

TOWARDS REUSABLE ADAPTIVE RULES

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Abstract. In this paper we describe a proposal to define adaptive rules that adjust learning designs to learner's knowledge and learning styles, using a collection of sets based mostly on the IMS Learning Design (IMS LD) specification. Authors will use this collection to define adaptive statements, which also could be used to define adaptive techniques and students stereotypes. The goal is to provide a formalism to describe adaptive rules that, on one hand, facilitates the authoring of the rules, and on the other, makes possible their reutilization among different adaptive educational hypermedia systems compliant with the IMS LD specification.

Keywords. Authoring adaptive hypermedia, Formalisms to describe adaptive hypermedia systems, Reusable adaptive educational hypermedia

1. Introduction

Learning Technology is defined as “specifications of methods and techniques that support the realisation of e-learning” (Hummel *et al.*, 2004). The aim of these specifications, which main characteristic is their independency of hardware and software, is to improve the “abilities” of the e-learning systems, such as their interoperability and reusability. The former is the ability to take instructional resources created for one platform in a different environment, and the latter is the ability to integrate instructional components in a variety of applications, systems and contexts (e-learning Consortium, 2002).

One example of a learning technology specification is IMS Learning Design (IMS LD, 2003). Its objective is to provide a common notational method to define any instructional design in a formal way. We claim the use of this specification can guarantee the reusability and interoperability of the elements of the adaptive educational hypermedia systems (AEHS).

In this paper we describe a formalism we are delineating to define adaptive rules based mostly on IMS LD. The goals are to facilitate the authoring process of the rules, to make possible their reusability and exchangeability within learning designs and AEHS compliant with this specification, and, at the same time, modularize the elements of AEHS.

The formalism is part of the Adaptive Learning Environment (ALE), our ongoing work to define a model to describe adaptive learning designs.

This paper is structured as follows. First, it outlines the IMS LD specification. Next, it briefly explains the ALE model and its components. Subsequently, it describes the formalism we are developing for the adaptive rule definition of the ALE model. Afterwards, it mentions the related work, and in the last section it presents conclusions and further work.

2. IMS Learning Design specification (IMS LD)

The IMS LD specification aims at providing a framework of elements that can describe any teaching-learning design following a consistent notation. A learning design is based on the pedagogical principles of the designer, and on the domain and context (e.g., designs for literature teaching can differ from designs for mathematics teaching). IMS LD uses a meta-language approach to enable the description of many kinds of educational designs, that could be implemented homogeneously in several courses or learning contexts, without prescribing any instructional design (IMS LD, 2003).

This specification has three levels of implementation and compliance. Level A contains the vocabulary to support pedagogical diversity, Level B adds attributes and conditions to level A, which allow personalization and a more elaborated interaction sequences based on students' portfolios, and Level C adds notifications to Level B.

IMS LD describes a learning design gathering three components: the conceptual model, the information model, and the behavioural model. The former expresses – as UML class models and vocabularies– models for aggregation and structure, as well as the IMS LD integration within the IMS Content Packaging (IMS CP, 2003) specification to obtain a so-called Unit of Learning. The information model represents an integration of the EML (Educational Modelling Language) (Koper, 2001), while the behavioural model expresses initialisation and runtime actions.

Figure 1 shows the hierarchical order of the IMS LD main elements (the asterisk * represents that an element may occur more than once). A learning design, which is the root element, contains objectives, prerequisites, components and the method of teaching. A method is formed by a play (the way the method is executed), conditions (if-then-else statements) and notifications.

