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On The Evaluation of Adaptive Web Systems

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Abstract

Adaptive Hypermedia Systems *(AHS) affect the way most of the Web-based applications are developed and used. One of the application domains affected by AHS is the domain of Web-based Support Systems (WSS), which is part of the more general online information systems domain. Since the very beginning of the research on AHS, different systems have been developed for different domains and application areas (such as educational systems, online information systems, etc.). Besides some general features, which are expected to be present in any software system, AHSs have their own extra features that make them different from non-adaptive systems. Through a careful study of a large number of adaptive hypermedia systems, a hierarchy of primary features based on which one can evaluate different adaptive web systems is proposed. An evaluation weighting scheme is also proposed for the given features. A comparative analysis is carried out for 4 major adaptive hypermedia systems (AHA!, InterBook, SETA and SeAN). The results of our detailed evaluation put AHA! at the top followed by SETA, SeAN and InterBook, respectively.*

1 Introduction

Adaptive hypermedia systems are those systems that change their behaviour according to their context. *Adaptive* refers to the ability of the system to change its responses in reaction to runtime environment, users, and other parameters. Adaptiveness affects all types of the Web-based systems, one of which is Web-based Decision Support Systems (WSS) category. WSSs are online information systems that provide decision-making information to its users (decision makers) based on available data, information, or knowledge. An adaptive WSS helps its users to quickly locate and find information they are looking for. It also maximizes a user's ability in finding relevant information by exploiting their historic usage (access) behaviour and other environmental contexts.

During the recent years, quite a few adaptive hypermedia systems have been developed. In addition, the current state of research in the adaptive hypermedia/Web-based systems suggests that a lot of new systems are being and will be developed. These systems have different domains, though some of them may be general enough to be applied to various domains. The point that needs to be taken into consideration is that although adaptive system may be developed for different domains, there are general functionalities, qualities and features expected to be present in them. Most of the systems focus on some specific areas, such as user modelling or data mining. Some of the them are not really systems, but algorithms or useful tools to be used in the development of AHSs. However, a complete and usable adaptive hypermedia/Web-based system is supposed to have all the important adaptive features as well as general software-related features. For instance, if a system proposes a new model for the adaptive hypermedia applications, then the corresponding methodology for the development of the suggested model should also be proposed. Otherwise, the new model cannot be practically applied.

There are some efforts to develop a general framework for AHS that offers all the functionalities, qualities, tools and methodologies. It would be useful if there were an evaluation framework to realize the features and functionalities of an AHS. In this paper, we propose such a criteria based on a hierarchy of features.

The rest of this paper is organized as follows. In the next section, we briefly review all the systems developed in AHS research. Section 3 presents a hierarchy of features that covers various aspects of an AHS. In Section 4, based on the proposed features, we evaluate four adaptive Web-based systems. Finally, the results and conclusions of the present study are summarized in Section 5.

2 Adaptive Hypermedia/Web-based Systems

In order to define an evaluation framework, it is helpful that the previous efforts toward building adaptive Web systems be reviewed. In fact, such evaluation criteria would be

the result of studies on the features those systems support and what they need to support (but don't support).

Table 1 shows a list of the projects in the area of AHS, including frameworks, prototypes (application), methodologies, models, and other kinds of software systems. We have identified these systems based on their domain and type (framework, prototype, etc.).

In the following sections, a short description of each of these systems is given:

ACT-R [12] is an electronic bookshelf, based on InterBook, which has been developed to support learning ACT-R, a theory in cognitive psychology.

ADAPTS [13] is an electronic performance support system that integrates an adaptive diagnostics engine with adaptive access to supporting information.

AHA! [10, 9, 11]is an adaptive website framework, which has been used to implement some adaptive website in educational area.

AHAM [25] is a model for adaptive hypermedia applications, based on Dexter reference model, which divides an AHS into domain model, user model, teaching model, and adaptation engine.

