# Defining adaptive learning design templates for combining design and runtime adaptation in aLFanet

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**Abstract.** Adaptive features are expected to improve the effectiveness of the learning process in online learning. Nevertheless, most current adaptive systems do not deal with combining design and runtime adaptations. To take advantage of this combination a new adaptive iLMS based on standards, called aLFanet, is being developed. The system includes: (*i*) an authoring tool to develop courses IMS-LD compliant, (*ii*) an adaptive engine based on a multi-agent architecture which is intended to cope with several adaptive tasks for various types of users (learners, authors and tutors), (*iii*) a set of advanced pedagogical scenarios that combine design and runtime adaptations to make the authoring of these type of adaptive courses feasible. In this paper we focus on the types of adaptations and the process we have defined to facilitate the construction of the adaptive scenarios.

## 1 Introduction

Despite the expected advantages of online learning there are some pending issues that prevent them from being presented as the best approach to solve some of the current problems of face-to-face learning. Specially, as an alternative to cope with the problems related to the lack of support to individual learners' needs. This is partly due to the fact that many online courses feature just two key issues: the lack of control over the user performance and the need to implement reusable and interoperable systems [3].

To clarify the state of the art of both issues a review of existing technologies and systems was done in the early stages of the aLFanet project. This analysis was needed to clarify the meaning of "active and adaptive learning" in a general iLMS and to fulfil user's needs in the light of a thorough review of the state of the art of related tools, research and developments. Moreover, an initial survey among project users showed the main adaptive features to be provided.

The result of the state of the art survey is twofold. On one hand, it is worrying to note that most LMS (WebCT, Blackboard, TopClass, Ingenium, Docent etc.) hardly offer any information about which didactical methods and models they use, nor is it possible to explicitly express them. Moreover, as far as adaptation is concerned, they just offer predefined settings that require extensive customisation.

Moreover, adaptive systems are the result of the evolution of three related areas: Intelligent Tutoring Systems (ITS), Adaptive Hypermedia Systems (AHS) and Computer Supported Collaborative Learning (CSCL) systems.

The main goal of the adaptive systems is to provide the user with efficient access to the site by first presenting the links and materials that could be of interest. To solve this problem they apply different forms of user models. In particular, they consider user, usage and environment data [9]. There are two approaches for developing these models. First, to apply predefined rules for situations that arise in the course of student interaction, which entails to know the situations beforehand [4], [5]. Second, to learn user models from the data collected from users' interactions. To this, several machine learning techniques have been applied [16]. The latter approach is applicable when there are hundreds of users attending some other hundreds of courses supported by an open LMS [7]. Precisely, this is the situation that aLFanet should address.

To cope with these issues a new approach based on standards for combining design and runtime adaptations has been developed. Active Learning For Adaptive interNET (aLFanet) is an IST Project (funded by the EC under the 5$^{th}$ Framework Programme, IST-2001-33288) that addresses the problem of effective adaptive learning. This project is related to others that are intended to provide the needed support to strengthen the convergence of adaptive learning environments and standard-based eLearning systems [12]. In particular, we focus on providing open and standard-based solutions to combine the two strands.

To present the advantages of this approach in this paper we describe its fundamentals and the project ongoing progress. Specially, we stress how we are dealing with adaptive scenarios, where the designer and learner needs are taken into account.

## 2 The aLFanet adaptive approach

The purpose of the aLFanet project is to provide an adaptive intelligent learning management system (iLMS) that consider two complementary types of adaptations. On one hand, advanced pedagogical models described in terms of standards (IMS Learning Design[1]), which cover the learning situations known beforehand that can be adapted by means of predefined rules. On the other hand, while interacting with the system, users provide a wide range of experiences that are unpredictable and depend very much on their profile (interests, needs, knowledge, preferences, learning style, etc.). From these interactions, similar profiles and experiences would come up and they can be used to support adaptive tasks to different types of users.

1 http://www.imsproject.org/learningdesign/

First, learners are provided with recommendation based on previous interactions. For instance, when the learner is working on the course materials and the system detects difficulties in completing a particular course activity, the learner is advised to consult additional information that turned out to be profitable for similar learners in resembling situations. In this respect, we have the problem of validating the recommendations provided to learners. To cope with this issue we consider a reinforcement learning approach to achieve unobtrusive and interactive recommendations [8], which is intended to overcome some of the open issues regarding the evaluation of the user's interest from their browsing activity.

