Description and Organization of Instructional Resources in an Adaptive Educational System Focused on Learning Styles *

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Summary. In this note we present an intelligent way of organizing learning material in an adaptive educational hypermedia system. We describe the use of instructional metadata which facilitates both the detection of student learning style and the application of various adaptation techniques. The advantage of our approach is that it is independent of a particular learning style model. Furthermore, the author has to supply only the annotated learning content (the static description) while the adaptation logic (the dynamic description) is provided by the system.

1 Introduction

Educational metadata is a special kind of metadata that provides information about learning objects. A learning object represents any reproducible and addressable digital resource that can be reused to support learning [20]. Currently there are several initiatives for standardizing educational metadata, addressing the issues of reusability, interoperability, discoverability, sharing and personalization [4].

IEEE LOM (Learning Object Metadata) [19] is the most prominent standard, being elaborated by the IEEE Learning Technology Standards Committee. IMS Global Learning Consortium also contributed to the drafting of the IEEE LOM and consequently the current version of IMS Learning Resource Metadata specification (IMS LRM v. 1.3 [19]) is based on the IEEE LOM data model. LOM contains nine categories of metadata: General, Lifecycle, Meta-metadata, Technical, Educational, Rights, Relation, Annotation and Classification. The attributes that are relevant from the point of view of instruction and pedagogy are the educational ones, specifically *Learning Resource Type*. Its possible values are: *Exercise, Simulation, Questionnaire, Diagram, Figure, Graph, Index, Slide, Table, Narrative Text, Exam, Experiment, Problem Statement, Self Assessment, Lecture*.

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Another widely known standard is *SCORM (Sharable Content Object Reference Model)* [2] which originates from e-learning requirements of the US Armed Forces, being produced by ADLNet (Advanced Distributed Learning Network) initiative. SCORM includes three types of learning content metadata: raw media metadata (that provide information about assets independently of learning content), content metadata (that provide information about learning contents, independently of a particular content aggregation) and course metadata (that provide information about the content aggregation).

Dublin Core metadata standard [12] is a simple yet effective general-purpose metadata scheme, for describing a wide range of networked resources. It was developed within the Dublin Core Metadata Initiative (DCMI). At present, there is a joint DCMI/IEEE LTSC Task Force activity, with the objective of developing a representation of the metadata elements of the IEEE LOM in the Dublin Core Abstract Model.

The main problem with these specifications is that they fail to include the instructional perspective [27]. In case of LOM, the property *Learning Resource Type* attempts to address this issue, but mixes instructional and technical information. Thus some of the values describe the instructional role of the resource (*Exercise, Simulation, Experiment*), while others are concerned with their format (*Diagram, Figure, Graph, Slide, Table*). Moreover, some important instructional types are missing, such as *Definition, Example* or *Theorem*. In order to overcome this issue, Ullrich introduced an instructional ontology, which is domain independent and pedagogically sound [27]. One of the most important advantages of this ontology is its pedagogical flexibility, being independent of a particular instructional theory. Moreover, as we will show in section 3, the ontology can also be enhanced to serve adaptivity purposes, from the point of view of various learning styles.

The rest of the paper is structured as follows: the next section gives a short overview of adaptive educational systems that focus on the learning style of the students and sketches our approach. Section 3 describes the suggested organization of the learning resources and introduces the educational metadata used. Sections 4 and 5 illustrate the use of these metadata for learner modelling and adaptation provisioning respectively. Finally, some related works are presented in section 6 and conclusions are drawn in section 7.

2 Learning Style-based Adaptive Educational Systems

One of the most important goals of today's research in e-learning refers to the provision of an adaptive educational experience, that is individualized to the particular needs of the learner, from the point of view of knowledge level, goals or motivation. The purpose of this adaptation is to maximize the subjective learner satisfaction, the learning speed (efficiency) and the assessment results (effectiveness) [3].