ALPHANET [44] aims to build a learning environment that offers intelligent personalization capabilities and addresses the problem of effective adaptive learning for individual learners.

AOAI [57] is an adaptive interface between a Web search engine and a user.

Arthur [22] is a Web-based instruction system that provides adaptive instruction.

AST [51] (Adaptive Statistics Tutor) is an adaptive courseware on the WWW.

BASAR [53] is an agent-based framework in which the agents filter information, initiate communication, monitor events, and perform tasks. The agents rely on usage profiles to adapt their assistance to specific users.

Broadway V1 [54] is a WWW browsing advisor reusing past navigation from a group of users.

CHEOPS [40] is an educational server-side package that can provide a requested page based on the user profile and history.

DI2ADEM [46] (Diffusion of Information with Interactive and ADaptive Environment in Medicine) aims at designing an interactive and adaptive environment, intended to improve the diffusion of medical knowledge.

ELM-ART [48] is a web-based course system to support programming in Lisp. In fact, ELM-ART is a hyperbook with two additional features: adaptive navigation support and intelligent problem solving support.

Fab [6] is a test-bed for comparing different adaptation techniques and it is based on agent technology. It's an automatic recommendation service that adapts to its users over time.

Table 1. Adaptive Hypermedia Projects

Project	Domain	Type
ACT-R	Educational	Prototype
ADAPTS	Miscellaneous	Prototype
AdaptWeb	Educational	Framework,Prototype
AHA!	General	Framework, Prototype
AHAM	General	Methodology
ALFANET	Educational	Miscellaneous
AOAI	Miscellaneous	Miscellaneous
ARNIE	Miscellaneous	Miscellaneous
Arthur	Educational	Prototype
AST	Educational	Prototype
BASAR	General	Framework
Broadway	General	Prototype
CHEOPS	Educational	Miscellaneous
DI2ADEM	Online Info. Sys	Prototype
ELM-ART	Educational	Prototype
Fab	General	Miscellaneous
GAHM	General	Model
GAS	General	Miscellaneous
GRAS	Miscellaneous	Algorithm
Hera	General	Methodology
HYPERADAPTER	Educational	Prototype
HyperAudio	Multimedia	Prototype
HyperContext	General	Model
ILEX	Online Info. Sys	Prototype
InterBook	Online Info. Sys	Framework
iWeaver	Educational	Framework
KBS HyperBook	Online Info. Sys	Framework
MASPLANG	Educational	Framework
METIORE	Multimedia	Miscellaneous
MMA	Online Info. Sys	Prototype
NetCoach	Miscellaneous	Framework
PageGather	General	Algorithm
Peba-II	Online Info. Sys	Prototype
PEGASUS	General	Framework, Model
PersonalWebWatcher	General	Miscellaneous
PowerBookmarks	Miscellaneous	Miscellaneous
PUSH	Miscellaneous	Prototype
PVA	Miscellaneous	Miscellaneous
RATH	Educational	Prototype
RLATES	Educational	Prototype
SeAN	Online Info. Sys	Framework
SETA	e-Business	Framework
SKILL	Educational	Framework
SmexWeb	Educational	Framework
SQLTutor	Educational	Prototype
SWAN	Miscellaneous	Framework
TANGOW	Educational	Framework
UWE	General	Methodology
VALA	Educational	Miscellaneous
WEAR	Educational	Miscellaneous
WEBMINER	General	Miscellaneous
WebWatcher	General	Miscellaneous
XAHM	General	Model, Framework

