Issues in developing adaptive learning management systems for higher education institutions

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Abstract. Adaptive Learning Management Systems (aLMS) have not yet reached the eLearning marketplace to provide life long professional development. Existing difficulties to cope with generic learning processes cover methodological, technological and management issues. Based on our experience in aLFanet (IST-2001-33288), in this paper we review relevant issues arisen when developing an aLMS based on a pervasive use of educational standards (IMS-LD, IMS-CP, IEEE-LOM/IMS-MD, IMS-LIP, IMS-QTI). In particular, we present the aLFanet approach and comment on the consequences of applying such type of systems in real large-scale situations that take place at mega-universities like UNED.

1 Introduction

Personalized learning is no longer a research issue faced in the so called adaptive learning environments but a concrete challenge fostered by most reports focus on promoting the use of the information and communication technology (ICT) at higher education (HE) institutions focused on "the learning and the learner" [9]. The purpose here is not only to help "the learner to match his or her own needs for personal development" but also to provide "facilities for lifelong learning (LLL) to upgrade the skills of people with disabilities". This "student-centered approach" poses too many challenges to traditional HE institutions and distance teaching universities as well.

One key question to be answered is how to construct LMS that support the HE user-centered scenario. Most courses on current LMS hardly offer any information about which didactical methods and models they use. As far as adaptation is concerned, they just offer predefined settings for a particular course that turn out to be the outcome of extensive customizations. Nevertheless, if the user is central, courses are no longer the key issue but a concrete scenario where each user satisfies a particular set of learning goals. The problem exceeds the limited scenario of the course at hand and learners, their needs, backgrounds, learning styles and observed behavior when facing alternative learning situations become relevant. This also implies that those learning situations have to be explicitly managed throughout different courses.

As far as HE institutions are concerned, eLearning services are included in a wide variety of ICT services that cover many other relevant issues that could eventually affect user's behavior in a particular learning situation within a concrete course. These other applications could cover management of users (faculty staff, students, tutors, and administrative people), contents of varied nature (exams, study guides, calendars, bibliographic resources, videos, audios, etc.) and communication channels and means (e-mail, forums, news, radio, educational TV, IP telephone, etc.).

Taking all that into account in this paper we will discuss relevant issues to be supported by aLMSs, the aLFanet approach and some learned lessons from its evaluation, along with related problems at HE institutions.

2 Adaptive LMS and the aLFanet approach

Adaptation is a general term that conveys too many features. From our experience working at aLFanet project [7], we have come up with two intertwine definitions of adaptation in a LMS [8]. From an initial survey done at aLFanet project based on "focus group" methodology (with experienced users) it was highlighted that learners rely on questionnaires for adaptation based on pre-assessment. In particular, learners relate pre-assessment adaptation strongly to their level of knowledge and moderately to their learning styles and motivation.

However, adaptation based on a predefined learning design cannot be fully achieved since it is not possible to foreseen beforehand the different types of situation each particular learner can came across during the course execution. Therefore, it is needed to consider two types of scenarios, i.e., 1) predefined rules to manage foreseen situations and 2) dynamic responses generated with the data collected from users' interactions by modeling different elements involved in the learning process (learners, learning material, LMS services, etc.) and applying several machine learning [4] and collaborative filtering techniques [2]. The latter approach is applicable when there are hundreds of users and hundreds of courses supported by an open LMS [1]. The management of both types of adaptation approaches is highly complex and can only be afforded if both educational and technological standards are used [10].

The aLFanet approach relates to other projects, such as OPAL, OLO and KOD, which are intended to extend existing standards to support adaptive course delivery [3]. Nevertheless, our focus is to effectively combine runtime and design time adaptations in an open aLMS based on standards. Thus, apart from using IMS-LD to cover the dynamic behavior of the system, we provide an adaptive runtime environment which extends learning design (LD) adaptations, integrates other educational standards (IMS-CP, IMS-LIP, IMS-QTI, IEEE-LOM/IMS-MD) and gives access to control the corresponding feedbacks between design decisions and runtime interactions.