Second, tutors in turn, when the learning design (LD) introduces this supportive, are given recommendations on how to support learners. For example, when the tutor organises a collaborative task the system provides automatic grouping of users based on their profiles.

Finally, authors, who are in charge of designing the course activities and materials, are provided with meaningful reports that show the progress of learners, e.g., the number of study hours for a given learner and activity.

From the modelling standpoint we differ from other approaches where the users' background, knowledge, objectives, and needs are hardly predictable [1]. On the contrary, in aLFanet we have concrete scenarios, explicitly described in terms of IMS-LD. These are made up of learning activities and materials, well known types of users with their corresponding roles (tutors, learners, moderators, etc.), relevant features to define users' profiles (learning style, knowledge, background, preferences, etc.), clear learning objectives to achieve and measurements (see below) to evaluate the effectiveness of the adaptive tasks.

Moreover, the aLFanet approach is related to recent projects, such as OPAL, OLO and KOD, which are intended to extend existing standards to support adaptive course delivery [12]. Nevertheless, our focus is to effectively combine runtime and design time adaptations in an open iLMS based on standards. In this respect, apart from using IMS-LD to cover the dynamic behaviour of the system, we are providing an adaptive runtime environment which extends LD adaptations and give access to control the corresponding feedbacks between design decisions and runtime interactions. More specifically, we are adopting an open approach to both issues. On one hand, we use LD templates to extend the adaptations of IMS-LD (see section 5) to cope with the runtime adaptations. On the other hand, the runtime adaptations are supported by a multi-agent architecture, which provides user modelling based on domain independent adaptive tasks [14], [7].

The idea here is to try to reduce the gap between design and runtime decisions. Nowadays, runtime decisions are supported by tutors (when available), and there is no a standard way for adjusting runtime decisions based on runtime feedback. Moreover, detailed design of contents and adaptation of the course based on the learners' interactions tend to be (too) expensive because of high development costs or high delivery costs through extensive support.

To conclude, we have to clarify that, considering the purpose of the work presented here, we prefer to differentiate between runtime and design time adaptations, instead of just referring to other categories focus on how the adaptation affect users (adaptive course delivery, content discovery and assembly, and adaptive collaboration support [4], [12]).

In the following sections, after introducing the use of standards in the aLFanet architecture, we describe the identification and management of adaptive features. In particular, we describe the process we have defined to facilitate the construction of the learning design templates that takes into account both types of adaptive features.

## 3 An iLMS based on standards

From the very beginning of the project, we knew that we could not achieve our objectives unless we benefit from the integration of existing standards, not solely from the educational point of view but also from the technological perspective.

Regarding the learning technology specifications, and as anticipated above, the IMS-LD[2] allows to describing the advanced pedagogical models dealt with in aLFanet. IMS-LIP[3] is used as a solid start for building the user model and exchanging it with different components. IEEE-LOM[4] describes the learning resources, which facilitate to provide the most appropriate learning resource to a certain learner in a certain situation. IMS-QTI is used to generate questionnaires to gather both initial data and results from evaluations, which are essential to the adaptation approach used. IMS-CP[5] defines a standardized set of structures to collect reusable content objects that are used to provide interoperability with different LMS.

From the technological perspective, we decided to develop a flexible and extendable architecture based on Java technologies that facilitates the integration, as aLFanet services, of 1) open source developments, such as CooperCore[6] (an IMS-LD engine developed by OUNL based on EJBs) and dotLRN[7] (a web application for supporting course management, online communities and collaboration developed by MIT and further extended at UNED), and 2) internal developments, such as an IMS-QTI interpreter and a Contents' Server developed by SAGE, and the Adaptation Module, a multi-agent architecture developed by UNED that includes JADE[8] agents and Lisp Agents with THEO maintenance truth system, and communicates with the modeling subsystem where the machine learning algorithms are implemented. These agents use FIPA-ACL[9] as communication language.

aLFanet LMS is developed under a J2EE[10] application server. The Security layer includes a JAAS[11] module to control the access to the application using JCA[12]. The Presentation layer builds the user interface using TrAX[13] to apply the transformations described in XSLT stylesheets to the XMLs responses produced by the different ser-

