Setting up a Framework for Comparing Adaptive Educational Hypermedia: First Steps and Application on Curriculum Sequencing

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Abstract. In this paper we present a framework aimed at comparing different approaches to adaptation in adaptive educational hypermedia. We will set up the basic concepts for such a description framework and discuss its applicability on some adaptive educational hypermedia systems. The proposed framework will allow us to study and compare different adaptation techniques.

1 Introduction

In this paper we present a framework for comparing adaptive educational hypermedia systems (AEHS) [8]. In the literature there already exist some frameworks for describing hypertext systems or adaptive hypertext systems like the Dexter Hypertext Reference Model [11] and Adaptive Hypermedia Application Model (AHAM) [4].

The Dexter Reference Model is an attempt to capture both formally and informally the important abstractions found in a wide range of hypertext systems. The goal of the model is to provide a principled basis for comparing systems as well as for developing interchange and interoperability standards. In particular, it concentrates on the so called "storage layer", which contains the nodes and the link structure; this layer corresponds to the domain model, meant as the author's view on the application domain. However, the Dexter model does not provide a way for modelling adaptation.

The AHAM model extends the Dexter model with the aim of capturing some important abstractions related to adaptation. In particular it introduces the concepts of "user model" and of "teaching model". The user model represents the user's characteristics, his/her preferences and behavior, and it is continuously updated. In an educational context, it keeps track of how much the user knows about the concepts that are in the domain model (e.g. well-learned, learned, read, not known). The "teaching model", on the other hand, is a set of rules which influence the way in which knowledge is presented depending on the user model contents. While the top-down approaches in Dexter and AHAM are general enough to describe many hypermedia systems, the development of system descriptions with these approaches sometimes yields vague results as relevant features of the hypermedia systems in question can not be expressed within the language defined by these models. In addition, the process flow inherently in these frameworks does not apply for all AH systems. Dexter and AHAM follow a top-down approach by describing the different components of hypertext and adaptive hypertext systems. However, inspired by the discussion on the *Workshop on Adaptive Systems for Web-Based Education* [9] about *concepts* in Adaptive Hypermedia (AH) we want to investigate how far a bottom-up, concept-driven description framework will help us to characterize adaptive hypermedia systems accordingly.

We experienced the need for such a system while discussing various methods for doing curriculum sequencing in AEHS: How to describe the different methods and concepts underlying the approaches? We decided to define a "common vocabulary" for concepts in AEHS in order to describe methods in a clear and comparable way.

2 The Framework

The first step for building a concept-driven description framework for adaptive educational hypermedia is to identify some relevant descriptors of the hypermedia system. In the following we will summarize the relevant concepts for adaptive hypermedia which we propose to use in the bottom-up, concept-driven approach. The next step is to describe the adaptation techniques and methods of AEHS on base of these concepts. We will show their use for the adaptation technique of *curriculum sequencing*. Curriculum sequencing is an important adaptive method in intelligent tutoring systems and adaptive hypermedia (see e.g. [6, 23, 21, 14]) method for determining learning or study paths (also called *trails*) through the hyperspace. There exists different methods on how to determine which path to select or to generate in order to support the learner in her/his current situation in an optimal way.

k We start by using the introduced framework for describing curriculum sequencing in four different AEHS: the KBS hyperbooks system [14], ELM-Art [22], WLog [1], and MetaLinks [16]. We have choosen these four systems because they really differ in their approach and we want to show the applicatility of this first framework for a wider variety of system. Other AEHS use e.g. similar techniques as the four example systems regarded here. However, we do not claim to be exhaustive. Further investigations on AEHS are necessary for defining the final framework.

2.1 Concepts used in Adaptive Hypermedia

To identify the main resource for adaptive hypermedia system we introduce the term *Information Entity* (IE).

Definition 1 (Information Entity (IE)). An Information Entity is some unit of information (see e.g. the OAIS-definition of information (OAIS: Open Archival Information System) [20]).

The granularity and the type of IEs may depend on the specific application domain and can widely vary. An atomic unit of information may, for instance, be a definition, a page, a book, a web site, the common characteristic being that it will in any case be considered as a single unstructured object. In any case, the corpus is to be made available to users who want to acquire part of the information contained in it for some purpose.

