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Guest Editors: Ignacio Aedo-Cuevas, Kinshuk, Demetrios G. Sampson, Antonio Sarasa-Cabezuelo, and José-Luis Sierra-Rodríguez


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Presentation

Learning in the Information Society:
New Approaches, New Tools

Ignacio Aedo-Cuevas, Kinshuk, Demetrios G. Sampson, Antonio Sarasa-Cabezuelo, and José-Luis Sierra-Rodriguez

e-Learning Systems are essential components, not only in current educational organizations, but also in today’s business environments, facilitating life-long learning and, therefore, the successful development of the modern knowledge society. Currently, it is possible to observe a constant growth in the complexity of such systems in order to maximize the pedagogical usefulness of each new advance in technology. Because of this, we thought it interesting to consider a monograph on the subject of Engineering eLearning Systems, presenting different perspectives concerning the design, development and maintenance processes of eLearning Systems.

In order to compile the monograph, we selected relevant papers from two scientific events in the e-learning area celebrated during 2010: 1st Workshop on Software Engineering in eLearning (ISELEAR’10) and 10th International Conference on Advanced Learning Technologies (ICALT ’10).

All the selected works shared a strong focus on technological and software development aspects, and therefore we invited the authors to prepare extended and revised versions of their conference papers. The resulting articles

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passed a second blind-review process according to Journal Quality Standards. Additionally, papers were exposed to a subsequent heavy editing process in order to adapt them to the characteristics of the monograph.

As result of this effort, the monograph includes the following papers:

- The work of González, Cabrera, López and Barroso presents a real case study in the context of the Universidad de La Laguna (Tenerife, Canary Islands, Spain), which illustrates the process of creating a system for the production, distribution and publication of educational materials in the form of lectures recorded in video format.

- The work of Ruddeck, Maciuszek, Weicht and Martens, as well as the work of Santos and Figueira, are focused on building a classical type of e-learning systems: intelligent tutoring systems. The work of Ruddeck et al. proposes a component framework for building such systems, and it develops a catalogue of design patterns that facilitate the use of the framework. In its turn, the work of Santos and Figueira proposes the use of SCORM, a set of specifications widely adopted by the e-Learning community, as a mechanism for the development of such intelligent tutoring systems, providing in this way a solution to the interoperability problem of intelligent tutoring systems between heterogeneous execution platforms.

- The work of Conde, Pozo and García, as well as the work of Jurado, Molina, Redondo and Ortega, and those of Monfort and Khemaja present different architectural approaches for advanced e-Learning systems. Indeed, Conde et al. illustrate different uses of the service-oriented support integrated in Moodle (one of the most popular e-Learning platforms). In their work, Jurado et al. propose a flexible integration architecture for heterogeneous e-Learning components and services based on a classical model of distributed computing: tuple spaces. Finally, the work of Monfort and Khemaja proposes architectural solutions for adaptive e-Learning systems based on the paradigms of software as a service (SaaS) and cloud computing, which are illustrated with a case study concerning training for navigation and fishing companies.

- In their turn, Malek, Laroussi, Ghezal and Derycke present a paper about the development of ubiquitous e-learning systems through an approach based on Model-Driven Software Engineering.

In addition to these works, as a part of the UPGRADE edition of the monograph we also include a work submitted and revised as a regular contribution to this journal by Gaspar, Prado and Teixeira, which addresses the important issue of reusing software components in Web 2.0 context, thus constituting way an excellent complement to the monograph.

Finally, as an introduction to the field of e-Learning Systems Engineering, we include a work from Sarasa, Rodríguez and Sierra about the role of standardization efforts in the development of e-Learning systems, taking digital repositories as a paradigmatic case study.

To conclude this presentation, we would like to thank all the authors who have made this monograph possible, for their excellent contributions and unconditional collaboration throughout the editing process. We also would like to express our more sincere gratitude to the Editorial Teams of UPGRADE and Novática, specially to Llorenç Pagés, Chief Editor of both journals, for giving us the opportunity to prepare this monograph and for his support during the preparation process.

In addition, we would like to thank Mercedes Gómez-Albarrán and Daniel Rodríguez-Cerezo for their translation efforts regarding the Spanish version of the monograph (published in Novática). Finally, we would like to indicate that the preparation of the monograph was partially carried out in the context of the project grant TIN2010-21288-C02-01, and the research network e-Madrid (ref. S2009/TIC 1650).
Useful References on "Engineering e-Learning Systems"

Books

Web Links
- JISC. <http://www.jisc.ac.uk/>.
- CelTech (Centre for eLearning technology). <http://www.celttech.de/>.
- EIFel (European Institute for ELearning). <http://www.eife-l.org/about/>.

Documents
e-Learning System Engineering and Standardization Efforts: A Case Study Concerning Learning Object Repositories

Antonio Sarasa-Cabezuelo, Daniel Rodríguez-Cerezo, and José-Luis Sierra-Rodríguez

Nowadays, the use of e-Learning systems transcends the purely academic field, as it spreads to all aspects of our modern Knowledge Society. Therefore, the adoption of systematic development, implementation and maintenance methods for the construction of this type of systems is rapidly arousing great interest and gaining in importance. In addition to facilitating interoperability, the use of recommendations, specifications and standards that regulate the different aspects of e-Learning systems are also mandatory to facilitate and systematize the development of such systems. Through a case study involving a representative class of such systems (Learning Object Repositories), this paper illustrates how specifications and standards constitute a key aspect of e-Learning System Engineering.

Keywords: e-Learning System Engineering, Learning Object Repositories, Software Engineering, Standardization.

1 Introduction
Through a case study concerning learning object repositories, in this paper we analyse how the use of specifications and standards can help organize the architecture and other aspects of e-Learning systems, thereby facilitating the engineering process of such systems.

2 Basic Concepts
2.1 Learning Objects, Metadata and Repositories
In e-Learning, the term learning object refers to a body of educational materials, equipped with a well-defined pedagogical objective, which can be reused in multiple contexts [1]. Learning objects usually consist of a set of interrelated educational resources (digital files, web page addresses, simulation tools, etc.), and a description of these resources.

The description of the resources that make up a learning object usually involves metadata that characterize different aspects of the object. Metadata is, as its name suggests, information about information. In this way, metadata associated with a learning object describes aspects such as the author, the field of knowledge addressed by the learning materials enclosed in the learning object, the technological requirements needed to expose / play those materials, etc.

Learning objects are catalogued and stored in repositories, so that users (teachers, students, etc.) can recover from these repositories objects to be used in different learning activities, as well as contributing with their own learning objects. Throughout this process, metadata associated with objects play a fundamental role in the cataloguing, searching and retrieval of the objects in the repositories.

2.2 Standardization in e-Learning and in Learning Object Repositories
The purpose of e-Learning standardization efforts is to regulate different aspects of e-Learning systems in order to

“Learning objects usually consist of a set of interrelated educational resources and a description of these resources.”
Metadata is, as its name suggests, information about information.

facilitate their development and to ensure interoperability between heterogeneous systems [2][3].

The advantages of standardization efforts can be appreciated by considering efforts concerning learning objects and repositories. Such standardization efforts can address different aspects, which include the following:
- How to package resources and other information associated with learning objects?
- How to sequence the educational content? (i.e. how to play and present that content in the tools connected to the repositories?)
- How to represent metadata?
- How to publish items in the repositories? (i.e. how to contribute new items to these repositories?)
- How to retrieve existing objects?
- How to exchange metadata between repositories?
- How to organize the global architecture of repositories and repository networks?

The rest of the article briefly reviews the standardization efforts related to each of these aspects.

3 Packaging

The most widespread specification regulating how to package learning objects is IMS Content Packaging (IMS CP), <http://www.imsglobal.org/content/packaging/>. This specification shows how to bundle in a single physical unit, called a package, all the educational resources along with any additional information concerning them (e.g. metadata). Each package consists of two main components: the educational content itself (resources), and an XML document called a manifest, which describes the structure and organization of the resources as well as additional features of the package (using metadata).

4 Sequencing

Regarding sequencing, two alternatives have emerged, based on two different teaching approaches:
- IMS Simple Sequencing (IMS SS), <http://www.imsglobal.org/simplesequencing/>. This specification makes it possible to describe the flow of educational activities that an individual student must follow, based on the results of his or her previous interactions with educational content.
- IMS Learning Design (IMS LD), <http://www.imsglobal.org/learningdesign/>. This specification allows the modelling of learning scenarios focusing on the activities involved in the learning process, on the resources and services used, and on the various participants in the process (e.g. teachers, students). Thus, instead of representing the perspective of an individual student, this specification makes it possible to describe the overall educational process as a result of the interaction and orchestration of all the aspects involved in it.

5 Metadata

The two most frequently used and widespread metadata specifications for learning objects are:
- Dublin Core, <http://dublincore.org/>. Initially aimed at the broader context of organization and management of digital libraries, this specification has also found a significant use in the field of e-Learning. It consists of 15 categories of metadata, such as title, key, editor, rights, etc., all generic, and applicable, in principle, to describe any digital resource. However, the specification also provides mechanisms for extension / specialization, which allows it to be adapted to specific domains such as education.
- Learning Object Metadata LOM [4]. It is a specification explicitly oriented towards the educational domain. It defines a metadata schema to describe learning objects, which is structured into nine main categories (general, technical, educational use, etc.). In order to accomplish the particular expressive needs of particular educational communities, the specification also provides a specialization mechanism called application profile. For example, LOM-ES is a LOM application profile tailored to the needs of the Spanish education system, <http://www.lom-es.es/>.

6 Publishing

The main proposals for publishing learning objects are:
- Simple Publishing Interface (SPI)[5]. It is a simple publishing protocol based on an API independent of the underlying technology.
- PENS (Package Exchange Notification Services), <http://pens.lmstesting.com/>. It offers a publishing protocol that supports a notification service for packages of content, allowing the publishing of URLs of objects, not the objects themselves.
- SRU Record Update, <http://www.loc.gov/standards/sru/record-update/>. A protocol that enables the creation, replacement, and deletion of metadata records. It does not however allow the publishing of resources.
- EduSource Communication Layer (ECL)[6]. It implements the publishing functionality of the IMS DRI, <http://www.imsglobal.org/digitalrepositories/>, (see the section about architectures below).

Learning objects are catalogued and stored in repositories, so that users (teachers, students, etc.) can recover them.
Retrieval of learning objects is supported by query languages that must be able to take into account the metadata that describe them.

7 Retrieval

Retrieval of learning objects is supported by query languages that must be able to take into account the metadata that describe these learning objects. Examples of these languages are:

- **ProLearn Query Language (PLQL)** [10]. It defines a standard query language to retrieve learning objects from heterogeneous repositories that can combine both exact and approximate searches.
- **CQL (the Contextual Query Language)**, <http://www.loc.gov/standards/sru/specs/cql.html>. It offers a highly expressive, easy-to-read, and easy-to-write query language. It does not support hierarchical metadata structures. The results of the queries are sorted by metadata fields.
- **QEL (the Query Exchange Language)** [11]. Query language for RDF expressed using a Datalog-like syntax. It was implemented for the Edutella network, a P2P network that provides an interoperable search through learning object repositories. It is independent of the metadata schema, and it offers bounded variables able to match with objects, predicates and RDF tuples.

Additionally, searches can operate not only on isolated repositories, but also on networks, or federations, of repositories. The resulting **federated search architectures** consist of [7]:

- A search engine that offers an API to search, making it possible to send queries to the federated systems and to collect the results.
- A record that contains all the addresses of the federated systems on which the search engine can search. The search engine can dynamically load information about new systems into the registry.
- The metadata repositories on which the search engine can search.
- A search client that interfaces with the search engine to conduct searches on the federation.

