Towards an open framework for adaptive, agent-supported e-learning

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Towards an open framework for adaptive, agent-supported e-learning

Peter van Rosmalen, Francis Brouns, Colin Tattersall, Hubert Vogten, Jan van Bruggen, Peter Sloep and Rob Koper

All authors are employed at the Educational Technology Expertise Centre (ETEC) of the Open University of the Netherlands. Address for correspondence: Peter van Rosmalen, Open University of the Netherlands, P.O. Box 2960, 6401 DL Heerlen, The Netherlands. E-mail: peter.vanrosmalen@ou.nl.

Abstract

E-learners require activities and content based on their preferences and prior knowledge, not merely fully static, page-turning sequences. In this paper we present a framework that integrates and supports two approaches towards adaptation to the learner needs – design *and* runtime adaptation. The framework is based on IMS Learning Design (IMS LD). IMS LD offers a semantic notation to describe an educational scenario in a formal way. At design time a teacher or a design team can create or inspect a learning design model and use it in multiple courses. At runtime a tutor *or* agent, an autonomous piece of software, can interpret a learning design and students' progress and subsequent take action while a course is in progress, e.g. make suggestions to learners. We will discuss the study that lead to the framework, and explain the role of IMS LD and the promising role of agents in adaptive e-learning.

Keywords

E-learning; adaptive e-learning systems; learning technology standards; IMS Learning Design; agent technology.

Biographical notes

Peter van Rosmalen has been active in educational technology since the early eighties both as consultant and in a variety of research projects around authoring tools, simulations, computer supported cooperative learning and knowledge management. In 2000 he was co-founder and director of a company in e-learning and knowledge management. Since 2003 he is researcher at ETEC. His research focuses on the use of agents in electronic learning environments. In particular how agents can help tutors to establish effective and efficient learning related interactions without increasing their workload.

Francis Brouns graduated from Wageningen University (Biology) and obtained a PhD in Agriculture at the University of Aberdeen. After returning to the Netherlands she worked for an international association for distance learning. After that she moved to the Open University of the Netherlands as ICT Developer. The main activities are in development of innovative e-learning environments, with focus on new educational and ICT technologies, standards, development of the IMS LD specification, and the application of new technologies to create efficient and effective learning environments

Colin Tattersall studied Computational Science before working on his PhD at the Computer Based Learning Unit at Leeds University. He subsequently moved to The Netherlands to work for the R&D arm of one of the major Dutch telecommunications operators. There, he investigated new technologies in the area of sales and marketing support systems, publishing several articles and participating in technology dissemination and consultancy exercises. In the mid-nineties, he moved into the software industry, working as Product Manager for a company specializing in (XML-based) support systems for knowledge-intensive processes. In mid 2002 he joined The Open University of The Netherlands as an educational technologist, where his responsibilities cover work related to innovation in e-learning and learning technology standardisation.

Hubert Vogten studied Informatics before starting working for the Open University of the Netherlands. After an intermezzo of five year working for the EADTU as staff member he has been working the last couple of year for the ETEC R&D department as senior developer. For ETEC he was involved in the development of the IMS Learning Design specification and in the development of e-learning environments supporting this specification.

Jan van Bruggen, PhD, is an educational technologist at ETEC. Before joining the Open University of the Netherlands he was with the University of Amsterdam and a company pioneering the use of computers in education. His current interests are in computer-supported collaborative learning, the use of argument visualization in collaborative problem solving and the application of techniques such as latent semantic analysis in education.

Peter Sloep is a senior educational technologist at ETEC and lecturer in Educational Functions of ICT at Fontys University of Professional Education, School of Education. He studied biology at the Free University of Amsterdam (MSc 1978) and received his PhD from the University of Groningen (1983). Since then he has worked at the Open University of The Netherlands, first as a course developer, later to turn his attention to educational technology. His research interest include distributed learning systems, particularly the technical affordances – including specifications for interoperability - and social networks that are conducive to the emergence of a viable learning object economy.

