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MODELS, TECHNIQUES AND APPLICATIONS OF E-LEARNING PERSONALIZATION

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Abstract: In recent years Web has become mainstream medium for communication and information dissemination. This paper presents approaches and methods for adaptive learning implementation, which are used in some contemporary web-interfaced Learning Management Systems (LMSs). The problem is not how to create electronic learning materials, but how to locate and utilize the available information in personalized way. Different attitudes to personalization are briefly described in section 1. The real personalization requires a user profile containing information about preferences, aims, and educational history to be stored and used by the system. These issues are considered in section 2. A method for development and design of adaptive learning content in terms of learning strategy system support is represented in section 3. Section 4 includes a set of innovative personalization services that are suggested by several very important research projects (SeLeNe project, ELENA project, etc.) dated from the last few years. This section also describes a model for role- and competency-based learning customization that uses Web Services approach. The last part presents how personalization techniques are implemented in Learning Grid-driven applications.

Keywords: Adaptive Learning Content, Customized learning, Grid technologies, Learning Management Systems, Personalization, Simple Sequencing, Web Services.

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Introduction

Personalised learning presupposes high quality teaching that is adaptive to the different ways students achieve their knowledge and skills. Therefore, the teaching courses, curricula, and school organisations have to be designed in a way to reach as many students as possible with diverse needs and experiences for as much of the time as possible. Personalised courses actively engage the learners by providing teaching strategies and materials that appeal to the learners' knowledge and preferences etc. Since it would be costly and unfeasible for teachers to produce personalised courses that meet all of these requirements, the LMSs are of prime importance for education. Such systems allow for delivering information outside the traditional bound of a classroom situation, where learners are taught by a static one-fits-all approach. An educational system that responds to individual needs by creating a personal learning path enables individual students to experience excellence in his or her learning. Analytical study of key functional LMSs requirements such as adaptability, personalization, modality, possibility for record-keeping on student's performance, and usage statistics for the system as a whole has been done in [Pavlov et al.'04].

The personalization includes how to find and filter the learning information that fits the user's preferences and needs, how to represent it and how to give the user tools to reconfiguration the systems, in consequence, reconfiguration system could be part of personalized environment in some systems. The user modelling is the process of constructing (often computer-based) users models, background knowledge and users behaviour

representation, while the user model means all the information collected about a user that logs to a web site, in order to take into account her needs, wishes, and interests. Every LMS has its techniques to modelling his users so as to construct the user model or profile.

In general the personalization might be examined in the following aspects [Zheleva'05, Graziano et al.'03, Gibson et al.'02]:

- Personalization of the learning content, based on learner's preferences, educational background and experience, learning content tailored to individual learning style of the user;
- Personalization of the representation manner and the form of the learning content (for example, learning content in the form of the adaptive learning sequences of learning objects).
- Full personalization, which is a combination of the previous two types.

The following approaches can be used to apply the learning personalization:

- Personalization, controlled by the learner – It requires direct input of the learner's needs and preferences by filling question forms or by choosing options and alternatives.
- Personalization, based upon an existing user profile and meta-descriptions of the information content - In this case, the learners' preferences are stored in their profile.
- Personalization via searching for a correlation between the learners - Correlation is through the values of the attributes, describing the learner's profile. If there is a strong correlation, there is a possibility that the content for a given profile is suitable for applying to its close (adjacent) profiles.

Personalization in current Learning Management Systems tends to be concerned with remembering which courses the user is allowed to view and how they like their pages to be presented. In some cases users are able to edit their own profile; to maintain their personal calendar which keeps track of their event transactions; to subscribe to forums, etc. Observing the educational process as a whole, learners are very rarely allowed to get access to learning objects which are conditioned on a wide range of personal data including achievement, date/time and class code. In [Paneva'05] the author gives an overview of several methods for implementing personalization, which are exploited in several widely used LMSs in the recent years.

Learning Modelling and Profiling

The student model enables the system to provide individualised course contents and study guidance, to suggest optimal learning objectives, to determine students' profiles and the actual knowledge they have acquired, to dynamically assemble courses based on individual training needs and learning styles, and to join teachers able to provide support in terms of guidance and motivation and therefore to help the students with different backgrounds and knowledge levels to achieve their learning goals effectively on the Web.

The software developers face a number of challenges and difficulties when trying to model student profile and activities on real eLearning systems. The process of collecting student modelling data is time-consuming and requires the development of complex data structures to represent student's personal information, knowledge and behaviour in the learning domain. Once student data is collected, it must be converted into a format compatible with knowledge representation and reasoning systems to function as the input for the adaptive systems. Faced with these requirements, student modelling data is often stored in proprietary, hard-to-access formats that don't encourage reuse or distribution. In addition, in most cases the student models can only be used with the learning application, which it was developed for and when the application is changed or replaced they will be useless.

