

From Web-based Educational Systems to Education on the Web: On the road to the Adaptive Web

Nicola Henze

University of Hannover
ISI- Knowledge-Based Systems
Appelstr. 4, D-30167 Hannover
henze@kbs.uni-hannover.de
<http://www.kbs.uni-hannover.de/~henze>

Abstract. Adaptive educational hypermedia systems have shown to improve web-based learning by providing support for learner orientation and individualized learning. In this paper, we discuss the relation of adaptive educational hypermedia systems and the Semantic Web: What can we learn from adaptive educational hypermedia systems for bringing adaptation to the Semantic Web?

keywords: semantic web, adaptive web, adaptive hypermedia, personalization.

1 Introduction

"The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation [16]." The vision of a "Semantic Web" includes the "Adaptive Web" [5] which knows like a personal agent the specific requirements of a user, takes goals, preferences or the actual context into account in order to optimize the access to electronic information. Fundamental research for the Adaptive Web has been carried out in the area of "Adaptive Hypermedia". Adaptive Hypermedia Systems bring together ideas from hypermedia systems and intelligent tutoring systems, and enable personalized access to information.

An intensively investigated application area for adaptive hypermedia are educational systems. Research on so called "adaptive educational hypermedia (AEH) systems" has carried out in theoretical foundations (cf. [3, 2]), practical systems (out of the many systems developed in adaptive educational hypermedia we cite only very few examples: [4, 7, 10, 18]), as well as their analysis and evaluation (cf. [15, 20]). The employment of adaptation in educational hypermedia has shown to improve learner guidance by showing e.g. the next reasonable learning step to take or by the individualized creation of learning sequences. It has shown to improve orientation by annotating hypertext links with hints on the students learning progress, and it supports learners by finding their own optimal learning strategy.

In this paper, we will analyze techniques and methods of existing adaptive educational hypermedia systems. The goal of this analysis is to determine how we can proceed to develop adaptation and personalization strategies for the Web. The analysis focuses on the employment of meta information about the documents in different adaptive educational hypermedia systems.

2 Semantic Web and Adaptive Web

In the Semantic Web we give information a *semantic* in a machine readable form. Currently, RDF (Resource Description Framework, [17]) has developed to be a de facto standard for describing the semantics of *resources*. We do not want to go into detail but will sketch the basic idea: Everything that has an URI (Uniform Resource Identifier) can be considered to be a *resource*. The information is binded to these URIs - and contained in formats like HTML and others. To access this information we use Web portals or search machines that match our query against the information indexed by the search machine. The processing of information, e.g. to collect several weather forecasts for Oxford's weather during the next three days, is not solvable within this current setting. We can be sure that there are several URIs, containing information about weather forecasts, containing especially information about Oxford's weather. But we can not extract this data from the information itself - without visiting these Web-sites and collecting it for further processing. Current web crawlers can not understand the *meaning* of the information thus they can not further evaluate the results or process them. And this is exactly the critical point for considering a *Semantic* Web: to add a meaning to the information that can be understood by machines.

A challenging question in this context is: How can we add personalization to the Semantic Web, how can we build the "Adaptive Web"? E.g. Which semantic is needed for doing personalization tasks on the Web, how to design these personalization tasks, how to employ personalization strategies?

In this paper, we will investigate the first part of the question for the area of adaptive educational hypermedia systems: Which semantic is currently used in adaptive educational hypermedia systems for doing the various adaptation tasks?

3 Review of a few Adaptive Educational Hypermedia Systems

Recently, many approaches like SCORM [14], LOM [13] or IMS [12] begin to standardize information for learning. They introduce metadata descriptions for so called learning objects which are entities containing some learning material. This metadata is e.g. an identifier, the creator of this material, the language, keywords describing its content, the interactivity level of this material, etc. In LOM there are currently about 80 metadata attributes defined. With these standardized descriptions of learning materials it is possible to build large learning

repositories in which teachers and students will be able to store or retrieve valuable materials for learning, for preparing courses etc. Current approaches are e.g. ARIADNE [1] or EDUTELLA [8].

These standardization approaches provide the functionality for coding and exchanging the meta information of documents, especially those metadata attributes that are required for adaptive educational hypermedia. However, the finding of appropriate values for these metadata attributes in open document spaces is an interesting but unsolved problem.

To take up the vision of the Semantic Web we need to identify a *meaning* of resources that can be processed by algorithms for adaptation. A starting point for this investigation is to take a closer look on the employment of documents in existing adaptive educational hypermedia systems: Which data about documents is used in current adaptive educational hypermedia systems?

In the following, we will exemplarily investigate the use of documents in a few adaptive hypermedia systems: The ELM-ART II system, the NetCoach system, the Interbook system and the KBS hyperbook system. The analysis is organized into the following steps: First - after a short system description - the document space in these systems is described. Second we state which meta data on these documents is used for doing the various adaptation tasks in the system in question.

3.1 Documents in ELM-ART

ELM-ART II [19] is a web-based adaptive course for learning the LISP programming language. The ELM-Art II System provides individualized feedback to students, based on analyzing the learning path of a student. It refers the student to adaptive selected examples and support the problem solving process of students in various manner. The adaptation component of ELM-Art uses the information about prerequisite and outcome knowledge which is added to the hypermedia documents.

Document space in ELM-ART The document space in ELM-ART II is organized hierarchically into chapters, sections, subsections and terminal pages. Terminal pages can introduce new concepts or offer problems to be solved. In addition, a special group of documents, the so called "testitems", is used.