From the technological perspective, we have developed a flexible, open-source and extendable architecture based on Java technologies, multiplatform communication (SOAP, WebDav) and multi-agent systems (FIPA) standards [7]. The system architecture is described elsewhere [11] and consists of a decouple set of independent open source components available under GNU GPL license: aLFanet LD and QTI Author-

ing Tools, LD engine Coppercore, aLFanet adaptive and interaction packages under the OpenACS/dotLRN projects.

2.1 Adaptive full life cycle to support user-centered e-learning

Adaptation is not an idea that can be plugged in a learning environment, but a process that influences the full life cycle of learning [6]. If we analyze current LMS, working on learning environments is a complex process of four interrelated steps: design of the learning experience (based on objectives and learning activities), administration (i.e., management of all data including users' roles, access rights and services configuration), usage (i.e., actual use of designed activities on the learning environment within the class context) and auditing (i.e., authors get reports on the actual use of course design, namely descriptions on how users have performed on learning activities, in order to adjust course design).

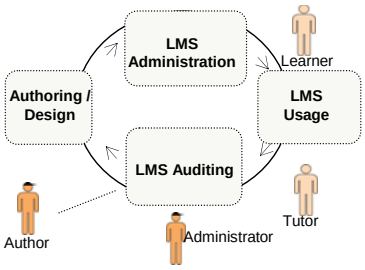

Fig. 1. aLFanet subsystems along the e-learning life-cycle

In aLFanet the four steps can be formulated as learner's driven tasks thanks to the combination of learning design and run time adaptations, which provide a learning scenario adapted to the particularities of each learner along the learning process. Central in the aLFanet adaptation process is the Design created in IMS-LD, which contains the logic for the pre-designed adaptation and provides the hooks and the information upon which the runtime adaptation bases its reasoning. The Design phase deals with the construction of contents, the organization of services and the preparation of learning activities within the LMS to achieve certain learning objectives. During Publication time (Administration) the runtime environment is prepared to provide an adapted experience to learners (i.e. interface personalization, services customization, publication of questionnaires to fill the user-profile, …). In turn, the Use phase focuses on the actual interactions of users (tutors and learners) with the contents and services available within the particular learning route built for each learner along the course. Dynamic adaptations based on the users' interactions (both individual and collaborative) are offered. The final step (Auditing) is to assess the actual use of learning materials and activities to feed back the author so that by means of design adjustments future learner's experiences can be improved.

2.2 Adaptive scenarios based on standards

Adaptive scenarios are meant to support different types of adaptations. Adaptive features can be managed at design time, when authors predefine learning activities, and at run time, when the system provides adaptive responses which takes into account users' interactions to solve situations that cannot be predicted at design time. It is important to note that system feedback to a particular user can be based not just on that user record (learning styles and preferences, knowledge level, ...) but on clusters of users with similar individual characteristics. To facilitate the production, management and re-usability of adaptive scenarios the pervasive use of standards is essential.

aLFanet provides new information (in terms of dynamically generated web pages) according to individual and collaborative user's needs. Methodological adaptations are twofold. First, alternative learning paths (pedagogical models described with IMS-LD) for different types of users (user models described with IMS-LIP) can be pre-coded at design time. Second, in order to lessen the work load at design time, the system manages two pedagogical scenarios to provide run time adaptations: lack of knowledge and high interest level. To this, a recommender subsystem launches a recommendation when any of these scenarios are detected. In turn, dynamic adaptive assessment (questionnaires described with IMS-QTI) is provided by a rule-based selection and ordering of questions for the relevant items bank, considering the particular user profile (metadata integrated in the LD). Finally, adaptive presentation uses the user model. Moreover, IMS-CP defines a standardized set of structures to collect reusable content objects and packages the materials produced at the authoring tools. In short, personalized learning in aLFanet comes from the combination of advanced learning methods specified at design-time in terms of IMS-LD and adaptive interaction supported at runtime by user modeling based on machine learning [5].