The student model needs to cover a certain amount of information that can be divided into two main groups:

- general student information such as learning goals, cognitive aptitudes, measures for motivation state, preferences about the presentation method, factual and historic data (personal information), etc.,
- information about student's behaviour in the learning domain such as overall competence level for the course, module competence level, concept competence level, module study time, test solving status, etc.

Naturally, student models "do not have to fully account for all aspects of student behaviour. In fact, we are interested in computational utility rather than in cognitive fidelity" (Self, 1990).

Learner model standards

The standards related to user model definition and representations are two:

- IEEE Public And Private Information (PAPI) - It specifies both the syntax and semantics of a 'Learner Model,' which will characterize a learner and his or her knowledge/abilities. [PAPI '02]
- IMS Learner Information Package (LIP) - It can hold information about the learner, including his progress and received awards. [IMS LIP '01]

In [Paneva'05] the author gives an overview of these main learning model standards.

Methodology for Development and Design of Adaptive Learning Content

The term "adaptive learning" means the capability to modify any individual student's learning experience as a function of information obtained through their performance on situated tasks or assessments. With the integration of the IMS Simple Sequencing Specification [IMS SS'03], SCORM [SCORM] allows the learning strategies to be translated into sequencing rules and actions, which are associated with the activities a learning experience consists of. The sequencing rules are based on learner's progress and performance and affect the availability of the learner is allowed to experience.

All learning activities can be associated with sequencing information defined by the content author. In run time, each activity experienced by the learner is associated with tracking status data, which may affect the overall sequencing process. This means that learners with difficulties in satisfying the learning objective should be able to experience additional activities (or repeat some of the activities) to improve their knowledge level and skills. Some restrictions concerning number of attempts and/or period of time for any activity could be set by the content author.

The process of defining a specific sequence of learning activities begins with the creation of a learning strategy for the achievement of the determined pedagogical aim/s. Learning strategy specifies types of learning activities and their logical organization (the activity tree) as well as the prerequisites and expected results for each activity. The rules for managing the instructional flow are the other important part of the strategy. Describing the rules by means of IMS SS elements and attributes the content author transforms the sequencing strategy into strategy for the activity tree traversal management. The author establishes an aggregation of learning objects associating leafs of the activity tree with appropriate Sharable Content Objects (SCOs). The outcome of this process is a content package. The imsmanifest.xml file of the package describes SCOs organization and their sequencing. The implementation of adaptive learning in given eLearning environment could be promoted and facilitated by providing of sequencing templates for the development and design of instructional flows.

The sequencing template describes the conceptual organization of the learning content as a sequence of template pages and provides the learning strategy implementation translating it into sequencing strategy. Such sequencing template can be used in different knowledge domains from different instructors who want to follow the described in the package content organization and the implemented learning strategy. In this case, instructor is responsible only to identify (or create) and then to incorporate the relevant multimedia content in each of the template pages accordingly the subject matter of the course taking into consideration the concrete learning objectives and context.

The main advantage of the Simple Sequencing approach is that the sequencing rules are described outside the learning objects' content. In this way, the instructional designer can change the rules (i.e. the learning strategy) without any changes in the content or its organization. Nesting manifests of the developed sample packages the content author can developed more complex strategies and content structures. The main disadvantage of the methodology is that selected strategy cannot be changed dynamically in time of learning.

Innovative Services for Learning Personalization and Customization

The future trends in ubiquitous learning point to the investigation and development of specialized learning services, methods and instruments allowing wide range of learners to access and to follow courses by web-based tools and Digital Video Broadcast tools at training institution and/or on workplace, or at home, combined with the

practically ubiquitous connectivity of the mobile devices. Following this idea we extract several innovative personalization services that are suggested by several very important research projects (ELENA project [ELENA], LOGOS project [LOGOS], SeLeNe project [SELENE], etc.) dated from the last few years.