Metadata of documents in ELM-ART

preq(D): a set of documents that are prerequisites for document \mathcal{D}

out(D): a set of documents that can be learned after document \mathcal{D} has been learned

related(D): a set of documents related to document \mathcal{D}

succ(D): the document that is the successor of document \mathcal{D} (given by the hierarchical structure of the document space)

part-of(D): the documents that are part of document \mathcal{D} (given by the hierarchical structure of the document space)

terminal_flag(D): A boolean value indicating whether a document \mathcal{D} has no further sub-documents

test_assignment(D): relates a document \mathcal{D} and a set of tests (testitems or testslots)

3.2 Documents in NetCoach

NetCoach [18] is the successor of ELM-ART II and provides a framework for building adaptive hypermedia systems. NetCoach uses a knowledge base which consists of concepts that are representations of pages that will be presented to the learner.

Document space in NetCoach Documents in NetCoach are structured hierarchically in a section – subsection – subsection manner. This hierarchical structure delivers information for adaptation, too, by giving for each concept – or document – a predecessor and successor in the document space. In addition, there are two special types of documents: the so called testgroups and testitems.

Metadata of documents in NetCoach

preq(D): a set of documents that are prerequisites for learning document \mathcal{D}

infer(D): a set of documents that can be inferred to be learned if document \mathcal{D} has been learned.

succ(D): the document that is the successor of document \mathcal{D} (given by the hierarchical structure of the document space)

part-of(D): documents that are part of document \mathcal{D} (given by the hierarchical structure of the document space)

terminal_flag(D): A boolean value indicating whether a document has no further sub-documents

criterion(D, value): numerical value indicating which amount of training is required for learning this document

test_assignment(D): a set of tests (testitems or testgroups) assigned to document \mathcal{D}

3.3 Documents in Interbook

Interbook [6] allows the creation of adaptive electronic textbooks based on hierarchically structured MS-Word files. Courses compiled with Interbook provide individual guidance to students by annotating the navigational structure of the hypertext due to the user's learning progress, by generating individually learning paths and by personalized embedding of exercises.

Document space in Interbook The documents in Interbook are units from indexed electronic textbooks. Each electronic textbook is assumed to be hierarchically structured into chapters, sections, and subsections. At the terminal level are atomic presentations, examples, problems, or tests. Thus, units in Interbook are chapters, section, subsections or terminal pages.

Metadata of documents in Interbook

- preq(D):** set of documents that are prerequisites for learning document \mathcal{D}
- out(D):** set of documents that can be learned after document \mathcal{D} has been learned
- succ(D):** the document that is the successor of document \mathcal{D} (given by the hierarchical structure of the document space)
- part-of(D):** documents that are part of document \mathcal{D} (given by the hierarchical structure of the document space)
- testitems(D):** The set of testitems assigned to document \mathcal{D}

3.4 Documents in KBS Hyperbook

The KBS hyperbook [9] system a web-based educational hypermedia systems for learning the Java programming language. It guides the students through the information space individually by showing next reasonable learning steps, by selecting projects, generating and proposing reading sequences, annotating the educational state of information, and by selecting useful information, based on a user's actual goal and knowledge. The adaptation component of this system is based on a knowledge model which described the learning dependencies in the Java course.

Document space in KBS Hyperbook Documents in KBS Hyperbook are grouped due to their role for the learning process. These roles can be defined by the authors, typical roles are "introduction", "theoretical description", "example", "exercise", etc. There is no further structure of the document space besides this grouping.

Metadata of documents in KBS Hyperbook

- keywords(D):** a set of keywords describing the content of document \mathcal{D}
- depends(C):** a set of keywords that are required to be learnt before the keyword \mathcal{C} itself can be learnt
- role(D):** the role of a document, being either a course, goal, lecture, example, etc.

4 Discussion

The chosen adaptive educational hypermedia systems in the above analysis show exemplary which kind of meta information about the documents is required for doing the various adaptation tasks. The normal case is to annotate a document with sets of documents that have a specific role, e.g. prerequisites or outcomes. Another approach is to introduce a set of concepts for the application domain of the system. The metadata annotation than includes set of concepts for describing

prerequisites of a document or the content of a document, etc. Further variations of these metadata annotation procedures are used in adaptive educational hypermedia.

We claim that these approaches have one thing in common: The meta information on documents is coded by using the documents itself or by using concepts of the application domain. That means that the values of the metadata attributes refer to the document space or concept space.

The implication of this is, that the current state of the space of documents (or space of concepts) influences the metadata annotation. Whenever new documents are added, or documents are modified or deleted, the metadata-annotation may become invalid because new prerequisites or outcomes can be found in the document space, other documents are prerequisites or prerequisites have been deleted. Thus, a metadata annotation is only valid with respect to some state of the document space, or, of course, for a fixed - so called closed - document space [11]. So far, adaptive educational hypermedia systems have work on a closed set of documents that are known at the design time of the system. This implies that the state of the document space remains unchanged and therefor the dependency of the metadata information of the state of the document space does not cause any problem. In the case of the Web this changes: Here the document space - the Web - is highly dynamic: New information occurs, information vanishes, is modified, etc. Thus we will not be able to provide such a *complete* metadata annotation of the document space as we have previously used in adaptive educational hypermedia.

We can conclude that a one-to-one mapping of existing techniques in adaptive educational hypermedia systems to the semantic web will not be possible. Even if we agree on a catalogue of metadata for adaptation in educational systems (please note that currently there is no such catalogue available which was the reason for us to start the analysis of chapter 3), we will still have to solve the problem how existing adaptation techniques can deal with more or less incomplete metadata.

5 Conclusion and Current Work

This paper discusses the relation between existing adaptive educational hypermedia systems and the Semantic Web. We review some adaptive educational hypermedia systems with respect to their use of metadata and discuss the results. Current work concentrates on logically characterizing adaptive functionality. The aim of this work is to encapsulate adaptive functionality and describe them as rules in a Semantic Web language.

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