On the Design of Adaptive Educational Hypermedia Systems

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DESCRIPTION OF THE LAB

The CoSy-LE Research Unit (Computer Supported Learning Engineering Research Unit) [http://www.softlab.ntua.gr/~retal/cosy.html] belongs to the Department of Technology Education and Digital Systems of the University of Piraeus, in Piraeus, Greece. The research unit was established in 2003 by Dr Symeon Retalis, Assistant Professor in the same department. Cosy members are 2 faculty members (S. Retalis and F. Paraskeva), 3 researchers (Dr. Aimilia Tzanavari and Dr. Andreas Papasalouros), 6 PhD students (P. Georgiakakis, M. Vasilikopoulou, E. Kontaxaki, S. Tsoukalas, Ch. Bouta, Ch. Datsikas) and a number of undergraduate students. CoSy members conduct research in the broader area of e-learning with emphasis on the engineering aspect of elearning. Elearning Engineering is concerned with the establishment and use of systematic and formal principles and methods for the successful development, deployment and maintenance of high quality Web-based elearning systems and applications. The term "E-learning" signifies the use of networked computer environments and tools as well as open, flexible and active learning methods for education, training and lifelong learning. A number of Cosy members is focusing on Adaptive Educational Hypermedia Systems. Specifically, they look into issues like the architectural design of such systems, adaptive educational hypermedia applications design and evaluation as well as adaptive assessment authoring environments based on the learning technologies standards (e.g. IMS ATI, IMS Content Packaging, ADL SCORM). The main techniques employed come from the field of hypermedia engineering, semantic web and human computer interaction. These techniques and methods include design patterns, conceptual modeling and component-based software systems architectures.

Cosy has coordinated and participated in a number of European Research projects in the area of e-learning, such as E-ELEN [http://www.tisip.no/E-LEN], TELL [http://www.softlab.ece.ntua.gr/research/research_projects/tell/], and so on, which has helped in developing numerous ideas and collaborate with other researchers in the field.

RESEARCH AREAS

Adaptive Educational Hypermedia Applications (AEHA) are gaining the focus of the research and development community as a means of alleviating a number of user problems related to hypermedia and web-based education (e.g. "lost in hyperspace", cognitive overload, guidance-mentoring, etc.). AEHA aspire to address these problems and provide an individualized and customized learning experience, tailored to the learner needs, facilitating content access and generally making the learning process easier and more profitable for the learner. However, despite the growing interest of the community and the increasing number of available systems, the actual

impact of these systems in e-learning remains low. The difficulty and complexity of developing such applications and systems have been identified as possible reasons for this low diffusion of Adaptive Hypermedia in web-based education.
The development of AEHA is a complex task engaging people with different backgrounds: instructional designers, subject matter experts, content developers, multimedia developers, user interface experts, programmers, etc.

Cosy proposes to invest on the experience from traditional Instructional Design as well as Software Engineering and Hypermedia Engineering. It makes a variety of proposals for the model-driven design, evaluation and implementation of AEHA. More specifically, CoSy members perform R&D in the following areas:

- Design of Adaptive hypermedia educational material based on design patterns
- Authoring of Adaptive Educational Hypermedia Applications
- Development of adaptive testing systems

DESIGN OF ADAPTIVE HYPERMEDIA EDUCATIONAL MATERIAL

An Adaptive Hypermedia Educational Application (AHEA) is a dynamic web-based application, which provides a tailored learning environment to its users, by adapting its key features, which are:

- the **content** - the educational material that the learner can explore in the application
- the **navigation** and **interaction** capabilities by which the user can explore the content and interact with it;
- the **activities** in which the user can be engaged and by which (s)he can modify the content and navigation structures (e.g., by marking some interesting material, by collecting material in personal "lessons") or the user representation (e.g., by answering some questions or tests);
- the **lay-out** - the concrete presentation on the screen of all the previous features.

Our research attempts to identify proven best practices in the design of AEHA and codify them in terms of design patterns. According to the classical definition of architect Alexander, the pioneer of design patterns, "… a design pattern describes a *problem* which occurs over and over again in our environment, and then describes the core of the *solution* to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice". In its simplest form, a design pattern is a recurrent problem associated to a design solution within a specific context. It provides a structure for integrating the analysis and solution of a problem, in a way that is sensitive to context and is informed by theory and evidence.