Rob Koper holds a masters degree in educational psychology from Tilburg University, the Netherlands, and a doctor’s degree in educational technology from the Open University of the Netherlands. He was director of a company for teacher training, before he became the head of ICT application development (e-learning infrastructures and educational software development) at the Open University of the Netherlands. In that time, he was responsible for the development of all the educational computer applications of the Open University of the Netherlands, including the campus-wide information systems (e.g. StudyNet). Since 1998 he is a full professor in educational technology, specifically in e-learning technologies. As director of RTD into learning technologies he was, among other things, responsible for the development of Educational Modelling Language (the predecessor of IMS Learning Design). His research focuses on self-organized distributed learning networks for lifelong learning, including RTD into software agents, educational semantic web, interoperability specifications and standards.

Introduction

Adaptation to a learner's personal interests, characteristics and goals is a key challenge in e-learning. Three decades ago, in the early seventies, when the use of computers to capture and transfer knowledge began, the first knowledge based tutoring applications appeared in artificial intelligence, a relatively small but influential research area. In contrast to the first generation of computer assisted instruction programs, which offered simple automated instruction, intelligent tutoring systems [1] used artificial intelligence approaches to capture and deal with aspects of knowledge. Microworlds were shaped; built in various ways, but in general containing at least a detailed domain or expert model, a personal or student model and a knowledge transfer or instructional model. Persons involved in such a microworld can acquire new knowledge actively or in a guided way. They can immerse themselves in e.g. a device simulation or a programming world and practice their skills, as well as receive feedback depending on their progress. Alternatively, they can be guided through the study domain, while the best fitting chunks of information are presented (according to their knowledge level and the instructional methods applied). The intelligent tutoring systems that have been built to date are qualitatively strong but offer only small chunks of information and knowledge from small-scale worlds and thus have limited applicability. Moreover, in general they were all built from scratch, little or no effort being paid to reusability thus making it difficult to come to a more widespread use.

In this paper we discuss an open framework developed in the aLFanet project that addresses the learners' need for activities and content based on their preferences and equally takes into account the designer's and tutor's need for efficiency. ALFanet aims to develop new methods and services for active and adaptive e-learning. Active means that the learners are involved in applying (new) knowledge or solving problems. Adaptive means that the learners are provided with a learning design that is adapted to their personal characteristics, interests and goals as well as the current context. The project's target is to deliver a tested set of components for e-learning providers that will provide significantly enhanced individual learning, through technologies with adaptive features and approaches.

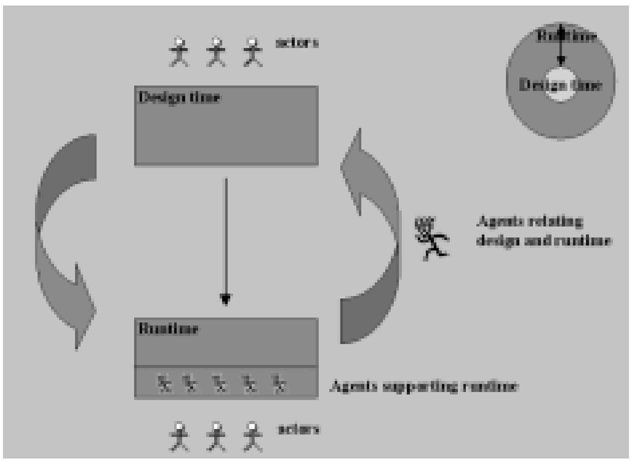

Figure 1. Relating design and runtime adaptation.

Within e-learning currently two approaches to adaptation are common. In the first, dominated by a strong tradition in instructional design, a team produces a detailed design of content, interaction and presentation. Within the design different options may be worked out for different learners based on *user* data, e.g. level, interest or learning style. The options for adaptation are prepared at design time and require limited, if any, interaction of tutors at runtime. The second approach is based on the assumption that author and tutor is one and the same person. The author designs the material. Next at runtime the author, now tutor, adapts the course based on a direct interpretation of *usage* data, i.e. how well the learners succeed and what questions arise. However, both approaches tend to be (too) expensive because of high development costs or high delivery costs through extensive support.

To enable the design of the framework, a study [2] was conducted of tools, technologies and methods that take into account and can support the outlined approaches in an efficient and effective manner. The next two sections give an overview of the results of this study and the most important conclusions. Next, the aLFanet perspective and framework is outlined and the validation of the approach in a first prototype is discussed. The paper closes with conclusions including an overview of further work to be done.