This federation model is implemented by various specifications:
- **Open Service Interface Definition (OSID)** from the Open Knowledge Initiative (OKI), <https://seguecommunity.middlebury.edu/sites/achapin-oki-repository>. This specification allows the publishing of resources by means of the JAVA Asset Interface, a component that provides methods to add and delete records, both metadata and resources.
- **SRU/W** [9]. These are two search protocols accessible via web services: Search / Retrieve via URL (SRU) is a REST-based implementation, while the Search / Retrieve Web Service (SRW) is based on SOAP.
- **EduSource Communication Layer (ECL)**. It also implements recovery facilities, allowing implementation of both state-full and stateless interactions.
- **OKI’s OSID**. This specification, in addition to the facilities for learning object publishing, also defines services that facilitate the search in the repositories, also making possible both stateful and stateless interactions.

8 Metadata Harvesting

The exchange of metadata between repositories (harvesting) is a technique to make local copies from metadata records. There are two specifications related to this functionality:

- **OAI-PMH**, <http://www.openarchives.org/OAI/openarchivesprotocol.html>, defines a way to exchange metadata between heterogeneous repositories that host any object with associated metadata. For this purpose, it uses the protocol PMH (Protocol for Metadata Harvesting).
- **OAI-ORE**, <http://www.openarchives.org/ore/>, defines a standard for identifying, describing and exchanging aggregations of digital web resources, establishing how a service provider can encode and decode aggregation descriptions, and how a user can discover and interpret such descriptions.

9 Architecture

There are several specifications that have attempted to globally standardize the functions and characteristics of a repository that interacts with others, among which the following can be highlighted:

- The already mentioned IMS DRI, which defines a reference model for interoperability between repositories. For this purpose, the specification considers eight functions that must be able to take into account the metadata that describe them.

“Simple Query Interface (SQI) [8]. It is a protocol which provides interoperability between federated systems and search and retrieval applications. To perform a query, the source must establish a connection to the destination via a non-persistent session. Once the session is established, the query interface on the target waits until it receives the search request. The interface can be configured, and the settings remain valid during the session or until it is set in a different manner. If not configured, it uses the default behaviour. Queries can be sent using synchronous or asynchronous methods.

- SRU/W [9]. These are two search protocols accessible via web services. Search / Retrieve via URL (SRU) is a REST-based implementation, while the Search / Retrieve Web Service (SRW) is based on SOAP.

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relevant both to the repository and the resource management levels (e.g., display, search, send, etc.).

- CORDRA (Content Object Repository Discovery and Registration/Resolution Architecture), <http://www.cen-ltso.net/>. It defines how a federation of repositories of learning objects should be designed and deployed on the network.


10 Conclusions

The use of specifications and standardization efforts can facilitate the process of engineering e-Learning systems. Indeed, it is not necessary to design components from scratch, but rather the design process can be based on the knowledge and experience distilled into the existing specifications. Therefore, this aspect complements the interoperability issues usually attributed to the standardization efforts. Because of the breadth of the field of standardization in e-learning, we have chosen learning object repositories as a representative case study. Similarly, the review has been necessarily partial, having omitted aspects no less important than the addressed ones: copyright management, learning objects identification, description of classification systems (taxonomies, thesauri, ...), etc. In [2][3], other reviews that complement ours can be found.

Acknowledgements

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References

PDP Systems for Audiovisual Educational Content: Development of a Solution for the Universidad de La Laguna

Carina-Soledad González-González, David Cabrera-Primo, Daniel López-Barrios, and Antonio Barroso-Díaz

This article presents an analysis of the different systems of production, distribution and publishing (PDP) of multimedia content in Spanish universities. We analysed several similar solutions in order to design and implement a PDP for the Universidad de La Laguna (ULL) and finally we selected two representative ones as models: POLIMEDIA for the production phase and PuMuKit for the distribution and publishing phases. The paper also presents the PDP system developed, called ULLMedia, which makes it possible to embed videos from other existing public platforms. ULLMedia also allows the integration of the teaching materials produced in the University with other services of the Virtual Teaching Unit. In particular, it enables the integration of ULLMedia contents with the virtual campus, which is based on Moodle, and with UDVBlogs, a platform based on Wordpress-MU.

Authors

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**Keywords:** Digital Content, Digital Repositories, Distribution and Publishing Systems, Learning Objects, PDP, Production Systems.

1 Introduction

Several Universities in Spain are currently working hard to create digital content repositories, with the aim of promoting, preserving and organizing materials generated by their teachers [1]. There are several software tools used for the operation of the repositories, although there is a strong tendency towards the use of DSPACE [2], a free software system for creating repositories. These repositories incorporate many types of content, including books, lectures, learning objects, multimedia, patents, theses, and preprints, among others. In the case of learning objects and multimedia materials, these repositories give support to the final documentation of the materials and the federation with other repositories.

However reality shows that most of the teaching material used in teaching is based on content that is not published in institutional repositories. The hypothesis to explain this fact is that the materials of daily use are best handled within a system over which the teachers have control, as well as the added ability to apply their own personal organization, perhaps via tags. It is a fact that teachers like to use a 2.0 system to publish their multimedia content, since they have access to, and they can control, the content created and published [3].

Two of the most important initiatives in the field of production systems, distribution and publishing of contents, or PDP, are the international project Opencast and the Spanish project ARCA. Opencast is an initiative led by universities oriented towards providing guidance and information to help choose the best option for the distribution and use of online multimedia resources. ARCA is a project created to federate information on media content and streaming webcast offered by members of the Spanish national academic and research network RedIRIS. We can say that ARCA is an RSS aggregator for the Spanish academic community. The

<table>
<thead>
<tr>
<th>Project</th>
<th>University</th>
<th>Licensing and Availability</th>
<th>ARCA Syndication</th>
<th>Content Management</th>
<th>Distribution system / Streaming / Live broadcast</th>
<th>User interaction</th>
<th>LMS integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>PuMuKIT</td>
<td>Universidad de Vigo</td>
<td>Open</td>
<td>Yes</td>
<td>Category / Series / Multimedia Object</td>
<td>Windows media Server / integration with Flash Media Server</td>
<td>No</td>
<td>Integration with Moodle to include multimedia objects.</td>
</tr>
<tr>
<td>POLIMEDIA</td>
<td>Universitat Politècnica de Valencia</td>
<td>Open</td>
<td>Yes</td>
<td>Category / Series / Multimedia Object</td>
<td>Flash Media Server</td>
<td>No</td>
<td>Integration with Sakai</td>
</tr>
<tr>
<td>MMEDIA</td>
<td>Universitat de València</td>
<td>Expected to release its code</td>
<td>Yes</td>
<td>Category / Video</td>
<td>Flash Media Server y Darwin Streaming Server</td>
<td>Scoring and comments</td>
<td>Integrated into the LMS and LMS integration at user-level</td>
</tr>
<tr>
<td>ARCAMM</td>
<td>Universidad Carlos III</td>
<td>Expected to release its code</td>
<td>Yes</td>
<td>Category / Series / Video</td>
<td>Windows media Server</td>
<td>No</td>
<td>-</td>
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<tr>
<td>CANAL UPC-TV</td>
<td>Universitat Politècnica de Catalunya</td>
<td>Proprietary</td>
<td>No</td>
<td>Flash based</td>
<td>Comments</td>
<td>-</td>
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</tr>
</tbody>
</table>
main objective is to address the current lack of vehicles to disseminate audiovisual content generated by the academic community, content which currently mostly goes unnoticed. ARCA is a feed aggregator that automatically collects all the information present in a range of XML documents with information about the contents provided by different member institutions, and integrates this information into a database to offer it to the user in a meaningful, browseable and searchable way. The XML dialect chosen for this information flow is RSS 2.0.

2 Analysis of PDP Solutions for University Multimedia Content

In an analysis of the solutions used by Spanish universities that send their content to ARCA, it is possible to observe two trends:

- Creation of custom systems. Examples of this trend are the solutions developed at the Universitat de València (MMEDIA), Universidad Carlos III de Madrid (ARCAMM) and the Universitat Politècnica de Catalunya (CANAL UPC-TV).
- Use of third-party solutions. Among these solutions we would highlight the solutions of the Universidad de Vigo (PuMuKIT) and the Universitat Politècnica de València (POLIMEDIA), projects that have been consolidated and extended to other universities in Spain. Among the organizations using PuMuKIT are the Universidad de Vigo itself, the Universidad de Murcia, the Supercomputing Center of Galicia, the Universidad del País Vasco, the Universidad Técnica Particular de Loja, and the Universidad Nacional de Educación a Distancia. For Polimedia, there are many universities and institutions that have adopted the model of audiovisual production, among which are Red.es, the Universitat Autònoma de Barcelona, the Universidad Politécnica de Cartagena, Universidad de Huelva, and the Universidad de Sevilla.

Table 1 summarizes the features used in the aforementioned PDP systems. Other PDP systems used in Spanish universities are URJC.TV (the PDP of the Universidad Rey Juan Carlos), CEFONT (currently obsolete, this system was used in the Universidad de Cantabria), YouTube (used by the Universidad Politécnica de Madrid), and the PDP systems of the Universidad de Castilla-La Mancha (ASP based) and Universidad Pablo de Olavide de Sevilla.

3 Selecting Solutions

After analyzing several systems existing at the Universidad de La Laguna, ULL (Canary Islands, Spain), POLIMEDIA was chosen for the production phase and PuMuKIT for the distribution and publishing phases. POLIMEDIA is a PDP system for multimedia content creation designed for tele-education, ranging from the preparation of material to its distribution through different media (DVD, streaming, etc.). Polimedia studios are studios equipped with low-cost audiovisual production equipment, which, however, does not hinder the quality of the final product. They have production, publishing, distribution and integration systems, and "POLIMEDIA" templates tailored to their own institutional systems. As the architectures of their publishing and distribution systems,

"Two of the most important initiatives in the PDP field are the international project Opencast and the Spanish project ARCA"
the repository of recordings uses Flash Media Server and Windows Server 2008, with a completely virtualized production environment, supporting up to 400 concurrent users. It is based on a pedagogical model of “pills”, which are documentation and packaging systems of objects and learning modules. For our proposal we are particularly interested in the types of materials in digital formats supported by this system. These materials are stored in repositories and databases, distributed through the network, and accessible from any standard browser with independence of particular operating systems in the computers accessing the resources. Such materials respond to the concept of Reusable Learning Object (RLO) model. RLOs are the smallest units of indivisible, independent, educational purposed, sequenced, uncontextualized content which can be reused in different educational contexts. In the POLIMEDIA model, RLOs are commonly called "learning pills". RLOs are contextualized through LRLOs (Linked Objects) on "Learning Modules" (LM), which, in turn, are aggregated in different learning units, subjects, courses (such as OpenCourseWare, or OCW), and even complete formative itineraries.

Moreover, as an alternative for distribution and publishing, we selected the PuMuKIT system, taking into account that it provides a smooth migration to
The main requirement of our system is the assembly, without any human operator assistance, of videos that include multiple videos and images. OpenCastProject. This system allows Internet publishing of audio-visual content produced in an institution, university, etc. PuMuKIT publishes multimedia content stored in the database in different ways: by creating a Web portal, creating a WEB-TV or creating ARCA compatible RSS feeds. The web portal created by PuMuKIT has an area for live broadcasts and a media library. In this media library it is possible to select the thematic channel of our interest, to see the series available, and to access the videoconference, class or event of our choice. It also has a complete search by keywords, subjects, authors, etc. to facilitate the location of the videos available. The technologies used in PuMuKit are the Symphony framework (PHP + MySQL) and Flash Media Server. This system seamlessly manages Production, Distribution and Publishing. It runs a transcoding farm. When the system uploads the "Master Copy" and the associated metadata, a publishing profile is generated and the material is put into the distribution system. After the production phase, a high-quality "Master Copy" is kept, and a lower-quality media file is passed to the streaming server. The system also manages metadata, and additionally it has a control panel for managing multimedia objects and the publishing process. This panel is simple, user-friendly, and contains all the necessary functions. It also provides different views of the system according to user level. PuMuKIT has been adapted for various academic institutions and works properly at over 15 universities.