To support this approach we have addressed several related issues. Firstly, to develop the instructional strategy that promotes active and adaptive learning [5]. Secondly, to overcome the practical problems that arise in dealing with design solutions, namely, their mapping and building. To this, we have developed IMS-LD templates to facilitate the management of different aspects These templates use the typical instructional arrangements for concept learning, assumed to be generic and applicable for any situation across problem domains. Thirdly, our experiments at pilot sites have shown another conceptual and practical problem, which is to understand and manage the conceptual meaning of design and run time adaptive features. In this respect, we have defined a methodology to cope with this type of scenarios to focus design on adaptive features and to illustrate how adaptive features can be used at runtime.

3 A course experience in aLFanet

aLFanet covers the full life cycle of eLearning for adaptive course delivery through an educational model platform independent and a flexible and modular architecture based on educational standards and open source developments. Three different roles are identified in the system along the eLearning life cycle. First the *Author*, who is the content expert and the responsible of designing reusable, platform independent, ob-

jective-based and adaptive courses following a methodological approach based on the integration of educational standards in a four step process (i.e. course material, metadata, pedagogic template and adaptive scenarios). Specifically, to create adaptive courses the following steps are followed in aLFanet: (1) creation of content materials, (2) creation of IMS-QTI assessments to (a) collect users' data and (b) measure the degree of understanding by the learner via dynamic questionnaires that can be adapted to each learner depending on the user's characteristics and course behaviour, (3) definition of the IMS-LD course structure and organization according to some pedagogical template, (4) addition of rules for adaptation using the information derived from IMS-QTI questionnaires and IMS-LIP users' profile, (5) adding metadata to trace and identify usage patterns based on the actual interactions of the learners, and (6) generation of the complete course package (IMS-CP) that contains both the course definition and the course resources.

Once the XML specification of the course is done by the author, it has to be published in the aLMS. The *Tutor* of the course (if no tutor exists, someone with administration rights) enters aLFanet and uploads the course design. Next, the learners and tutors have to be assigned to the course just uploaded. Moreover, based on the characteristics of the context of each particular run of the course (i.e. learners, tutors, institution, previous experiences, …) the tutor may decide to configure new services (e.g. forums, folders, …) and/or predesigned recommendations or motivational messages to complement the design defined by the author (who think on ideal rather than on particular situations). Moreover, at runtime the tutor plays the role of a course assistant, giving support to learners.

In turn, *Learners* receive an adapted educational experience depending on the user model and the course objectives. Only the activities relevant for the learner at each particular situation, context and background are shown. Each one implies the usage of different learning objects and different services. Nevertheless, the system also provides run time support to learners via free-to-follow recommendations.

3.1 Standards interoperability

Adaptive features can be technically implemented in aLFanet with the use of the educational standards (see above). The starting point is the course flow defined by the author, which specifies the different parts of the course, the conditions to go on to the next part, the individual and group work activities, and the evaluation criteria.

IMS-QTI questionnaires are key elements in the course flow because i) they allow gathering information about the user profile (IMS-LIP), as well as the interests and background in relation to the learning objectives, and ii) they follow the learning progress through intermediate assessments and assess the learners' performance at the course milestones. From adaptation point of view, it is very useful to know in which materials the learner has weakness to produce recommendations in order to overcome such weakness. However, IMS-QTI questionnaires generate score values according to item definition, but the information about the required score for passing an exam lies in IMS-LD design. Therefore, to manage the scoring variables within the learning design, they have to be created first at item definition time. The scoring variables are

synchronized with the LD engine during course execution by defining a set of properties (e.g. scoring variables, list of tests passed, results from users' profiles questionnaire, flags to know if a submodule is passed) and a set of conditions (if-then) to differentiate the different learners' profiles, to hide or show certain activities, and to be aware of the modules passed. For instance, the following XML specification taken from the UNED pilot site course ("How to teach through the Internet") shows how the result from the profiles questionnaires determines which learning activities are to be shown to the learners belonging to this profile:

```
<imsld:if>
 <imsld:is>
   <imsld:property-ref ref="MyLearningStyle"/>
   <imsld:property-value>Deductive</imsld:property-value>
 </imsld:is>
</imsld:if>
<imsld:then>
 <imsld:hide>
  <imsld:activity-structure-ref ref="LOb1_Inductive_AS"/>
  <imsld:activity-structure-ref ref="LOb2_Inductive_AS"/>
 </imsld:hide>
 <imsld:show>
   <imsld:activity-structure-ref ref="LOb1_Deductive_AS"/>
   <imsld:activity-structure-ref ref="LOb2_Deductive_AS"/>
 </imsld:show>
</imsld:then>
```