E-learning platforms and the options for adaptation

The overall e-learning market in Europe is in a very early stage of development. It is highly fragmented and has a low transparency, showing a wide array of products and services offered by many different types of suppliers. Many tools arose following the promise Internet offers to organize learning, teaching and education. Internet should allow for flexibility in delivery but also in learning, in time and place. It should also be easier to differentiate didactical models and scenarios depending on users' preferences. According to Hambrecht [3] the supply side of the global e-learning market currently comprises approximately 5,000 participants offering every imaginable method of e-learning.

In the context of aLFanet only those environments or tools are relevant that consist of at least content delivery and tutoring facilities via internet technologies. They should allow for personalised and active learning. Following Merrill [4] learning environments are effective if they are problem based and address the first principles of instruction for each phase of the activation-demonstration-application-integration learning cycle, i.e. learning is facilitated when:

- learners are engaged in solving real-world problems;
- existing knowledge is activated as a foundation for new knowledge;
- the instruction demonstrates what is to be learned rather then merely telling information about what is to be learned;
- learners are required to use their new knowledge or skill to solve problems;
- learners are encouraged to integrate (transfer) the new knowledge or skill into their everyday life.

It is important to note that Merrill does not see collaboration as first principle of instruction. In Merrill’s view collaboration is only one of many possible ways for implementing first principles. For the aLFanet environment we underline the importance of discussion and interactions with others. Learning is not just on a one-to-one basis with a student and information [5].
A review of systems (WebCT, Blackboard, TopClass, Ingenium Docent etc. [2, 6]) commonly used in universities and higher education showed two types of platforms. The first type takes a course as a basis, the second the organisation. Systems that take the course as basis (e.g. WebCT, TopClass) normally do not distinguish between teacher and author (course-developer). In this way they allow the teacher much flexibility but also assume that the teacher will create material. Systems that take the organisation as basis (e.g. Ingenium, Docent) have clearly defined and distinct roles. Content can be developed outside the system. All systems advertise themselves to be innovative and to offer new possibilities. The systems do stress the importance of content, but unfortunately for both types of systems there is hardly any information about which didactical methods and models are used and it is not possible to explicitly express them. As far as adaptation is possible it would require extensive customisation. Most of the systems do support collaborative learning tasks; however they do not allow imposing any specific scenario. They allow collaboration by merely providing the basic tools.

Currently, originating from research, a new generation of systems emerges, e.g. Edubox, that builds on an educational modelling language [7]. Edubox does not prescribe a learning scenario; instead every scenario can be modelled in EML [8]. EML is a formal language that allows a learning design to be described in a way so that automatic processing is possible.. EML allows to fully describing the teaching-learning process including integration of the learners’ and staff members’ activities, integration of resources and services used during learning and support for both single and multiple user models of learning. Every activity or piece of content can be personalized or made available for specific users. EML is accepted as basis for the IMS Learning Design (IMS LD) specification [9].

How to prepare a learning design is the main goal of any instructional design process, i.e. to construct a learning environment in order to provide learners with the conditions that support the desired learning processes. With regard to models that may sustain this process, van Merriënboer [10] makes a distinction between Instructional Systems Development (ISD) models and Instructional Design (ID) models. ISD-models have a broad scope and typically divide the instructional design process into five phases: (1) analysis, (2) design, (3) production, (4) implementation and/or delivery, and (5) summative evaluation. In such stage-models, formative evaluation is typically conducted during all phases. ISD-models provide guidelines and directions for performing the activities that form part of each of the phases. ID-models are less broad in scope and focus on the first two phases of ISD-models (i.e., analysis and design). They concentrate on the analysis of a to-be-trained skill in a process of job and task analysis and the conversion into a training strategy, or the design of a learning environment (often taking the form of some kind of blueprint) that is ready for production. If it comes to the analysis of to-be-trained skills and the design of learning environments, ID-models typically provide more specific guidelines and directions than ISD-models.

Despite these more specific guidelines it appears to be difficult to use these ID-models outside the context of specialized teams. Koper [11] summarizes the current practice in the following way. When teachers have to design or plan a lesson or course, there are several ways they can proceed. The majority of teachers employ an implicit design idea based on 'knowledge transmission'. When preparing a lesson or course they think about the content, the potential resources (texts, figures, and tools), the sequence of topics and how to assess the learners. In e-learning practice this results in a sequence of topics with dedicated content without a learning design that can be inspected or processed.