2 IMS-LD IMS Learning Design http://www.imsglobal.org/learningdesign
3 IMS Learner Information Package - http://www.imsglobal.org/profiles/index.cfm
4 IEEE Learning Object Metadata - http://ltsc.ieee.org/wg12/
5 IMS Content Packaging Specification – http://www.imsglobal.org/content/packaging/index.cfm
6 CooperCore - http://www.coppercore.org/
7 dotLRN - http://dotlrn.org/
8 Java Agent DEvelopment Framework - http://sharon.cselt.it/projects/jade/
9 FIPA ACL Message Structure Specification - http://www.fipa.org/specs/fipa00061/
10 Java 2 Platform Enterprise Edition - http://java.sun.com/j2ee/j2ee-1_4-fr-spec.pdf
11 Java Authentication and Authorization Service - http://java.sun.com/products/jaas/index.jsp
12 J2EE Connector Architecture - http://java.sun.com/j2ee/connector/

13 Transformation API for XML - http://xml.apache.org/xalan-j/trax.html

vices according to the corresponding DTD. This flexibility makes possible to adapt the user interface depending on each learner's user model. The Dispatcher implements different protocol interfaces that allows to integrating the different services of aLFanet. In particular, a JAXM interface (which implements SOAP messaging) has been defined for integrating the new Java developments. A Tracker facilitates the data gathering from the request dispatched to build the user models needed.

Furthermore, an authoring tool has also been developed by ACE-Case to facilitate the design of courses IMS-LD compliant. It communicates with aLFanet Common Repository via WebDAV protocol.

Based on the above standards, technologies and components, a first version of aLFanet has been built. The next figure shows the course area of a learner, where the Instructional Design specified in the LMS-LD is integrated with the run-time environment that supports it.

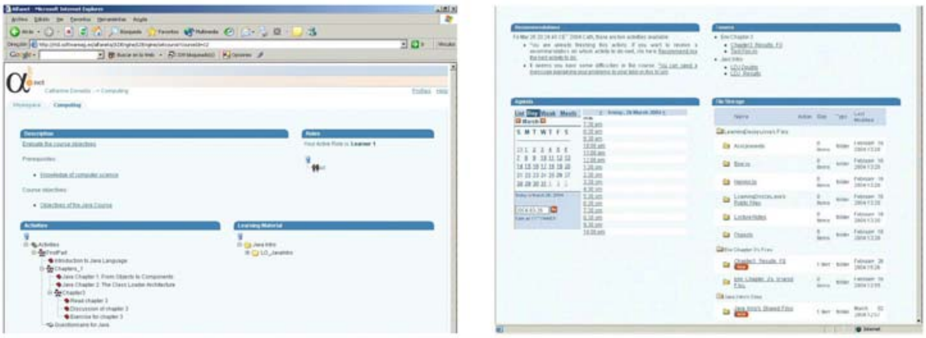

**Fig. 1.** aLFanet course area. It shows how the specifications given in the IMS-LD in terms of objectives of the course, activities to do and roles to perform (left) are integrated in the runtime environment where different services (e.g. agenda, fora, file storage) and recommendations are provided. Portlets are used to group them.

Let's be Catherine for a moment. She logged in aLFanet, entered her workspace area where an integrated view of the contributions of other users in the different courses where she is enrolled was provided and accessed the space area corresponding to the Computing Course, as shown in Figure 1. This course is defined according to an instructional design IMS-LD compliant. The author had probably defined different learning routes for different types of users. Now, at run time, the system has selected the appropriate one to Catherine, depending on her Learning Style and User Model, which are accessible from the top left of the page (Profiles link), and her course objectives, that she should have filled in when starting the course from the link on the top (Evaluate the course objectives). Each activity implies the use of different Learning Objects and different services, which are offered in the corresponding portlet. For instance, the activities included in Chapter 3 told the learner to read some learning material (*I_Java_intro*), upload a personal work to *Chapter3_Results_FS* folder of the File Storage Area and start a discussion about its solution in *Chapter3_Results_FO* forum. Nevertheless, the system also provides run time support to Catherine and two recommendations are provided to Catherine at this particular moment. One relates to complementing the instructional design. The other relates with the analysis of the interactions done by Catherine in the course. In any case, Catherine is not forced to follow any of the recommendations.

This standards-based architecture gives the appropriate support to provide the adaptation features in aLFanet.