Learning style-based adaptive educational systems (LSAES) are a special case of adaptive educational systems (AES), which focus on students' learning preferences as the adaptation criterion. According to [21], learning styles represent a combination of cognitive, affective and other psychological characteristics that serve as relatively stable indicators of the way a learner perceives, interacts with and responds to the learning environment. At present there is a large number of learning style models proposed in the literature (over 70 according to [10]), which differ in the learning theories they are based on, the number and the description of the dimensions they include. There are also a few educational systems that deal with them [25]. Some examples include: INSPIRE [23] (based on Honey and Mumford learning style model [18]), EDUCE [22] (based on Gardner's theory of multiple intelligences [15]), CS383 [8], Heritage Alive Learning System [9] and ILASH [5] (all based on Felder-Silverman learning style model [14]).

The main problem of the above systems is that they only take into account a single learning style model. Moreover, most of them use an explicit learner modelling method, asking the student to fill in a dedicated psychological questionnaire. The resulted membership to a particular learning style is stored once and for all in the student model kept by the system and is subsequently used for adaptation. A few systems also adopt an implicit learner modelling method, trying to identify the student learning preferences dynamically, by monitoring and analyzing student behavior in the system. The approach that we propose in [24] is included in the latter category; furthermore it is not tied to a particular learning style model, but it integrates the most relevant characteristics from several models proposed in the literature, such as:

- perception modality: visual, auditory, kinesthetic
- processing information (abstract concepts and generalizations vs. concrete, practical examples; serial vs. holistic; active experimentation vs. reflective observation; careful vs. not careful with details)
- reasoning (deductive vs. inductive)
- organizing information (synthesis vs. analysis)
- motivation (intrinsic vs. extrinsic; deep vs. surface vs. strategic vs. resistant approach)
- pacing (concentrate on one task at a time vs. alternate tasks and subjects)
- social aspects (individual work vs. team work; introversion vs. extraversion; competitive vs. collaborative).

Our first objective is to dynamically model the learner: identify the learning preferences by analyzing the behavioral indicators and then, based on them, infer the belonging to a particular learning style dimension. The second objective is to consequently adapt the navigation and the educational resources to match the student learning preferences (see figure 1 for a schematic description of the process). In order to achieve these two objectives, we need an intelligent way of organizing the learning material as well as a set of instructional metadata to support both the learner modelling and the adaptation.

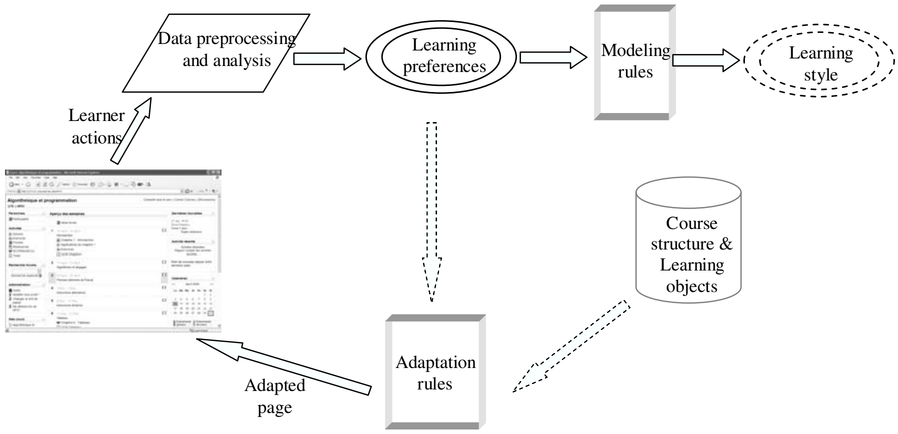

Fig. 1. Schematic representation of our LSAES

3 Organizing the Educational Material in an LSAES

According to [20], learning objects represent any digital resources that can be reused to support learning. In our case, the most complex learning object (with the coarsest granularity) is the course, while the finest granularity learning object is the elementary educational resource. We have conceptualized the learning material using the hierarchical organization illustrated in figure 2: each course consists of several chapters, and each chapter can contain several sections and subsections. The lowest level subsection contains the actual educational resources. Each such elementary learning object corresponds to a physical file and has a metadata file associated to it.