Adaptive e-learning systems and technologies

Web-based Adaptive Educational Systems (AES) are not an entirely new or unique kind of systems. Historically, web-based AES inherit from two earlier kinds of AES: intelligent tutoring systems and adaptive hypermedia systems. Traditionally, the problems addressed in AES were investigated in the area of intelligent tutoring systems (ITS). Intelligent tutoring systems use knowledge about the domain, the student, and about teaching strategies to support flexible individualized learning and tutoring. Adaptivity was one of the goal features of any ITS. Adaptive hypermedia is a much newer research domain. Adaptive hypermedia systems apply different forms of user models to adapt the content and the links of hypermedia pages to the user. Adaptive hypermedia research also includes e.g. information retrieval. However, the most applied examples are hyperspaces of educational material. The goal here is to guide the students through the material and show them the optimal path or the optimal content. This can be achieved in several ways. The most popular use is direct guidance, i.e. they offer the best page given the student's current knowledge and learning goal. This is done through adaptive link annotation and hiding (i.e. annotating the most suitable links and disabling a link, if a page is not yet ready to be learned). Brusilovsky [12] gives an extensive overview of what can be adapted. He describes a taxonomy with two main areas of adaptation i.e. adaptive presentation and adaptive navigation. Adaptive presentation includes text adaptation and multimedia adaptation. Adaptive navigation or link level adaptation includes direct guidance, link hiding, link sorting and link annotation, link generation and finally map adaptation.

Looking at existing examples of AES, three important issues arise, i.e. (1) the use of agents, (2) standards and (3) the types of user data available in web-based systems and how they are obtained.

Agents. Web-based technologies [13] in conjunction with multi-agent methodology form a new trend in modelling and development of learning environments. Multi-agent methodology has recently appeared as an alternative to conceive distributed learning applications. The main reasons for this are the evolution of multi-agent technology itself and the fact that multi-agent methodology deals well with applications where crucial issues, such as distance, cooperation among different entities and integration of different components of software, are found. Agents have proven to be useful in many different types of applications [14] from e-mail filters to traffic control. Still, researchers do not share the same vision of what agents are. The most common way in which the term agent [15] is used is to denote a (usually) software-based computer system with the following properties:

- *autonom*y: agents work by their own and have some kind of control over their actions and internal state;
- *social abilit*y: agents interact with other agents (and humans beings) via some kind of *agent-communication language*;
- *reactivit*y: agents perceive their environment, (which may be the physical world, a user via a graphical user interface, a collection of other agents, the Internet, or all of these combined), and respond in a timely fashion to changes that occur in it;
- *pro-activenes*s: agents do not simply act in response to their environment; they are able to exhibit goal-directed behaviour by *taking the initiativ*e.

Both weaker and stronger notions of agents are used. For our case it is probably more important to notice that the application of agents in AES not necessarily stops with the taxonomy described for adaptive hypermedia systems. For example Ayala [16] reports on agents that support the construction of knowledge. WebDL [17] includes agents to guide cooperation and communication among students and with lecturers. The new Learning Technologies Development Programme at the Open University of the Netherlands [18] will explore the use of autonomous agents to support tutors and others to perform their tasks more effective and efficiently e.g. by using natural language technology to answer questions [19] or assess essays [20].

Standards. Starting at the beginning of the nineties, steps were made to design and develop authoring systems for intelligent tutoring systems [21] and to deal with generic approaches, e.g. how to use a task and domain ontology [22] to support reusable components and how to use agent architectures, which enable agents (e.g. a learner modelling agent [23]) to be reused in different settings. Similarly for aLFanet, to enable an *open* framework, it is important to build upon existing standards. Current learning technology standards only allow for simple ordering and sequencing of resources (e.g. SCORM, IMS Content Packaging, and IMS Simple Sequencing [24]).
Only IMS LD, based on EML, adds to this the ability to integrate learning designs (instructional designs) to enable more advanced e-learning applications, e.g. to model competency based education, portfolios, collaborative learning and personalisation. It is a semantic specification, based on a pedagogical meta-model, which describes the structure and processes in a unit of learning. It aggregates learning objects with learning objectives, prerequisites, learning activities, teaching activities and learning services in a workflow (or better learning flow), which itself is modelled according to a certain learning design. IMS LD can be used to prepare a design and to communicate it between the different actors, teachers and agents, in the framework.