Personalization service - It can be recognized as a functionality, which customises access to learning services and learning resources (in the context of the delivery of a learning service) based on learner profiles (career development plans can even be part of such a profile). The result of the personalization service is usually a customized view on a learning repository or a learning management network (connecting various educational nodes that facilitate the provision of additional educational services). The customization can be performed in many ways using techniques such as collaborative filtering or rule-based personalization in order to modify a user's query or to reduce the results produced by the query. A special personal learning assistant (PLA) can support learners in searching for, selecting and contracting learning services. PLAs can also trigger the delivery of the following services:

- *Query rewriting service* - The query rewriting service extends a user query by additional restrictions, joins, and variables based on various profiles. This extension is performed based on heuristic rules/functions maintained by the query rewriting service. Query rewriting services can be asked for adding additional constraints to user queries-based on user preferences and language capabilities. They can also be asked to extend a user query based on previous learner performance maintained in learner profiles, if a query is constructed in the context of improving skills. Query rewriting services can also be asked to rewrite a user query based on information the connected services need.
- *Recommendation service* - The recommendation service provides annotations for learning resources in accordance with the information in a learner's profile. These annotations can refer to the educational state of a learning resource, the processing state of a learning resource, etc. The service holds heuristic rules for deriving recommendations based on learner profile information. Recommendation services can be asked to add recommendation information to existing instances based on learner profile information.
- *Link generation service* - A link generation service provides (personalized) semantic relations for a learning resource in accordance with the information in a learner's profile. These relations can show the context of a resource (e.g. a course in which this learning resource is included), or they can show other learning resources related to this resource (e.g., examples for this learning resource, alternative explanations, exercises). The link generation service holds heuristic rules for creating semantic hypertext links. Some of the rules refer to information from the learner profile, in absence of learner profile information the service can at least provide some, not optimized, hypertext links. Link generation services can be asked for adding links and link type annotations to a given learning resource. They can be asked to generate a context for a given learning resource, or to generate a context for several learning resources by adding hyperlinks between them. They can be asked also to generate a learning path.

Customized learning, presenting just the right material to the learner on demand, can be described using data representations from learning technology standards (learner profiles, competency definitions, sequencing rules, learning objects). William Blackmon and Daniel Rehak [Blacmon et al.'03] offer a web services-based methodology for customization by profile, specifically one of eliminating LOs from a course because either:

- Learner's current role does not require the learning objective taught by the LO, or
- Learner's profile indicates the learner has already achieved the objective taught by a LO.

The learning content and data used in customization are represented in a set of standards-based data models. These are used in a content authoring and delivery process that customizes the activities delivered to the learner based on the learner's role and competencies [IMS Competency Definition, IMS LIP].

For content and learning activity customization are used six sets of data elements:

- Learning Objects - the collection of content and learning resources maintained in a content repository.
- Content Structure - the organization of learning objects in a tree or hierarchical structure.
- Roles - definitions of the job roles of a learner.
- Competency Definitions - definitions of the skills and knowledge acquired by a learner.

- Learner Information Package - the collection of stored profile information about a learner.
- Sequencing -- rules used to select content and sequence the learner through a content structure.

The major steps for a customized course preparation and delivering are[3]:

- Create Course and Content Description -- describe the course (content structure and set of LOs) and behaviour rules used to express the progression of the learner through the content:
  - Associate role and competency definitions with each learning object by mapping a sequencing objective id (used to label the objective) to a competency definition id or to a role id.
  - Specify the conditional rules used to customize the course by eliminating learning objects from the activity sequence.
- Establish Learner Profiles -- specify the role of the learner (which in turn may yield a set of competencies required to perform the role), and contain data on the learner's record relative to each of the specified competencies.
- Register Learners -- register the learner for the course.
- Deliver Course -- deliver the course, matching the course description to the learner's profile to select content. As the learner completes instruction, the profile may be updated to include mastery of subject matter. Delivery and customization continues until all required activities have been completed.

The customization process has been implemented through a set of web services. Rather than building large, closed systems, the focus is on flexible architectures that provide interoperability of components and learning content, and that rely on open standards for information exchange and component integration. The overall web services architecture for learning is divided into layered services. The layers from top to bottom in this services stack are:

- User Agents -- provide interfaces between users (both end user applications and program agents) and the learning services. Agents provide the major elements of learning technology systems: authoring of content, management of learning, and actual delivery of instruction to learners.
- Learning Services -- collection of (many small, simple) data models and independent behaviours. Service components are characterized as providing a single function that implements a particular behaviour. Each service is identifiable, discoverable, (de)referenceable, and interoperable. They include built-in security and rights management, and assume an unreliable underlying network. Services are grouped into logical collections, where upper-level services rely on the support from the lower-level services:
  - Tool Layer - Tools provide high-level, integrated server applications. Accessed via known, published interfaces, they provide the public interface to the learning tools (tutors, simulators, assessment engines, collaboration tools, registration tools, etc.). User agents and end user applications are built using collections of tool services.
  - Common Applications Layer - These are services that provide the commonly used learning functions and application support behaviours used by tools and agents (sequencing, managing learner profiles, learner tracking, content management, competency management, etc.).
  - Basic Services Layer - Basic services provide core features and functionality that are not necessarily specific to learning, but which may need to be adapted for learning (storage management, workflow, rights management, authentication, query/data interfaces, etc.).

