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A Critical and Comparative Study of Adaptive Hypermedia Technologies

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Abstract: Hypermedia systems give freedom of navigation to users but majority of these systems provide same view to all of them which cause lack of interest. Adaptive hypermedia technologies resolve this problem through personalisation. Adaptive hypermedia systems adapt to the users' preferences and previous knowledge regarding one particular domain by maintaining user model. In this way, adaptation improves human computer interaction and leads users towards more relevant information. In this paper, the structure of adaptive hypermedia system (AHS) comprising of domain model, user model and adaptation model is described. Then types of user model and different methods and techniques used to implement adaptation mechanism are critically and comparatively discussed. Some future prospects are also highlighted.

Keywords: Personalisation, Adaptive hypermedia, Adaptive presentation, Adaptive navigation, User modelling.

1. INTRODUCTION

Most of the hypermedia systems offer similar views to all of their users but people with diverse educational, social and cultural background look for a view more pertinent to their needs, tastes and idiosyncrasies. Everyone prefers personalised content and facility of customising overall look while interacting with hypermedia systems. Personalisation plays a vital role in maintaining exclusive relationship with users especially customers of e-commerce systems. It is also called individualisation (Özyurt and Özyurt, 2015), customisation or adaptation.

Static view of classic hypermedia systems results in lack of interest of users. Adaptive hypermedia technologies resolve this problem through personalised view of systems. According to Brusilovsky (2001) "adaptive hypermedia systems build a model of the goals, preferences and knowledge of each individual user, and use this model throughout the interaction with the user, in order to adapt to the needs of that user" (p. 87). Greenberg and Witten (1985) gave breakthrough when they described successful adaptive hypermedia system for the first time but this field was revolutionised when Brusilovsky (1996a) discussed the taxonomy of adaptation comprehensively. The objective of this paper is to give a critical and comparative view of adaptive hypermedia technologies used for the development of adaptive hypermedia systems.

2. STRUCTURE OF AHS

Adaptive hypermedia system (AHS) is comprised of domain, user and adaptation models. Every AHS is meant for one particular domain like tourism, education or health etc. Complete knowledge of a domain resides in domain model. User model keeps record of users along with their preferences and knowledge backgrounds that help in personalisation. The whole adaptation mechanism in adaptation model is implemented with the help of some specific methods and techniques. This model interacts with both domain and user models. It brings most relevant content from domain model and presents to users through user interface.

3. DOMAIN MODEL IN AHS

This model contains domain knowledge comprised of different chunks of information or concepts. Each concept is either a topic or an explanation of one particular entity. Domain model is basically the set of all relevant concepts (Brusilovsky, 1996b). These concepts may exist at three levels: 1) small units of information represent atomic concepts; 2) similar atomic concepts can be combined into a web page; 3) higher level or relatively bigger concepts are called abstract concepts (Fu *et al.*, 2000).

If there are no semantic relationships between concepts then domain model is called a *set model* or *vector model* (Brusilovsky, 2003). Relationships can be existed like *is-a* relations or *prerequisite* relations (Kump, 2010). Relationships based domain model can be a network model (Brusilovsky, 2003) or an entity relationship model. These relations are used for defining desirable navigational paths to linkup the web pages of AHS (De Bra, 1999).

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4. ROLE OF USER MODEL IN ADAPTATION

Data about all users is stored in user model and it helps in adaptation process. Kobsa *et al.* (2001) described three different kinds of this data: user, usage and environment data. User data comprises of personal information about user. Usage data describes user's interaction with AHS like selection of web pages and social interaction with other users. User's activities are continuously observed and stored in user model. Some AHSs also consider environment data such as user's platform and geographical location. Platform is mostly referred to hardware, software and bandwidth speed.