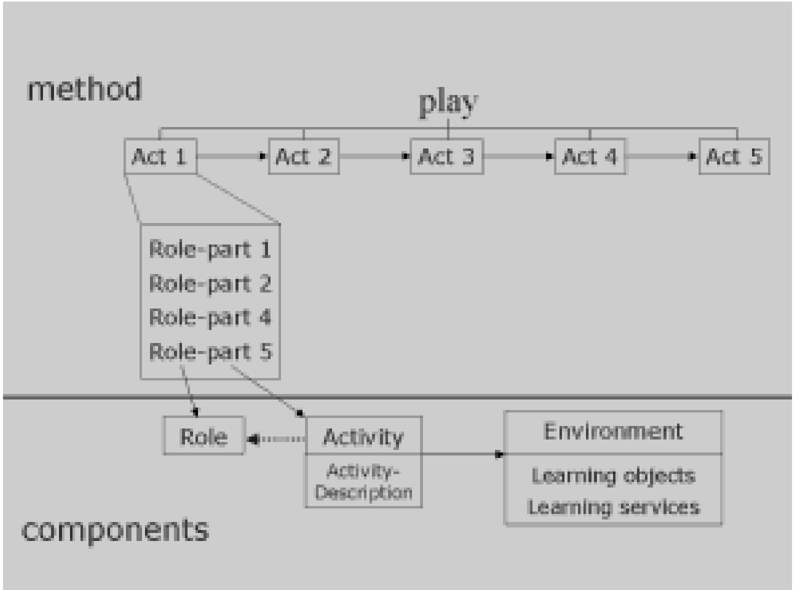

Figure 2. A schematic overview of a unit of learning in IMS LD.

This does not necessarily imply that an actor's internal reasoning deals with IMS LD. Suppose we have an actor that can assess an essay. The actor will only want to communicate about information on the activity that imposes the essay and the learner associated with it. The assessment itself will be based on the actor's internal knowledge. The actor could be a domain expert as well as a software agent applying text data mining algorithms.

User data. Originally adaptation would take place on user data e.g. goals, tasks, background, experience, preferences combined with their progress. However, based on the characteristics of the web user modelling is extended with data about the interaction with a system by monitoring the actual behaviour. A well-known example of this approach is the Amazon bookshop. It is based on a data mining technique called nearest neighbourhood or affinity grouping or clustering. Once customers are registered, a profile is composed of their interests and their behaviour i.e. the actual books ordered. The profiles are compared and clustered. The purpose of this is to give an individual advice to each customer, i.e. an advice to have a look at books that have been ordered by people with similar interests. This approach uses little knowledge about the topic involved; to a large extend it relies on the actual shopping behaviour of the customers. A wide range of possible tasks, each relying on different kinds of machine learning techniques (see [25] for an overview of techniques), exists that automatically can contribute to an e-learning environment: e.g. grouping of users in collaboration subgroups or identifying students who progress through their learning differently from their peer group members.

ALFanet perspective and architecture

In the introduction we started to formulate the aim of aLFanet, i.e. to develop new methods and services for active and adaptive e-learning. Next, we gave an overview of tools, technologies and methods in the context of the framework. In this section we look into detail into how the main requirements of the framework are fulfilled, we will discuss how we used an early prototype to check the validity of the approach and finally we will introduce the framework itself and the experiments planned.

The requirements of the framework can be summarized into three main categories, i.e. to which extent the framework:

(1) supports active and adaptive e-learning;
(2) is open both with regard to the use of different types of learning models and to new components, e.g. agents;
(3) supports the user in an efficient way.

Active and adaptive learning. The commonly used e-learning systems hardly offer any information about which didactical methods and models they use nor is it possible to explicitly express them. IMS LD offers the possibility to explicitly define the pedagogical model. Learners can be provided with a learning design that is adapted to their personal characteristics, interests and goals as well as the current context. Obviously, this requires that the framework includes the required services to execute a design, e.g. facilities for collaborative learning tasks. A learning design approach does not imply that everything can (or should) be foreseen. During the actual learning process a lot of unforeseen events can take place or specific support can be demanded. However, an explicit learning design makes it possible to interconnect the actions proposed following the results of the automatic monitoring of the learning behaviour and the specific support actions anticipated.