GAHM [45] is a formal approach to the modelling of personalizable, adaptive hyperlink-based systems.
GAS [50], Group Adaptive System, is a collaborative environment that provides the interface and tools for a group of people to share their browsing experience.
GRAS [28] (Gaussian Rating Adaptation Scheme) is a new personalization algorithm for hypermedia databases, which combines content-based and social filtering.
Hera [26, 7] is a design methodology aiming at automated generation of adaptive hypermedia presentations.
HYPADAPTER [24] is an adaptive hypertext system designed to individually support exploratory learning and programming activities in the domain of Common Lisp.
HyperContext [52] is a new model for adaptive hypertext. HyperContext achieves adaptation of the information and hyper-links through explicit context.
ILEX [43, 34], the Intelligent Labeling Explorer system, uses NLG (Natural Language Generation) technology to generate descriptions of objects displayed in a museum gallery.
InterBook [49] is a tool for authoring adaptive textbooks on the web.
iWeaver [56] is an interactive web-based adaptive learning environment, which aims to create an individualized learning environment that accommodates specific learning styles.
KBS Hyperbook [41] is a framework for designing and maintaining open, adaptive hypermedia hyperbooks in the Internet.
MASPLANG [32] is focused on the utilization of intelligent agents in online learning environments.
METIORE [14] is a Personalized Information Retrieval system that keeps a user model based on objectives.
MMA [20] (Mars Medical Assistant) uses a combination of user, situation, and task models to create virtual hypertext structures by piecing together medical information components.
NetCoach [55] is an authoring-system, which allows to create adaptive and individual course modules without programming-knowledge.
PageGather [47] is an algorithm to find collections of related pages at a web site, relying on the visit-coherence assumption.
Peba-II [35] is an on-line animal encyclopedia, which produces descriptions and comparisons of animals as world wide web pages.
PEGASUS [17] (Presentation modelling Environment for Generic Adaptive hypermedia SUpport Systems) is a generic presentation system for adaptive educational hypermedia that is highly independent from domain knowledge representation and application state management.
PersonalWebWatcher [37] (PWW) is a search assistant based on WebWatcher. The main difference is that PWW establishes a user model for individual users and recommends to the users based on these learned models.
PowerBookmarks [31] is a Web information organization, sharing, and management tool, which parses metadata from bookmarked URLs and uses it to index and classify the URLs.
PUSH [19] is an adaptive help assistant for users of SDP(the documentation of a software development method).
PVA [18], Personal View Agent, is a system that can automatically organize a personal view by learning the users interests, and adapt the personal view to the users changing interests.
RATH [23] is an adaptive tutoring WWW software prototype combining a mathematical model for the structure of hypertext with the theory of knowledge spaces from mathematical psychology.
SeAN [3] is a an adaptive system for personalized access to news.
SETA [5, 4, 2] is a prototype toolkit for development of adaptive Web stores.
SKILL [42] provides the students a collaborative and adaptive learning environment utilizing new web technologies proposed by W3C.
SmexWeb [1] (Student Modelled Exercising on the Web) is an adaptive web-based tutoring system, which implements a user model considering cognitive and knowledge aspects as well as general abilities of the students.
SQL-Tutor [36] is a knowledge-based teaching system, which supports students learning SQL and can adapt to the needs and learning abilities of individual students.
SWAN [21] (Adaptive and Navigating Web Server) aims at designing adaptive web servers for on-line multimedia information systems about nautical publications.
TANGOW [16] is a tool for developing Internet-based courses, which facilitates the construction of adaptive learning environments for the Web.
UWE [30] is a UML-based Web engineering approach .
VALA [33] focuses on developing a learning architecture with user interface adaptability that provides a personalized learning environment for each learner.
WBI [8] (pronounced WEB-ee) is a multi-agent system that organizes agents on a users workstation to observe user actions, proactively offer assistance, modify web documents, and perform new functions.
WEAR [39] is a Web-based authoring tool for the construction of Intelligent Tutoring Systems (ITSs) in Algebra-related domains, such as physics, economics, chemistry, etc.
WEBMINER [38] is a system for pattern discovery from WWW transactions.
WebWatcher [27] is a program, which guides the user of a website through different pages of that website based of a

set of given interests of that user.
XAHM [15] is an Adaptive Hypermedia Model based on XML, which is relatively more expressive than other models, in defining the domain and adaptation models.

