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Abstract. The paper describes adaptive methods developed in the area of adaptive educational hypermedia according to a simple taxonomy schema based on three dimensions: What components of the educational system are adapted? To what features of the user and the current context does the system adapt? Why does the system adapt? Based on this taxonomy several classical methods of adaptive educational hypermedia are classified. In a second step the paper shows how those methods could be implemented in a standardized way using IMS Learning Design.

Keywords: Adaptive learning, IMS Learning Design, Adaptability, Unit of Learning.

1 Introduction

In adaptive educational hypermedia a variety of research work about questions on how to adapt curricula and learning content to individuals and groups of learners has been done [1-5]. From our point of view the application of adaptive methods to educational hypermedia applications can mainly be structured according to four main questions:

What parts or components of the learning process are adapted? This question focuses on the part of the application that is adapted by the adaptive method. Examples can be the pace of the instruction [3] [6] that can be modified based on diagnostic modules embedded in the learning process or adaptation of content presentations, the sequencing of contents and others. Extensions with new forms of information delivery allow the distribution of learning materials to different learning contexts relevant to the individual user or groups of users.

What information does the system use for adaptation? In most adaptive educational hypermedia applications a learner model is the basis for the adaptation of the previously given parameters of the learning process. Nevertheless there are a several examples where the adaptation takes place not only to the learner knowledge, preferences, interests, cognitive capabilities, but also to tasks and learner goals.

How does the system gather the information to adapt to? There are a variety of methods to collect information about learners to adapt to. Mainly implicit and explicit methods like described in works from user modeling can be distinguished. A overview can be found at Jameson [7].

Why does the system adapt? This question mainly focuses on the pedagogical models behind the adaptation [8-10]. Classical educational hypermedia system mainly adapted according for compensation of knowledge deficits, ergonomic reasons, or adaptations to learning styles for an easier introduction into a topic.

Table 1. A classification schema for adaptive methods

What is adapted ?	To which features ?	Why ?
Learning goal • Content • Teaching method • Content Teaching style • Media selection • Sequence • Time constraints • Help Presentation • Hiding • Dimming • Annotation	Learner • Preferences • Usage • Previous knowledge, professional background • Knowledge • Interests • Goals • Task • Complexity	Didactical reasons • Preference model • Compensation of deficits • Reduction of deficits Ergonomic reasons • Efficiency • Effectivness • Acceptance

Furthermore examples for adaptive methods can be found in different research areas as Intelligent Tutoring Systems [11-13], Adaptive User Interfaces [14, 15], Adaptive Hypermedia [1], Intelligent Multimedia or Intelligent Agents [16, 17] for Learning. Examples found in the literature can be mostly classified to the scheme introduced above. The following section will give an overview with some examples. In the following we will pick out some examples and discuss the possibilities to implement them in IMS-LD.

Table 2: Examples of classified adaptive methods

What?	To what?	Why?	How?
Adaptive Sequencing			
Sequencing Content or Learning Activities	Learner tested knowledge or navigation history	Compensation of Deficits or Encouraging	Tests, Tracking
Incremental Interface			

Complexity of Interface, Number of functionalities	Tasks, Skills, Domain Knowledge	Usability	User Tracking, Questionnaires
Adaptive Presentation			
Selection of media	Knowledge preferences goals	Compensation of deficits	Diagnostic
Adaptive navigation support			
Hyperlinks, restriction of navigational freedom	Knowledge, background, preferences	Adaptation to zone of proximal development	Diagnostics, Tests

2 Elements in IMS Learning Design to realize adaptive Units of Learning

IMS Learning Design [18] is focused on the design of a pedagogical method able to sequence learning activities linked to learning objects. The learning flow is structured in plays, acts, activities, activity structures and environments and can be defined in a flexible way, providing several itineraries depending on the role assigned of on a set of rules.

Although there is an increasing amount of literature about the specification [19-21] it is not so usual to find references to some specific modelling showing concrete elements and educational applications of IMS Learning Design. This section aims to provide some support on this approach.