Openness. Open in this context we defined in two meanings. First of all the system should make it possible to express any kind of learning design and to execute it. As discussed earlier IMS LD should be capable of expressing this diversity. A successful execution will depend -as mentioned above- on the services integrated. Secondly, it should be possible to integrate new components, services and agents. Adding a new, general service at the design level is relatively straightforward. IMS LD functions as a high level wrapper to the service. At runtime it is mainly a technical issue, which we will discuss later in this paragraph. Adding agents it is more complex. Agents perform a certain task, that has to be allocated and coordinated and agents may need to communicate on the context of their task. This is achieved in the following manner. First, a task can be allocated by modelling the agent as a staff role and assigning the task to the staff role. Next, IMS LD can be used to coordinate its functioning by defining the appropriate conditions at the concerning level, i.e. activity, act or unit of learning (c.f. Figure 2 and [9]). Finally, the agent can query or parse a learning design for the required information, because a learning design can be read both at a semantic and a machine interpretable level. For example it can ask information on the current activity for a selected learner and its system log and subsequent compare the design with the actual results and report or give an advice on this. Openness at the technical level is strived at by using Java and a J2EE environment, allowing multi-platform applications, for the current implementation of the system and services. This does not preclude any other type of technology, which can be added by the inclusion and configuration of new service interfaces.

Efficiency. IMS LD enables the use of templates for and examples of different learning scenarios without the need for course developers or teachers to design them themselves. This facilitates the enhancement and promotion of (advanced) ID-models. During the actual course a tutor will be active to support the students. The role of the tutor is specified with IMS LD. In addition the tutor may want to intervene if unforeseen events occur. This will be easier in the case of an explicit and therewith inspectable design. Finally, because also agents can interpret the learning design they can be incorporated for many different types of tasks to support the tutor direct or indirectly by helping the learner.

Validation - a first prototype to validate the approach

The assumption underlying the use of IMS LD is that it can be used to represent learning scenarios in a way that both tutors and agents can operate on it. To validate the idea behind this approach a minimal learning scenario (c.f. figure 3 and 4) was designed, which involved the active participation of a tutor and two agents.

Narrative: In a course in Political Sciences students get -as soon as they have answered a number of questions- the task to read and comment upon an article:
- An agent that continuously monitors the student interactions assesses the level of the student. The agent triggers himself to finalize the assessment as soon as a set of questions is answered that is sufficient to determine the level. The agent notifies a tutor of the outcome of the assessment.
- As soon as the student level is known, the tutor decides on which topic the student should focus first.
- However, the actual material to study is selected by an agent that uses an external article database to select the best fitting article. As soon as the selection is made the agent notifies the student.

Figure 3. The narrative for the validation.

IMS LD is not explicit on how agents should be integrated; in our case it was chosen to model the agents as a staff role. The agents communicated with the other actors by sending a notification when they were finished. The resulting unit of learning was successfully executed in the e-learning environment Edubox to which two dedicated agents had been added.

Method: Agents Supported Education			
Play 1:	Activity 1	Role 1: Student	• Read and answer a set of questions
	Activity 2	Role 2: Staff - agent to score assessment	• Monitor the assessment • Score the assessment • Notify the tutor
	Activity 3	Role 3: Staff Tutor	• Select topic area for student
	Activity 4	Role 4: Staff - agent to select a resource from an article database	• Monitor • Select an article for the article database based on (level, topic) • Notify the student
	Activity 5	Role 1: Student read the introduction and the advised article	• Read the article

Figure 4. The main design of the unit of learning.

The framework

After the initial validation a final architecture has been worked out. The following diagram shows the the aLFanet framework, the technical architecture and the way in which IMS LD is positioned.

