State of the Art of Adaptivity in E-Learning Platforms

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Abstract

Adaptivity has been an important research topic during the past two decades, especially in the field of e-learning. This paper deals with the question of whether and to what extent adaptivity is actually being used in e-learning systems. It describes the state of the art of adaptivity features and gives an overview on the most frequently used learning management systems (LMSs) as well as on a number of research projects and systems providing adaptivity.

1 Introduction

Adaptive Hypermedia (AH) has been explored and researched for several years now. In 1996 Brusilovsky claimed that [Brusilovsky, 1996b, p. 1]

> "AH systems can be useful in any application area where the system is expected to be used by people with different goals and knowledge and where the hyperspace is reasonably big. Users with different goals and knowledge may be interested in different pieces of information presented on a hypermedia page and may use different links for navigation."

In the same paper he pointed out that adaptivity can be especially helpful in education and listed some first approaches to educational AH systems. There has been a lot of work and research in adaptive educational hypermedia in the intervening years, evidenced by the number of publications and dedicated events.

This paper examines the extent to which adaptivity is employed today in widely used e-learning systems. The rest of the paper is structured as follows: Section 2 deals with the question whether and how adaptivity can enhance e-learning. Moreover, it introduces several adaptation techniques. Section 3 presents a list of popular LMSs as well as an overview on some systems already providing adaptivity features. The paper is concluded with a summary and discussion of the findings.

2 Adaptivity in E-Learning

This section deals with adaptivity in e-learning systems and explains why and how adaptivity is able to improve the quality of e-learning environments.

2.1 Why Can Adaptivity Enhance E-Learning?

According to [Brusilovsky, 1996a] adaptivity is of particular importance in the field of e-learning for two main reasons. First, a learning system might be used by learners differing in their goals, learning styles, preferences, knowledge and background. Moreover, the profile of a single learner changes (e.g. the knowledge increases as an effect of learning). Second, the system can help the learner to navigate through a course by providing user-specific (not necessarily linear) paths.

Taking care of these differences, the system is able to provide personalized access to the content (fitting the individual user's needs). The fact that the decisions on what is presented are based on the user's profile (e.g. goals, knowledge) allows taking care of a single user. This compensates for one significant problem of common e-learning systems that provide the same view of the information for all learners.

2.2 How Can Adaptivity Enhance E-Learning?

There are several different ways to categorize adaptivity features. [Beaumont and Brusilovsky, 1995] distinguish between adaptation on content level (adaptive presentation support) and on link level (adaptive navigation support).

Adaptive presentation support Adaptive presentation support describes the presented content as an assembly of fragments. Depending on how these fragments are put together [Beaumont and Brusilovsky, 1995] divide adaptive presentation support into "conditional presentation" ([Fischer *et al.*, 1990]), the "stretchtext" technique ([Boyle and Encarnacion, 1994], [Kobsa *et al.*, 1994]) and the "frame-based" technique (used in HYPADAPTER [Böcker *et al.*, 1990] and EPIAIM [De Rosis *et al.*, 1993]).

[Henze, 2000] adds page or page fragment variants as another adaptation technique which is – although similar to the frame-based technique – a more general approach.

[Brusilovsky, 1996b] differentiates between adaptation techniques (implementation level) and adaptation methods (conceptual level). [Brusilovsky, 1996b] lists the following methods for adaptive presentation support:

- Additional explanations: Displays the parts of a document matching the user's knowledge or goal (used in MetaDoc [Boyle and Encarnacion, 1994], KN-AHS [Kobsa *et al.*, 1994], ITEM/IP [Brusilovsky, 1992], EPIAIM and ANATOM-TUTOR [Beaumont, 1994]).
- Prerequisite explanations: If prerequisites for a concept are not sufficiently known, the corresponding information is inserted by the system (used in Lisp-Critic [Fischer *et al.*, 1990] and C-book [Kay and Kummerfeld, 1994]).

- Comparative explanations: Emphasizes similarities between the currently displayed concept and known ones (used in (ITEM/IP, Lisp-Critic and C-book).
- Explanation variants: In some cases displaying or hiding parts of information is not sufficient which leads to creating different variants of a piece of information and presenting the best fitting one (used in ANATOM-TUTOR, Lisp-Critic, HYPADAPTER, ORIMUHS [Encarnação, 1995], SYPROS [Gonschorek and Herzog, 1995] and WING-MIT [Kim, 1995]).
- Sorting: The fragments of information are sorted according to their relevance for the user (used in HYPADAPTER and EPIAIM).