According to the internal structure, user model is generally categorised into three types including overlay, stereotype and Bayesian network models. In overlay model, understanding level of a user on a domain concept is stored as a Boolean value (0 for not known concept or 1 for learned concept), a qualitative value (like low, medium or high), or a quantitative value that indicates probability of user's familiarity about the concept (Brusilovsky, 1996b). Therefore user's related data is stored as a group of pairs in the shape of "*domain concept* - *value*" in a tabular form. **(Fig. 1)** illustrates the understanding level of a user about concepts of an online course with the help of qualitative values. Personal characteristics of a user can also be stored in this form.

concept name (uid)	Knowledge value	read	...
Xanadu	well learned	true	...
KMS	learned	true	...
WWW-page1	well learned	true	...
WWW-page2	not known	false	...
WWW	learned	false	...
...	...	...	...

Fig. 1: Structure of an overlay model

In stereotype model, different groups of users are made according to their backgrounds and personal information. For example, in any particular domain users can be termed as three stereotypes like beginner, intermediate and expert. Number of stereotypes depends on situation and group of pairs for each stereotype is defined separately (Brusilovsky, 1996b).

Bayesian network model (Henze and Nejdl, 1999) is a graphical representation of user's aims, needs and knowledge level. In this model, a directed acyclic graph is developed in which the values of domain concepts are represented through nodes while links show probabilistic relationships among these concepts. This Bayesian network covers all prerequisites of one particular domain concept (see **Fig. 2**). Further, it models both dependencies among all concepts and inferring mechanism for measuring the system's belief about user's level of understanding concepts.

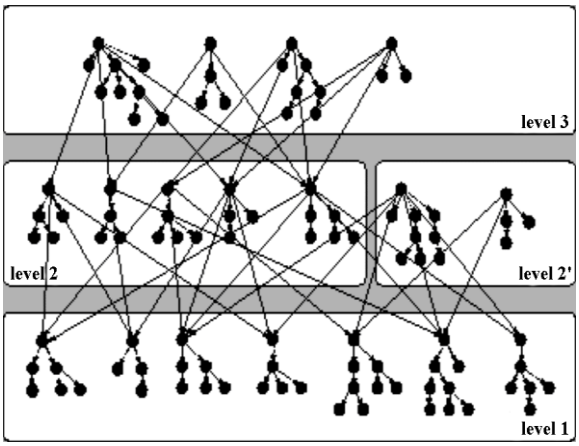

Fig. 2: Bayesian network underlying the user model

Fig. 2 shows simple concepts at level 1. Some of them are prerequisites of concepts at level 2. Similarly, relatively advanced concepts at level 2 are prerequisites of concepts at level 3. Some concepts which are not prerequisites for level 3 are shown separately at level 2'. There can be many other levels of concepts in a Bayesian user model. Bayesian network updates user model by estimating the user's knowledge continuously. For example, if a learner is unable to understand a domain concept completely then this network manages the uncertainty in learner's understanding level between "*failed*" and "*not failed*" instead of changing his or her status from skilled to novice. Each type of user model has its own advantages but better results can be achieved by combining good features from all of them.

5. ADAPTATION MODEL IN AHS

Brusilovsky (1996a) classified adaptation into two different types: adaptive presentation (at content-level) and adaptive navigation support (at link-level). Adaptation model in AHS incorporates both kinds of adaptation.

5.1 Adaptive Presentation

When a system customises presentation of a web page through addition or removal of content considering user's aims, characteristics and preferences then it is called adaptive presentation. For instance, some basic concepts of one particular domain are shown to novices first then they are directed towards difficult concepts later. On the contrary, experts are directly exposed to advanced concepts. Adaptive presentation can also be

possible through making same content available in different formats like text, audio or video (Brusilovsky, 1996a).

5.1.1 Methods for Adaptive Presentation

The following methods are used to achieve adaptive presentation (Brusilovsky, 1996a):

- *Additional Explanations*: Additional information about any concept is presented to a novice user but not to expert.
- *Prerequisite Explanations*: Prerequisites to any concept are shown first according to a user's knowledge and background before presenting that concept directly to the user.
- *Comparative Explanations*: If a user comes across any domain concept which is similar to already known concept then similarities and differences between them are presented to the user.
- *Explanation Variants*: Different explanations of a domain concept are stored in the system and then shown to the users according to their preferences and knowledge level (Fu *et al.*, 2000).
- *Sorting*: All hyperlinks are sorted from the given node or *hyperdocument* according to their relevance to preferences and goals of a user.