4 The ULLMedia System

Based on the analysis made and in the reference models selected, we developed the ULLMedia as an audio-visual content PDP for the Universidad de La Laguna. ULLMedia contains content specifically related to education and the university community, and solves different problems: using labels instead of metadata, as in existing public repositories; legal issues regarding hosting content, produced in a public university, in a service offered by commercial companies such as YouTube or iTunes; and searches conducted by and within the university environment. ULLMedia can also include videos from other platforms and integrate ex-

Figure 4: Publishing and Distribution ULLMedia Portal.
Our system has been designed to take into account the actual ways in which university teachers work, therefore unnecessary features were removed.

Existing public educational materials with other ULL services, such as the Digital Library and the Virtual Teaching Unit, enabling the integration of ULLMEDIA content with the Virtual Campus (Moodle) and the UDVBlogs platform, while maintaining a unified access.

In the production phase, ULLMedia follows the POLIMEDIA production model. The main requirement of our system is the assembly, without any human operator assistance, of videos that include multiple videos and images (Figure 1 and Figure 2). This means that we must automate the assembly. In this sense, for this prototype we have created some small scripts and templates for the assembly of the videos. The main script is ullmedia.sh. It deals with the assembly of recording sessions involving various videos. For this purpose, it uses the parameters stored in templates to generate a final video with a background and a specific video distribution. This script takes the location of the source files, the selected template and the output file as parameters.

For the publishing and distribution phases of audio-visual content, ULLMedia working prototype is supported by PuMuKIT and Flash Media Server (Figure 3). To integrate the previous installation script in PuMuKIT, a transcoding profile for each envisioned template was added. Additionally, for each pill a form should be filled out with the corresponding metadata modelled in LOM. Once published, the contents are distributed, in a federated manner, to the ULL digital library and to various repositories, including ARCA.

It should be noted that ULLMedia is a compendium of solutions, chosen after an exhaustive analysis. Unlike other solutions, ULLMedia encompasses the entire process of production, distribution and publishing of audio-visual materials. The main advantage is its ability to autonomously deploy, material to any operating environment, without the need of any other system or specific integration. Therefore, ULLMedia provides technical improvements on each of the solutions used, in order to ensure proper integration, and to improve, enhance and tailor the internal processes of each solution in appropriate specific ways, using scripts or specific codec to improve the final outcome.

Also, this system has been designed to take into account the ways in which university teachers actually work. Therefore unnecessary features that complicate the use of the solution by non-advanced users were removed. It provides a web 2.0 style interface to the repository, letting teachers control the access and the organization of the content (Figure 4). Before releasing it and offering it to the entire university community, the system was initially used by thirteen research groups involved in the University’s ICT and Education Structuring Project APD08/09. These groups were made up of nearly one hundred researchers. This validation included not only the technical validation of ULLMedia system, but also incorporated the validation of the structure of the audiovisual materials and training needed to use the system. ULLMedia is still being developed, and is currently in its production and continuous improvement stage.

References

Web Sites
The concepts and technologies that define Web 2.0 have revolutionized and extended collaboration assisted by computational systems. Recent developments in new technologies make it possible to represent, in a Web environment, elements that are common to face-to-face collaborations. The Web environment is formed by synchronous collaborative multimedia applications with rich interfaces using the Web as a platform. The authors’ experience in projects in the domain of synchronous collaborative applications has allowed the identification of a complex and broad domain with many commonalities. This paper presents a software component reuse approach for synchronous collaborative Web 2.0 application development. It describes the construction of such components as well as an approach to reuse software by taking advantage of a shared architecture and components library to aid domain developers.

Keywords: e-Learning, Multimedia, Software Reuse, Synchronous Collaboration.

1 Introduction

Web 2.0 [1] is a term that originated in the concepts and technologies employed by a set of companies during the "Dot-Com bubble" in 2000. That set of companies stood out from others by employing services and applications that had a number of characteristics in common, such as rich interfaces, the Web as a platform, harnessing collective intelligence, multi-device software, and others. A Web 2.0 application does not usually exhibit all those characteristics simultaneously, but only a subset of them.

Humans relations and knowledge production are changing rapidly. This is partially due to new forms of information production and consumption created by the Web 2.0. Collaborations play a key role in such changes and are fundamental to content production. Although the practice of collaboration has become popular, synchronous collaborations are not as popular as asynchronous ones through blogs, social networks, wikis, and others. This is due to many factors, but a major one is technological barriers such as software and broadband network availability. Some of these factors are changing and it would be no surprise if, in a few years’ time, most of our meetings with bank managers, helpdesk support, or guitar teachers were online, through Web applications.

The available bandwidth for Internet access nowadays supports rich media content production. Sites like YouTube, Flickr and Justin.tv are examples of the increasingly rich media content available on the Web. In January 2009 alone, 139 million, or 75% of US Internet users, had access to online multimedia content [2]. Despite the large amount of rich media content being produced and consumed today, most collaborations are still text based.

Synchronous collaborations supported by computational systems may evolve by adopting richer media. The ideal scenario is to collaborate remotely the same way as in face-to-face collaborations, so that geographic barriers would become less restrictive. Computer aided collaborations offer possibilities not found in face-to-face collaborations, such as database information persistence, content search, content production support or remote collaboration.

Synchronous collaborations usually have some elements in common such as audio, video or text interaction. Those basic collaboration elements can be seen as synchronous interaction units that provide a way to exchange information. The software components that represent those synchronous interaction units allow software reuse among different synchronous collaborative applications as they share basic characteristics.

The Tidia-Ae (Information Technology in the Development of Advanced Internet - Electronic Learning) project, in which this article’s authors contribute, is an initiative that aims to construct an open source web electronic learning environment. The Ae is a portal which has a set of tools and
This paper presents a software component reuse approach for synchronous collaborative Web 2.0 application development.

Functionalities to support learning activities. Part of this project is dedicated to the research and development of multimedia synchronous collaborative applications with rich interfaces. *Ax* has been used as a learning platform in many universities and there is therefore a demand to expand the existing set of applications [3].

However, developing synchronous collaborative applications with rich interfaces can be costly and difficult. Compared to desktop applications, these applications must meet non-functional requirements related to security, fast response, elaborate user interfaces, browser-related issues, and so on. Technological barriers cause development teams to spend long hours addressing these non-functional requirements. Heterogeneity of browsers, platforms and programming languages are another problem affecting the productivity of development teams. This complex scenario makes it harder to compose teams, predict project costs, and maintain existent applications. Therefore, efforts in software reuse might be an important issue.

Mili et al. [4] state that software reuse improves the overall quality of a system if quality components are used in the construction of that system. With a reuse process, the more the process is automated, the more productivity increases. And the more quality-enhancing processes are systematized, the more quality increases.

This paper proposes a component-based development approach for the Web 2.0 synchronous collaborative applications domain. The purpose of this approach is to help domain application developers reuse software in a systematic manner. The reuse approach is divided into domain engineering, in which the domain components are developed and stored in a library, and application engineering, in which applications are assembled using the components library. All applications resulting from this approach share the same architecture, although applications might use different sets of synchronous interactive components according to their requirements.

2 Synchronous Collaborative Domain

Face-to-face collaborations such as business meetings or classroom lessons may have counterparts in the computer-mediated synchronous collaborative domain. Interactive elements present in a business meeting, for instance, such as sight, voice, or a piece of paper can be represented in a computer-mediated scenario by video, audio, and whiteboard representation respectively. One could use those computer-mediated representations to build applications which support the same functionalities that are available in face-to-face collaborations. The idea is to bring those collaborations to the computer-mediated domain so it is possible to have a remote business meeting, attend a classroom, or talk to a bank manager and have a similar experience.

Human senses play an important role in face-to-face collaborations. In a classroom, not only the image or the voice of the teacher might have influence in the learning process, but also the smells and the classroom environment itself. It is difficult with today’s technology to provide an accurate real life experience in terms of human senses stimuli. The digital representation of smell, for instance, is not quite ready yet. Although several studies [5][6][7] and products are available [8], those devices are far from effective.

Despite the lack of a better support for human senses stimuli, collaboration supported by computational systems may offer possibilities not found in face-to-face collaborations. Functionalities such as database information persistence, content search, content production support and remote collaboration are a few examples. In order to make those functionalities accessible for most users, the Web environment sounds appropriate since it is becoming an ubiquitous environment.

Web synchronous collaborative applications are characterized by an intense demand for efficient communication services, user management services and complex rich web interfaces. Those characteristics can be very expensive to implement for each application. In order to lower costs and reduce development complexity, services, components and a reuse approach are proposed throughout this paper. Some of the components support a set of synchronous interaction units such as text, audio, video, whiteboard and desktop sharing. Others are meant to support more background tasks such as communication, user management, session management and persistence.

Applications developed with the proposed approach are OS independent and do not require specific software installation. To take advantage of the synchronous interaction provided by these applications, the user must have installed programs that are already available on most personal computers, such as a browser and the *Flash* plugin. Other devices such as smartphones and PDAs that have a browser and a *Flash* plugin are also able to support rich interfaces and synchronous interactivity.

The concepts and technologies that define Web 2.0 have revolutionized and extended collaboration assisted by computational systems.
3 Reuse Approach

The proposed reuse approach was motivated by the development of synchronous collaborative Tidia-Ae applications. The first applications, such as Instant Messenger, were developed without reuse. As these applications were being developed, it became clear that they all share some functionality. Each application developed contributed to incrementally map the domain’s requirements, and with a reuse approach, assets such as components and architectures were gradually developed and refined. After a process of three years, it finally reached a more stable state, as we describe below.

The proposed reuse approach is based on the building blocks reuse approach with separate activities defined in [4]. The activities are divided into domain engineering and application engineering as shown in Figure 1.

Domain engineering identifies common aspects of a domain and makes them available for later reuse by domain applications. The view is broader, centred not on one particular application but on a set of them. Domain requirements, shown in Figure 1, are usually the result of the comparison of applications’ requirements. As a new application is being specified, a comparison with the developed applications takes place.

If a commonality is identified and there is no developed component, then a decision to develop a component is made based on the domain engineer’s expertise. That process is repeated for each new application and can be applied to many domains. All components resulting from domain engineering are stored in a components library for timely reuse, whether by applications or in the development of new components.

Unlike domain engineering, which targets a broader universe, application engineering addresses application development by reusing an architecture and components from domain engineering. The applications use the components library to compose part of its functionality.

3.1 Domain Engineering

Domain engineering is characterized by the development of artefacts in order to bring reuse to domain applications. The development model of domain engineering follows the evolutionary prototype paradigm aided by the spiral development model proposed by Boehm [9]. In each increment, four phases take place: Analysis, Design, Implementation and Testing.

The components resulting from domain engineering are divided into 3 tiers: View, Logic and Persistence. In the View area, rich interface components are reused by JSF (Java Server Faces) tags. In the Logic area, the components, also referred to as services, aid communication, authentication, and collaborative session management. In the Persistence area, the components abstract complexities in the creation, retrieval, update and deletion operations of persistent information in databases. Figure 2 shows an overview of the components library.

Dependencies among components or applications are managed by the Inversion of Control design pattern (IoC) [10]. An XML configuration file keeps all dependencies. The components’ implementations are gathered together in that file. If any of the specific implementations of those components need to be replaced, the changes are restricted to the configuration file only, as long as the declared interfaces remain unchanged.

Listing 1 shows an example of persistence and communication services injection in the logic bean of the Instant Messenger application.

