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Abstract

For almost three decades the concept of adaptation of computer education has been an important topic. Approaches to giving the student a central role in his/her own learning process have been described in literature from early Computer Based Training systems to more recent Adaptive Learning Hypermedia Systems. However, the approaches have tended to be highly specific in their implementation, hampering comparison and extension of results in the field.

The IMS Learning Design specification (IMS LD) addresses many requirements for computer based adaptation and personalized eLearning.

In this paper we give an overview of a number of approaches, definitions and features of adaptive learning; in the second section we identify how adaptive features and elements can be addressed by IMS LD, detailing a number of example Units of Learning which illustrate adaptation in different ways. In the final section we discuss issues in attaining the right balance between effort invested and results acquired while modelling IMS LD adaptive Units of Learning.

Keywords

Adaptive learning, adaptability, personalized learning, IMS Learning Design

1. Introduction

There are many definitions of adaptation in eLearning systems [1]. Usually the concept is focused on the student, although adaptation involving tutors is clearly also possible. From the user interface to the eLearning resources to the process there are many aspects to take into consideration. In this section we show and briefly analyze several approaches to this issue.

From the early eighties, where Computer Based Training was used to fully control the flow of a learning process [2, 3], to the concept of Adaptive Guidance, which provides rich information and a diagnosis to help the learner to take effective decisions about his own learning [4], there is a wide collection of approaches. For instance, to incorporate the tutor as a key factor in the adaptation process [5], or to build a blended system strongly supported by AI agents [6]. All are based on the proposal of personalized learning adaptation to the context of each student to stimulate his learning process and to encourage his involvement in this process [7-9] These approaches also hold that the largest benefit comes from personalized instruction [10]. This does not necessarily imply that a user/student should keep full control over his training, because this would mean that 1) the student knows what is the best for him along a learning script; 2) the student is aware, knows and controls all the contributions that he can make to his own process; and 3) the student is able to carry out the right decision when all this information is collected [11].

We define adaptive eLearning as a method to create a learning experience to the student, but also to the tutor, based on the configuration of a set of elements in a specific period aiming to increase of the performance of a pre-defined criteria [5]. These criteria could be educational, economic, time-based, user satisfaction-based or any other involved in eLearning. Elements to modify/adapt could be based on content, time, order, assessment, interface and *etcetera*.

In modern learning theory there are four main approaches to adaptive learning [12, 13]:

- *macro-adaptive*, selecting a few components that define the general guidelines for the eLearning process, such as learning goals or levels of detail and mainly based on the student's profile;
- *aptitude-treatment interaction*, proposing different types of instructions and/or different types of media for different students;
- *micro-adaptive*, monitoring the learning behavior of the student while running specific tasks and adapting the instructional design afterwards, based on quantitative information;
- *constructivist-collaborative*, focused on how the student actually learns while sharing knowledge and activities with others.

A modern system based on adaptation should consider all of them to provide a wide range of possibilities on eLearning.

2. Types of adaptation

Taking as a start that neither books nor computers guarantee that a student actually learns [14], a combination of the following proposals on adaptation could support the performance of every role in a learning process [7, 15].

Traditionally, three types of adaptation have been proposed:

1. *Interface-based* (also called adaptive navigation and related to usability and adaptability) where elements and options of the interface, are positioned on the screen and their properties are defined (color, size, shadow, etc) [16]; this is closely related to general customization and for people with special needs which influence personalization, such as color blindness or poor hearing, for instance [17].
2. *learning flow-based*, where the learning process is dynamically adapted to explain the contents of the course in different ways;
3. *content-based*, where resources and activities dynamically change their actual content, as in Adaptive and Intelligent Web-Based Educational Systems based on adaptive presentation [18, 19]

Additional kinds of adaptation are [20]:

4. *interactive problem solving support*, that guides the user about the next step to take in order to get the right solution of a problem;
5. *adaptive information filtering*, taking care of an appropriate information retrieval that provides only relevant and categorized outputs to the user [21];
6. *adaptive grouping*, that allows *ad hoc* group creation and collaborative support on carrying out specific tasks.