Hypermedia systems can be described as a set of nodes (containing multiple forms of media such as text, video, audio, graphics, etc.) which are connected by links (see e.g. [18]). Following the definition of IE, each node in a hypermedia system is an IE.

Adaptive hypermedia systems are defined as follows:

Definition 2 (Adaptive Hypermedia System). "By adaptive hypermedia systems we mean all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user."[5].

We will not characterize user models and user modeling techniques in this paper. Instead we will restrict ourselves on those characteristics which are mainly used in adaptive educational hypermedial. These characteristics include the *knowledge* of a user, her/his *goals*, her/his *preferences*, her/his *background* and *experience* with hypertext systems [5] or the *learning speed* [12]. The most prominent characteristic in AEH is naturally the knowledge of a user.

For identifying a user's knowledge we define the term *knowledge entity*. This term is - like the information entity - not new but once again helps clarifying the terms and concepts used.

Definition 3 (Knowledge Entity (KE)). A Knowledge Entity is some identifiable piece of knowledge.

Examples for knowledge entities are the domain model concepts used in [7], the knowledge units in [10], the KIs in [14] and many more. We are aware of the difficulty of the above definition of knowledge item: Which granularity shall such a KE have, how to identify KEs, which validity shall they have? (See e.g. the discussions on this topic in ontology finding and knowledge modeling). However, answers to this questions may be given by the various AEH in different ways thus we need to continue with this general definition for our purpose.

2.2 A catalogue for curriculum sequencing

With these two basic concept definitions we propose a catalogue of questions for describing the concept of *curriculum sequencing* in AEH.

- **Connection between KE and IE** Is there a one-to-one connection, can a KE occur on more than one IE (one-to-many connection) or may several KEs occur on one or more IE (many-to-many connection)?

- **Learning Dependencies** How and where does this system code information about prerequisite knowledge for a IE or outcome knowledge of IE, etc.?
- **Input for Curriculum Sequencing** Which input information is used in the curriculum sequencing method?
- **Sequencing Technique** How does the algorithm(s) work?

3 Curriculum Sequencing methods in four example AEHS: KBS Hyperbook, Elm-Art, WLog, and MetaLinks

KBS Hyperbook System The KBS hyperbook system[1] is an adaptive hypermedia system which 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 [13].

The adaptation component of this system is based on a knowledge model which described the learning dependencies in the Java course. The documents of the hypermedia system were annotated by a short metadata description which contained a set of keywords describing the content of each document [15].

Curriculum Sequencing in KBS Hyperbook system allows to compile a sequence of pages for helping a user to reach a certain learning goal. This sequence is compiled in advance and presented as a trail to the user.

Connection between KE and IE Each IE has an associated set of KEs describing its content.

Learning Dependencies Learning dependencies are stored in a separate model, the so called knowledge model. The knowledge model contains all KEs and codes the learning dependencies between the KEs.

Input for Curriculum Sequencing
- User's goal or learning goal. A goal is a set of KEs.
- User's knowledge.
- The knowledge model.

Sequencing Technique For Curriculum Sequencing, KBS Hyperbook uses a depth first traversal algorithm in the knolwedge model.

ELM-ART The ELM-Art Systems provide individualized feedback to students, based on analysing the learning path of a student. They refer the student to adaptive selected examples and support the problem solving process of students in various manner [22]. The adaptation component of ELM-Art uses the information about prerequisite and outcome knowledge which is added to the hypermedia documents. Curriculum Sequencing in ELM-ART allows to compile

[1] http://www.kbs.uni-hannover.de/hyperbook

a sequence of pages for helping a user to reach a certain learning goal. The sequence is compiled step by step.

Connection between KE and IE Each IE is a KE and vice versa.

Learning Dependencies Learning Dependencies are coded on level of IEs: Each IE has a set of prerequisites IEs which need to be learned before this page can be accessed. In addition there is a list of IEs which can be accessed after the IE in question has been learned.

Input for Curriculum Sequencing
- User's knowledge
- Sequence of pages read so far.

Sequencing Technique The next page a user can access is calculated by comparing her/his actual reading path to the required knowledge (the list of prerequisite IEs) that need to be known before accessing this page.