Sites like YouTube, Flickr and Justin.tv are examples of the increasingly rich media content available on the Web.”
To illustrate how IoC works, let us suppose, in Listing 1, that the persistence tier (represented by the `dao` property) is MySQL database dependent. If MySQL needs to be changed to PostgreSQL, for instance, then, considering that the PostgreSQL DAO class implements the DAO interface, the only modification required is to update the `dao` property value. IoC brings adaptability to components and applications, reducing coupling and providing better maintainability.

In the following sections, the most relevant components developed by domain engineering are described, starting

Listing 1: An Application IoC Configuration File.

```xml
<bean id="br.fapesp.tidia.ae.im.logic.IMLogic" class="br.fapesp.tidia.ae.im.logic.impl.IMLogicImpl" init-method="init" singleton="false">
  <property name="dao" ref="br.fapesp.tidia.ae.im.dao.IMDaoMySQL"/>
  <property name="commController" ref="br.fapesp.tidia.ae.scs.logic.LogicImpl"/>
</bean>
```

Listing 2: Simple Synchronous Text Interaction Application.

```jsp
<%@ taglib uri="http://br.fapesp.tidia.ae.ccsw2_0/jsf/rwic" prefix="rwic"%>
<f:view>
  <rwic:textWindow participants="#{logicBean.participants}" style="..."/>
</f:view>
```
Engineering e-Learning Systems

UI Components. One of the most time-consuming tasks of the synchronous collaborative web applications domain is the development of Web rich interfaces. Roughly 60% of all the development effort in the first developed applications was devoted to that issue. In order to reduce that development effort, UI components were developed. Most of those components are encapsulated by floating windows with resizing, drag, pop-up, maximize, minimize, close functionalities and AJAX communication support.

To show how those UI components can be used by applications, Listing 2 shows a JSF file that displays a Web page with a synchronous text interaction window. That simple file allows users, represented by the logicBean's property participants, to exchange synchronous text messages.

The developed UI components were grouped into two JSF tag libraries: RWIC (Rich Window Interface Components) and RISCom (Rich Interactive Synchronous Components). RWIC components were designed to provide some basics functionalities, such as audio, video and text interac-

Figure 3: RWIC Class Model.

Figure 4: Synchronous Communication Service (SCS) Class Model.
“Synchronous collaborations supported by computational systems may evolve by adopting richer media.”

Synchronous collaborations supported by computational systems may evolve by adopting richer media.

RISCom offers a set of more meaningful components such as an instant messenger, a chat room, a list of participants, a whiteboard and desktop sharing.

**RWIC.** RWIC provides support to synchronous updates through AJAX, window actions (minimize, maximize, resize, popup, drag, and others), layout management and integration with the SCS (Synchronous Communication Service) and MSS (Media Streaming Service) messaging services, both described in later sections.

Figure 3 shows a class diagram of the RWIC’s internal objects. Abstract classes like GenericCommWindow and AudioVideoWindow encapsulate rich interfaces and communication complexities. TextWindow is a JSF tag that can be used for text exchange. PublishVideoWindow is a JSF tag that can be used for audio and video capture and streaming. PlayVideoWindow is also a JSF tag that displays a multimedia stream.

**RISCom.** UI components reuse is also available through a more meaningful set of components. The JSF tag library RISCom provides components that can be combined in several ways. Some of those components are:

- **Instant Messenger:** UI component for synchronous n-to-n participants interaction that supports audio, video, text, emoticons and file exchange.
- **List of Participants:** UI component that exhibits online and offline participants in a collaboration. It allows participant selection actions to be customized in order to activate other applications such as Instant Messenger or Whiteboard.
- **Mosaic:** UI component that exhibits multiple video panels of participants and automatically arranges them to maximize internal space usage. It can also receive custom parameters such as video rows and columns.
- **Chat:** UI component to text communication that provides content moderation functionalities.
- **Whiteboard:** UI component of an electronic synchronous shared whiteboard. Annotations, figure drawings and slides changes made on the whiteboard are synchronously updated and can be persisted for later reference [11].
- **Desktop Sharing:** Applet based UI component that allows participants to access and interact with other participants’ desktops.

**Communication Services.** Synchronous communication services are perhaps one of the most fundamental commonalities of this domain. Every synchronous application needs to exchange messages between two or more participants. In order to provide that functionality, a communication service was developed to allow simple and efficient message exchange.

Synchronous Communication Service (SCS) allows message exchange following the Publish-Subscribe design pattern [12]. SCS supports text, files, notifications or custom application messages. The service also supports offline messages that are delivered as soon as the participants go online. SCS provides a domain semantic to synchronous collaboration message exchange and depends of an external message service such as JMS (Java Message Server) [13].

Figure 4 shows the internal class diagram of the service. In this figure, the SCSCIClientReceiver class acts as mediator to an external messaging service, receiving messages and forwarding them. Clients must specify that class to receive messages. SCSLogic mainly provides ways of establishing connections and sending messages. The SCSProviderAdapter class adheres to the Adapter design pattern [12] in order to reduce coupling with the external messaging service. Both SCSCIClientReceiver and SCSLogic are injected into the applications by the IoC container and, therefore, the external messaging service replacement will not require any code changes.

The Media Streaming Service (MSS) provides audio and video live streaming using the RTMP (Real Time Messaging Protocol) protocol [14] and it also can persist media streamings. A communication bridge between MSS and SCS was developed to allow notification events such as video and recording events (start and finish). Some application instance might need to be notified when an audio/video publication has been started by another application instance, so it is possible, for example, to open PlayVideoWindow and display the participant’s streaming media.

**Other Services.** Other services present in the components library are:

- The Session Service provides session management such as email notification, timeout notification, parameters

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1 Although AJAX updates are asynchronous, the user has the impression of synchronous updates due to the server’s short response times (Reverse AJAX [27]).

2 A specific messaging service replacement during the Tidia-Ae project motivated the adoption of the design pattern.

The Tidia-Ae project is an initiative that aims to construct an open source web electronic learning environment.”
configurations, schedule conflicts, participants’ information, and others.
- The Authentication Service provides session authentication, user management, role management and participant detailed information.
- The Persistence Service (GenericDAO) supports data persistence management. It provides functionalities to data creation, retrieval, update and deletion.

4 Application Engineering
The proposed application engineering provides developers with an approach to build synchronous collaborative Web applications aided by the services and UI components described in previous sections.