Adaptive navigation support Adaptive navigation support deals with all the possibilities of modifying visual links enabling navigation (e.g. by reordering, hiding or annotation).

As for adaptive presentation support [Henze, 2000] defines various methods for adaptive navigation support (based on [Brusilovsky, 1996b]):

- Direct guidance: The user is provided a sequential path through the system, either using the "next best" strategy (guidance with a "next"-button) or "page sequencing or trails", where reading sequences through (parts of) the system are generated.
- Adaptive sorting: The links of a document are sorted according to their assumed relevance (based on previous knowledge or similarity to the current document).
- Adaptive hiding: Links are hidden or disabled if the system assumes that they are not relevant and/or distracting.
- Link annotation: Links are annotated by text, colouring, an icon, or dimming in order to give some extra information to the learner.
- Map annotation: The discussed annotation methods are used for adapting graphical overviews and/or maps.

Criteria for adaptation An adaptive system may be either concept-based or not bound to a specific concept ([Aroyo *et al.*, 2006]). Concept-based systems use a model of the content (the "domain model" or "content model") to structure the information. If the structure of the content is relatively straightforward or the content is of small size, it may not be necessary to develop a specific model.

Especially in the area of adaptive learning systems concept-based architectures are more commonly used.

According to [Aroyo *et al.*, 2006] the adaptation itself is based on a user's preferences (e.g. learning and cognitive styles, language) as well as on assumptions about the current user's (knowledge) state. [Kareal and Kléma, 2006] state that the presented information should adapt to the learners' prior knowledge and skills, learning capabilities, learning preferences or styles, performance level and knowledge state, interests, personal circumstances (location, tempo, etc.) and motivation.

3 Overview of E-Learning Systems

The first section of this section gives an overview on popular e-learning systems. The second section of this section provides a list of systems using the adaptivity features mentioned in section 2.2.

3.1 Popular E-Learning Systems

The number of e-learning systems has constantly been increasing during the past years as a lot of companies, faculties, universities and other institutions developed systems for common or personal use. Therefore, it is practically impossible to set up a complete list of e-learning systems. The following list includes some of the systems most frequently used in e-learning (mainly Learning Management Systems (LMSs)).

- .LRN [.LRN] is an open source e-learning and community building software originally developed at MIT. Today it is supported by a worldwide consortium of educational institutions, non-profit organisations, some industry partners and open source developers. .LRN is built on the top of OpenACS (Open Architecture Community System) [OpenACS] which is a toolkit for building scalable, community-oriented web applications.
- ATutor [ATutor] is an open source system supporting learning and content management and specifically considering accessibility and adaptability issues. It was first released in 2002 after two studies conducted that evaluated the accessibility of learning platforms to people with disabilities. Several features are planned for the near future, including a barrier free authoring tool and a streaming media server.
- Blackboard [Blackboard] was founded in 1997 and provides course and content management systems, collaboration tools and a number of other services combined in the "Academic Suite" and the "Business Suite". It is one of the most popular and successful commercial e-learning systems. It can be extended according to own needs.
- Bodington [Bodington] is an open source LMS specialized on higher and further education developed by the University of Leeds. Bodington uses the metaphor of "buildings", "floors", and "rooms" to structure the Virtual Learning Environment (VLE). The main target is to be pedagogically flexible. In September 2006 the University of Oxford, the University of Cambridge, the UHI Millennium Institute and the University of Hull announced the "Tetra Collaboration" between Sakai and Bodington.
- BSCW [BSCW] (Basic Support for Cooperative Work) is a commercial shared workspace system mainly supporting advanced document management. Additionally it offers group and time management facilities as well as communication features like discussion boards, annotations and surveys. The project was initiated in 1995 and is still developed by FIT (Fraunhofer Institute of Technology) and OrbiTeam.
- CLIX [CLIX] is a commercial LMS developed by the imc (information multimedia communication) AG. It is available in different releases especially suitable for several different application scenarios.Additionally there are a couple of auxiliary features that can be added to the basic application in order to fit the individual needs of a scenario or project.
- Dokeos [Dokeos] is a quite complex e-learning and CM system and evolved out of the LMS "Claroline".

