
Adaptive Hypermedia Authoring: From Adaptive Navigation to Adaptive Learning Support

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Abstract. Educational hypermedia systems seek to provide adaptive navigation, whereas intelligent web-based learning systems seek to provide adaptive courseware generation. The design of powerful authoring frameworks by merging the authoring approaches used in the above mentioned systems is recognized as one of the most interesting questions in adaptive web-based educational systems. In this paper we address adaptive hypermedia authoring proposing an authoring framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems based on the use of ontologies and learning object metadata.

1 Introduction

Educational hypermedia systems seek to provide adaptive navigation, whereas intelligent web-based learning systems seek to provide adaptive courseware generation. Adaptive navigation seeks to present the content associated with an on-line course in an optimized order, where the optimization criteria takes into consideration the learner’s background and performance on related knowledge domain [1], whereas adaptive courseware generation is defined as the process that selects learning objects from a digital repository and sequence it in a way which is appropriate for the targeted learning community or individuals [2]. The need for gradual merge between the
authoring approach of adaptive educational systems and the authoring approach of adaptive hypermedia systems has been already identified in literature [3]. In this paper we address adaptive hypermedia authoring proposing an authoring framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems. The paper is structured as follows. Initially, we survey the adaptive techniques used in educational hypermedia systems, classifying them in two main classes namely adaptive presentation and adaptive navigation techniques. The second part discusses the main steps in the adaptive educational hypermedia design process and presents the abstraction layers of adaptive hypermedia authoring process proposing an authoring framework that enables the definition of learning objectives and automatic authoring of adaptive activities. This framework is based on the use of pedagogical templates which include the rules for adaptive navigation and can be processed by an adaptive content selection mechanism in order to serve adaptive web-based courses based on a diverse set of pedagogical strategies. The selection of learning path takes into consideration learner’s cognitive characteristics and preferences.

2 Adaptivity in Educational Hypermedia Systems

In the literature there are several adaptive techniques employed in educational hypermedia systems that can be classified in two main classes, namely:

- Adaptive Presentation. The goal of the adaptive presentation techniques is to adapt the web-based content to the user’s goals, knowledge and other information stored in the user model [3].
- Adaptive Navigation. Adaptive navigation seeks to present the learning objects associated with an on-line course in an optimized order, where the optimization criteria takes into consideration the learner’s background and performance on related learning objects [4].

Adaptive Content Selection is the first step to adaptive navigation and adaptive presentation and is based on a set of teaching rules according to the cognitive style or learning preferences of the learners [5]. Adaptive Content Selection, Adaptive Navigation and Presentation are recognized as among the most interesting research questions in intelligent web-based education [6].

3 Adaptive Educational Hypermedia Authoring

The information structure of an adaptive hypermedia system can be considered as two interconnected networks or “spaces” [3]:

- a network of concepts (knowledge space) and
- a network of educational material (hyperspace or media space).

Accordingly, the design of an adaptive hypermedia system involves three key steps:

- structuring the knowledge
- structuring the media space
- connecting the knowledge space and the media space.

3.1 Authoring Abstraction Layers

The process of Adaptive Hypermedia Authoring can be represented by the use of five abstraction layers as shown in figure 1. In the literature several authoring frameworks have been proposed e.g. the LAOS [7], but those frameworks are focusing more on the concept and the adaptation logic layers. In our approach we propose an additional layer called Pedagogical Strategy Layer that focuses more on the pedagogical characteristics rather than the concepts covered by the educational resources. At this layer a pedagogical template based on the IMS Learning Design specification is introduced that is responsible for filtering the learning paths according to the selected pedagogical strategy. The proposed authoring abstraction layers are the following:

- **Learning Objectives Layer.** In this layer the author (or the learner if the educational hypermedia system includes an automatic courseware generator) can define a “learning goal”. The learning goal is a node in a concept hierarchy graph that corresponds to the desirable by the learner knowledge.

- **Conceptual Layer.** In this layer related to the learning goal concepts are selected based on the structure of the knowledge space. The use of educational ontologies can significantly assist the structuring of the knowledge space.

- **Content Layer.** In this layer the learning resources that are related to the previously selected concepts are selected based on the connection of the knowledge space with the media space. The result of the selection is a directed acyclic graph (DAG) of learning objects inheriting relations from both spaces. This graph con-

![Figure 1. Abstraction Layers of Adaptive Hypermedia Authoring](image-url)
tains all possible learning paths in order for a learner to achieve the specified learning goal.

- **Pedagogical Strategy Layer.** This layer filters the media graph and produces a sub-graph which:
  1. is also a directed acyclic graph (DAG)
  2. includes all possible learning paths in order for a learner to achieve the specified learning goal, according to a specific pedagogical strategy.

The “pedagogical filtering” is based on the use of reusable templates allowing the definition of generic learning activities. These templates include the rules for adaptive navigation and can be processed by an adaptive content selection mechanism (previous abstraction layer) in order to serve adaptive web-based courses based on a diverse set of pedagogical strategies.

Figure 2 presents examples of such templates following the “diagnose-and-remedy” pedagogical strategy and an alternative “behavioral” approach.