Developing synchronous collaborative Web applications differs from conventional development such as desktop applications due to the previously mentioned non-functional requirements such as security, rapid response, browser related issues, elaborate UIs, and so on. In order to address those non-functional requirements, UI components and services were developed. RWIC and RISCom provide functionalities that can be useful to most of those applications. Text, audio and video interactions are the most basic forms of information exchange in a synchronous computer

```java
<%@ taglib uri="http://br.fapesp.tidia.ae.ccsw2_0/jsf/rwic" prefix="rwic" %>
<%@ taglib uri="http://br.fapesp.tidia.ae.ccsw2_0/jsf/riscom" prefix="riscom" %>
<f:view><h:form>
  <h:commandLink value="Leave room" action="finish" style="...">
  <riscom:whiteboard participants=#{MeetingLogic.participants} editAll="true" style="...">
  <riscom:chat participants=#{MeetingLogic.participants} moderate="false" style="...">
  <rwic:publishAV serverUrl=#{MeetingLogic.MSSServerUrl} stream=#{MeetingLogic.userId} moderate="false" debug="true" style="...">
  <riscom:mosaicAV serverUrl=#{MeetingLogic.MSSServerUrl} streams=#{MeetingLogic.participantsId} moderate="false" debug="true" style="...">
</f:view></f:view>

Listing 3: Main JSF Page Code.
mediated collaboration.

Developing synchronous collaborative Web applications with rich interfaces has proven to be a difficult task. Therefore, evolutionary prototyping with small increments might be a good practice. In each increment, a small deliverable is made to the client. This practice allows developers to focus on small defined tasks and also allows clients to be a part of the development process, making the requirements clearer.

As shown in Figure 1, applications are developed by the same domain engineering disciplines: Analysis, Design, Implementation and Testing. The specific activities that take place in each of these disciplines, with regard to application engineering, are:

- Analysis: application requirements are identified, as well as a set of existing candidate services and UI components that might meet part of its requirements.
- Design: the set of candidate services and UI components are refined and attached to a defined architecture. The design of the remaining requirements is guided by the application’s specific requirements (not fulfilled by the domain’s artefacts).
- Implementation: specific application functionalities are implemented, services and UI components are connected to the application’s code.
- Tests: after unit testing the application’s specific functionalities, integration, system, and acceptance tests take place on the selected services and UI components already in place.

After an increment on all those disciplines, a small deliverable should be available for appraisal. If the deliverable is not approved by the client, then a new cycle must begin with the feedback from the previous increment. After the client’s approval, a new set of requirements will be addressed by the next increment. The process goes on until the application is considered complete and accepted by the client.

Figure 5 shows an application architecture. It is instantiated to an example that will be detailed later, but it should be emphasized that all applications in the proposed approach follow the same architecture. The internal application structure is divided into three tiers, analogously to the domain components division: View, Logic and Persistence. Each tier has sets of responsibilities and depends only on the tier directly below. Messages are exchanged in a top-down fashion without jumps between tiers. The dependency among tiers are managed by an IoC container. The design pattern IoC lowers coupling, allowing, for instance, a whole tier switch by changing the XML configuration file.

Meeting, a proof of concept application whose architecture is shown in Figure 5, was designed to support online meetings so that participants can see, hear, text each other, scribble on a whiteboard and, at the end of the meeting, draw up minutes on the points discussed. This example was selected to emphasize how the proposed architecture supports reuse of domain and application specific requirements. Notice that, except for the minutes part, most of the requirements of Meeting are covered by existent components. Through reuse, it is possible to focus mostly on the application’s specific requirements.

Main JSF page, as seen in Figure 5, gathers together all
UI component reuse while *Minute* JSF page is responsible for the minutes UI. *MeetingLogic* and *MeetingDAO* are devoted only to minutes functionalities, by reusing existent services to access user information, and persistence functionalities, respectively. Notice that an application’s developers do not need to know the details of the reused UI components and their complexities regarding audio, video, text and whiteboard.

Listing 3 shows the reuse of the UI components by the Meeting application in the *Main JSF page*.4

Figure 6 shows a screenshot of the *Main JSF page*. A whiteboard component is at the top left of the screen and a chat component is at the top right. On the bottom, a *PublishVideoWindow* component and a *Mosaic* component can be seen.

Most of the proposed services described in this work provide semantic layers to other services and frameworks that are commonly used in software development, particularly in JAVA. Some of those services used in developed applications, including Meeting, are: JSF and ZK framework for UI, Hibernate as ORM framework, MySQL as DBMS, JMS messaging service, Red5 for audio and video streaming service, Tomcat as application container, and Spring as IoC manager.

### 5 Related Work

Web 2.0 synchronous collaborative works with software reuse concerns are still rare in the literature. However, many synchronous collaborative development approaches have been proposed in the past, particularly in the field of groupware toolkits. These include Groupkit [15], COAST [16], Clockworks [17] and Rendezvous [18]. Although these toolkits are elaborate, some of them proposing languages for domain specification, they lack more practical approach in technological terms. They tend to propose custom services and components that do not take advantage of the scalability and robustness that the frameworks and services already available can provide. Another issue is that they are mostly desktop applications.

PowerMeeting [19] is a recent work and proposes a Web environment for rich user interface synchronous collaboration using GWT and AJAX. It supports whiteboard, brainstorm and chat tools. PowerMeeting also provides a plugin oriented framework in order to allow developers to build plugin applications. However, despite a concern for reuse, as demonstrated by its framework and plugin facilities, it does not provide a defined reuse process. Its structure does not support much flexibility, the outcome being that all developed applications reside inside its web portal.

There are several commercial applications that allow synchronous collaboration such as Skype and Adobe Connect. Those applications have proven to be very successful supporting audio, video, text, screen sharing and whiteboard collaborations. Although the applications resulting from this work may share similar functionalities to these commercial ones, our reuse approach allows for the development of more specific applications and components. These specific applications may not be supported by any existing applications, but they can be developed by reusing components which could reduce the overall cost and increase software quality.

The following section describes an evaluation of the reuse approach quantifying the benefits of reusing software through software metrics.

### 6 Approach Evaluation

Part of the software engineering community is dedicated to quantify software quality through software metrics. Those metrics can be used to measure attributes such as error-proneness, maintainability and development effort gains or losses in a reuse process. Such quantification is important to demonstrate the benefits of the reuse process and influ-

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*The code listed has been simplified to emphasize the use of RWIC and RISCom tags.*

---

<table>
<thead>
<tr>
<th>Applications</th>
<th>WMC</th>
<th>DIT</th>
<th>RFC</th>
<th>NOC</th>
<th>LCOM</th>
<th>CBO</th>
<th>LOC</th>
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</thead>
<tbody>
<tr>
<td>IM without reuse</td>
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<td>0.65</td>
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<td>0</td>
<td>0.71</td>
<td>10.35</td>
<td>3315</td>
</tr>
<tr>
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<td>12.25</td>
<td>1.62</td>
<td>21</td>
<td>0</td>
<td>0.40</td>
<td>5.63</td>
<td>547</td>
</tr>
</tbody>
</table>

Table 1: C&K Metrics Applied to IM Application developed without Reuse and IM Application developed with Reuse.
ence strategies within any software development team.

Comparing an application developed without reuse with the same application developed with reuse can be a way to accurately measure reuse benefits, since the two applications share the same set of functionalities. Thus, the Instant Messenger (IM) version without reuse is compared to the IM version with reuse in order to measure the gains or losses in the proposed reuse approach.

Many software metrics can be found in the literature [20], particularly relating to object-oriented software, such as [21][22][23]. One of the most popular metrics and one with substantial empirical validations is the metric proposed by Chidamber et al. (C&K) [24]. C&K metrics measure code aspects such as complexity (Weighted Methods per Class – WMC), inheritance (Depth of Inheritance Tree – DIT), sub-classes (Number of Children - NOC), coupling (Coupling Between Object – CBO), collateral effects of a method call (Response For a Class – RFC) and internal lack of cohesion (Lack of Cohesion in Methods – LCOM).

Basili et al. made a quantitative evaluation of error-prone programs and the correlation to the C&K metrics [25]. WMC, DIT, RFC, NOC and CBO metrics, in particular, showed a strong correlation to error occurrences. Li and Henry made a similar study correlating C&K metrics to maintainability [26] in Classic-Ada programs. They showed that maintainability could be predicted in 90% using the metrics WMC, DIT, RFC, NOC and LCOM.

Table 1 shows some C&K metrics and the LOC (Lines of Code) of the IM application developed without reuse and the IM application developed with reuse. With the exception of the DIT metric, IM with reuse showed significant improvements in software maintainability and error-prone tendencies. Another significant gain was shown in LOC, IM with reuse showing 84% of code size reduction.

7 Conclusions and Learned Lessons

This work presents an approach motivated by real needs to reuse software in the development of synchronous collaborative Web 2.0 applications. The experience in the Tidia-Ae project was fundamental to the proposal conception, providing a realistic view of the domain and associated risks in the development of such applications.

Some Tidia-Ae applications were developed using the described components library and architecture such as a remote teaching application (REFACE), a videoconference application with teleprompters (Tete-a-Tete) and a thesis defence application (Viva). The approach results in Section 6 showed significant improvements in LOC reduction, error-prone tendencies and maintainability. Those results state that it is possible, in a well delimited scope and with a defined reuse process, to obtain interesting benefits using component-based development.

The construction of a components library was not an easy task; it demanded technical as well as domain vision, planning and knowledge. As result, the development of applications became faster and simpler.

One interesting aspect learned from this domain is that UI development is responsible for over 60% of development efforts. This is due to the fact that many factors such as HTML’s lack of support for a richer set of UI components, browser rendering incompatibilities, and poor AJAX debugging support. Because of such difficulties, a large part of our effort was focused on developing UI web components that can be easily used. The UI tag libraries proposed in this work allows developers to use those components simply by adding tags to the source code as shown in Listings 2 and 3.

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References


Communication Patterns in Component-Based Intelligent Tutoring Systems

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Design patterns are reusable solutions to recurrent problems. Generally described in the context of object-oriented programming, only a few contributions can be found in the domain of eLearning in general or Intelligent Tutoring Systems (ITS) in particular. Based on several approaches to describe the systems’ underlying architecture in terms of pattern collections, we have developed a component-based framework. This framework provides a foundation for the development of flexible and reusable ITS. It also provides a basis for the development of other eLearning systems. Still, the complexity of the inter-modular communication requires experience and self-discipline from the programmer. Thus we investigated the framework for additional patterns. We extracted useful communication patterns and integrated them into an editor. Patterns and editor are presented in this paper as they have already proved themselves very useful regarding programming efficiency and consistency.

Keywords: Component Pattern, Framework, Intelligent Tutoring System, Software Engineering.

1 Introduction

Having their roots in architecture [1], patterns have been adopted by Computer Science and software development since the late 1980s [2]. Since the early 2000s, researchers in the domain of eLearning have made attempts to describe their systems using patterns. The first approaches can be traced back to Devedzic, who collected and described patterns for Intelligent Tutoring Systems, ITS, in 1999 [3]. Harrer and Martens have extended this work towards a catalogue of patterns for ITS (see e.g. [4][5]). Martens and Cap [6] showed that patterns can be used to describe eLearning systems in general, and Maciuszek and Martens extended the pattern catalogue with regard to game patterns [7] in the domain of game-based learning.

Generally, the pattern catalogue started in [5] is based on the idea of combining patterns at different levels of abstraction and integrating them into one collection. It contains ITS-specific patterns and general eLearning patterns, and software design patterns based on the work of Gamma et al. [2]. The catalogue aims at providing a collection of descriptions to be re-used at different levels of project development. While the core patterns of the ITS can easily be used in project structuring and inter-team communication [8], the detailed patterns are best suited for domain expert communication. The related software design patterns support the implementation phase of an eLearning system.

But why do we continue to develop patterns, and why do we think this is a valuable approach? ITS research can look back on a long tradition, and the resulting systems are usually based on more or less the same basic elements. These basic elements can be traced back to a description by Clancy in the 1980s [9]. He noted that, although the names vary, ITS mainly consist of four “models”, i.e. user interface, user model, expert knowledge model, and pedagogical knowledge model. However, the drawback of this description is that role and functionality of each of the models are com-
This article emphasizes the importance of communication in component-based software engineering, specifically in the context of Intelligent Tutoring Systems or ITS.

The importance of communication in ITS development is often overlooked. While ITS architectures are not really comparable, where each ITS developer "re-invents the wheel" and where neither parts of existing software nor main ideas underlying the implementation or design of an ITS can be re-used (see e.g. [5][10]). The same situation (and even worse due to the large amount of different system types) can be observed in eLearning development.

To demonstrate the usability of our patterns, we used them in the development of a component-based framework [11] called JaBInT [10]. In the following we will use the terms "semantic component", "module" and "framework", which will be explained briefly in Section 2.

The idea underlying the JaBInT framework is called "plug-n-train", as modules can be plugged together to develop or extend the functionalities of an ITS.

In the following, we will sketch the framework before describing the communication patterns which we have detected in use of the framework. These patterns facilitate the development and re-use of modules (i.e. the "plugs") for eLearning systems developed with our framework. They have been integrated into an authoring system for ITS, allowing the user to very easily "click 'n plug" an ITS from the defined patterns.

2 The JaBInT Framework for ITS