Most parts of the software can be downloaded for free, whereas others are offered on a commercial basis by the like-named company. In terms of adaptivity Dokeos provides progress-based learning paths (teachers may define prerequisites for items).

- Ilias [Ilias] is a service-oriented open source LMS, whose first prototype was developed within the VIRTUS project in 1997/1998 at the University of Cologne. In 2000 Ilias became an open source software. Currently, it is being developed by a collaboration network of several universities and companies.
- InterWise [InterWise] is a commercial conferencing and collaboration tool. It provides mainly synchronous possibilities of interaction including audio and video conferencing, desktop sharing, instant messaging, whiteboard, etc. Although it is no traditional learning platform, but more a conferencing tool, its main focus lies on e-learning (primarily in companies). InterWise provides virtual classrooms with possibilities going further than those of usual conferencing systems, e.g. by implementing different roles and the possibility to pose questions and receive statistics on the answers.
- Moodle [Moodle] is a very popular free Course Management System (CMS) that has its origins in the 1990ies. In 2003 the company moodle.com was launched to provide commercial support, managed hosting, consulting and other services. Since 2005 there is a fixed team of lead developers employed by Moodle, in addition to a large community of developers and supporting organisations contributing source code, ideas, etc. to the project. The general design tries to consider pedagogical principles and learning theories. The lesson module of Moodle also provides different learning paths. As the user's possible answers on a question can be used as starting points for different learning paths, some kind of "weak adaptivity" is supported (depending on the definition of adaptivity - as there is no user model).
- The OLAT [OLAT] (Online Learning And Training) project was started in 1999 at the University of Zürich. OLAT is a free LMS that is, since 2001, officially supported by the IT Department of the University of Zürich. In 2004 OLAT became open source.Today further development ist still lead by the University of Zürich, commercial support for the LMS is offered by various companies.
- OpenUSS with Freestyle Learning [OpenUSS] was developed by the University of Münster (starting in 2000). According to the website [OpenUSS] "Freestyle Learning (FSL) and Open University Support System (OpenUSS) are specifications for Learning Content System (LCS) and Learning Management System (LMS). They provide J2SE, J2ME and J2EE reference implementations on those specifications". OpenLMS is now also collaborating with OpenUSS.
- Sakai [Sakai] is a service-oriented Java-based open source LMS developed in 2004 by the universities of Michigan, Indiana, Stanford and the Massachusetts Institute of Technology. They contributed their existing LMSs to the new e-learning platform. Later other projects and partner institutions joined the Sakai community and developed Sakai tools based on their products (e.g. OSPortfolio, Samigo, Melete). Today Sakai is developed by 116 cooperating organizations and funded via a partners program.
- WebCT [WebCT] was a commercial Course Management System created in 1996 at the University of British Columbia. In 2006 WebCT was acquired by Blackboard [Blackboard], but it is still in use.

Unfortunately these systems provide no or just weak adaptivity features. Although adaptivity has been a research topic for about fifteen years, it is still used mainly in research projects rather than in the most frequently used LMSs (see table in figure 1).

3.2 Adaptive E-Learning Systems

The previous section provided a brief overview of popular, widely used e-learning systems. This section focuses on well-known historical and modern adaptive e-learning systems instead, which, while not as popular, have extensive support for adaptivity; most of these systems provide both adaptive presentation support and adaptive navigation support.