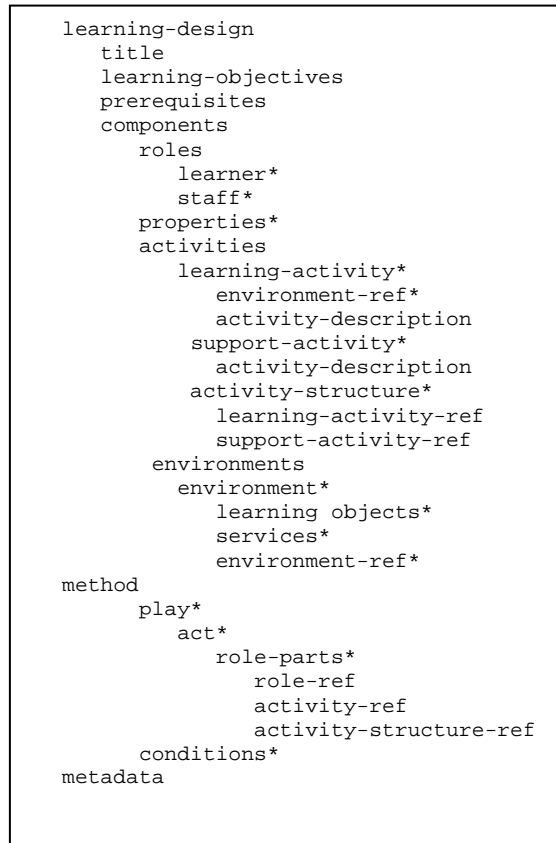


Figure 1. IMS LD main elements (IMS LD, 2003)

3. Adaptive Learning Environment (ALE)

The ALE objective is to provide students with an e-learning environment based on adaptive learning designs, as well as to give teachers authoring tools to configure those learning experiences (Berlanga and García, 2004). To configure the learning experience, ALE will provide a framework to describe AEHS in such way that authors could define the learning domain considering their pedagogical approach, domain and context. Afterwards, authors will audit if their learning experiences definitions have been effective to aid the students to understand the knowledge domain.

The author of the learning experience will define the learning domain describing elements as learning styles, tests (learning style and initial, current and final knowledge), adaptive rules, and learning designs. These definitions will be taken into account by the adaptation model to generate

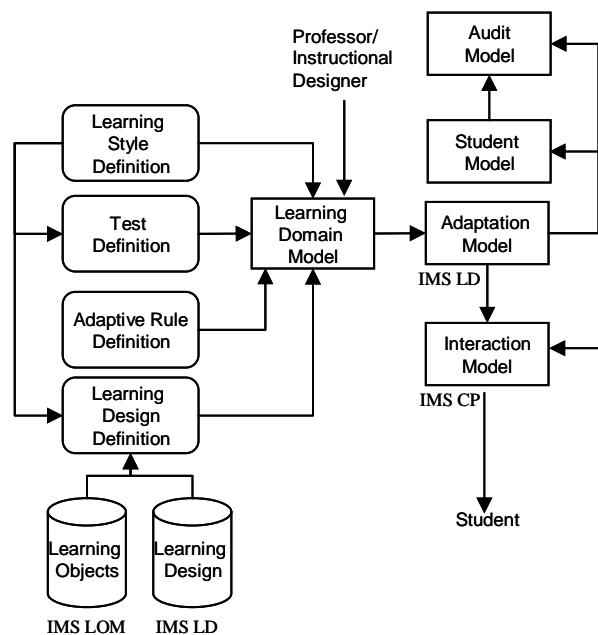


Figure 2. ALE initial model

adaptive learning designs. The interaction model will integrate the learning designs into a unit of learning modelled in IMS CP. Then, this model will deliver it, and will track the students' behaviour to update the student model. Afterwards, the audit model will check if the definition of the adaptive rules is coherent, well constructed and does not interfere with other definitions, and will determine if those rules are succeeding in providing an effective learning. To do so, it will consider the time the student spent to complete the learning activity, and her/his grades on the different tests. In addition, this model will help us to verify whether the proposed ideas are effective (see Figure 2).

At present, we are developing the learning domain model and its components four definitions: learning style, test, adaptive rule and learning design. As we already mentioned, we plan to use the IMS LD to define them. Therefore, authors will specify the learning design definition specifying its learning objectives, prerequisites, components, and method of instruction (see Figure 1). Also, the adaptive rule definition will be based on IMS LD. In the next section we introduce how we are planning to do it.