Last, we should extend the two lists aforementioned with:

7. *adaptive evaluation*, where the evaluation model, the actual content and the running of the test can change depending on the performance of the student and the guide of the tutor [5];
8. *changes on-the-fly*, the possibility to modify/adapt a course on-the-fly by a tutor or author in run-time [22], moving beyond the previous types which are set-up and defined in design-time [23, 24].

In this report, we see up to eight different kinds of adaptation being carried out in eLearning systems. All of them use various inputs provided during the learning process and aim to tune the activities and actions of the learner to get the best learning experience as possible [25]. A wide and strong set of rules of dependencies among users, methods and learning objects is needed to describe these eight types of adaptation, and moreover their possible combinations [26].

3. IMS Learning and adaptation

IMS LD [27] provides a modelling language able to design and run Units of Learning [28-30]. An initial analysis [10] takes the adaptation fully modelled inside a Unit of Learning (UoL), without an external link, as an autonomous entity, and describes four areas in IMS LD where some kind of adaptation could take place: *environment, method, roles* and *activities*. This scope of the paper is limited to possible modifications related to the *environment* element of IMS LD and is based on the *method*. Van Rosmalen and Boticario [22] additionally address on the external adaptation of a UoL, making modifications to both the internal elements of the UoL and the orchestrating layer through which the UoL is delivered. We now examine how IMS LD can be used to represent each of the eight types of adaptation aforementioned.

3.1 . Interface based

This issue relates to the user interface provided with IMSLD players such as the player included with *CopperCore* [31], the *Reload Player* [32] and *Sled* [33]. The current generation of these tools do not provide facilities to allow interface adaptation in run-time, although *Sled* can be customized during the set-up.

3.2 . Learning flow based

The description of an adaptive learning flow is mainly based on four different elements of IMS LD, available at Level B [30, 34]: *properties, calculations, global elements* and *conditions*. In addition, monitoring services can be added to track users' behaviour and adapt the flow dynamically. An example of these features is provided by *Learning to Listen to Jazz* (all the examples can be found at [35]). A student can learn something about four different Jazz styles in a sequential way, and he can choose between a thematic itinerary and a historical itinerary, following different milestones in the course. An additional example is *GeoQuiz 3* where the activities are defined by the performance of a student after answering an evaluation form. Depending on the final score and the related level acquired, one or another activity is shown. A final example is *Cándidas II* showing full learner control by the student, who directly selects which is the best method to study a lesson among four different options.

3.3 . Content based

The content of an activity needs a resource linked to the element Activity Description. Although this link cannot be changed at run-time, three other elements can be modified dynamically:

- the content inside an XHTML resource, defining classes and DIV layers that can be hidden and shown based on certain parameters;
- the content of pre-defined properties/variables, that can be replaced with other content typed-in on the fly;
- the content of an activity can be adapted switching showing or hiding one of several linked environments.

Two examples of the use of environments are *Learning Activities with Conditions*, where a student decides the granularity level that he wants and *From Lesson Plan to LD Level B*, where again a student takes control and switches on and off the audio support of the UoL. Finally, *Learning to Listen to Jazz* provides contents linked to several Activity Descriptions and related environments, progress-based.

An additional way of content-based adaptation is the modification of contents linked to fixed resources and based on external tools. For instance, a resource linked to a wiki service hosted outside an IMS LD UoL could adapt its content dynamically, based on users', tutors' or authors' actions.

3.4 . Interactive problem solving support

This kind of adaptation could be considered as an extension of *learning flow based*, with the appropriate definition of properties and conditions modelling the itinerary, and the incorporation of a monitoring service allowing the tracking of the learning process of the student, making *ad hoc* remarks and changing the process as needed. These changes can be carried out 1) by modifying specific arguments by the tutor, 2) by the execution of specific design-time rules, or 3) by a combination of both mechanisms. An example is *What is Greatness* where the tutor moderates the contributions of a group of students on an open question, providing access to the next step when the tutor thinks that the current one is finished. A further example is *Free Style Assessment* where a tutor and a student carry out a commented open evaluation of an assessment. The tutor is entitled to close and block every step and to provide contextual feedback.