- AHA [AHA] is an open Adaptive Hypermedia Architecture providing adaptive content presentation based on fragments as well as link annotation and link hiding [De Bra and Calvi, 1998]. The current version is based on AHAM (Adaptive Hypermedia Application Model) [De Bra *et al.*, 2002]. User Model and Adaptation Engine are strictly separated.
- ALFANET [ALFANET] (Active Learning For Adaptive Internet) was developed within a European project from May 2002 to April 2005. Its architecture is service-oriented, uses multi-agent technology and is based on several standards [Santos *et al.*, 2004] (e.g. IMS-LD, IMS-QTI, IMS-CP, IEEE-LOM, IMS-LIP).
- ANATOM-TUTOR [Beaumont, 1994] is an adaptive system for teaching anatomy. It can be used in three different modes: browsing mode (without any adaptivity), question mode (using the user model extensively to find questions and to evaluate the answers) and hypermode (adaptive presentation and navigation support).
- AnnotatEd [Farzan and Brusilovsky, 2006] is an adaptive tool for annotating web pages. Based on the annotations (peer review) this tool is able to provide social navigation support. AnnotatEd can be used in combination with Knowledge Sea (see below).
- CHEOPS [Negro *et al.*, 1998] uses an internal knowledge model to provide adaptivity and is implemented as a set of CGI-BIN PERL scripts. The main information taken into account is the history of visited pages. Moreover, the system allows annotations on specific pages.
- ELM-ART [Weber and Brusilovsky, 2001] provides information as an interactive adaptive textbook and uses a combination of an overlay model and an episodic student model to provide adaptive navigation support, course sequencing, individualized diagnosis of student solutions, and example-based problem-solving support.
- EPIAIM [De Rosis *et al.*, 1993] is used for statistics in epidemiology and generates user-taylored messages.

The main focus of this adaptive system lies on the generation of natural language based on the experience of a user within a certain knowledge domain.

- HYPADAPTER [Böcker *et al.*, 1990] supports exploratory learning in the domain of Common Lisp and offers adaptive presentation support as well as adaptive navigation support (sorting, hiding, annotating).
- InterBook [InterBook], [Brusilovsky *et al.*, 1998] is an authoring tool for the development and delivery of adaptive electronic textbooks that transforms plain text to specially annotated HTML. It includes a web server for the publication of the textbooks, stores an individual model for each user and provides adaptive guidance, adaptive navigation support, and adaptive help.
- ITEM/IP [Brusilovsky, 1992] (Intelligent Tutor, Environment and Manual for Introductory Programming) supports a course on introductory programming based on the minilanguage Turingal. "The mini-language serves as a tool in mastering the main concepts of programming, programming languages' structures and skills in program design and debugging." ITEM/IP consists of several interacting components providing support for the different phases of the learning process: the pedagogical module (enhancing the choice of teaching operations), the programming laboratory (enabling students to work independently) and the information kernel (including all factual knowledge).
- iWeaver [Wolf, 2003] is a PhD project designed to provide an adaptive, flexible learning environment for the Java programming language. The system creates a learner profile by assessing learning styles with the help of a range of multiple choice questions when the user first enters. Later users receive personalized recommendations and an individual view of the available learning tools. iWeaver combines adaptive navigation and adaptive content presentation techniques.
- KN-AHS [Kobsa *et al.*, 1994] is an adaptive hypertext client for the user modeling system BGP-MS. It provides automatic adaptation of hypertext to a user's state of domain knowledge. KN-AHS draws assumptions about the user's knowledge by an initial interview and some of the hypertext actions the user performs. When a new concept is introduced, its presentation is adapted to the user's familiarity with it, e.g. by offering additional explanations after having retrieved the respective information from the related user model.
- KnowledgeSea II [Brusilovsky *et al.*, 2006] is a system for personalized information access. It offers various methods of accessing information, including two-level visualization, hypertext browsing, recommendation and social search. Personalization is provided by social navigation support which is an approach for browsing-based and recommendation-based information access. KnowledgeSea II includes an adaptive search facility combining a common vector search engine and social navigation. By that every user may benefit from the whole community's knowledge; search results are adapted to the user based on the history of activities.
- KnowledgeTree [Brusilovsky, 2004] is a distributed architecture for adaptive e-learning based on the reuse of intelligent educational activities. It combines learning content and learning support devices and presumes the existence of at least four kinds of communicating servers: activity servers, value-adding servers, learning portals (e.g. KnowledgeSea) and student modeling servers.
- MetaDoc [Boyle and Encarnacion, 1994] introduces an adaptive presentation technique based on stretchtext. It handles nodes as stretchtext pages and presents a requested page collapsing all extensions not relevant and uncollapsing all extensions relevant for the user.
- METOD [METOD] (MetaTool for Educational Platform Design) is a European Union funded project basically aiming at creating a general paradigm for educational platform development. Part of the project's results is MetaTool that allows creating METOD projects storing various kinds of content and (meta) information, e.g. topics, student types, learning styles, exercises and learning paths. The projects can then be exported to various Content Management Systems that have to support a specific METOD plugin in order to provide adaptive learning.
- NetCoach [NetCoach] is a further development of ELM-ART containing an own authoring system that allows the development of adaptive courses. Generally all material belonging to a course is organized in a tree structure and can be freely browsed by the learner. Additionally, the system offers personalization of courses by adaptive curriculum sequencing and adaptive link annotation.
- SQL-Tutor [Mitrovic and Ohlsson, 1999] combines Intelligent Tutoring and Adaptive Hypermedia in a constraint-based architecture. It provides support for university-level students learning SQL and consists of an interface, a pedagogical module and a student modeling unit analyzing students' answers.