We have initiated a pattern language in the domain of AHEA for the user modelling component, which plays a pivotal role in the adaptation that takes place as part of an AHEA. It is responsible for forming and maintaining an accurate "image" of the user, which at the same time has to be meaningful and useful to the system. This is subsequently used in the adaptation phase, where primarily content and presentation are tailored to the user's needs. The patterns that have been presented by CoSy members and collaborating researchers [4, 6, 9], attempt to cover the entire user modelling process, both at design and runtime. Furthermore, we have recently started exploring [3, 5] the area of learning styles and their importance in the design of AEHA.

AUTHORING METHODS OF AEHA

AEHA have presentational, behavioral, pedagogical and architectural aspects that need to be taken into account. Systematic and disciplined approaches must be devised in order to overcome the complexity and assortment of EAHA and achieve overall product quality within specific time and budget limits. One such approach is the use of a systematic authoring process with the accompaniment of CASE (Computer Aided Software Engineering) tools and standards. Existing software engineering and hypermedia engineering approaches are not adequate for developing EAHA. They cannot capture the issues specific to learning adaptivity or describe the semi-structured educational nature of such applications. Designing and authoring EAHA is an open research issue [10].

We have proposed the CADMOS-D method which captures the outcomes of the instructional analysis process and drives the design and authoring of the whole EAHA, till the moment when a prototype of the EAHA is automatically generated via the synthesis of learning resources according to its design. CADMOS-D provides two distinct models for EAHA authoring: A process model, that pertains to the detailed definition and specification of the various design steps, their temporal relationships and sequencing and a list of the outcomes of each step, and a product model that refers to the detailed specification of the outcomes of each step, capturing the design decisions, the relationships and dependencies between these outcomes and the mechanisms that allow these outcomes to drive the development of the actual application.

CADMOS-D is proposing a formal conceptual design model of an EAHA which contains information about concepts that must be acquired by learners, tasks in which learners must be involved and resources that will be used. Our method [1, 2, 8] uses UML as the modeling language and defines the design process in three distinct steps: the conceptual model, the navigational model and the user interface (or presentation) model. We have proposed an RDF encoding of the Conceptual Model, which is the outcome of the first step, following a specific RDF schema that is appropriate for such applications. The design model of an AEHA can be created with CASE tools like the IBM Rational Rose tool. CADMOS-D suggests the utilization of such tools because UML models can be stored in XMI file, the OMG standard XML metadata interchange format files. The XML manifest file conforms to the IMS Content Packaging learning technology specification. With the use of a specially developed tool, called CGA (Courseware Generation Application), the XMI description is transformed into a structured hypermedia educational applications. More specifically, the CGA tool accepts as entry the XMI description with the relevant learning resources (HTML pages, pictures, files of sound and video, active objects as Applets, ActiveX, Flash, etc.) and produces as output a prototype of the AEHA.

ADAPTIVE TESTING SYSTEMS

Adding the adaptation capability to the assessment process has been proven advantageous, primarily for the reason that users are presented with personalized tests, tailored to their needs, preferences and current knowledge, but also because the number of assessment items required can be adjusted, most of the times resulting in fewer items, which implies a shorter, less tedious assessment.

We have developed [7] a web-based adaptive testing system, AthenaQTI (Athena is a Learning Management System with which AthenaQTI will be integrated). The AthenaQTI tool has been designed taking into account three very important issues. Firstly, that the user model used by the

system conforms to a widely used standard so that other related applications are able to use it. Second, that the system conforms to the IMS QTI specification; IMS QTI provides the basic structure for the assessment (representation of questions, results, etc.). It also enables the interoperability and portability of the assessments among either web-testing systems or even Learning Management Systems (like WebCT, Blackboard, etc.). Thirdly, the system provides an authoring environment that allows the author of an assessment, i.e. the educator and/or an instructional designer, to make decision on matters such as:

- the different types of questions: multiple choice, fill-in the blanks, etc.),
- the difficulty levels of questions,
- what is considered a qualifying grade and under which circumstances,
- how are grades to be interpreted in terms of the user's knowledge level,
- how is a new learner handled,
- how many questions are necessary to estimate the user's knowledge with confidence,
- how does the user's performance affect the user model.

FUTURE PLANS

CoSy members plan to continue research in the aforementioned topics, but also attempt to explore new ones. Plans can be summarised in the following:

- Evaluation of the degree in which and the reason why an adaptive system supports the educational process;
- Exploration of learning styles and the efficiency of their codification, to form a basis for adaptation;
- Refinement of the design patterns developed, further validation and evolution.
- Development of an open adaptive educational system following practices from the software engineering architectures

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