The term "framework" is used here in the software engineering sense: a framework is a set of re-usable structures which contain the main functionality. They are implemented as concrete and abstract classes defining their basic functionality. New components must implement the interfaces to extend the basic functionality. Software components are part of a composition (a software system or a framework) and can be deployed independently by other software developers. The single component is usually developed based on a component model, describing the basic structure of the component, its interfaces and the communication structure. A well-known example of a component based approach is the Eclipse framework, <http://www.eclipse.org>. Just like Eclipse, JaBInT is developed as a framework – in contrast to other approaches, e.g. service oriented architectures.

The JaBInT framework defines four "semantic components": User Interface, User, Expert and Process Steering. The actual functionality of the ITS is implemented in modules, which can communicate via ports and communication channels. Each module is assigned to a semantic component based on the aim of its functionality, e.g. a user history or user preferences are assigned to the User semantic component. Module assignment to a semantic component and inter-module communication are provided by JaBInT. On the design level, semantic components can be seen as containers for modules. They have no functionality themselves but serve the system developer(s) to clarify the structure of the ITS and the repartition of its functionalities. On the implementation level, the semantic components are only mentioned in an XML, Extensible Markup Language, file describing the structure of the ITS, while modules are packages possibly containing several classes, simulators, databases etc.

The real functionality of the ITS is contained within the modules. They communicate with each other along connections joining output ports to input ports. The input ports can be either "master" or "slave", which means that an incoming message will either "wake up" the module or will wait to be read. The input ports and output ports are the only interface between the modules. Communication in our sense is a unidirectional logical channel between a specific output port and a specific input port, defined in an XML configuration file. It can "carry" a message, which in Java is an instance of a specific message class. We may, for example, define a class NewTaskRequest containing three variables CurrentTaskID, CurrentTaskDifficulty and UserID along with their corresponding "get" and "set" methods. A NewTaskRequest object with all the variables set to the appropriate value can be sent via a connection between two modules from the User Interface to the Process Steering semantic component. We would do so to carry the information about a current task and user in order to receive a new task in return. This way, when replacing a module by another, the developer only needs to ensure that the ports and messages are the same in both modules. Otherwise the modules are completely independent from each other.

This is indeed a very flexible framework, but it also provides the programmer with far more possibilities than would make sense. For instance, one could misuse a communication channel between two ports to convey different message types. Another drawback of the framework lies in the management of the ports and communications: Implementing a new communication between two modules A and B is a rather complex task, as it is necessary to define:

- an output port for module A
- an input port for module B
- the input port type ("master" or "slave")

Patterns have been adopted by Computer Science and software development since the late 1980s.
a message class and
a logical connection between the two created ports. This is time-consuming and represents a considerable source of errors. Inconsistencies in the naming of ports, connections and messages (i.e. use of a different name for the input port, the output port and the message) do not constitute a real error but are strongly to avoided, as they make the implementation much harder. At the implementation level, the structure is slightly more complex than described on the design level. JaBInT holds the general structure of modules and communications in an XML file. Modules can be composed of several Java classes, some external resources, databases etc., and each module needs its own XML file to define its ports. Each message between two ports needs to be implemented in its respective Java class. The precise structure of an ITS implemented with JaBInT is illustrated in Figure 1.

Both to avoid misuse of the possibilities of JaBInT and to provide a more usable and secure framework, we defined some useful patterns regarding the inter-module communication and implemented them into an editor. These steps originate from our practical experience with JaBInT and provide modularity-friendly solutions to recurrent situations. They also limit some undesirable possibilities offered by the framework and spare the programmer much work.

3 Communication Patterns in Component-Based ITS

We define as communication the process of sending a message over a connection between an output port and a slave or master input port (we will speak of slave or master connection). Therefore communication patterns describe a structure of ports and connections enabling this communication.

3.1 Atomic Patterns

We define as "atomic pattern" a communication pattern containing a minimum of communications, so that all communication flows can be described as a combination of instances from the set of atomic patterns. From all the possible combinations involving two modules, we identified two which define a sufficient vocabulary for most issues:

- The first is the request pattern. It is used when module A needs information or any job done from module B. Module A sends a request message to a master port of module B and waits for the answer. Module B "wakes up" by the message, executes the order and sends the answer to a slave port of module A. The structure is very basic: a master connection from A to B and a slave connection from B to A (see Figure 2a top). In order to distinguish connection types, connections to master ports are represented with a plain arrow and connections to slave ports with a dashed arrow.

- The second and even more basic communication pattern is the instruction pattern. It is used when module A requires module B to perform a task without the need for feedback or simply transmits information for storage. Module A sends an instruction message to a master port of module B, which "wakes up" and executes the order or saves the information. This structure is only composed of a master connection from A to B and a slave connection from B to A (see Figure 2a bottom). In order to distinguish connection types, connections to master ports are represented with a plain arrow and connections to slave ports with a dashed arrow.

Other basic combinations of connections (single connection at a slave port or return connection at a master port) seem to be irrelevant or can be substituted by one of the two patterns described above. Our experience showed that these two types of atomic connections are sufficient to implement all connections needed in our ITS. Moreover, it is
much more convenient to deal with request and instruction communications than with mere master and slave communications. We therefore declare these atomic patterns as a suitable and sufficient basic vocabulary for the development of ITS with JaBiInT and will use them in the following for our work.

Another benefit of the exclusive use of the two atomic patterns is that cyclic connection pathways are avoided. Cycles increase the interdependency between modules and consequently decrease the simplicity of exchanging a single module. It is preferable to limit the connections to requests and instructions, even if it increases the total amount of connections.

3.2 Composed Patterns

Some features can be found in any ITS and are therefore considered worthwhile to be described in detail. These features, once formalized in pattern form, can then be used for the development of further ITS. This increases the flexibility of the resulting system while decreasing its implementation costs.

One of these recurrent situations is when the learner is required to complete a task and, in order to do so, performs several actions like clicking or writing. We name every such action an "entry" from the learner. The ITS may want to check whether the entry is correct and, if necessary, provide appropriate feedback.

Figure 2: (a) The Two Atomic Communication Pattern: Request (top) and Instruction (bottom); (b) User Entry Check and Feedback Pattern; (c) Conversation Pattern; (d) Crafting Pattern; (e) Management Pattern.
To demonstrate the usability of our patterns, we used them in the development of a component-based framework called JaBInT.

Usually many steps are required to check whether a user entry is correct and to retrieve a feedback for the learner. First, the module UI from the UserInterface semantic component sends the data about the entry on a master input port of the appropriate module P to the ProcessSteering semantic component and waits for an answer (request communication). As checking every single entry may be too expensive, ProcessSteering should comprise a module Pc computing the necessity of a correctness checking. If the necessity is established, P proceeds to the actual check by requesting the respective expert knowledge from the appropriate module E of the Expert semantic component and eventually decides about the correctness and returns an answer to UI.

In order to give feedback, the module P needs two sorts of information: pedagogical rules from the didactical module Pd of the ProcessSteering semantic component, and information about the user (error history, personal preferences or learning type) from the module U of the User semantic component. These were ignored in the first step of our pattern definition but can be defined separately and then merged.

We may now combine both patterns. Considering that the learner’s errors should be stored, another connection needs to be added from the P module to the Ud module, where the error is processed and stored. Since this task requires no answer, it is a typical example for instruction connection usage. The resulting global pattern representing all ports and communication is shown in Figure 2b.

Thus, we saw a simple example of a very typical situation described as a pattern. Patterns can be combined as needed to adapt to a particular situation, allowing the implementer to consider the whole ITS communication at several abstraction levels, e.g. a "check and feedback" pattern composed of "entry and check", "compute feedback" and "save user entry" pattern, implemented using the instruction and request atomic patterns.

4 Integrating the Patterns into an Editor

To simplify JaBInT handling, we implemented an editor which provides an overview of the structure of the ITS including its semantic components, modules, ports and connections, and permits editing of this structure using the defined atomic and composed patterns. A new connection may be added easily on the design level by assigning a name and choosing the type of connection (request or instruction). This simplifies the process of adding new connections by automating the naming of ports and messages, and obliges the developer to think about the aim of the new connection in terms of expected answer (for a request) or independent information or command (for an instruction). This approach simplifies the complex process of adding a new connection to the essential component (providing a root name and a type), and ensures a systematic naming of all involved elements.

The editor (see Figure 3a) abstracts the implementation level and provides an overview of the structure of the ITS at the design level. It shows all modules sorted by semantic component in the upper part of the window. Ports (left) and connections (right) of the selected module are listed in the

Figure 3: (a) Screenshot of the JaBInT editor; (b) Screenshot of the Flow Visualization in the Editor (the flows are listed at the top left box; the rest of the window shows the involved connections and the steps of the communication sequence).
middle. Selecting a connection highlights the corresponding ports and vice versa. At the bottom, a console displays the latest connections selected by the user along with their corresponding modules. A dialog for creating a new connection popped up on the left.

Since only two possibilities for creating a new connection are provided, the editor grants the exclusive use of the two atomic patterns (see Figure 3a, bottom left). Selecting the request pattern deactivates the "master" and "slave" radio buttons, since these only make sense for the instruction pattern. We chose to keep a certain flexibility in the editor rather than to hinder ourselves by our own pattern restriction in case the situation comes up that a slave instruction is inevitably required. If this situation never occurs in the course of our work with JaBInT, the "master" and "slave" radio buttons will be erased from the dialogue window.

As the number of connections in an ITS implemented with JaBInT increases quickly, it is important to keep an overview of communication sequences (called "flows") that take place in different situations. These sequences are partly built on predefined patterns, but may also be combinations of existing patterns, modified versions of a pattern or completely new sequences. The editor proposes a visualization of the connections and an interactive visualization of communication flows (see Figure 3b).

5 Special-Purpose Patterns
The patterns discussed so far document very general communication processes needed in any component-based ITS. The next step is to help developers working on more specialized applications. These could be ITS following a certain instructional approach, e.g. ITS based on collaborative inquiry learning, or game-based ITS that merge adaptive training with digital games [12]. Adaptive educational games promise to support intrinsic motivation, free experimentation, and illustrative simulation, adding personalized support. In our work, we apply a further differentiation between game-based ITS belonging to certain genres. We are working on ITS based on computer role-playing games

“The idea underlying the JaBInT framework is called "plug-n-train"”

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Communication patterns describe a structure of ports and connections enabling this communication

(RPGs), and ITS based on Construction and Management Simulations, CMSs. These can be further divided into subgenres – tycoon games being a specialization of CMS centering round the construction of infrastructures within a virtual organization. Genres may be mixed, e.g. resulting in CMS with role-playing elements.

A game genre is defined by certain design conventions, e.g. sets of typical game rules and the activities the player performs. Some typical activities in RPGs are the crafting of items or conversation with Non Playing Characters, NPCs. In an educational game – or game-based ITS, in our case – crafting would work well when teaching engineering skills, while conversations are useful in the humanities, e.g. interacting with characters in a game version of a classical drama. Typical activities in a CMS game include acquisition, production, sale, construction, and management. Naturally, these activities are particularly suited for teaching sub-domains of economics.

From a software design perspective, the game mechanics of a certain genre acting as a basis for adaptive educational games constitute a specialized instantiation of our framework. Game functionalities distribute among semantic components and modules. Game activities as a central form of established gameplay conventions draw on several of the basic functionalities. Software designers can therefore regard them as communication patterns – in fact, composed communication patterns, as they can build on the two atomic patterns introduced above.

Figure 2c illustrates a basic version of conversation as a communication pattern in our JaBiNt-based adaptive educational RPG architecture. The player acts in a VirtualWorld where his or her Player Character, PC, can engage in conversation with NPC's. The VirtualWorld module sends a PC's question to the NPCManager. It fetches the NPC's answer from the NPCRules via a request communication and forwards it to be presented in the VirtualWorld. This will repeat until the end of the conversation. The pattern already includes a step of reflection on the exchanged content – educational content in an educational RPG – by providing port connections to the CharacterSheet, where the conversation is recorded and possibly annotated.

We have not yet included connections for adaptation or intelligent tutoring that would determine questions available to an individual user or how a NPC reacts to a particular PC.

Figure 2d illustrates a basic version of the crafting RPG pattern. It differs from the conversation pattern in that it involves three modules within ProcessSteering and communication in-between. The ItemManager sends an instruction to EnvironmentManager notifying it that environment parameters have changed. This reflects a typical game scenario where a player modifies the environment using a tool, e.g. cutting a tree with an axe in the process of crafting a wooden boat.

Again, we have so far omitted an adaptation part where e.g. the character sheet would store which recipes the player has learned and which new recipe the tutor should present next.