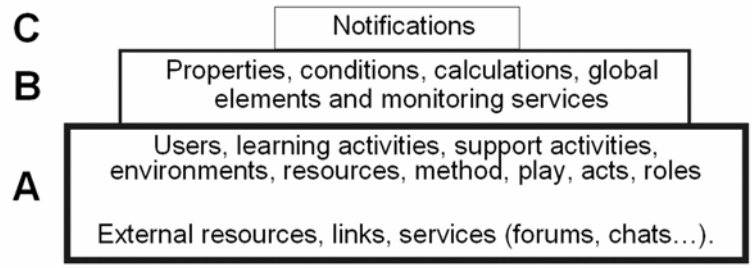

Fig. 1. IMS Learning Design and three levels specification

IMS LD consists of three levels (Figure 1). Each level itself provides specific features to the educational information pack, called Unit of Learning. Furthermore,

Level A provides method, plays, acts, roles, role-parts, learning activities, support activities and environments; Level B provides properties, conditions, calculations, monitoring services and global elements; and Level C provides notifications. Every level is built on the previous one. As Level A is the main part of the specification, as gives the ground to build any Unit of Learning, Level B adds powerful features to create more complex e-learning lesson plans, and Level C sums a specific use of a trigger system.

Besides the basic and crucial structure provided by Level A, the elements of Level B become the actual key for adaptation, as they combine properties with conditions and other features that encourage and make more flexible the content and the learning flow.

IMS LD is able to carried out six main types of adaptation [22]: Learning flow based, content based, interactive problem solving support, adaptive user grouping, adaptive evaluation and changes in run-time. They are also useful to address complementary issues to adaptive learning, like active learning, collaborative learning, dynamic feedback, run-time tracking, ePortfolios and assessment [23]. All these types of adaptation and specific applications to educational purposes make an intensive use of several features in Level B, as we describe in the next section.

3 IMS LD Level B and adaptation

The elements in Level B providing support to adaptation in Units of Learning are categorized as 1) properties, 2) conditions, 3) global elements, 4) calculations and 5) monitoring services

3.1 Definition, set-up and use of properties (group, values…)

Properties are taken as variables to store values. There are several types of properties: local, global, personal and role. A variable must be defined and initialized. In the following lines we define a property, String type, and a second one, Integer type, and we initialize this last one to 0:

```
<locpers-property identifier="LP-name">
  <title>your name</title>
  <datatype datatype="string"/>
  </locpers-property>
<locpers-property identifier="LP-age">
  <title>age</title>
  <datatype datatype="integer"/>
  <initial-value>0</initial-value>
</locpers-property>
```

When several properties are defined around a category they can be grouped. This process facilitates the data input providing one single confirmation button per group, instead of one per every property:

```
<property-group identifier="LP-group-profile">
```

```
    <title>User information</title>
    <property-ref ref="LP-name"/>
    <property-ref ref="LP-age"/>
  </property-group>
```

After the definition, the property can be used to set and view values, using *global elements* - see 3.3 later in this text. A property can also change the stored value internally, without any user input:

```
    <change-property-value>
      <property-ref ref="QuestionTrue1"/>
      <property-value>100</property-value>
    </change-property-value>
```

3.2 Conditions

IMS LD is able to define a basic structure if-then-else, for instance to change the value of a property. In this case, the value *100* is stored in the property *QuestionTrue* if the property *Answer* contains the value *Circle*. In other case, the value to store is *0*:

```
  <if>
    <is>
      <property-ref ref="Answer"/>
      <property-value>Circle</property-value>
    </is>
  </if>
  <then>
    <change-property-value>
      <property-ref ref="QuestionTrue"/>
      <property-value>100</property-value>
    </change-property-value>
  </then>
  <else>
    <change-property-value>
      <property-ref ref="QuestionTrue"/>
      <property-value>0</property-value>
    </change-property-value>
  </else>
```