5.1.2 Techniques for Adaptive Presentation

Brusilovsky (1996a) described following techniques for the implementation of methods for adaptive presentation:

- *Conditional Text*: This simple technique is used for all kinds of methods except *sorting*. Concepts are divided into small chunks of text and then presentation of each chunk is conditioned according to the user's needs and preferences.
- *Stretchtext*: This technique is used for *additional explanations* method. While visiting a web page, few terms require further explanation. When someone clicks on such kind of terms, they get stretched like small boxes containing short explanations about them rather than jumping to another page (Fu *et al.*, 2000).
- *Fragment and Page Variants*: This is useful for the implementation of *explanation variants* method. Variants of small chunks of information or complete web pages are stored in AHS.
- *Frame based Technique*: This technique is used for all methods of adaptive presentation except *prerequisite* and *comparative explanations*. Different variants of one domain concept are stored in several slots of a frame then only most relevant slots are shown to user.

5.2 Adaptive Navigation

This type of adaptation prevents user from being lost in hyperspace. It helps in navigation within the environment of AHS through customised presentation of hyperlinks according to user related data.

5.2.1 Methods for Adaptive Navigation

The following methods are used for adaptive navigation (Brusilovsky, 1996a):

Global Guidance: User is suggested at each step about next possible web links to be followed.

Local Guidance: Most of the time user needs guidance while navigating the system, so AHS recommends next most relevant link from current web page.

Global Orientation Support: A complete map is provided to user which indicates his or her exact position in the hyperspace of AHS.

Local Orientation Support: This method helps in understanding relative position of user in the system by giving information about all accessible links from current web page and hiding irrelative links.

Managing Personalised Views: Different options are provided to user for customisation of overall look of system including colour scheme, content language and font style.

Techniques for Adaptive Navigation

Brusilovsky (2007) described following techniques for the implementation of methods for adaptive navigation:

Direct Guidance: In this technique, "next best" link is suggested to user from current web page. It is used to implement *global* and *local guidance* methods.

Link Sorting: This is also used to implement *global* and *local guidance* methods. Web links are sorted according to user's preferences for searching information and his or her knowledge level, eventually the most relevant links are appeared.

Link Hiding: Method *of local orientation support* can be implemented through this technique by removing irrelevant hyperlinks from link list. *Link disabling* is another form of this technique through which irrelevant links become inactive so there is no effect when user clicks on them (De Bra, 1999).

Link Annotation: This technique is used for *local* and *global orientation support* methods. It helps in indicating the current state of links to different concepts on the basis of user's previous progress. Basically, it distinguishes domain concepts into different types like not-known, known and well learned etc. Annotation can also be used to distinguish links as very relevant, relevant and less relevant. Ng *et al.* (2001) explained another form of link annotation which is based on time spent on web pages by users and actual time required to visit and understand them. Annotation is implemented by applying different icons, colours or font sizes to

links. Mostly traffic light colours are used to annotate links.

- *Link Generation*: It is also called link augmentation. In this technique, web pages related to different domain concepts are considered in spatial context of user's browsing history and preferences. Links to all context based web pages are stored in a *linkbase* (database of links) and then generated or augmented into the set of links on current web page according to their context (Bailey *et al.*, 2001).

6. CONCLUSION

Adaptation can make online systems more personalised and convenient so there is a dire need to extend the taxonomy of adaptive hypermedia. It can be made possible if more methods and techniques for adaptive presentation and adaptive navigation are identified.

User modelling plays a key role in adaptation process. User models of different AHSs working in same domain can share knowledge with each other if they are based on open ontologies instead of different conceptual structures. In this way, one AHS can learn easily about the users of other AHS and provide services to them also.

If users of an AHS are categorise into different groups inside user model then adaptive navigation support can be improved by suggesting useful hyperlinks based on common interests of same group users. Data mining techniques can be helpful to observe the common interests among the users.

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