Figure 2e shows the management pattern as one example of communication patterns in an educational CMS game architecture. The player composes a business plan in the only User Interface module CompanyWorld, which sends it to the EconomyManager for validation. This is done through communication with the EconomyRules in the Expert semantic component. The validated business plan is then returned to the user via the CompanyWorld, and the old business plan stored in the User component (Competence) is updated. This pattern does already allow for adaptation by an intelligent tutor. EconomyManager may consult the modeled Competence, before sending off the business plan to be validated. One application of this communication might be to check where to annotate the business plan in order to help an individual learner.

We have identified similar patterns for the other CMS activities. In a turn-based (i.e. discrete, not real-time) CMS, we also consider an overall game turn involving all user-initiated planning activities and their simulation along with scoring during that turn as a pattern. As a final note, all three presented game patterns exhibit the idea of User and Expert as the "model", UserInterface as the "view", and ProcessSteering as the "controller", where port communication mediates between these classical architectural layers.

6 Conclusions and Future Work

This article emphasizes the importance of communication in component-based software engineering, specifically in the context of Intelligent Tutoring Systems. While typical components in ITS have long been identified and have been translated into a framework architecture recently, this makes just for half of the design work. Designing communication flow between components or modules is tricky. By starting to collect and document design patterns, this article contributes to facilitating the work of software designers in the Technology Enhanced Learning field.

"Usually many steps are required to check whether a user entry is correct and to retrieve a feedback for the learner"
The editor abstracts the implementation level and provides an overview of the structure of the ITS at the design level.

We are going to collect more communication patterns, structure this collection, and assemble all patterns into a catalogue. Figure 4 shows a first overview that includes most of the patterns discovered so far. It uses Unified Modeling Language, UML, syntax to document composed patterns (aggregation, diamond) as well as special patterns that extend (inheritance, triangle) more general patterns. The two atomic patterns (cf. Figure 2a) are displayed in the centre. All composed patterns are made up of these, sometimes only one type, sometimes of both. The bottom left of Figure 4 shows the general-purpose patterns leading to the examples shown in Figure 2b. They include a pattern not discussed above, show secondary window, which realizes a user interface where different modules present information in different display areas (the secondary windows), contained in one container area (the primary window). Communication between hierarchically organized windows can be seen as a specialization of communication between hierarchically organized modules. User interaction with a secondary module is handled by the pattern user entry secondary window, which can be further composed with user entry check feedback (Figure 2b) to result in the rather complex pattern user entry secondary window check feedback.

The top and the right-hand side of Figure 4 situate the special-purpose game patterns in the catalogue draft. Here, we can use abstract generalizations (pattern names in italics). These will never be implemented alone; instead they provide communication flows shared by their specializations. In the case of educational CMS, acquisition, production, sale, and management all use the same ports and connections, merely exchanging different message data. Each activity in an educational RPG (Figure 2 c-d) may result in a learning journal entry in the CharacterSheet module. The catalogue draft models this by a pattern journal entry that is a part – by composition – of any RPG activity.

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References


Intelligent Tutoring Systems with SCORM

Gustavo Soares Santos and Álvaro Reis Figueira

The research community in the field of Intelligent Tutoring Systems (ITSs) have persistently confirmed that an ITS can increase learning outcomes and assist the educational process. The advances in state of the art of tutoring systems have constantly improved over the years. However, it is still hard to find an ITS outside academia, and one of the main reasons is because tutoring systems cannot be loaded in different platforms or Learning Management Systems (LMSs). This interoperability issue is an important shortcoming, since nowadays most of the electronic educational content comes from artifacts that can be loaded into LMSs (like PDFs, PPTs or HTML content). The main objective of this paper is to describe our approach for solving the interoperability issues of ITSs using the SCORM e-Learning standards. Our approach will be conceptually described and implementation aspects will be exemplified using a prototype.

Keywords: Adaptive Instruction, e-Learning Standards, Intelligent Tutoring Systems, Learning Objects, SCORM, Sequencing and Navigation.

1 Introduction

For several years Intelligent Tutoring Systems (ITSs) have been developed and shown to lead to impressive improvement in student learning in a range of domains including middle school math, physics and programming languages [1][2][3]. Some of the most important shortcomings of ITSs are that their development is very time consuming [4], and they cannot be reused or imported to different platforms [5].

In order to solve the interoperability issues of ITSs we have developed an approach for implementing them using the Shareable Content Object Reference Model (SCORM) e-learning standards [6], and we have implemented a prototype with this approach [7]. The focus of our method is on the implementation of the main features of ITSs, the inner loop and the outer loop.

2 Background and Related Work

2.1 Intelligent Tutoring Systems

Intelligent Tutoring Systems are computer systems that provide direct customized instruction and feedback to students. They usually implement theories of learning by doing [8] and may also employ a range of different technologies for implementation. In general, these systems are conceived as artificial intelligence systems, more specifically expert systems that were initially developed to simulate aspects of a human tutor [9].

ITSs were originally described as having four main modules [10] see Figure 1, but nowadays when it comes to building an ITS, what is really important is to ensure their most significant functionalities: the inner loop, and the outer loop [11]. Indeed:

- The inner loop is responsible for giving appropriate feedback and hints to students while they are working on an activity. The inner loop can also assess the student’s competence and register it on the student model, which is a repository of information about the student. This repository can be used at any time by the tutor to make decisions about the instruction, and it is also used by the outer loop.

- The primary function of the outer loop is to select a task/activity for the student to work on. The most important design issues are selecting a task intelligently, and obtaining a rich set of tasks to select from [11].

An ITS outer loop is about tasks, and an ITS inner loop is about steps within a task. The inner loop executes once per step, while the outer loop executes once per task. According to Vanlehn, an ITS is comprised of two loops as illustrated in the Pseudo-code 1 [11].

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1. Until tutoring is done, do:
   1.1. Tutor poses a task;
   1.2. Until the task is achieved, do:
      1.2.1. Tutor may give a hint;
      1.2.2. Student performs a step;
      1.2.3. Tutor gives feedback on the step;
   1.3. Student submits the solution to the task;

**Pseudo Code 1:** Tutoring System Loops.

A step is a user interface action that is part of completing a task/activity (e.g., solving a problem). Because tutoring systems can support learning in many ways when students are working on steps, let us simplify by assuming that ITSs offer students services as they work. In particular, the following are some of the most common services [11]:

- Minimal feedback on a step indicating only whether the step is correct or incorrect
- Error-specific feedback on an incorrect step to help the student understand why a particular error is wrong
- Hints on the next step to help the student to continue solving the problem without getting stuck
- Assessment of knowledge to evaluate answers that students give to steps
- Review of the solution to help the student to understand the final solution of a problem

The terms *inner loop* and *outer loop* should be understood as behavioral descriptions, rather than software structures. The software structures of an ITS can vary from one tutor to another and can sometimes be very complex [12]. However, the structure is generally irrelevant to the end user if the behavioral descriptions are implemented. One interesting software structure that is commonly used by researchers of the Pittsburgh Science of Learning Center (PSLC, a joint research group between the University of Pittsburgh, Carnegie Mellon University and others), is to build *tutoring artifacts* that contain both graphical widgets, but also everything that the tutoring system knows about that artifact such as, correct steps, incorrect steps, hint sequences for various conditions, error-types and error-specific feedback [11]. That is, a tutoring artifact represents a miniature tutoring system for a particular problem that has everything it needs to run (in one way, similar to a SCORM learning object).

### 2.2 SCORM

SCORM is a collection of standards and specifications for Web-Based learning developed by the Advanced Distributed Learning initiative (ADL). SCORM is adopted by the USA government and nowadays it is also the *de facto* e-Learning standard. The main benefits of SCORM are interoperability, reusability and accessibility [13].

SCORM defines the communication between the client-side content (the user interface) and the server-side (which is usually a LMS). One of the most important concepts in SCORM is the concept of SCO (*Sharable Content Object*). SCOs are standardized learning objects that can communicate with an LMS and can be grouped in organizations to

> **Intelligent Tutoring Systems (ITS) are computer systems that provide direct customized instruction and feedback to students**
create parts of a course, or even an entire online course. The main benefits of SCORM are interoperability, reusability and accessibility [13]. SCORM is composed of three main specifications [13]:

- **Content Aggregation Model (CAM)**, which specifies how content should be packaged and described
- **Run-Time Environment (RTE)**, which specifies how content should be launched and communicate with the LMS
- **Sequencing and Navigation (SN)**, which specifies how the learner can navigate between parts of the course.

By establishing the specifications above, SCORM makes it possible to run educational content that is compliant with these standards in any educational system or LMS that also complies with the standards. It is as simple as many other types of standards (like the ones that allow DVDs to play in equipments developed by different manufacturers).

Because tutoring systems are required to do task selection, the most important SCORM specification for implementing ITSs is the **Sequencing and Navigation specification**. Consequently, in this paper we are only going to focus on the details of the SN specification.

Sequencing in SCORM is what happens between SCOs and outside of SCOs [13]. When a student exits a SCO or makes a navigation request, the sequencing module is responsible for deciding what happens next. SN orchestrates the flow and status of the course as a whole. In SN, aggregations of SCOs are referred by the generic term **activity**. Activities are nested in parent-child relationships that form them into an **activity tree**. Every SCORM activity has two sets of data associated with it:

- **The tracking data**, which represent the state of an activity (its score, status, etc).
- **The sequencing definition**, which is a set of rules that define how the activity should be sequenced.

The tracking data and the definition rules are used by the sequencing loop. This loop is composed of a set of algorithms to apply the sequencing rules to the tracking data and determine which activity should be delivered next. A sequencing loop could result in an activity being delivered, the course exiting or an error condition. The algorithm for the sequencing loop is shown in the Pseudo-code 2 [13]:

1. End the current activity;
2. Transfer the run-time data to the activity-tree;
3. Roll up state data to all clusters in the activity tree;
4. Check from sequencing rules what activities could be delivered;
5. Determine which activity could be delivered next;
6. Deliver the identified activity to the learner;

**Pseudo Code 2: SCORM Sequencing Loop.**

### 3 Conceptual Description of the Approach

We propose to use SCORM for solving the interoperability issues of ITSs. In contrast to previous approaches, our solution for implementing interoperable ITSs is not based on mapping ITS software structures (such as the modules presented in Figure 1) to SCORM modules [14]. We believe that the idea that SCORM modules can be considered "analogous" to ITS modules is not appropriate. First, there is no evidence that SCORM modules can behave as ITS modules. Second, what defines an ITS is not an architecture or software structure, but the behavior. Therefore, we focus our approach on using the SCORM model for implementing what defines an ITS in terms of functionalities: inner loops and outer loops.

#### 3.1 Inner Loop

To design the inner loop services with our approach we recommend doing a **Cognitive Task Analysis (CTA)** and code it in SCOs with ECMAScript (a scripting language). CTA consists of a set of techniques for describing knowledge, and also a set of strategies for knowledge engineering [15]. It has implications for the development of ITSs [16], training and instructional design. CTA is extremely popular for the development of ITSs [17] and there are several examples of tutors designed with CTA in the literature [8][3]. Basically, a CTA can provide a set of guidelines for the implementation of the inner loops services, and it gives you a theoretical foundation to design the user interface, write the rules for hints, and error specific feedback.

Using the CTA guidelines we can design SCOs with inner loops that will behave appropriately to the domain of instruction. Each SCO will be a mini-tutor for a specific problem. However, one of the most important features of the inner loop is to assess the students, and record this assessment in the student model. In fact, regardless of the connotation of the term, the student model is nothing more than a fancy grade book [11]. To implement the student model and "record grades" we will use the SN tracking data, and, in particular, we will rely on SCORM objectives. Objectives are part of the tracking data that provide a way to track the status of individual learning, and share this status across activities. Objectives can store numerical values that represent grades, or **proficiency of skills**.
While students are working on the SCOs/activities, the proficiency of skills can be recorded in the SCORM objectives using the SCORM ECMAScript functions of the RTE.

In short, to implement the inner loop one should carry out a CTA, implement it in SCOs with ECMAScript and use the SCORM RTE functions to populate the student model with constructs of the SN tracking data (mostly SN objectives).

3.2 Outer Loop

While the inner loop uses the tracking data for creating the user model, to implement the outer loop, in addition to the SCORM objectives we need to use the sequencing definition. As stated before, the sequencing definition is a set of rules that define how an activity should be sequenced. These rules can access the information in the SCORM objectives to make decisions. The basic mechanism is (1) to specify a set of sequencing rules, (2) the rules can access in run-time the student model stored in the SCORM objectives, and (3) based on the rules and the objectives define what activity should be launched.

If we think carefully about the mechanism of the SCORM sequencing loop (see the Pseudo Code 2) it does almost exactly what an ITS outer loop has to do, which is task selection. Therefore, it is not hard to technically explain how to do an outer loop in SCORM. However, the practical implementation of the outer loop with SCORM constructs it is a bit more complicated than it looks. Indeed, the implementation of a regular outer loop involves knowing the set of activities available, and how to alternate appropriately between them. Additionally, it is also necessary to deal with the innards of the user model to determine the most suitable activity for a student. When we try to implement an outer loop with SCORM, it becomes a bit more complicated because it is necessary to master the SCORM SN specification that has a flat learning curve. However, this effort pays out due to the enhancement in interoperability of the resulting ITSs.

4 Architecture and Software Structures

4.1 SCORM Software Structures