We can also use conditions to hide and show elements in the learning flow, for instance between two *Activity Structures*, in case there is a certain value (*Sports*) in a property:

```
  <if>
    <is>
      <property-ref ref="LP-choose-activity"/>
      <property-value>Sports</property-value>
    </is>
  </if>
  <then>
    <show>
      <activity-structure-ref ref="AS-Sports"/>
    </show>
    <hide>
     <activity-structure-ref ref="AS-Music"/>
    </hide>
  </then>
```

3.3 Global elements

Global elements provide a communication flow between the *IMSmanifest.xml*, where the different levels of IMS LD are set-up, and other XML files. Mainly, they can get an input from the user and they can show a value of a property:

```
<ld:set-property-group ref="LP-name" property-of="self"/>

<ld:view-property-group ref="LP-name" property-of="self"/>
```

Furthermore, they can manage DIV layers (classes) in XHTML, for instance to show and hide specific content. In the following case the class called *Feedback_Right* is on the screen when the property *Answer* contains the value *Green*:

```
<if>
  <is>
    <property-ref ref="Answer"/>
    <property-value>Green</property-value>
  </is>
</if>
<then>
  <hide>
    <class="Feedback_Wrong"/>
  </hide>
  <show>
    <class="Feedback _Right"/>
  </show>
</then>
```

3.4 Calculations

IMS LD is able to make some basic calculations (sum, subtraction, multiplication and division) and some combination of a number of them in a row, to get a more complex formula, like a simple average, for instance. Following, we define the sum between *Value_A* and *Value_B* and we divide this partial result by *2*, storing the final result in the property *Simple_Average*:

```
<change-property-value>
  <property-ref ref="Simple_Average"/>
  <property-value>
    <calculate>
      <divide>
        <sum>
          <property-ref ref="Value_A"/>
          <property-ref ref="Value_B"/>
        </sum>
        <property-value>2</property-value>
      </divide>
    </calculate>
  </property-value>
</change-property-value>
```

3.5 Monitoring service

The specification allows monitoring any kind of property assigned to a user, a group or a role, for instance. In order to start this action, firstly the component *monitor* must be set-up inside an environment (in this specific case):

```
<environment identifier="E-qualifications">
  <title>Which are the qualifications of the others?</title>
  <service identifier="S-qualifications">
    <monitor>
      <role-ref ref="Student"/>
      <title>Qualifications of the other students</title>
      <item identifierref="R-qualifications"/>
    </monitor>
  </service>
</environment>
```

Moreover, this property can also be traced with the *monitor* component. For instance, the following code allows reading (*view*) the property of a different student (*supported-person*), using a global element.

```
<ld:view-property property-of="supported-person" ref="LP-
qualifications"/>
```

In these lines, the monitoring service is defined for a learner (Student). This means that every student can view the content of the properties of other classroom partners. When a tutor needs to view students' properties, a similar structure can be designed, providing a proper tracking of each participant in a course.

Basically be the combination of Properties, Calculations, Conditions, Global elements and a Monitoring service quite a variety of classical adaptive methods can be modeled, e.g., Properties allow for making use of user features, group features, and adaptation to stereotypes [24]. Beside the classical adaptation to individual learners especially the adaptation to learning groups or properties of roles offer new possibilities. The use of environments in IMS-LD allows for the adaptation and personalization of supporting learning environments for different learning activities.

4 Specific examples

In the previous section, we define all the key elements in the Level B of IMS LD to create adaptive Units of Learning, based on sequence, groups, content, evaluation and other features. But how to realize this adaptation? To illustrate the appropriate combination of some of some elements in Level B that carry out a type of adaptive learning we show two full examples, *Learning to listen to Jazz* and *Geo Quiz 3* (LN4LD, 2005).

Learning to listen to Jazz is a course about the different music styles in Jazz. There are two different routes to follow, one thematic and another one historic, and the user can swap between both in different moments of the learning flow. In this case, the

adaptation comes from the user, based on a pre-design of the course by the author/tutor.