**Figure 2.** Example of Behavioral Template (a) and Diagnose-and-Remedy Template (b)

- **Learner Adaptation Layer.** This layer includes the process of adaptive learning path selection in order to produce a personalized learning path. The selection process takes into consideration educational characteristics of learning objects, learner cognitive characteristics as well as learner preference-related information stored in the learner profile. In our case, we use learning object characteristics derived from the IEEE Learning Object Metadata (LOM) standard [8] and learner characteristics derived from the IMS Learner Information Package (LIP) specification [9].
3.2 Discovering Optimum Learning Path

In order to extract from the resulting directed acyclic graph of learning resources the “optimum” learning path, we need to weight each connection of the DAG. The weighting process consists of two phases:

- **Selection of Criteria.** In Table 1 and 2 we have identified the LOM and LIP characteristics respectively, that can be used as criteria for the selection of the learning path.

**Table 1. Learning Object characteristics for Learning Path Selection**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>IEEE LOM</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>General/Structure</td>
<td>Underlying organizational structure of a Learning Object</td>
</tr>
<tr>
<td></td>
<td>General/Aggregation Level</td>
<td>The functional granularity (level of aggregation) of a Learning Object.</td>
</tr>
<tr>
<td>Educational/Interactivity Type</td>
<td>Predominant mode of learning supported by a Learning Object.</td>
<td></td>
</tr>
<tr>
<td>Educational/Interactivity Level</td>
<td>The degree to which a learner can influence the aspect or behavior of a Learning Object.</td>
<td></td>
</tr>
<tr>
<td>Educational Semantic Density</td>
<td>The degree of conciseness of a Learning Object, estimated in terms of its size, span or duration.</td>
<td></td>
</tr>
<tr>
<td>LOM/Educational/Typical Age Range</td>
<td>Age of the typical intended user. This element refers to developmental age and not chronological age.</td>
<td></td>
</tr>
<tr>
<td>LOM/Educational/Difficulty</td>
<td>How hard it is to work with or through a Learning Object for the typical intended target audience.</td>
<td></td>
</tr>
<tr>
<td>LOM/Educational/Intended End User Role</td>
<td>Principal user(s) for which a Learning Object was designed, most dominant first.</td>
<td></td>
</tr>
<tr>
<td>LOM/Educational/Context</td>
<td>The principal environment within which the learning and use of a LO is intended to take place.</td>
<td></td>
</tr>
<tr>
<td>LOM/Educational/Typical Learning Time</td>
<td>Typical time it takes to work with or through a LO for the typical intended target audience.</td>
<td></td>
</tr>
<tr>
<td>LOM/Educational/Learning Resource Type</td>
<td>Specific kind of Learning Object. The most dominant kind shall be first.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Learner characteristics for Learning Path Selection**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>IMS LIP</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>Accessibility/Preference/typename</td>
<td>The type of cognitive preference</td>
</tr>
<tr>
<td></td>
<td>Accessibility/Preference/prefcode</td>
<td>The coding assigned to the preference</td>
</tr>
<tr>
<td></td>
<td>Accessibility/Eligibility/typename</td>
<td>The type of eligibility being defined</td>
</tr>
<tr>
<td></td>
<td>Accessibility/Disability/typename</td>
<td>The type of disability being defined</td>
</tr>
<tr>
<td>Qualifications</td>
<td>QCL/Level</td>
<td>The level/grade of the QCL</td>
</tr>
<tr>
<td>Certifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Activity/Evaluation/noofattempts</td>
<td>The number of attempts made on the evaluation.</td>
</tr>
<tr>
<td></td>
<td>Activity/Evaluation/result/score</td>
<td>The scoring data itself.</td>
</tr>
</tbody>
</table>
\[ g = (g_1, g_2, \ldots, g_n) \]. The assessment model of the inverse suitability of each learning object for a specific learner, leads to the aggregation of all criteria into a unique criterion that we call a weighting function and is defined as an additive function of the form: \[ W(g) = \sum_{i=1}^{n} w_i \times g_i \in [0,1] \] with the following additional notation:

- \( g_i \): the value of the ith selection criterion in the range \([0,1]\) with 1 the less suitable value and 0 the most suitable value,
- \( w_i \): the inverse suitability weight factor of the ith selection criterion

Higher weighting value, means that a learning resource is less suitable, thus the link in the DAG that leads to that resource has less possibility to be included in the learning path.

After weighting the DAG with the use of the weighting function, we need to find the optimum (shortest) path by the use of a shortest path algorithm.

4 Conclusions

In this paper we address adaptive hypermedia authoring proposing an authoring framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems based on the use of ontologies and learning object metadata. The main advantage of this framework is the use of pedagogical templates which can be processed by an adaptive content selection mechanism in order to create adaptive web-based courses based on a diverse set of pedagogical strategies.

Acknowledgements

The work presented in this paper is partially supported by the European Community under the Information Society Technologies (IST) programme of the 6th FP for RTD - project ICLASS contract IST-507922 and the Greek Ministry of Development - General Secretariat for Research and Technology, project “eLand-An Integrated Virtual Environment for Supporting on-line Learning Communities” contract 2823/4-3-03.

References