Based on our teaching experience, this is the natural and most common way a teacher is usually organizing his or her teaching materials. Additionally, this hierarchical approach presents several advantages, facilitating:

- good reuse of the educational resources
- detailed learner tracking (since we know all the information about the learning resource that is accessed by the learner at a particular moment) - see section 4
- fine granularity of adaptation actions - see section 5.

As far as the educational metadata is concerned, one possible approach (which is used in [16]) would be to associate to each learning object the learning style that it is most suitable for. One of the disadvantages is that this approach is tied to a particular learning style. Moreover, the teacher must create different learning objects for each learning style dimension and label them as such. This implies an increase in the workload of the teacher, and also the necessity that she/he possesses knowledge in the learning style theory. Furthermore, this approach does not support dynamic learner modelling, since accessing a learning object does not offer sufficient information regarding the student (a learning object can be associated with several learning styles).

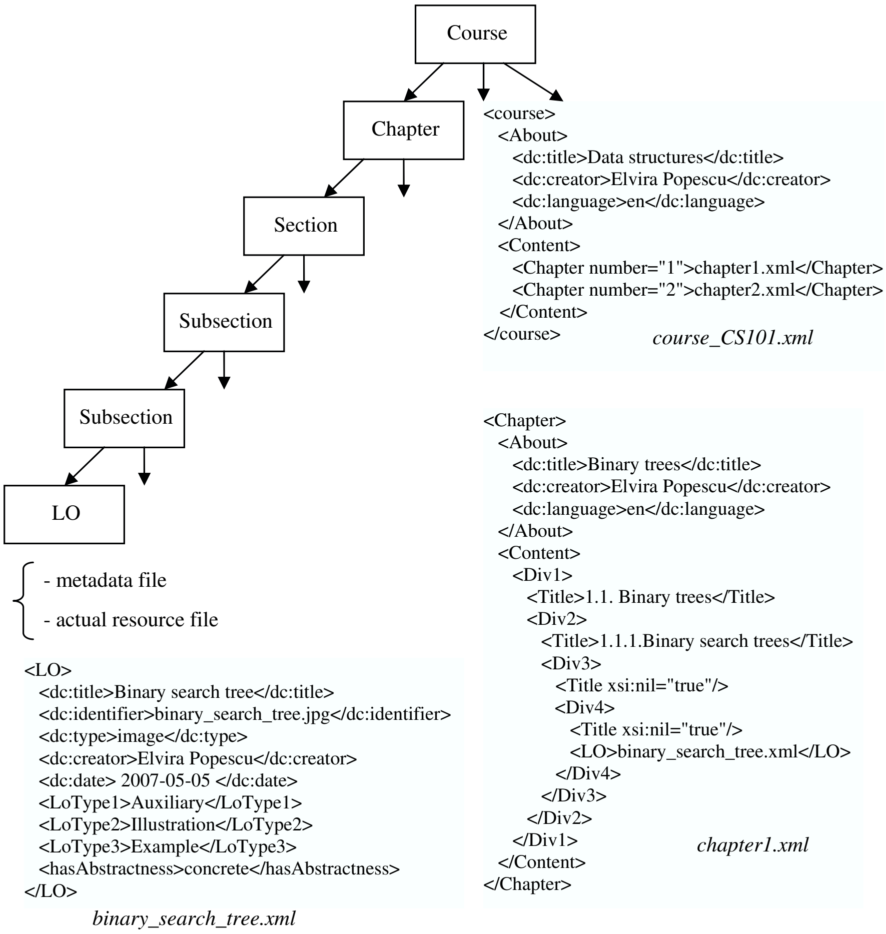

Fig. 2. Suggested organization of the learning content in an LSAES

Instead, we propose a set of metadata that describe the learning object from the point of view of instructional role, media type, level of abstractness and formality, type of competence etc. These metadata were created by enhancing core parts of Dublin Core [12] and Ullrich's instructional ontology [27] with some specific extensions to cover the requirements of an LSAES. Thus some of the descriptors of a learning object are:

- title (the name given to the resource) → dc:title
- identifier (a reference to the actual resource, such as its URL) → dc:identifier
- type (the nature of the content of the resource, such as text, image, animation, sound, video) → dc:type

- format (the physical or digital manifestation of the resource, such as the media-type or dimensions of the resource) → dc:format
- instructional role, either i) fundamental: definition, fact, law (law of nature, theorem) and process (policy, procedure) or ii) auxiliary: evidence (demonstration, proof), explanation (introduction, conclusion, remark, synthesis, objectives, additional information), illustration (example, counter example, case study) and interactivity (exercise, exploration, invitation, real-world problem) → LoType1, LoType2, LoType3, LoType4.

Obviously, these descriptors are independent of any learning style. However, by analyzing the interaction between the student and the learning objects described by these metadata (time spent on each learning object, order of access, frequency of accesses), the system can infer a particular learning preference of the student. Furthermore, the teacher has to supply only annotated learning content (the static description) while the adaptation logic (the dynamic description) is provided by the system. This means that the adaptation rules are independent of the learning content and that they can be supplied by specialists in educational psychology. The next two sections illustrate the use of these metadata for modelling the learner and providing adaptation respectively.

4 Educational Metadata and Learner Modelling

The first step towards dynamic learner modelling is to track and monitor student interactions with the system. Student observable behavior in an educational hypermedia system includes: i) navigational indicators (number of hits on educational resources, navigation pattern); ii) temporal indicators (time spent on different types of educational resources proposed); iii) performance indicators (total learner attempts on exercises, assessment tests). Based on the interpretation of these observables, the system can infer different learning preferences. Knowing the media type, the instructional role as well as other characteristics of the learning object the student interacts with is essential for an accurate identification of the learning preferences. Figure 3 illustrates the possible use of some of the learning object metadata.

5 Educational Metadata and Adaptation Logic

Modelling the learner is not a goal in itself. The value of a student model lies in its usability for providing a learning experience which is most beneficial for the student. Specifically, this could mean several things: in some cases, the most suitable attitude is to offer the student the educational resources that match their learning preferences, in terms of media type, order of resources, communication and collaboration facilities, level of navigation guidance etc. In other situations, students could benefit more from being faced with a mismatched learning environment, which provides the necessary challenge to boost learning [22]. Moreover, when learners are firstly offered

Learning preference	**Behavioral indicators**	**Corresponding metadata tag**
Visual preference	High amount of time spent on contents with graphics, images, video	<dc:type>image</dc:type> <dc:type>video</dc:type>
Verbal preference	High amount of time spent on reading text	<dc:type>text</dc:type> <dc:type>audio</dc:type>
Abstract concepts and generalizations	Access of abstract content first (concepts, definitions) High amount of time spent on abstract content	<LoType2>Definition</LOType2> <LoType2>Law</LOType2> <hasAbstractness>abstract</hasAbstractness>
Concrete, practical examples	Access of concrete content first (examples) High amount of time spent on concrete content	<LoType2>Illustration</LoType2> <LoType2>Fact</LOType2> <hasAbstractness>concrete</hasAbstractness>
Active experimentation	Access of practical content (simulations, exercises, problems…) before theory	<LoType2>Interactivity</LoType2>
Reflective observation	Access of theoretical content before practical content	<LoType1>Fundamental</LoType1>
Synthetic	High performance on exercises requiring synthesis competency	<hasCompetency>synthesis</hasCompetency>
Analytic	High performance on exercises requiring analysis competency	<hasCompetency>analysis</hasCompetency>

Fig. 3. Correspondence between learning preferences and educational metadata

the educational content that doesn't match their learning preferences, they will usually not limit themselves to that particular resource, being inclined to access more of the available resources on the subject.