4 Discussion and Conclusion

The previous section shows that over the past two decades a lot of effort was put into exploring and researching the benefits of adaptivity in e-learning. Therefore a large number of research projects and systems (including the ones mentioned in section 3.2) already uses adaptivity.

Unfortunately, none of these systems is already being used by a large and worldwide community outside the research area. Most of the popular e-learning platforms have not yet taken advantage of adaptivity, possibly because the expected profit does not yet justify the high effort of implementing and authoring adaptive courses. Moreover, most adaptive systems do not support e-learning standards [Paramythis and Loidl-Reisinger, 2004].

Table 1 presents an overview on features supported by some representative systems (listed in section 3).

Within this table we may identify two groups of systems. The first group – systems mentioned in section 3.1 – supports a lot of "standard features" a learning platform is expected to include, but as already mentioned they do not provide adaptivity features. The second group – systems mentioned in section 3.2 – provides these features, but as many of the "standard features" are missing, they are rather not suitable for common e-learning scenarios.

The next step in order to make the knowledge and experience gained in research projects on adaptivity available

	Bodington	Dokeos	Moodle	OLAT	OpenUSS	Sakai	AHA	Alfanet	ELM-ART	InterBook	KnowledgeSea	METOD	NetCoach
Learning													
Assignments – Choice	X	X	X	X	X	X	X	X	X	X		X	X
Assignments – Text	X	X	X	X	X	X	X	X	X	X		X	X
Assignments – Files	X	X	X	X		X	X					X	
Stored Evaluation	X	X	X	X	X	X	X	X	X	X		X	X
Glossary			X	X	X	X			X	X			X
Bookmarks	X			X									
Annotations	X			X	X								X
Search	X		X	X	X	X				X			X
Cooperation													
Forum	X	X	X	X	X	X		X					X
News	X		X	X	X	X		X					X
Email	X		X	X	X	X							X
Personal Messages			X		X			X					
File Management	X	X	X	X	X	X		X				X	X
Calendar	*)	X	X	X	X	X		X					
Polls	X	X	X	X		X							
Nickpage Authoring	X	X	X	X	X	X		X					
Collaboration													
Chat	X	X	X	X	X	X							X
Audio Conferencing		X	*)		*)	*)							
Video Conferencing		X	*)		*)	*)							
Whiteboard		X			X	*)							
Desktop Sharing					*)	*)							
Learning Management													
User Group Support	X	X	X	X		X				X	X	X	X
Creating Content Online	X	X	X	X	X	X	X	X				X	X
Importing Content	X	X	X	X	X	X		X	X	X		X	X
Stored Learner Model							X	X	X	X	X	X	X
Personalization	X	X	X	X	X			X					X
Adaptivity													
Adaptive Guiding							X	X	X	X	X	X	X
Link Annotation							X	X	X	X	X	X	X
Link Hiding							X	X	X	X	X	X	X
Adaptive Pres. Support							X	X	X	X		X	X
Standards													
IMS CP	*)	X	X	X		X		X					
IMS QTI	X	X	X	X		X		X					
SCORM	*)	X	X	X	*)	X	X[1]	X					
IEEE LOM		X	X	*)		X		X					

X...Supported *)...Planned to be supported
[1] not part of the original system, but added as an extension

Figure 1: Features of e-learning systems

to a large community of learners would be their combination with commonly required features. As research projects usually neither aim at the implementation of already widely used features nor have the capacities and resources to redevelop them, a better approach would be the transfer of achievements in the field of adaptivity into the development of the large and most frequently used systems.

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