3 The Features and Their Rationale

In order to establish how a system is adaptive and how many important aspects of an adaptive web system it supports, a set of features must be defined. These features include adaptation-related features, software quality features, software engineering features and technology features. These features are described in the following subsection.

3.1 Runtime Features

Runtime features are the most important factors in evaluating a system. They can describe how a system behaves and how it accomplishes its objectives. They also describe how well the system can be used, either as a black box or as a reusable and/or extendable set of components or library.

Adaptation Dimensions: The adaptation may take place based on various information about the user, runtime context parameters, and other related information. Generally, the following context information might be used in the adaptation process [15]:

(a) *User/User Community (Group)*: This specifies if the user preferences and browsing behaviour are taken into account in the adaptation. Also, user communities might be taken into account when the system is responding to an individual user. These user communities (groups) are usually extracted and updated by mining techniques referred to as *group mining*.
(b) *Environment*: This feature, realizes the consideration of external environment status, like time, location, etc.
(c) *Technology*: Technology feature, targets the different capabilities and characteristics of the client terminal or network. For example, a system can adapt the pages for delivery to a mobile client.
(d) *Unexpected Events*: There are other kinds of information that could be taken into account in adaptation process. In a system with more than one actor, for instance, at some point, one of the actors may impose some constraints on the system which affects other actors. To be more specific, imagine an online course system, with teacher, student and administrator, as three kinds of users (actors).

Adaptation Features: *Adaptation features* target the different aspects of adaptation in adaptive hypermedia systems as described in [29].
(a) *Navigation*: Direct guidance, link sorting, link hiding, link removal, link disabling, link annotation
(b) *Content*: Fragment addition/removal (conditional inclusion of fragments), fragment's level-of-detail support, fragment generation, fragment annotation
(c) *Presentation*: There are three different presentation adaptation: presentation adaptation based on user model in which the system decides how to present certain components to the user, based on the user model (e.g. the order of the information fragments); presentation adaptation based on environment where external environment can change the presentation format (e.g. language, location of the client, time); presentation adaptation based on technology: not all kinds of media or graphical elements can be used on all kinds of client machines (e.g. tailoring the presentation for handheld devices).

Authoring: Authoring features, describe how a system supports the development of an adaptive web site (if it is a framework or model), or the integration of its components into a system (if it is a technique or library), or any other useful task that can be automated. We consider simplicity, hierarchical development support (different roles for different levels of development), expressiveness, and other useful tools supported, as important authoring features.

Usability: This feature is concerned with how easy it is for the user to use the system and how much effort is required to learn, operate and interact with the system. For example, the way a system gathers user's feedback, affects usability. If the system requires that the user give explicit feedback, at some point the user might get tired or not feel comfortable using the system. The point that is of a great importance here is that, one of the goals of adaptive systems, is to help users find their way in the system and use the system easily. So, it doesn't seem logical to compromise the usability for the adaptability/adaptivity.

Security: All the systems, especially multi-user web-based software systems, must have some mechanisms to ensure that the system is secured, that is, no unauthenticated person may use the system and also, no unauthorized action may be accomplished in the system by a user. This concern is more evident in adaptive hypermedia systems, since the system services change in accordance to users and environment.

Privacy: Whatever mechanism a system uses to provide adaptivity to a user, it should not violate the user's privacy. So, it is considered as an important feature in a system. As an example, a system that uses Cookies to keep track of user sessions is somehow violating the user's privacy.

Performance: As adaptive systems usually use AI techniques and algorithms to do adaptation, it seems reasonable to consider the performance of such systems as a characterizing feature, since AI algorithms are most often time-consuming. For instance, automated reasoning in First Order Logic is a very slow procedure, though may be effective for some problems. If it is used in a system, then the performance of the system would be much slower than a system that doesn't use it.

Scalability: The AHS should be scalable in relation to both the content size and the number of users.

