Recommender System for Adaptive Hypermedia Applications

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Abstract. Most adaptive web-based hypermedia systems adapt presentation of the content and/or navigation using predefined set of rules. Considering different behavior and preferences of each user it may be hard to generalize and construct all appropriate rules in advance. In this paper we explore this problem in context of educational adaptive hypermedia systems. We focus on recommending lessons (learning objects or concepts) that students should study next while using adaptive hypermedia system. We present architecture of a web-based recommender system, which uses results of knowledge discovery to improve adaptation.

1 Introduction

Adaptive hypermedia systems have become popular in last few years in many application areas such as educational hypermedia, on-line information systems or information retrieval hypermedia [1]. Adaptive hypermedia application in the field of educational systems is natural, as each student generally has different characteristics related to learning, so an adaptation to the student’s characteristics can help the student to master topics more effectively.

However, it is quite difficult for an author of the course to develop appropriate adaptation model. This requires respectable knowledge of students’ behavior to create such adaptation rules, which will result into an effective adaptation of presented knowledge together with appropriate navigation in the course information space. We propose to use knowledge extracted from educational adaptive hypermedia system by means of knowledge discovery for the adaptation model improvement.

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In this paper we present a recommender system, which employs knowledge discovery for purpose of finding patterns of a characteristic behavior of students from data collected by the adaptive hypermedia educational system. Discovered patterns are used in the process of recommendation of relevant concepts to students, mainly for curriculum sequencing.

2 Navigation recommendation approaches

Following discovered patterns various approaches have been proposed for navigation recommendation (global or local, direct or indirect guidance). In [5] authors have proposed to conduct the recommendation directly with discovered patterns. Active user session is used to search the patterns and find the matching ones. Suffixes of these patterns become candidates for the recommendation. Only the most recent part of the active user session is used for matching.

Another approach [4] is aimed to group stored user sessions or discovered frequent item sets into session clusters using techniques of clustering. Representative usage profile is computed for each cluster. Active user session is then matched against computed usage profiles.

Mentioned approaches deal with one kind of patterns and provide support for this specific kind. We propose using several kinds of patterns (e.g., sequential and traversal patterns) distinguished during the process of recommendation and describe software framework for a recommender system, which extends architecture of adaptive web-based hypermedia applications. Properties of used patterns and methods for discovering them are discussed in greater detail in [3].

3 Recommender system for adaptive hypermedia

3.1 Recommender system architecture

Proposed recommender system as a back-end for an adaptive hypermedia system is based on modular software architecture. The software architecture (see Figure 1) follows the flow of two main processes carried out in the system: (1) knowledge discovery and (2) concept recommendation.

The system is designed to be independent of underlying adaptive hypermedia application as much as possible. Therefore the architecture incorporates a wrapper, which acts as a facade between an adaptive hypermedia system and the recommender system itself. This approach allows using various adaptive hypermedia systems as sources of data for knowledge discovery without modification of the recommender system itself.

Wrapper. All the adaptive hypermedia system dependent tasks are performed in the wrapper module. This includes usage data retrieval as well as tasks related to the processing and deploying generated adaptation rules, and the user model update. Using the recommender system with several adaptive hypermedia systems requires a wrapper
module for every adaptive hypermedia system. This module forms also the interface to an authoring tool, where adaptation knowledge is defined by the author.

**Data preprocessing.** The data preprocessing module takes the stream of user actions as its input. These actions are preprocessed and searched for potential errors and inconsistencies. The module also takes care of identification of user’s sessions. Sessions are filtered according to their length (short sessions are dropped) and/or overall knowledge level of respective user. Finally, the module stores sessions into database of the recommender system.

**Data mining.** In the data mining module various algorithms for pattern mining (see [3]) are applied on data stored in database. Traversal patterns, sequential patterns and association rules are discovered using different views on data (e.g., different levels of concepts in domain hierarchy, concept types). Discovered patterns are stored into the knowledge base.

**Knowledge presentation.** The main purpose of the knowledge presentation module is to present selected discovered knowledge (e.g., association rules) to the author of a course. The author can then make modifications to the domain structure and the contents of the information fragments.