3.5 . Adaptive information filtering

IMS LD is not designed to provide adaptive information retrieval. Some rudimentary facilities are available through the *index-search service*. More practically, IMS LD could point out to an external searching service providing the container for the run of this application and also for the visualization of the results.

3.6 . Adaptive grouping

User management has two approaches, one based on roles' creation and one based on users' creation. Using the management system provided by several tools and engines – Coppercore, Reload, CopperAuthor [36] – once the UoL is published, the administrator (maybe the teacher himself) can add and delete users and assign them to a specific run of that UoL. This means a *de facto* group [37]. However, the dynamic creation of roles after the publishing process is not currently possible. Once a definition of roles or stakeholders is available, and a run of a UoL is defined, specific users can be added to, or removed from, any of these groups and they can be played in a run. Some representational facilities are available in IMSLD to support creation of groups (min-persons and max-persons) and although assignment of users to groups can be achieved, fully automatic on-the-fly creation of groups may require additional representational devices.

3.7 . Adaptive evaluation

Taking the performance of a student in a Unit of Learning as input, a full set of parameters can be stored in local properties to be used in the adaptation of formative or summative evaluations. As we have already explained related to *Geo Quiz 3*, certain actions and answers of a user can be allocated into variables pre-defined in design-time and they can also be interpreted in run-time following a set of rules. In this way, both the evaluation system and the content itself, and even the interpretation of the results, can change for each user. An example is *Quo Builder 2* where a questionnaire can be fully set-up with questions, answers, thresholds and feedback being defined in run-time. Again, the main obstacle to overcome is the run-time modification of the skeleton itself, such as the ordering, grouping and numbering of questions and answers. However we can define a wide set of questions that can also be hidden and shown on demand, providing a top-down 'simulation' of adaptive extensibility.

3.8 . Changes on-the-fly

Every UoL has three clearly different steps in its own life-cycle: design-time, publishing-time and run-time [28]. Once a UoL is published it is not possible to change structure, method or definition of basic parameters (such as conditions or properties, for instance). Of course, if a UoL is so designed, a tutor is able to change the way a student perceives the course and the flow: 1) tutors can update the content, based on pre-defined content or on new contributions; and 2) tutor can also influence the learning itinerary, uploaded files, shown and hidden content elements and structure elements, etc This means that a tutor is able to change things on the run, as long as he had previously defined that possibility in design-time. This solution comes with a high expense on implementation and support, though. An example is the already mentioned *Quo Builder 2* where a tutor makes the set-up and initialization of an evaluation form within run-time, that is subsequently filled by students.

4. Discussion

IMS LD can be used to represent a wide-variety of approaches to adaptivity in eLearning. Using the specification as a language into which adaptation strategies could be exported would allow for comparison of approaches adopted by different research groups. Furthermore, support for the importing of adaptive Units of Learning into adaptive engines would allow additional application of adaptive approaches, helping to reveal any implicit assumptions and promote a shared understanding of the what, why and how of adaptive eLearning. Using IMSLD in this way would also force a debate on the use of standards for the representation of the information upon which adaptation occurs (eg [38])

The possibilities for adaptation supported by IMSLD are diverse. *Learning flow*, *content*, *evaluation* and *interactive problem solving support* are well supported. Some support is available for *grouping* and *modification of a course on-the-fly*, as long as this is pre-defined in design-time. Last, as some pending issues are *dynamic modification of learning structure and method in run-time*, and *adaptive information filtering and retrieval*. With several types of adaptation, like *content* and *information retrieval*, it is also possible to link an activity to an external tool providing this service, keeping IMS LD as a container for external adaptation. In conclusion, with the appropriate support, IMS LD can build adaptive and rather flexible learning experiences for every stakeholder.

The current state of the art in IMS LD editors, such as *CopperAuthor* and the *Reload Editor*, makes the creation of adaptive UoLs technically possible, but the process is a complex one. A learning designer is required to know the technical editors in depth and to have intimate knowledge of the specification. Currently, this means a significant effort is needed to create adaptive UoLs in IMSLD editors. However, the use of IMSLD as an inter-lingua for existing tools from the Adaptive Hypermedia arena seems a promising line of investigation.

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