Generality: This feature determines if a system is general enough to be used in multiple application domains. Some systems are general to some extent. For instance, they can be used to author online information systems, whether an online help system or an online course. However, they cannot be used to develop an e-Business Web system. It is obvious that the more general a system is, the more difficult it's development is. Therefore, the efforts of a system to provide a general adaptive Web system should be taken into account.

Cost: The cost of a system may be calculated regarding various parameters, including the minimum required technology to run the system, the start-up time of the system (the time required to get the system up and running).

3.2 Technology

This category of features, capture the use of different technologies in the projects. For example, there are a lot of AI algorithms and techniques that can be integrated into an adaptive system. These techniques can range from information extraction algorithms (data mining) to the intelligent agents application in the system architecture.

Mining Techniques: An AHS may apply mining techniques to extract useful information. These mining techniques include usage mining, content mining, and structure mining.

Agent-based Features: The use of agent technology is considered as a distinguishing feature in software systems in general, and adaptive web-based systems, in particular. On one hand, using multi-agent architectures helps systems achieve a set of goals, such as distribution, high-level communication, and problem solving. On the other hand, these architectures have their own issues and problems to be addressed. Through this feature, the extent to which the agent technology is exploited in a particular system, is realized.

Page Synthesis: Page synthesis is the dynamic generation of Web pages. The adaptive Web systems usually have different degrees of synthesis. That is, some of them have pages stored somewhere, and change them on demand, whereas some of them produce the pages from a set of data in the database. Page synthesis feature is considered a noticeable feature since it captures the power of the adaptation in the system as well as the number of free parameters that are controllable in the adaptation process. There are different levels of synthesis, which might be used in an AHS: natural language generation, template-based page generation, and totally dynamic page generation.

3.3 Software Engineering

This category contains features that address the software development process.

Portability: It is very important that how portable an AHS is. For example, since most of the adaptive systems are based on server-side web development, it really matters if they can be ported to different Web servers, such as Windows-based or Linux-based servers.

Extendability: This feature addresses how the system can be extended across different dimensions. It is desirable that a system be extendable by new algorithms, techniques or functionality. As an example, suppose that a new mining algorithm needs to be integrated into the system. How much effort is needed to do this integration?

Flexibility: The way the system can be customized and changed to meet different configurations for an application, determines the flexibility of the system. It is an important feature that the system be flexible enough to be tailored easily and effectively. For example, in an application, there might be no need for group mining. Then, the efforts needed to remove this feature from the system determines its flexibility.

Maintainability: As a software quality attribute, maintainability is considered important, especially in the context of AHS; some AHSs have an adaptation model, which consists of some rules or programs. It is a concern that how the maintainability of the system is affected, regarding this extra model in the system. If a problem is detected in the system, how difficult it is to find the source of the problem and to change the required parts of the system, regrading the extra models that the system has.

Support for Design Models and Methodologies: If a system proposes a design process or a modelling procedure,

then it's considered a design feature. It is desirable that an AHS be model-driven. For such a system, we are interested in determining how the system supports the design of different models, that is, the domain model, the user model, and the adaptation model.

Implementation: This category deals with the features related to the implementation issues of the system. We consider the programming language used in the development (the popularity, simplicity, etc.) and the platform on which the system works on.

Support: This section addresses the features that evaluate the way a project is supported for later developments or use:
(a) *Documentation*: is there any documentation about the system functionality?
(b) *Running Prototype*: is there any sample application that shows how the system works?
(c) *Continuing*: is the project still under development and research?

Open Source: If a project is open source, everybody can look at the source code and learn a lot. Some developers and researcher may change the code in some specific direction. In this way, it may become a test-bed for many other projects in the field. So it is a very important feature.

4 Selected Systems for Evaluation

We have carried out detailed evaluations on 4 AH systems: AHA!, InterBook, SETA, and SeAN. There is no concrete reason why we have selected these four out of the huge list of Table 1, however, we had some factors in mind (such as, documentation, implementation, etc.) when choosing them. AHA! is a rather general system mostly used in educational domains. InterBook is a general tool for developing online books. SETA is a framework to build adaptive Web stores. SeAN is an adaptive news system. The following is a summary of some of their features and functionalities.