4. The Adaptive Rule Definition

In most cases, the definition of adaptivity is pre-defined by the designers of the AEHS. Nevertheless, we claim authors must have freedom to describe –in a user-friendly and simple way– what characteristics and variables have to be considered to perform adaptivity, giving their pedagogical approach, domain and context. In addition, in order to make possible their interoperability and reusability, the adaptive rule definition should use standardized metadata. This would bring benefits to students and authors, and introduce the option of modularize the components of the AEHS.

Therefore, we aim at providing authors a formalism to define adaptive rules that adjust the learning design to learner knowledge and learning styles. The definition of these rules starts with the creation of adaptive statements that can be used to define adaptive techniques or students stereotypes. Once authors have defined the adaptive rules, the AEHS (e.g. the adaptation model in the ALE) will automatically integrate all the learning domain model definitions to generate an adaptive learning design.

4.1 Adaptive Statements Description

Adaptive statements depict the conditions that will be taken into account to execute an action that will adapt the learning design. These conditions and actions can include elements such as the learning design structure, the learning style of the student, the learning style of the activity, the knowledge of the student, the attributes of the activities, the time the student spent to complete an activity, and logic or relational operators. Moreover, actions include elements to define adaptive functionality as, for example, show or hide elements.

The following rules (BNF notation) define the adaptive statements:

$\langle \text{adaptive-statement} \rangle ::= \text{IF } \langle \text{condition} \rangle \text{ THEN } \langle \text{action} \rangle$ (1)

$\langle \text{condition} \rangle ::= \langle \text{element-set} \rangle [\langle \text{unitary-op-set} \rangle] \text{ “(” } \langle \text{expression} \rangle \text{ “)” } [\langle \text{binary-op-set} \rangle \langle \text{condition} \rangle]$ (2)

$\langle \text{expression} \rangle ::= [\langle \text{spec-element} \rangle \text{ “,”}] [\langle \text{value} \rangle | \langle \text{binary-op-set} \rangle \text{ “,” } \langle \text{value} \rangle] [\text{“,” } \langle \text{relational-op-set} \rangle \text{ “,” } \langle \text{value} \rangle]$ (3)

$\langle \text{action} \rangle ::= \langle \text{action-set} \rangle \text{ “(” } \langle \text{expression} \rangle \text{ “)” } [\langle \text{binary-op-set} \rangle \langle \text{action} \rangle]$ (4)

$\langle \text{spec-element} \rangle ::= \text{specific-element-identified-by-its-id (learning-design-structure-set; student-set)}$ (5)

$\langle \text{value} \rangle ::= [\langle \text{data-set} \rangle | \langle \text{integer} \rangle | \langle \text{string} \rangle | \langle \text{percentage} \rangle]$ (6)

Table 1 shows the elements that can be included in the definition of adaptive statements. They are divided into “sets” based mainly on IMS LD elements. This will help authors to easily identify the elements of the learning design structure, and the characteristics of the student or learning activity s/he wants to use to define an adaptive statement. In addition, the definition of sets would make possible that the formalism could be used in other AEHS, players or engines compliant with IMS LD.

However, observe that subsets such as the learning-style, student-data, or attributes-data are not part of IMS LD. The AEHS has to provide the values of these elements. We decided to include the learning-style-set because effective instructional strategies (or learning designs) also should consider the learning style of the learner (Merrill, 2000). The student-data-set will make possible to define adaptive rules that consider the learner knowledge (not just visited pages), and the attributes-data-set will facilitate the authoring process and the student follow-up.

Table 1. Collection of sets to describe adaptive statements

Name of the set	Subset	Elements	Comments
element-set	learning-design-structure	Prerequisite Learning-objectives Learning-activities Activity-sequence Support-activity	Contains the main elements of IMS LD
	student-element-set	Student	The student, as s/he logged in the AEHS
data-set	learning-style-set	Learning-style	Learning style of the student. The AEHS provides the values
	student-data-set	Initial-knowledge Current-knowledge Final-knowledge	The knowledge of the students. The values are obtained by tests included in the AEHS
	attributes-data-set	Completed Visited Recommended Sequence Selection	Completed, Visited, and Recommended are provided by the AEHS. Sequence and Selection are attributes of the IMS LD learning-activity element
	time-data-set	Time-unit-of-learning-started Date-time-activity-started	Elements of IMS LD
logic-set	binary-op-set	And Or	Elements of IMS LD
	unitary-op-set	Not	Elements of IMS LD
relational-set	relational-op-set	Greater-than Less-than Equal Greater-or-equal-than Less-or-equal-than	Elements of IMS LD
action-set		Show Hide Show-menu Hide-menu Sort-ascending Sort-descending Number-to-select	Show, Hide, and Number-to-select are elements of IMS LD. The others are functions that need to be transformed by the AEHS