**Rule generator.** The task of the rule generator module is to construct static adaptation rules (i.e., rules where current learning session of a student is not considered) based on patterns in the knowledge base. These rules are deployed to the adaptive hypermedia system through the wrapper.

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**Fig. 1.** Architecture of recommender system.
Recommender module. The recommender module creates a sequence of recommended concepts based on the current session of a user and the knowledge stored in the knowledge base. The concepts in the current user session are matched against the ones in patterns of the knowledge base. When appropriate (similar) patterns are found, the concept recommendation is carried out. The result is a sequence of recommended concepts and the evaluation of their suitability and relevance for the user. This sequence is generated on demand of the adaptive hypermedia system (each time the user moves to another concept or fragment, or after some time period or at the beginning of each session).

3.2 Use case scenario

Sequential diagram in Figure 2 describes typical usage scenario of proposed recommender system. While users work with the adaptive hypermedia system, it logs and
stores all their actions (e.g., logins, logouts, concept visits) (see part A in figure). When scheduled, the recommender system retrieves usage data, preprocesses it and stores it into database. Data mining algorithms are executed on stored usage data and usage patterns are discovered and stored in the knowledge base (see part B in figure).

With knowledge base filled up, the recommender system can recommend a sequence of relevant concepts for particular user, when asked to do so. An adaptive hypermedia system provides the recommender system with the user identification and his current session and the recommender system returns recommended sequence of concepts, which the user should visit next. The adaptive hypermedia system may annotate concepts in the sequence according to suitability evaluation provided by the recommender system (see part C in figure).

When author of the content decides to improve it, visualization of discovered knowledge can help to decide which modifications should be made. The author can also compare historical records and evaluate the effect of his previous changes to the adaptive hypermedia system content (see part D in figure).

4 Experiments

To verify our approach to knowledge discovery in adaptive web-based hypermedia we developed a prototype of the recommender system. We implemented three data mining algorithms for pattern discovery (traversal patterns, sequential patterns and association rules) suitable for educational hypermedia applications.

Results of the knowledge discovery are markedly dependent on source data. We chose the ALEA educational adaptive hypermedia system [2] for our experiments since we have had available usage logs gathered during 3 years of its usage in the Functional and logic programming course. At time of experiments the database contained 1 170 sessions.

Experimenting with the ALEA data, we found out that even though algorithms find some patterns in the data, these patterns have quite low support (around 15%). To outline this fact, we analyzed and visualized visits of individual concepts as well as the navigation between them. We discovered that all visits are almost equally distributed between all concepts. There were only slight trails of increased navigation between certain concepts. This issue may be caused by the restricted way the ALEA system was used. The primary goal of students was not to master whole domain but to prepare themselves for a programming test. The second reason may be the existence of a guidance that the ALEA system already offers. We suppose that direct guidance implemented in the ALEA system (by means of the “Next” button) influenced such students’ behavior and was proved in this way as appropriate.

5 Conclusions

The adaptation in most of current educational adaptive hypermedia systems is driven by a fixed set of rules. The construction of such rules is a complex task and the author may not be able to completely assess all intricacies found in different learning styles of
students. Techniques for data mining can provide knowledge needed either to recom-
mend students concepts according to their characteristics or to assist the author of the
course to improve the structure of the domain.

Main contribution of this paper is proposal of the recommender system, which is
based on an idea of adaptation model development using data mining techniques. It
connects the process of knowledge discovery with on-line recommendation of concepts
based on discovered knowledge. The architecture of system allows using different un-
derlying adaptive hypermedia systems, enabling us to share common knowledge (not
specific to certain adaptive hypermedia system and its content). The architecture also
incorporates the module for visualization of discovered knowledge helping the author
of the course to prepare modification to the content.

In our approach, association rules, sequential patterns and traversal patterns repre-
sent automatically generated knowledge about students’ behavior. Based on a student’s
current learning session and discovered patterns, the recommender system is able to
recommend a sequence of concepts, which the student should study next.

Future development of the recommender system will focus on enhancing the set
of data mining algorithms, e.g., to use clustering techniques in order to discover user
clusters according their learning style. We plan to evaluate quality of recommendations
carried out by our recommender system using data produced by other educational hy-
permedia systems. The evaluation will be based on a feedback from students as well as
on results of the recommendation performed on a testing set of data.

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