## 4 Users' requirements and adaptive features

An initial survey among target users was conducted to identify the main adaptive features to be provided. This analysis was needed to clarify the meaning of "active and adaptive learning" in a general iLMS like aLFanet and to fulfil user's needs in the light of a thorough review of the state of the art of related tools, research and developments [6]. The inquiry, having in mind the attention to be paid to innovative or latent needs, was based in "focus group" methodology (with experienced users), since the quality and variety of the needs captured was of major importance. The details of this analysis are described elsewhere [13]. What follows are some general concluding remarks related to the adaptive issues:

- Users want to have control over the adaptive features: They want to be permanently informed (to take advantage of their profile analysis) and do not want to loose their freedom of choice.
- The importance given to communication and collaboration between users (clearly stated in the high valuation received by all the correlated needs) lead us to think we face a critical success factor (CSF) for supporting these activities with appropriate adaptive tasks.
- Learners rely on questionnaires (tests, checklists) 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.

The study includes a list of over 100 concrete functionalities to be provided. Here we illustrate the type of functionalities with some examples:

- There must be a tool allowing the learners to perceive the evolution along the course.
- The system must help learners to select the units of learning needed to fulfil their objectives.
- The system must allow learners to select the route that better fits their learning style.
- The systems must establish a learning route adapted to each learner according to an initial assessment, adjusting the route with complementary assessments.
- In the case of wrong answers or failure in the proposed activities, the platform must allow and suggest the learners the use of alternative learning activities.
- The system must be able to detect risk situations and automatically launch some kind of warning.
- The system must generate groups and subgroups according to criteria specified by tutors and using information stored for each learner.
- The system must help the tutor in detecting useful information for learners, such as the most relevant learning objects, the most difficult concepts, the most frequently asked concepts, etc.

These functionalities were grouped into different categories (individual work, content interaction, interaction between learners, learners-tutors, etc.), which served to come up with the final system use cases.

In the following section we focus on describing the support we have developed to construct LD scenarios that consider learners' and authors' needs when dealing with a diverse set of adaptive features.

## 5 Adaptive scenarios

aLFanet is being developed to provide adaptive and personalised educational services to learners. In particular, the first system version (P1) follows from the users' requirements and functional specifications and includes a usable LMS that assures overall project goals. aLFanet provides user models that support different adaptive tasks, such as adaptive presentation, navigation and collaboration, and intelligent class monitoring. This means that aLFanet provides new information (in terms of dynamically generated web pages) according to the individual and collaborative user's needs. For self-learning scenarios the adaptation is based on users' personal information (learning styles, level of knowledge, learning preferences, etc.), and it is complemented with information derived from learned clusters of users with similar individual characteristics. The latter is supported by collaborative filtering techniques [11], [2]. For collaborative settings there are adaptive tasks to support explicit relationships between learners/helpers/tutors (contact with students with similar characteristics, access to relevant comments or materials sent by other learners, collaborate with a particular workgroup, etc).

In short, the key feature of personalised learning in aLFanet comes from the combination of advanced learning methods specified at design-time in terms of learning design standards and adaptive interaction supported at runtime by user modelling based on machine learning techniques [17].

From the learner's perspective aLFanet provides a combination of active and adaptive learned-centred scenarios where individual and collaborative activities will be provided to cover learner's needs and preferences.

From the pedagogical designer's viewpoint aLFanet facilitates the specification of active and adaptive learning scenarios based on effective learning design templates and feedback obtained from real learners' experiences with these scenarios.

To support this approach we have addressed several related issues. First, to develop the instructional strategy that promotes active and adaptive learning [17]. Second, to overcome the practical problems that arise in dealing with design solutions, namely, their mapping and building. To this, apart from following the basic instructional arrangements for concept learning [10], we are developing IMS-LD templates to facilitate the management of different aspects: concept definition, concept classification and casual-effect understanding. Later on we comment on the concept definition template.

Thirdly, our experiments at pilot sites with the first version of aLFanet have shown another conceptual and practical problem, which is to understand and manage the conceptual meaning of the twofold variety of adaptations, namely design and runtime adaptive features. In this respect we have enriched the initial LD templates, which were focused on general concept learning issues and we have defined a methodology to cope with this type of adaptive learning scenarios. The purpose here is of varied nature:

- To clarify the conceptual complexity in dealing with design and runtime adaptations.
- To focus design on adaptive features and to illustrate how adaptive features can be used.
- To improve the construction and maintenance of adaptive learning scenarios.

Furthermore, our purpose is not solely to facilitate the construction of adaptive LD scenarios that take into account runtime adaptive task but to provide feedback to authors with sensible reports of the course based on learners' interactions, and by comparing the design and the expected results with the actual use and performance [17].