4.2 Adaptive Techniques Description

The objective to describe adaptive techniques is to configure the behaviour of the system when students are interacting with the learning design. Authors could store their adaptive techniques to use them in other

learning contexts. In ALE, authors could evaluate the success of their adaptive techniques using the audit model.

Adaptive techniques, which will be performed on learning designs, are defined as:

$$\langle \text{adaptive-technique} \rangle ::= \text{TECHNIQUE} \langle \text{<} \rangle \langle \text{name-technique} \rangle \langle \text{>} \rangle \langle \text{=} \rangle \langle \text{adaptive-statement} \rangle \quad (7)$$

4.3 Students stereotype description

The creation of students stereotypes allows authors to group students considering one or more characteristics or variables.

As in the adaptive techniques description, the definition of students stereotypes is based on the adaptive statements description. But, in this case, we intend to use the IMS LD element $\langle \text{role-part} \rangle$. We argue that, internally, the AEHS could use this element to define students stereotypes, in such way that every *role-part* covers a set of learning activities related to a specific learning-style.

The following formula defines the students stereotype description:

$$\langle \text{student-stereotype} \rangle ::= \text{STEREOTYPE} \langle \text{<} \rangle \langle \text{name-stereotype} \rangle \langle \text{>} \rangle \langle \text{=} \rangle \langle \text{adaptive-statement} \rangle \quad (8)$$

4.4 Adaptive rule definition authoring tool

In order to facilitate the authoring process, we plan to develop an authoring tool that will guide the authors in the definition of the adaptive rules, assist them adding the necessary parenthesis, commas, etc., and validating the new elements added. Figure 3 shows a prototype of its interface. The tool will show the collection of sets of Table 1, buttons that represent each part of adaptive statement definition (if, condition, then, action), and a display area that will show the adaptive statement definition that the author is creating. The authoring tool also will have buttons to add elements into the rule definition, such as a selected element of the collection set, a value (i.e. integer, string, data-set), or a specific element (id). At the bottom of the screen, the adaptive rule will be showed. Once the author press the save button, s/he will have the possibility of saving the rule as adaptive technique or student stereotype.

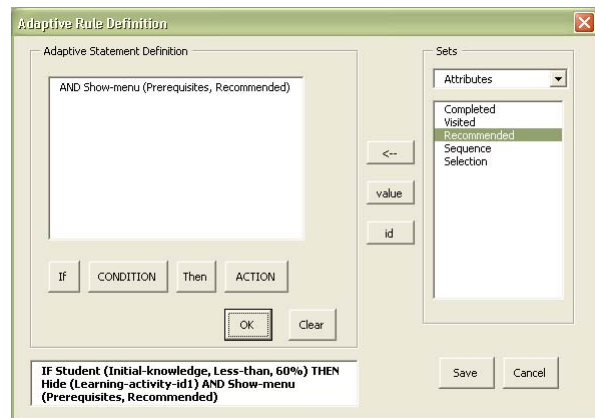


Figure 3. Adaptive Rule Definition Tool prototype

Using the formalism, and the tool, authors could define adaptive statements. For example, the following rule takes into account the students' initial knowledge to hide a specific learning activity (i.e. learning-activity-id1), and shows a menu with the recommended prerequisites:

$$\begin{aligned} & \text{IF Student (initial-knowledge, less-than, 60\%)} \text{ THEN} \\ & \text{Hide (learning-activity-id1) AND Show-menu (Prerequisites, Recommended)} \end{aligned} \quad (9)$$