4.1 AHA!

AHA! is a general adaptive hypermedia framework used in educational domains. In this framework, the domain is modelled through concepts and relationships between them. Concepts can be related to a resource (page or fragments, for instance). AHA! adapts the pages based on the user model. In AHA! the adaptation model and the domain model are interwoven. There are two tools provided to facilitate the authoring: Graph Editor, which is a high-level tool for defining concept relations, and Concept Editor, which is relatively low-level and used for rule definition. However, the tools generate XML files that can be edited manually. The AHA! has a predefined page structure in the sense that the pages are not synthesized, however, the author can include conditional fragments so that if some conditions hold, the fragment is not shown. No tool is provided for creating pages. The author has to use XHTML to define the pages. AHA! has content adaptation (conditional fragments) and link adaptation (link coloring). AHA! is an ongoing project. AHA! uses Java language and Servlet technology and it is platform independent. This project is open source and there is a quite good documentation online.

4.2 InterBook

InterBook is a tool for authoring adaptive textbooks on the Web. It uses a domain model of concepts and a user model to provide adaptivity. It provides two major parts, the glossary and the indexed textbooks. The glossary is the structured hierarchy of the domain. The textbooks are indexed so that each unit has a set of related concepts and the role of that concept. In addition to regular navigation support (back and forward, etc), InterBook provides an adaptive set of links between the textbook and the glossary based on the current user's knowledge. Also it provides visual cues about each link (adaptive annotation) and direct guidance about the suggested next place the user should visit. Another kind of direct guidance is used to provide prerequisite-based help for the user. Since the system knows the prerequisite relationships between concepts, when the user has difficulty understanding a concept or solving a problem, the system can suggest the unit that contains the concepts that are the prerequisite concepts of the difficult unit. InterBook is implemented based on CL-HTTP Web server using LISP language. The authoring has different stages and it uses pre-existing tools. It seems that in the hyperbook area, InterBook is a dominant tool for developing adaptive online books, since it has the tools and the server for serving the books online. However, it cannot go beyond this domain, hence, it is not considered a general AHS.

4.3 SETA

SETA is a prototype toolkit for development of adaptive Web stores. It exploits a multiagent-based three-tier software architecture, and is designed to allow building different Web stores by authoring tools, that is, all the domain-dependent knowledge about users and products can be configured by tools.

SETA dynamically generates the pages of a Web store catalog and selects the content of the pages based on the user's interests and familiarity with the products. Also the system sorts the available items for a product class based on

Table 2. The evaluation features and their corresponding weights.

Features			AHA	Interbook	SETA	SeAN
Run-time	Adaptation Dimensions(1)	User/Group(out of .75)	.5	.5	.5	.5
		Environment(.1)	0	0	0	0
		Technology(.1)	0	0	0	0
		Unexpected Events(.05)	0	0	0	0
	Adaptation Features(3)	Navigation(1)	.4	.5	.2	.2
		Content(1)	.5	0	.8	.8
		Presentation(1)	0	0	0	0
	Authoring(1)		.6	.8	.8	0
	Usability(1)		High	High	High	High
	Security(1)		Medium	Low	-	-
	Privacy(1)		Low	High	-	-
	Performance(1)		High	Medium	Medium	Medium
	Scalability(1)		Medium	Medium	Medium	Medium
	Generality(1)		High	Low	Low	Low
	Cost(1)		Low	Low	Medium	Medium
Technology	Mining Techniques(.4)	Usage Mining(.2)	0	0	.2	.2
		Content Mining(.1)	0	0	0	0
		Structure Mining(.1)	0	0	0	0
	Agent-based Features(.2)		0	0	.2	.2
	Page Synthesis(.4)		0	0	.1	.1
Software Engineering	Portability(1)		High	Medium	High	High
	Extendability(1)		High	Medium	Medium	High
	Flexibility(1)		High	Medium	Medium	Low
	Maintainability(1)		Medium	Low	High	Low
	Design(3)	User Model(1)	1	1	1	1
		Domain Model(1)	.5	1	1	1
		Adaptation Model(1)	.5	0	0	1
	Implementation(1)	Language(.5)	.5	.2	.5	.5
		Platform(.5)	.5	.5	.5	.5
	Support(3)	Documentation(1)	1	.5	.3	.2
		Prototype(1)	1	.5	.5	.5
		Continuing(1)	1	0	-	0
	Open Source(1)		1	1	0	0
Overall Normalized Result			.55	.37	.50	.47