### 5.1 Building adaptive learning templates

We focus on how to extend an LD template to deal with design and runtime adaptations but it is out of the scope of this paper to comment on the details related to the general guidelines to develop instructional design templates [10]. Another remark is that, although we are dealing with IMS-LD due to its capabilities to cover users' behaviours, the following process is described in a general way, without mapping the required elements to their corresponding labels (with the exception of the provided examples).

The process consists of a sequence of steps with increasing levels of details and possibilities for adaptation. The starting point is to develop the skeleton of the IMS-LD template (e.g., a design template for concept learning) and to perform a *differential analysis* that guarantees the identification of the following LD features:

- *Users' characteristics*: level of knowledge (e.g., beginners, advanced), learning style (e.g., inductive, deductive), cognitive modality (e.g., visual, verbal), interest level, preferences, etc.
- *Course characteristics*: learning tasks (e.g., concept definition, concept classification, causal-effect understanding), learning objectives (e.g., "Given … circumstances… learners should be able to… distinguish… in order to meet the following level of performance… measured by…), instructional tactics (e.g., inductive presentation, deductive presentation, exercising, feedback…).
- *Users' group characteristics*: information about users' groups who have been explicitly grouped by the designer. Their characterizations cover course and users' characteristics. The concept of groups depends very much on the learning tasks and instructional tactics and it is omitted in self-learning scenarios.

Users' characteristics in aLFanet are initially obtained from questionnaires, within the pre-assessment stage, and they are subsequently adjusted by means of learned knowledge from users' interactions and additional assessments based on IMS-QTI tests.

Note that the course, users' and users' group characteristics provided in the first step are general elements from the pedagogical standpoint and are drawn from the basic guidelines to develop LD templates. The intention here is to provide general types of templates that can be re-used in a wide variety of learning courses.

The second step, called *material analysis*, is an additional level of specification to state explicitly additional characteristics of learning objects and services, which are strongly dependent on the course domain and the system level.

- *Learning objects (LOs)*: apart from the LOM features (e.g. Type: theoretical, practical, assessment; Difficult level; Interactivity level; Quality level…), we have identified specific features that can be used in runtime adaptations. So far we are using: interactivity level, users' comments, users' valuation, users' categories and designers' categories.
- *Course services*: services within *environments* which coincides with e-learning resources, i.e., forums, news, calendar, document area, bookmarks, FAQs, comments, surveys, etc. They also include interactivity level, users' comments, users' valuation, users' categories and designers' categories.

The above two steps are focused on LD. On the other hand, the third step, called *situated analysis,* introduces the concept of "learner situated in a course context". This is meant to consider extra features from the runtime environment which are out of the scope of the IMS-LD.

- *Interaction item (II)*: constructed items by users, e.g., a particular user's comment on a LO.
- *Interaction event (IE)*: users' interaction events, e.g., messages' read through a forum.
- *Learning item (LI)*: it covers II and LO and their relationships.
- *Link item*: it is intended to establish explicit relationships between two LI.
- *Recommendation item*: recommendations provided to users.
- *Evaluation item*: it represents the results from QTIs tests.
- *Sessions*: they usually reflect the concept of a running class.
- *Navigation path*: this is the most basic information that can be used to infer any other relation between different items at runtime.

With these extra features we control the recommendations given to learners, the management of the results of the users' evaluation, the identification of recurrent navigation paths, new relationships provided by learners' between learning items, etc. All of them are characteristics of interest that are included and managed by the adaptation module.

## 6 Conclusions and future work

Most current adaptive systems do not deal with combining design and runtime adaptations. In fact, there is a gap between design and runtime decisions. The former are mainly supported by tutors while the latter are provided by authors. The problem here is that there is no system support to get feedback from runtime interactions to consequently adjust design time decisions. aLFanet is intended to fill this gap through design and runtime adaptive tasks in an open and flexible system architecture based on educational and technological standards. Nevertheless, there are other related projects intended to extend current standards to control the adaptive behaviour of the system [12].

With this goal in mind in this paper we have discussed the type of adaptive features considered and the sequence of steps we have defined to construct learning design templates that combines design and runtime adaptations.

At the moment the first system version has been delivered and evaluated at different pilot sites. This version includes the whole system architecture, i.e., the authoring tool, the QTI interpreter, the IMS-LD interpreter, the interaction module and the adaptation module. From this evaluation follows the necessity to provide LD templates that facilitate the management of both types of adaptations. The next milestone is to provide, by July 2004, the second prototype, which will include the adaptive tasks.

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