A Reference Architecture for Adaptive Hypermedia Systems

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Web-based hypermedia systems are becoming increasingly popular as tools for user-driven access to information. They typically offer users a lot of freedom to navigate through a large hyperspace. Unfortunately, this rich link structure of the hypermedia applications causes some serious usability problems:

- A typical hypermedia system presents the same links on a page to all users. To eliminate *navigation problems* the system should offer each user (some) personalized links or navigation tools (such as a table of contents or a map). The system should thereby take into account what the user read before, and possibly what the user's interests are.
- Navigation in ways the author did not anticipate also causes *comprehension problems* for the user: for every page the author makes an assumption about what foreknowledge the user has when accessing that page. However, this is an impossible authoring task because there are more ways to reach a page than any (human) author can foresee. A page is always presented in the same way. This may result in users visiting pages containing redundant information and pages that they cannot fully understand because they lack some expected foreknowledge.

Adaptive hypermedia systems (or AHS for short) aim at overcoming these problems by providing *adaptive navigation support* and *adaptive content*. The adaptation (or personalization) is based on a *user model* that represents relevant aspects of the user such as preferences, knowledge and interests. The system gathers information about the user by observing the use of the application, and in particular by observing the *browsing* behavior of the user.

Many adaptive hypermedia systems exist to date. The majority of them are used in educational applications, but some are used, for example, for on-line information systems or information retrieval systems. An overview of systems, methods and techniques for adaptive hypermedia can be found in [B96]. Adaptive websites are also becoming popular. They typically have a name that starts with "My" (My Yahoo, My Excite, etc.) Some systems are only *adaptable*, meaning that the user enters a user profile through a registration form, and the system doesn't change that profile unless the user explicitly updates the profile through a form. An *adaptive* system performs updates to the user profile automatically by observing the user's browsing behavior. A primitive form of adaptation is found in systems that log which pages a user accesses, in order to be able to mark pages as "new" or "old" and in order to be able to generate "what's new" pages.

We have developed a reference model for the architecture of adaptive hypermedia applications: AHAM (for **A**daptive **H**ypermedia **A**pplication **M**odel) [DHW99], which is an extension of the Dexter hypermedia reference model [HS90, HS94]. AHAM acknowledges that doing "useful" and "usable" adaptation in a given application depends on three factors:

- The application must be based on a *domain model*, describing how the information content of the application or "hyper-document" is structured (using concepts).
- The system must construct and maintain a fine-grained *user model* that represents a user's preferences, knowledge, goals, navigation history and other relevant aspects.
- The system must be able to adapt the presentation (of both content and link structure) to the reading and navigation style the user prefers and to the user's knowledge level. In order to do so the author must provide an *adaptation model* consisting of *adaptation rules*. The rules define both the process of generating the adaptive presentation and that of updating the user model. An AHS may offer some built-in rules for common adaptation aspects and user model updates. This reduces the author's task of providing such rules.

The division into a *domain model* (DM), *user model* (UM) and *adaptation model* (AM) provides a clear separation of concerns when developing an adaptive hypermedia application. Unfortunately, a common shortcoming in many current AHS is that these three factors or components are not clearly separated [WHD00]. The AHAM model advocates the separation of these components in future AHS. This separation makes design of each part become clearer and make the system more flexible when each part can be changed. AHAM reference model make it easy to understand what adaptive hypermedia systems and provides a reference to compare different adaptive hypermedia system by translating the adaptive hypermedia systems to AHAM. AHAM aims to light the authoring burden on author side to make writing an adaptive hypermedia application more practical, of course authoring tools are needed to provide user-friendly interface [WHD99]

To understand how exactly the adaptive hypermedia system work we studied the behavior of *adaptation engine* (AE) which consists of *rule definition* and the *rule execution*. In our paper [WDAH00] we argued that *adaptation rules* should exist at the author level and the system level. System-defined rules simplify the task that remains for the author. However, for the analysis of the complete rule system this distinction is irrelevant and therefore not considered. In our new paper to the 12th ACM Conference on Hypertext and Hypermedia [WDD01], we describe *design issues for general-purpose adaptive hypermedia systems*. We define the rule language associated with AHAM as a subset of CA rules [BW00], and explain how the triggering works in AHAM. Because our AE is more powerful than that of most AHS, some of the design problems we present may not be present in many AHS with a simpler rule system. We focus on two design issues for the rule system in that paper:

- The designer wants to verify conditions that guarantee that the rule execution always terminates.
- The execution of the adaptation rules by the AE should be confluent. This means that under the same conditions (same domain model and same user model instance) the same action should always result in the same presentation and the same user model update.

We use research results for active database [BW00] to perform termination and confluence analysis, and improve on its results by applying domain knowledge. The analysis of is undecidable in general, but useful in many practical applications.

Aside from termination and confluence there is also the issue of efficiency (or "fast" termination and confluence). The detecting algorithm in [WDD01] has an exponential time complexity in some cases. In [WD01] we proposed sufficient conditions to guarantee termination and confluence for simple adaptive hypermedia applications. The complexity of

detecting algorithm is order of $N^2 \times M^2$ where N is the number of rule instances and M is the number of attributes in the user model.

Description of AHAM and AE are main contributions of my research on adaptive hypermedia, my future work is to describe two existing adaptive hypermedia system AHA [DC98] (designed by our group) and InterBook [B98] (designed by Brusilovsky et al.) in AHAM, and collect all my research results in my Ph.D. thesis.

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