All services are built on and use a common infrastructure model. The infrastructure layer relies on basic Internet technologies (e.g., HTTP, TCP/IP) to connect service components over the network. The services themselves are implemented using web services bindings. Messaging is done with SOAP; service descriptions are catalogued with UDDI, and described in WSDL - all are XML representations [Samtani et al.'02]. Overall service coordination is expressed in a workflow or choreography language. These standard technologies permit the upper-level services to be implemented in a platform-neutral manner, and provide interoperability across different implementations of the actual learning services.

[3] Assuming there is a globally defined set of learner job roles and competency definitions

Grid technologies. Personalization in Learning Grid-driven applications

The utilisation of currently available communication and information technologies has turned traditional location based education into location independent one. Nowadays, learning is equivalent to searching for sources and selecting the appropriate source to study from. The multitude of sources available on the Internet makes the selection of the appropriate source a rather difficult task. Learners need to access large volumes of data, most times distributed in many locations. Learners also need a variety of services available on demand that can be used and accessed from their environment to satisfy their learning needs. All of the above can be enabled by the utilisation of grid technologies.

Grid is a modern technology for the flexible, secure and coordinated sharing of distributed resources and data. Grid technologies define a new powerful computing paradigm where the customer of the grid will be able to use his or her private work place (Workstation, PC, UMTS phone....) to invoke any application from a remote system, use the system best suited for executing that particular application, access data securely and consistently from remote sites, exploit multiple systems to complete complex tasks, or use multiple systems to solve large problems that exceed the capacity of a single one. Another interesting aspect of grid technologies is their support for resource sharing and problem solving in dynamic, multi-institutional virtual organizations. In this vision, the sharing does not mean simply exchange of data or files but rather a concrete access to resources. This “sharing capability” imposes the definition and implementation of well-defined resource management policies to specify what is accessible, from whom and under which conditions.

The philosophy and approach behind Grid technologies [Hsing-Chuan et al.’04] show the right characteristics for achieving an effective learning. Indeed, they allow to access and integrate the different technologies, resources and contents that are required in order to realise new paradigms in eLearning. They are the most promising approach to realise an infrastructure that will allow learning process actors to collaborate, to take part in realistic simulations, to use and share personaliselly high quality learning data and to innovate solutions of learning and training. Grid will be able to support learning processes allowing each learner to use, in a transparent and collaborative manner, the resources already existing on-line, by facilitating and managing dynamic conversations with other human and artificial actors available on the grid, etc.

A high quality example of personalization techniques implementation, based on grids is demonstrated in SeLeNe (Self eLearning Networks). This project was funded as an EU FP5 Accompanying Measure (IST-2001-39045) running from 1st November 2002 to 31st January 2004. SeLeNe was part of action line V.1.9 CPA9 of the IST 2002 Work Programme, contributing to the objectives of Information and Knowledge Grids by allowing access to widespread information and knowledge, with eLearning as the test-bed application. The developers conducted a feasibility study into using Semantic Web technology for syndicating knowledge-intensive resources (such as learning objects) and for creating personalized views over such a Knowledge Grid.

A self e-learning network consists of web-based learning LOs that have been made available to the network by its users, along with metadata descriptions of these learning objects and of the network’s users. The architecture of the network is distributed and service-oriented. The personalization facilities include: querying learning object descriptions to return results tailored towards users’ individual goals and preferences; the ability to define views over the learning object metadata; facilities for defining new composite learning objects; and facilities for subscribing to personalised event and change notification services.

Summary

One of the main goals of contemporary eLearning is the possibility for learning adaptation to be assured for each learner in respect to her/his necessities, preferences, needs, performance, and progress. The achievement of interoperability and content reusability in the existing diversity of software and hardware platforms is a real challenge. One big limitation of the web-based interaction is the smaller communication bandwidth than traditional face-to-face interaction. The term bandwidth represents the amount of information that can be transferred in a unit of time through any means possible. In the face-to-face communication mode, if a verbal instruction is not understood, the clue can be available to the counterpart through gestures, group dynamics and other such means, but the clues in the web-based mode are not always so clear and in many cases not available at all. Therefore, tailoring the information to the right-level for the receiver to understand and integration of different appropriate methods for learning adaptation are crucial factors for the success of any LMS.

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