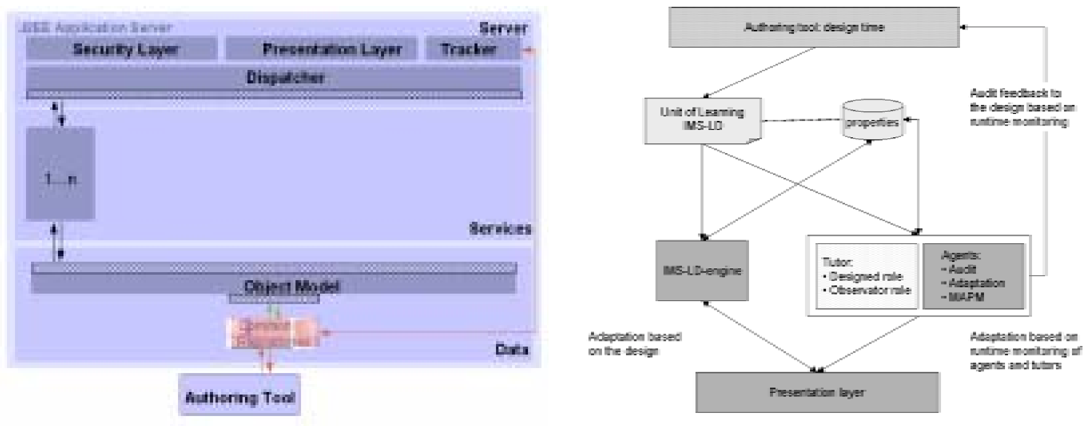

Figure 5. The aLFanet framework: (left) the technical architecture (right) 'IMS LD as communicator' in between the various services.

Authors use the authoring tool to create new IMS LD compliant courses, from scratch or based upon existing learning scenarios. After publication this results in a personalized unit of learning and a set of properties to capture the dynamic data related to the learner and the unit of learning. The IMS LD engine processes this into a learning scenario that can be presented and executed, i.e. with the required services activated. An Interaction Module will offer the facilities for the common collaborative tasks. The Learning Adaptation Module (LAM) provides the personalized guidance to the learner. For this purpose it uses different agents applying a suitable combination of machine learning algorithms to analyse the data gathered from the user interactions. Additionally, the MAPM module will offer support depending on the instructional model applied. As a consequence the tutor should benefit from a reduction of workload since the system will take over tasks. The Audit module will supply reports including an analysis of the difference between the design and the actual learning process. This will help the author to adapt their design if required. The agents -LAM, MAPM and Audit- and the tutor can if required for their tasks query the design or the properties.

The architecture is a three layer composition where:

- The *Server* layer is in charge of the user front-end, managing the application security, showing user interface and tracing user interactions.
- The *Services* layer is a group of services, which provide the application functionality and main logic. It is open to include new (types of) services.
- The *Data* layer comprises the data management and storage.
- The *Authoring Tool* is an independent component that allows the user (authors and editors) to create the courses.

The architecture offers an open framework in order to allow the integration of any kind of services, both in the first development and for future services. At first it will start the integration of the core modules i.e. the Interaction Module and the IMS LD engine, followed by the Learning Adaptation Module and the Audit Module.

Figure 6. A screen shot of the interface

Figure 6 gives a first impression of the interface as it is currently being developed. Two parts are of interest. The first is ‘Recommendations’. It contains both the suggestions automatically created by the system and those provided by the tutor for the learner. The second one is 'Roles' identifying the role the learner has within the current context; if appropriate the learner can switch to another role.

The actual system will be built in three steps. The first prototype will contain the authoring tool, the IMS LD engine and the Interaction Module and a first proof of concepts of the agents' modules (start of 2004). The second prototype will integrate the agents (mid 2004). The 'final' system will elaborate on the second prototype and address any technical issues pending. At each step a validation round is included with students from different backgrounds, company, private and university students, and in different domains, internet technology, language and waste management. The validation will mainly focus on authors, tutors and students and include a full cycle from course development, to actual use, to a course update.

Conclusions

The objective of this paper was to outline a framework for an e-learning environment that integrates new methods and services for active and adaptive e-learning. The proposed framework is based upon IMS LD. With IMS LD it should be possible to describe any design in a formal way. IMS LD will be used to communicate between the different actors, tutors and agents, in the framework. Additionally we introduced the first set of modules and agents that will populate the framework.

The first 'proof of concepts' of the approach was giving in a mock-up prototype. Obviously, the validation results of the real experiments will have to look into more detail whether the approach taken is successful. This will include questions on the usability of the approach but also the functional level e.g.:

- what types of interventions (and when) will be appreciated by the learner;
- whether the planned cooperation between humans and agents is successful and efficient;
- to which extent authors can successfully use IMS LD;
- whether IMS LD is sufficient to enable and structure the communication between the different actors.

At a later stage with the introduction of new modules and agents, it will be possible to validate the claim of openness for new components of the framework. For this it will be important to continue the analysis in which tasks agents can be of use and which techniques should be explored to enable them.

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