Moreover, metadata (e.g. objective, learning style) are also needed in learning objects to select the most appropriate ones for each learner at each situation. As an example, learning objectives can be specified for learning objects in IMS-MD:

```
<imsmd:catalogentry>
   <imsmd:catalog>objective</imsmd:catalog>
   <imsmd:entry>
      <imsmd:langstring>Text describing objective
      </imsmd:langstring>
   </imsmd:entry>
</imsmd:catalogentry>
```

Properties and if-then-else rules could be too rigid if they are used by itself, but provide solid methodological hooks when complemented with dynamic analysis of interactions and on the fly recommendations.

3.2 Evaluation results

The system has been evaluated at four different pilot sites: "Spanish course for German Learners" (KLETT), "Environment and Electrical Distribution" (EDP), "How to teach through the Internet" (UNED) and "Communication technology" (OUNL). During the evaluation process (done by 111 users: 22 at KLETT, 28 at EDP, 40 at UNED and 21 at OUNL), both strengths and weak points were detected in aLFanet system. As strengths (compared to existing LMS known by the users) , students mention: 1) dynamic adaptation and recommendations supplied; 2) flexibility of task order; 3) residing on the internet (i.e. all information is available and can be updated and accessed); 4) variety of different exercises and assessments; 5) good guidance and feedback by the use of tests (i.e. interactivity and direct self-assessment of the level of understanding of the course material); 6) course material is adapted at each

personal learning profile. On the contrary, authors asked for 1) improvement and integration of the authoring tools, and 2) more documentation explaining how to implement different adaptive scenarios.

The outcomes from evaluation activities at use phase were: 1) the effectiveness (which measure how aLFanet features facilitate the learning process to students) of the LMS is rated positive (i.e. it is possible to reach the learning objectives, obviously depending on the quality of the course contents); 2) the efficiency is rated less positive (most participants suffered performance problems); 3) the usability and navigation using the current interfaces was low rated (the possibility of defining different presentation templates may help to fix these problems in the future).

Some of the learned lessons from the evaluation activities are as follows: 1) the design phase is experienced as a complex task and the effectiveness of the design process is improved with a design methodology (authors were only able to design the course when the methodology was provided in terms of the LD template), 2) defining the adaptations within a course still needs technical knowledge and skills in order to successfully orchestrate the course flow, 3) experiencing adaptation requires an open design that provides diversity in learning materials and open learning paths, 4) the user characteristics considered to provide adaptation (cognitive modality, learning style, interest, knowledge level, level of activity and similarity between learners) were found useful to provide an adapted response to each learner.

4. Conclusions

Most HE institutions are improving their ICT support, including e-learning services, with the aim of developing user-centered scenarios which support a more integrated and personalized provision of ICT services, especially in mega-university like UNED [8], which has over 160000 students enrolled last year.

Because of the increasing number and variety of services that could cause problems of usability and accessibility, and the interoperability required to provide diverse functionalities adaptive services are becoming a required support. The key questions are what?, how? and when? those services have to be delivered to each individual with personal and framework changing conditions. In particular, learners evolve while they are learning and their personal situations can be of varied nature. To answer those questions it is required to manage features of individual and group profiles, contents, devices, interaction modes, and their relationships with each particular ICT service. This is precisely what the aLFanet system provides but circumscribed to e-learning courses and in a R&D European project environment, where users are expected to accept difficulties in using authoring tools, performance problems due to a decouple system architecture (which, in turn, has provided a set of available open-source independent components), lack of knowledge in dealing with alternative learning templates and usability and navigation problems.

