

In adaptive ordering or sorting technology all the links of a particular page are sorted according to the user-model using some easily recognisable means of conveying this to the user, such as having the more relevant links closer to the top. This technology exists within ELM-ART [10] and Interbook [11]. Adaptive ordering has a limited applicability since it can be used with non-contextual links, but it cannot be used for indexes and content pages (which usually have a stable order of links), and can never be used with contextual links and maps.

Hiding is an annotation technology which restricts the navigation space by hiding links to irrelevant pages. A page can be considered as irrelevant for several reasons: for example, if it is not related to the user's current goal or if it presents materials which the user is not yet prepared to understand [12].

Adaptive annotation technology augments the links with a comment which informs the user about the current state of the nodes behind the annotated links [13]. Link annotations can be provided in textual form or in the form of visual cues, for example, using different icons, or colours, font sizes, or font types. Typically the annotation in traditional hypermedia is static, that is independent of the individual user. Adaptive navigation support can be provided by dynamic user model-driven annotation. Adaptive annotation in its simplest history-based form (outlining the links to previously visited nodes) has been applied in some hypermedia systems which shows a folder as unread with a "U" until all of the items within that folder have been visited, including several Web browsers. Even the form adaptive annotation which distinguishes two states of links is quite useful.

As an example, an application of adaptive link annotation technology in *NavEx* system helping students to choose the example to browse by augmenting each example link with an adaptive icon that visualizes the status of the example, [14], is shown as in Fig. 2. It provides a list of links to all examples and augmented each link with an adaptive icon that visualized the status of the example, adapted to the current state of the student's knowledge and history of past interactions. These icons help students to distinguish new examples from examples that have already been partially or fully explored in the past; as well as to distinguish examples that are ready to be explored from examples that demand prerequisite knowledge the student lacks.

The simple taxonomy above enables to classify several methods and techniques present recently and described in the review. There is no sufficient space here to describe the whole taxonomy in detail, the review will concentrate on the changes that are required of the original taxonomy in order to accommodate the new methods and techniques suggested and explored lately. From this point of view, new methods and techniques can be divided into three groups [5]. The first and the largest group can be considered as variations of methods and techniques reported earlier, and can thus be easily classified using the old taxonomy. The second group requires relatively small extensions of the taxonomy. The third group demands more considerable changes. Here the last two groups will be discussed in more detail.

Small extensions of the taxonomy require addition of new technologies on the terminal level of existing taxonomy. Some have suggested and implemented several different variants for what was known as link hiding: *disabling, hiding*, and *removal*. Therefore, these are classified as independent technologies within a more general hiding technology. Another innovative way of adaptation is text dimming. This also be considered as a separate technology. At this time it would probably be wise to refine text adaptation further by dividing it into two essentially different groups: *canned text adaptation* and *natural language adaptation*. The main ways of canned text adaptation can now be considered as adaptation technologies: *inserting/removing fragments, stretch-text, altering fragments, sorting fragments*, and *dimming fragments*. Natural language adaptation can not be classified further at the moment. Of course, many natural language generation systems do, in fact, make use of fragments (and even paragraphs) of canned text. The distinction here is made between those systems that use natural language technology as a foundation and those that do not. It may be needed to refine this distinction at a later stage.

A few methods and techniques developed lately demand more considerable changes to the taxonomy to be accommodated. First, it is named that *adaptation of modality* as a high-level content adaptation technology. Modern adaptive hypermedia systems may have a choice of different types of media with which to present information to the user; that is, in addition to traditional text, we can also use music, video, speech, animation, and so on. Quite often fragments of different media present the same content, and hence the system can choose the one that is the most relevant to the user at the given node. In other cases, these fragments can be used in parallel, thus enabling the system to choose the most relevant subset of media items. Currently, we can identify several different methods for adapting the modality of presentation on the basis of user preferences, abilities, learning style and context of work, in several kinds of adaptive hypermedia systems.

The rise of recommender systems makes it necessary to distinguish between two essentially different ways of adaptive navigation support: adapting the links that were present on a page at the time of hyperspace authoring, and generating new, non-authored links for a page. Link generation includes three cases: discovering new useful links between documents and adding them permanently to the set of existing links; generating links for similarity-based navigation between items; and dynamic recommendation of relevant links. The first two groups have been presented in the neighbouring research area of intelligent hypertext for years. Recent techniques of adaptive creation of global and local links and adaptive similarity-based navigation demand their inclusion into the ”taxonomy of adaptation”. The third group of methods dealing with the generation of a dynamic list of additional relevant links is new, but already well-explored in the areas of information retrieval hypermedia, on-line information systems, and educational hypermedia. It is suggested considering adaptive link generation as a new high-level technology of adaptive navigation support. This technology can be used in conjunction with existing technologies such as annotation and sorting.

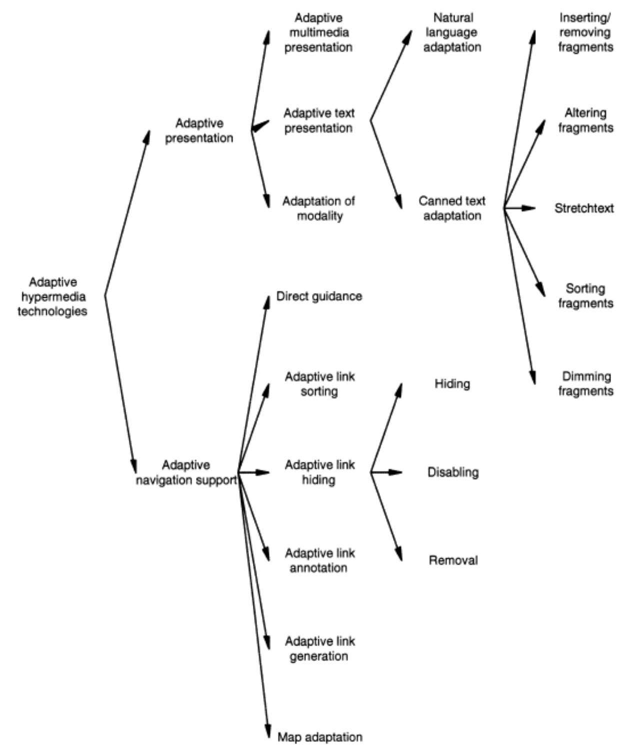

Fig. 3. Taxonomy of Adaptivity Methods [5]

In summary, the updated taxonomy of technologies is pictorially shown in Fig. 3.

III. Conclusion

The existing main taxonomy of adaptation methods in intelligent web-based learning system is refined, mostly at the terminal levels based on changes of adaptation technologies implemented lately. For the adaptive presentation method, adaptation of modality added and further classification is made under text presentation: natural language and canned text. Under adaptive navigation support, link generation and map adaptation are specified. Link hiding is divided further into hiding, disabling, and removal.

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