The application of one or the other of the above methods depends on the intended pedagogical objective and the characteristics of the target students (knowledge level, motivation, goals). The advantage of our approach is that it allows complete independence between the learner model and the pedagogical model: various adaptation actions can be associated with each learner preference. Furthermore, we could combine several pedagogical goals, using some of the identified learning preferences to improve the efficiency of the learning process (matching), others to provide the needed challenge and variety or to develop weaker skills (mismatching) and others to increase student's self-awareness about her/his strengths and weaknesses in the learning process (open model approach). Figure 4 illustrates a possible use of the detected learning preferences for a particular student. The adaptation techniques suggested are classified according to the levels of adaptation identified in [7] and [3].

As we can see, the adaptation techniques can be decomposed into elementary adaptation actions (sorting/inserting/removing learning objects) based on various criteria, all of which are included in the metadata:

- media type → dc:type
- instructional role → LoType1, LoType2, LoType3, LoType4
- level of abstractness → hasAbstractness
- type of competency required (in case of exercises) → hasCompetency

Learning preference	Matched learning experience	Adaptation techniques
Visual	The course should include plenty of multimedia objects based on video and images; the content will be presented as much as possible using graphics and schemas.	Content level adaptation (specific media type filtering)
Concrete, practical examples	The course should be focused more on facts, practical aspects and examples. Each new concept will be first illustrated by an example and only then the theoretical aspects will be covered.	Content level adaptation (content hiding, specific item filtering) Presentation level adaptation (sorting fragments, dimming fragments)
Holistic	The course will include outlines and summaries for each course item, which will be presented at the beginning and end of each chapter and will be permanently accessible through a menu. The links to related or complex topics will be integrated in the content, to help situate the learnt subject and contribute to create the big picture. The exercises will be placed at the end of the chapter, not after each course item, in order to give the users the opportunity to holistically understand the subject first	Navigation level adaptation (link annotation, link generation) Content level adaptation (additional explanations) Presentation level adaptation (inserting fragments, sorting fragments)

Fig. 4. Ways of providing adaptivity for different learning preferences

6 Related Works

Currently there are several works that address aspects related to ontologies and metadata for personalized e-learning, such as: [1], [6], [13], [16], [17], [26]. A few of them, that we will briefly discuss here, also take into consideration learning styles.

In case of [16] the ontology is tied to a particular learning style model, namely Felder-Silverman (FSLSM) [14]. There is a special class, *LearningStyle*, which represents the FSLSM dimension associated to a particular learning object (active-reflective, visual-verbal, sensing-intuitive, sequential-global). Thus all learning objects have to be indexed according to FSLSM in order to allow for delivering of adapted content.

Paper [6] proposes a learning style taxonomy, based on Curry's onion model [11]. In the LAG adaptation model, each learning style can be associated with a specific instructional strategy, which can be broken down into adaptation language constructs, which in their turn can be represented by elementary adaptation techniques. It is the role of the author to specify not only the annotated learning content (the static description) but also the adaptation logic (the dynamic description).

Finally, paper [26] introduces the concept of Open Learning Objects, which represent distributed multimedia objects in SVG format. They incorporate inner metadata in XML format which is structured on several levels (content, adaptation, animation...). Each Open Learning Object is tied to a particular learning style dimension; however any learning style model can be employed, by configuring the adaptation markup.

7 Conclusions

In this note we sketched an intelligent way of organizing the learning resources in an LSAES. Based on Dublin Core metadata [12] and Ullrich's instructional ontology [27], we introduced a set of educational metadata that are independent of any learning style. We then showed how these metadata can be employed for modelling the learner and applying various adaptation techniques. Currently, an adaptive educational system based on the proposed approach is under development, which will provide a validating framework for our conceptualization.

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