the user's preferences. During a session, the system monitors the user's selections to figure out her needs for product functionalities and recommends potentially interesting product classes.

SETA system is developed using JDK 1.2 and uses the Apache Web Server.

4.4 SeAN

SeAN is a an adaptive system for personalized access to news. This system has a three-tier multi-agent architecture that is inherited from SETA project. SeAN has three goals: first, to select news topics relevant to the user. Second, to present an appropriate level of detail of the news based on the user model and third, to provide advertisement most relevant to the page and the user. SeAN uses a structured hierarchy to represent news (domain model). In fact, each news is considered as a composite entity having several attributes that define its components. For example, title, abstract, full text, author, pictures, video. Based on this representation, different levels of detail can be used for news according to the user model. This system relies on a modular and compositional approach to user modelling. SeAN has been implemented using Java.

5 Evaluation

Table 2 shows the evaluation results for the systems reviewed in the previous section. The value inside the parentheses in front of each feature indicates the maximum value for that feature. The values in each level of the feature hierarchy have been normalized and used in the higher level category. Due to the lack of evidence, some features are

not assigned any values. These features have not been used in the normalization process. For the features for which we have used linguistic terms in Table 2, the corresponding numeric values[1] are used in the computations as well as in the normalization process. After normalization, each high-level category (i.e, Run-time, Technology, and Software Engineering), has a value between 0 and 1. Note that in our evaluation the *Run-time* and the *Software Engineering* features are considered to be more important than the *Technology* features. We gave the latter a weight of 0.2 compared to a weight of 0.4 for the other two categories. Taking these weights into account, we normalized the values and obtained a final value between 0 and 1 for a system. This value gives an estimate of the overall support of an AH system for the set of proposed features.

The results of our (subjective) evaluation of the above 4 adaptive hypermedia projects are summarized in Table 3. AHA! has received the highest value. This is mainly because of AHA!'s generality and software engineering considerations. SETA and SeAN are ranked very close because they use the same software architecture. InterBook is a useful system for adaptive online books, however, it doesn't have AHA!'s generality or software engineering considerations.

Table 3. The results of a (subjective) evaluation of 4 adaptive hypermedia projects.

Project Name	AHA!	SETA	SeAN	InterBook
Eval. results	.55	.50	.47	.37

6 Conclusions

Adaptiveness is becoming one of the most important features of hypermedia/Web-based systems. Web-based support systems, as part of the Web-based systems family, benefit from the advantages of AHS technology.

The features hierarchy presented in this paper gives a general evaluation framework to compare adaptive web systems regardless of their domains. The proposed hierarchy along with a weighting scheme made it possible for us to evaluate a number of adaptive hypermedia systems. The results of our comparative analysis of 4 major adaptive hypermedia systems (AHA!, InterBook, STEA and SeAN), show that AHA! is the winner. This is mainly due to the fact that AHA! is a fairly general AH system. Our evaluation results put SETA, SeAN and InterBook in the second, third and fourth positions, respectively.

Through careful study of the proposed features for an AHS, one may notice the weak points of the system under study and look for ways to compensate them. We are currently developing an adaptive hypermedia/Web-based framework, considering all these features.

[1] High: .9, Medium: .5, Low: .2

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