To define an adaptive technique as, for example, adaptive ordering –which sorts in order of significance all the links of a particular page (Brusilovsky and Nejdl, 2003)– for students who have a current knowledge less than the 50%, the following rule can be defined:

$$\begin{aligned} \text{Technique } \langle \text{Adaptive-Ordering} \rangle = & \text{IF Student (Current-knowledge, Less-than, 50\%)} \text{ THEN} \\ & \text{Sort (Activity-sequence)} \end{aligned} \quad (10)$$

In addition, a students stereotype “Advanced” could be defined for those that have an initial knowledge greater than 90%:

$$\text{Stereotype } \langle \text{Advanced} \rangle = \text{Student } (\text{Initial-knowledge}, \text{Greater-than}, 90\%) \quad (11)$$

Authors could use this student stereotype description to define adaptive statements, or adaptive techniques. For instance, the following rule takes into account if the learner is “Advanced” to show two specific activity sequences (e.g. activity-sequence-id1, activity-sequence-id2):

$$\text{IF Student } (\text{Stereotype } \langle \text{Advanced} \rangle) \text{ THEN Show } (\text{Activity-sequence-id1}) \text{ AND Show } (\text{Activity-sequence-id2}) \quad (12)$$

5. Related work

Although research in the AEHS field has been done for many years –some well-known examples are InterBook (Brusilovsky *et al.*, 1998), AHA (De Bra and Calvi, 1998), KBS-Hyperbook (Henze and Nedjl, 1999), and TANGOW (Carro *et al.*, 1999)–, studies on how to design authoring tools to define adaptive rules, or how to integrate learning technology specifications into AEHS, are relatively new areas of interest.

At present, there are two European funded projects directed to adaptive learning environments. The ADAPT project (Cristea and De Bra, 2002) and the aLFanet project (Santos *et al.*, 2003). In the former, the 3-LAG Model (Cristea and Calvi, 2003) has been defined. This model classifies adaptive techniques into three levels of adaptation granularity. The lowest contains direct adaptation rules or techniques. The medium, groups the lowest level, and defines an adaptation programming language to describe adaptivity rules. The highest level wraps the other two levels, and defines adaptation strategies that consider the users’ cognitive styles, preferences and learning strategies. The LAG context free grammar (Cristea and Verschoor, 2004) has been defined to describe adaptive rules for the three layers. However, the grammar can be difficult to understand for those without computer background. Our proposal is based on simpler conditions that can be defined using sets that contain elements easily understandable for any user. Moreover, the LAG Model does not consider the adaptation of a learning design, or the use of learning technology specifications, as our proposal does.

The objective of the aLFanet project is to build a learning environment that offers intelligent personalization and adaptivity capabilities. The adaptation to the users’ preferences and needs is defined in three different areas: adaptation by the instructional design, adaptation of the interaction, and adaptation of the presentation. The idea is based on a framework that supports active and adaptive e-learning, and is open to any type of learning model. All these features are designed using IMS LD (Van Rosmalen *et al.*, 2003). Therefore, they use IMS LD to define adaptive rules as our proposal does. Conversely, we consider the learning style and knowledge of the learner, and the learning style of the learning activity to define adaptive rules.

6. Conclusions and further work

In this paper we presented an ongoing research that explores the definition of adaptive rules. We aim to designing adaptive environments based on learning designs and to proposing new ideas to reuse adaptive rules among AEHS and learning designs compliant with IMS LD.

Currently, we are extending the functionalities of an application we have developed for authoring hypermedia books –the Hypermedia Composer (HyCo) (García and García, 2004)– in order to utilize it as the learning design authoring tool (García *et al.*, 2004). We are working on the interface to define learning designs conform to IMS LD Level A specification. The next steps are continuing the design of the adaptive rule definition tool, and the definition of how the adaptive rules will be transformed (using the <method> element), and included in an IMS LD file. Afterwards, we plan to work with teachers of

different contexts (i.e. university, vocational schools, and informal education) to test if they find the formalism useful and easy to define adaptive rules, as well as check if it can be reused in other learning designs or AEHS.

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