The second example, Geo Guiz 3, provides a general quiz on geography with five questions and multiple answers, where the user gets some score, average and percentage of accuracy, and also where the next activity to study depends on these results, coming out of four possible activities. This example guides the learning flow of the student based on his performance and a set of pre-defined rules. The conceptual graph is shown in Figure 2.

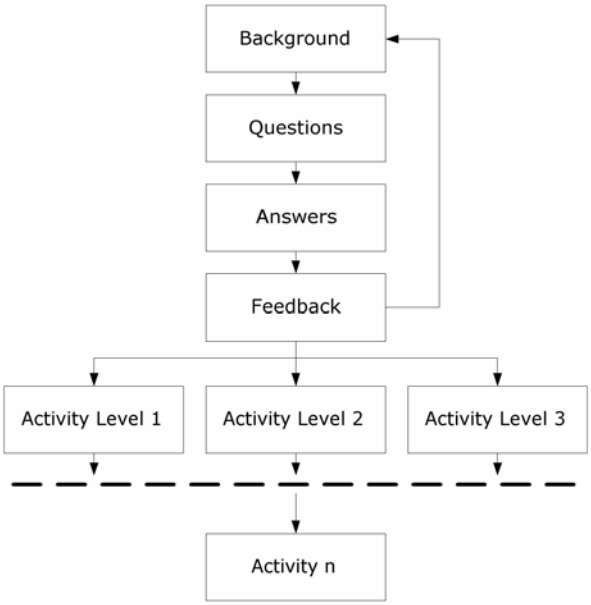

Fig. 2. Learning flow in Geo Quiz 3

5 Integration and Outlook

IMS-LD enables a standardized way for designing personalized learning experiences as shown in the specific examples. In the following we try to map the dimensions of the classification model the first part of this paper and map them on the parameters in IMS-LD to represent personalized learning.

What information is used for adaptation and how is this represented in IMS-LD? Basically properties are a very open and flexible way to represent information about users ranging from preferences, knowledge, interests, and even more complex calculations can be used to compute more complex models. Using properties not only for single users but also for groups of users allows to synchronize collaborative learning activities in which we see a very interesting opportunity for future research in contextualized and mobile distributed learning. Furthermore the possibilities of Level C in IMS LD, which have not been considered in this paper, will allow for updating user

and role properties based on arbitrary events in the collaborative learning or tutoring activities. Another strength of IMS-LD definitely lies in the role properties that can be used in a variety of ways like shown in the jazz example but also for adaptation to stereotypes.

What can be adapted and how is this represented in IMS-LD? IMS-LD allows for description of learning processes and the connection of resources, activities and Units of Learning, furthermore like described in the specific examples and parameters IMS-LD can also be used for navigational guidance where dependent on properties certain elements in a navigations tree can be annotated or hidden and content adaptation in which certain elements are visualized or not. More research needs to be done on ways how to describe learning designs an certain adaptation rules for them on a meta level, e.g. to describe rules for all activities and knowledge resources based on properties.

Why does the system adapt and what is the pedagogical aim? The strength of IMS-LD for reuse of pedagogical patterns and applying them to different domain instantiations can easily seen in projects like AUTC [25] or LN4LD [26] where a variety of reusable patters for collaborative and individual learning experiences have been developed. In the upcoming research our team aims at developing reference examples for adaptive methods taking into account group and individual learning models for adapting not only sequencing and content adaptation but also run time adaptation of pedagogical patterns. A main strength of IMS-LD in comparison to several adaptive educational systems is the pedagogical background coming out of EML.

How does the system get the information about the user? As seen in the first example IMS-LD can support adaptability as also adaptivity. The integration with the IMS specifications on Questions and Tests Interoperability [27], Reusable Competence Definitions [28] and Content Packaging [29] is definitely a strong plus for both the integration with assessment on the level of knowledge, competences and goals as also the possibilities for content delivery.

We foresee high potential for IMS-LD to be a powerful approach for modeling adaptive methods in education and will continue to investigate its potential with the implementation of specific examples as also the participation in the Adaptive Hypermedia communitiy and the IMS bodies.

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