WLog In the WLog system[2] [1, 2] adaptation is obtained by exploiting a rational agent which adopts the user's goals, defines the navigation possibilities that are available to the user, and determines which page to display. The agent reasoning process is based on a modal logic for reasoning about action and change [3] and it uses knowledge about the user represented in terms of different mental attitudes (beliefs and goals), in the style of well-known BDI agent paradigm [19].

In WLog, curriculum sequencing allows to help users to build study plans for learning some desired concept (learning goal), where the study plan is a sequence of courses that the student will attend. It relies on the capability of a logic agent to formally reason about the dynamics of course outcomes and preconditions and allows to generate a conditional plan, rather than a sequence of pages (linear plan), for achieving the user's goal. Each branch point requires an interaction for getting, run-time, the user's preferences among equivalent alternative courses. The system also allows a user to check whether a given sequence of courses will allow him/her to achieve a given learning goal (verification of correctness).

Connection between KE and IE Each IE is formalized as an action and it is described by: a set of KEs that are the IE prerequisites, and a set of KEs that are the conditioned and the unconditioned outcomes of the IEs.

Learning Dependencies Learning Dependencies are inferred both from the KEs, that are in the prerequisites and the effects of the IE descriptions, and from a hierarchical structure that relates the KEs.

Input for Curriculum Sequencing When constructing a conditional plan the required inputs are: the learning goal and the user's initial knowledge (in terms of KEs). Moreover, when presenting a conditional plan, the user's preference is requested whenever a branch in encountered.
When verifying the correctness of a sequence the required inputs are: the learning goal, the user's initial knowledge and the sequence of IE to validate.

Sequencing Technique Both the plan construction and verification are performed by means of reasoning about actions techniques. The inferential engine is a goal-directed proof procedure.

[2] http://www.di.unito.it/~alice

MetaLinks MetaLinks [16] is an authoring tool and web server for adaptive hyperbooks. MetaLinks aims to support inquiry, exploratory, or curiosity driven learning. Further, it aims to support the construction and conceptualization of content through different epistemic forms and to overcome disorientation problems in hypermedia, cognitive overload and poor narrative and conceptual flow.

The equivalent to Curriculum Sequencing in MetaLinks is "narrative flow": The "narrative flow (a linear navigational path for which the reading or organization of the content is most natural or perspicuous) is breadth-first rather than depth-first, and organized for 'horizontal reading' " ([16], page 8).

Connection between KE and IE No explicit KEs used, only the IEs themselves.

Learning Dependencies Instead of learning dependencies, MetaLinks uses decompositional dependencies: The IEs are structured hierarchically in a way that parent concepts are summaries, overviews or introductions to all of their children, while children contain more detailed descriptions.

Input for Curriculum Sequencing
- The page the user is currently visiting

Sequencing Technique The next page a user can access is calculated by finding the sibling of the page s/he is currently visiting. Sibling is a page which is on the same level in the IE hierarchy. Thus the next page has always the same level of granularity as the current page.

4 Conclusion and Future Work

We have proposed a bottom-up framework for describing adaptive educational hypermedia systems. The advantages of a bottom-up, concept-driven framework have been discussed and compared to other approaches. After having identified a vocabulary of concepts for describing adaptive educational hypermedia we have used the framework for describing the curriculum sequencing technique in four adaptive hypermedia systems which use completely different methods for information handling, knowledge modelling and sequencing.

However this is not exhaustive and research on our framework has to be continued. Our next steps are to compare other adaptational functionalities besides curriculum sequencing in AEHS. In addition, systems should be compared in relation to ease of maintenance: how easy is to add a new IE? If it adds new KE, will they be considered by the system? How easy is to update the system knowledge about the domain? If, instead, the IE supplies already known KEs, how to integrate them in the system? More generally, if different sequences allow to achieve a same learning goal, how are they managed?

For answering to these questions a deep study of the knowledge representation techniques and their inferring mechanisms is necessary used in the various approaches. We want to determine the impact of the choice of a knowledge representation technique to architectures of AEHS. We plan to start this investigation from the KBS hyperbook system, which uses a bayesian [17] approach and the

WLog system, which is based on a logic framework for reasoning about actions [3].

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