In particular, the aLFanet approach consists of an adaptive LMS based on a pervasive use of educational standards (IMS-LD, IMS-CP, IEEE-LOM/IMS-MD, IMS-LIP, IMS-QTI), which combines predefined rules for adaptations with dynamic responses on runtime based on the current learners interactions.

Based on the evaluation results of this project, more than a direct application of aLFanet at HE institutions the lessons learned are as follows: (1) inter-service user models based on standards are needed to facilitate any type of adaptation, specially if the user has special needs [12] they could not afford a repetitive process of providing basic information about their own needs for each new service (or course) (2) users' needs and preferences evolve over time and this relates very much to users' experience on available services (3) developing extensive specifications present serious difficulties when dealing with limited learning scenarios and therefore templates and interactive assistance tools should be provided, (4) monitoring and tracking facilities should focus on providing qualitative features related to the service at hand, and (5) personalized feedback to users should take into account a detailed description of users' needs and preferences, service and environment features.

References

1. Gaudioso, E. and Boticario, J.G. Towards web-based adaptive learning communities. In Artificial Intelligence in Education, Ed. by H.U. Hoppe et. al. IOS Press, (2003) 237-244
2. Mobasher, B. Web Usage Mining and Personalization. Chapter in Practical Handbook of Internet Computing Munindar P. Singh (ed.), CRC Press (2004)
3. Paramythis A., Loidl-Reisinger S., and Kepler J. Adaptive Learning Environments and e-Learning Standards. Electronic Journal of eLearning, EJEL: Vol 2. Issue 1, March, (2004)
4. Smith, A.S.G. and Blandford, A. ML Tutor: An Application of Machine Learning Algorithms for an Adaptive Web-based Information System. IJAIED Vol. 13, (2002)
5. Van Rosmalen, P., Boticario, J.G. Using IMS LD to support design and runtime adaptation. In Koper, Rob; Tattersall, Colin (Eds.). A Handbook on Modelling and Delivering Networked Education and Training. Springer Verlag, (2005)
6. Van Rosmalen, P., Boticario, J.G., Santos, O.C. "The Full Life Cycle of Adaptation in aLFanet eLearning Environment".Learning Technology newsletter. Vol:4.Oct (2004) 59-61
7. Fuentes, C., Carrión, M.J., Arana, C., Boticario, J.G., Barrera, C., Santos O.C., Van Rosmalen, P., Schmidt, J.A., Hoke, I., Barros, F., Canada, R. aLFanet D82 – Public Final Report, (2005) aLFanet public deliverables are available at: http://rtd.softwareag.es/alfanet/
8. Boticario J.G., Santos, O.C., Rosmalen P.Technological and Management Issues in Providing Adaptive Education in Distance Learning Universities. EADTU Annual Conf, 2005.
9. eLearningPR. Adopting a multi-annual programme (2004-2006) for the effective integration of Information and Communication Technologies (ICT) in education and training systems in Europe (eLearning Programme)
10. Santos, O.C., Barrera, C., Boticario, J.G., Gaudioso, E.. An overview of aLFanet: an adaptive iLMS based on standards. Adaptive Hypermedia and Adaptive Web-Based Systems. Springer-Verlag in Lecture Notes in Computer Science (LNCS 3137). pp 429-432, 2004.
11. Santos, O.C., Boticario, J.G., Barrera, C., aLFanet: An adaptive and standard-based learning environment built upon dotLRN and other open source developments. Foro hispano de .LRN y software libre educativo. Congreso de usuarios y desarrolladores de .LRN: Una iniciativa abierta de eLearning, Madrid, Spain, 2005.
12. Velasco C A, Mohamad Y, Gilman A S, Viorres N, Vlachogiannis E, Arnellos A, Darzentas J.S. Universal Access to Information Services - the Need for User Information and its Relationship to Device Profiles. In: Gulliksen J, Harker S, Vanderheiden G (eds), Special issue on guidelines, methods and processes for software accessibility. Universal Access in the Information Society, 3 (1), pp. 88—95, 2004.