When it comes to the SCORM software structures involved in our approach, here is an example illustrated in Figure 2. Let’s say a student is practising to solve math problems in a SCORM course. First, the students log in and requests an initial math problem. This request will be forwarded from the user interface to the SCORM RTE server-side implementation using the SCORM RTE client side API (step 1). The server-side RTE on the LMS receives the request and then consults the SN module to determine what activity should be delivered (step 2). The SN module requests the SCORM manifest (an XML file that contains data and metadata about the course being taught) to the CAM (step 3). The CAM delivers the manifest to SN (step 4). Using the tracking data and also the sequencing rule set, SN consults the SCORM manifest, determines the next activity (step 5) and tells the RTE what activity should be launched (step 6). Finally the LMS sends the activity to the user interface (step 7).

While the student is solving the problem, the tracking model is registering data about the performance of the student, or in other words, updating the student model. Once the student finishes solving the problem, the sequencing mechanism will start another iteration (steps 1 to 7 in Figure 2) and use the updated student model to choose the next suitable activity.

"SCORM is a collection of standards and specifications for Web-Based learning developed by the Advanced Distributed Learning initiative (ADL)"
4.2 ITS Architectures

In an inner loop level, our ITS architecture consists in building tutoring artifacts, following the approach adopted by researchers of the PSLC. This approach has been very successful because it applies a *divide and conquer* strategy for implementing the tutors: by dividing a large tutoring system into several small tutoring artifacts, which can be grouped together to create an ITS as whole, it is possible to reduce the complexity of the development process. The architecture of a tutoring artifact built with our approach is illustrated in Figure 3a.

A tutoring artifact basically represents a task or a problem that can be delivered to students so they can exercise. Once we are talking about interaction with the students, we are referring to problem solving events that are dealt with by the inner loop, and the architecture presented above is also able to support the inner loop tasks. As we can see in Figure 3a, a tutoring artifact has its own interface, pedagogical model and expert model. The boundaries of the models have intersections because sometimes it is hard to distinguish whether some parts of the code belong to the pedagogical model or the expert model. In fact, many tutors make no distinction between the two models and they are both coded together in the same file or package [18].

As we can also see in the picture, the whole tutoring artifact is designed following CTA guidelines and it communicates directly with the user model to store and consult information about the student.

We can also illustrate the architecture of an ITS designed with our approach from the standpoint of the outer loop (see Figure 3b). The outer loop is responsible for selecting a tutoring artifact that will be the problem to be solved by a

“SCORM is adopted by the USA government and nowadays it is also the *de facto* e-Learning standard”
student. It has therefore a set of task selection scripts that are basically composed of rules to determine the most suitable problem. These scripts use an expert model and a pedagogical model while they communicate with the student model. However, once again, the expert and pedagogical models do not have to be coded separately. They can be easily embedded in the conditions of the rules and that is why in Figure 3b the boundaries of the models have intersections. Additionally, in order to correctly write the task selection rules we rely on the CTA guidelines.

To represent the union of the architectures presented in Figure 3a and Figure 3b, we describe the architecture of our approach from a coarse grained point of view. Figure 3c represents the top level architecture of an ITS developed with our approach. As we are using tutoring artifacts, the user interface has intersections with the expert and pedagogical models. This is due to the fact that a tutoring artifact has its own interface, pedagogical model and expert model. The pedagogical and expert models have also intersections in the outer loop level, where they are absent of an interface. The student model is the only model that is represented separately. This is because it works as a separate data repository that communicates with the other models that can read and write in the student model. Once again, CTA provides the guidelines for the development of the tutor. It is interesting to do a comparison between the upper level ITS architecture of our approach with the classical ITS architecture that is presented in Figure 1. As it is noticeable, the classical ITS architecture stresses the existence of modules [19] [20][21] and not models, in contrast to our architecture. These modules are represented separately and they communicate to each other, slightly suggesting the idea of software agents. Conversely, in our approach we focus on tutoring artifacts that do not rely on this modular structure and the borders of our models are not strictly defined.

5 Prototype Description

To validate our approach we have implemented a small SCORM-compliant ITS [7]. The domain of our tutor is middle school Geometry.

As we can see in Figure 4a, the SCORM activity tree has one aggregation and two SCOs. Our prototype keeps looping and alternating between the two SCOs until tutoring is finished. The looping aggregation is responsible for the ITS outer loop. It implements the task selection mecha-

**Figure 4:** (a) SCORM Activity Tree; (b) SCO/Exercise Sequencing Structure.
We focus our approach on using the SCORM model for implementing what defines an ITS in terms of functionalities: inner loops and outer loops.

The objectives are manipulated in the inner loop of the SCOs/exercises that are inside the looping aggregation (Figure 4b shows the sequencing structure of the SCOs/exercises). Each SCO consists of a problem for a set of predefined skills. These SCOs are mini-tutors, or in other words, tutoring artifacts. When a student solves a step of a problem correctly, the objective that is associated with the correspondent skill has its score increased by 20 points. If a student fails to solve a step, we decrease the score of the corresponding skill by 10 points. A skill is considered to be mastered when it hits 100 points (the values of 10, 20 and 100 were arbitrarily chosen just to allow testing of the task selection loop). To complete an objective, a student has to answer correctly questions involving a skill at least 5 times, and this gives us enough flexibility for testing all the looping mechanisms in the prototype.

The development tools were the RELOAD IDE, for creating SCORM packages, and Adobe® Dreamweaver® for CSS, XHTML and JavaScript. The prototype was executed in several Operating Systems (OSs), SCORM compliant LMSs, and Web browsers:

- Figure 5a shows one of the SCOs loaded in the SCORM SRTE using the Internet Explorer Browser and the Windows XP OS. This SCO keeps track of the performance of two skills: identify corresponding angles and calculating corresponding angles. In our prototype every time
Our ITS architecture consists in building tutoring artifacts, that represents a task or a problem that can be delivered to students so they can exercise

a SCO/exercise is loaded, the values of the problem are generated randomly and one image is picked arbitrarily from a set of possible images. This allows using the same SCO to generate different problems for the skills tracked in the SCO. As the SCOs were also built with artificial intelligence techniques and CTA guidelines, they can therefore give students intelligent assistance even when the values of the problem are randomly generated.

- Figure 5b shows our prototype loaded in the Odijoo LMS (a SCORM-compliant LMS), using the Chrome Browser in a Windows 7 OS. As we can see, the SCO randomly selected a pair of corresponding angles, arbitrarily picked a reasonable value for this pair of angles and selected one image to illustrate the problem.
- Finally, Figure 5c shows our prototype loaded in the Rustici SCORM Cloud, using the Safari Browser in a Mac OS 10.5.8.

Our prototype ran correctly in all these OSs, SCORM compliant LMSs, and Web browsers used for testing. In addition, to guarantee that our prototype is fully compliant with the SCORM standards we ran the ADL SCORM Test Suit (TS) compliance test. The results of this compliance test are shown in Figure 5d. As we can see, our prototype is fully conformant to all three SCORM specifications.

6 Conclusions

This paper presents an approach for implementing interoperable ITSs using the SCORM e-learning standards, and it also presents a prototype that was implemented using the approach. We do not ground our approach on mapping ITS modules to SCORM modules, but on using SCORM constructs for implementing what defines an ITS in terms of behavior, outer loops and inner loops. The heart of our approach is the SCORM sequencing and navigation specification because it allows the implementation of real-time sequencing of learning activities, based on information that is acquired about the performance of the students at run-time.

References


The unstoppable advance of new technologies has made evident the need for updating learning platforms. This update is based on the incorporation of new functionalities in order to satisfy the changing users’ needs. One of the ways to carry this out is in the evolution of learning environments into a Service-Oriented Architecture (SOA). The implementation of these architectures will allow the creation of clients and external tools that can work with the resources contained in the platform, giving users a freedom of movement that they did not have before. Moodle 2.0 is an example of this evolution and this article presents some of the new possible applications.

Keywords: e-Learning, LMS, Moodle 2.0, SOA, Web Services.

1 Motivation

The big scientific and technological progress that has occurred in society in recent years has caused new educational trends to appear [1][2]. e-Learning has brought in a different approach to learning processes, which introduces new requirements that learning platforms will support. Only a few years ago, using a computer as a tool for supporting the teaching and learning process was considered a technological step forward, but now it is seen as an everyday activity. It is sought to further enrich this process with the ability to access all the information wanted, when it is wanted, that is to say that knowledge can be available all the time. This objective could be considered as the main target of learning platforms (LMS, Learning Management Systems). However they are not always able to satisfy these requirements.

This is due to LMS being too generic, poorly adapted to specialized circumstances, and hardly scalable [3], which hinders their growth and sustainability.

Taken this into account, it must also be considered that in most cases, the power of the LMS is not fully used. For example, many of the features of learning platforms are ignored, making them become in many cases mere resource containers[4][5][6].

Because of this situation, there are a number of initiatives that are trying to provide a degree of independence to these e-Learning platforms, so that they are no longer monolithic and closed platforms. They aim to provide development capacity and technology-independent growth. This independence is achieved by implementing service-oriented architectures, which facilitate interaction to and from the platform, and therefore the incorporation of new functionalities and the possibility to work with new contexts such as mobile devices.

This article will introduce this architecture and some of the applications developed to work with it. In the next section we talk about SOA, Service-Oriented Architecture, and its possibilities, also presenting the relationship between...
SOA and Web services. Then the inclusion of web services within Moodle 2.0 will be analyzed, and how these allow integration with different utilities. We will also explain an example of a service and its implementation.

2 Service-Oriented Architecture (SOA)

To be able to consider the latest advances that LMS can provide it is necessary to define what the service-oriented architecture is and what its potential applications are in the context of e-Learning. SOA is a concept in software architecture that is based on creating a set of services between business processes and applications of varying granularity [7]. This architecture has as its main objectives: 1) Model the business logic as services; 2) Provide access to functionality without knowing the underlying technology; 3) Minimize technological dependencies between the business layer and the application layer, so being able to change both independently.

The architecture and service concepts will be defined to facilitate the understanding of SOA architectures. According to IEEE-STD-1471-2000 ("Recommended Practice for Architectural Description for Software-Intensive Systems") an architecture is "the fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution" [8]. The architecture could be seen as the structural organization of the components of a system.

Once the term architecture has been explained, it must also be known what a service is. There are different approaches to what services are. They can be considered from a business point of view as "a functionality built as a reusable component for being used in a business process" [9] or from a technical point of view as "self-described elements independent of the platform that support rapid, cheap and distributed composition of applications" [10]. In any case, applications or service providers will provide services in order to furnish functionality without showing their implementation. That is, we know what the service does but not how that action is done internally.

The main benefit in implementation of this architecture is the structuring of the component elements and the establishment of communication elements, so that if two systems want to communicate each other they do not need to see how the other works, only using this layer as an intermediary which does know how these systems work. If at any time it is necessary to replace or make a change in one of the two systems, the change is then independent of the other, as they have been developed to be independent of the other system, depending only on the data returned [11]. This way of linking components provides the following advantages: 1) It allows the replacement of individual components without affecting other components; 2) all systems are connected to the exchange layer in the same way, making the system more homogeneous; 3) ease of operation and maintenance; 4) a simple, robust and scalable architecture.

2.1 SOA and Web Services

It is important to understand that SOA is not synonymous with Web services. While SOA is a development paradigm (and a strategy of Information Technology, IT), Web services are one of the technologies that can be used to implement SOA. It is however to be noted that the implementation of SOA is becoming more rapid due to Web services and these are becoming the de-facto standard for the implementation of these architectures.

Once the difference between SOA and Web services have been established, it is necessary to explain what Web services are. There are several definitions of what Web services are, involving complexity in giving an adequate explanation of all they are and mean. They could be considered as a set of technologies or applications that exchange data with each other in order to offer services. Providers offer their services as remote procedures and users request a service by calling these procedures through the Web [12]. These services provide standard communication mechanisms between different applications, which interact with each other to present dynamic information to the user. The use of Web services provides a range of advantages (many of them derived from the benefits of implementing a Service Oriented Architecture) as:

- Promoting interoperability, since the interaction between a supplier and a service requester is designed to be completely independent of platform and language.
- Promote standards and protocols based on text, making easier the access to their content and the understanding of their operation.
- Since Web services are based on HTTP, they can take advantage of firewall security systems without changing the filtering rules.
- Reduce complexity through encapsulation, because service requesters and service providers deal with their own interfaces they need to interact. As a result, a service requester does not know how the provider implemented the

"e-Learning has brought in a different approach to learning processes, which introduces new requirements that learning platforms will support"
service, and at the same time, the provider does not know how the customer uses the service.

- Allow interoperability between platforms from different vendors by using open standard protocols, since specifications are managed by an open organization, the W3C.

2.2 SOA in e-Learning

In order to incorporate interoperability in learning platforms and make them flexible and scalable, it is necessary to define a new generation of learning platforms. These kinds of platforms are going to be based on Service Oriented Architectures. This type of solution will provide a separation between the service interface and its underlying implementation. It will no longer be important whether an application that wants to connect to a platform is implemented in a different technology from the core of the LMS. SOA provides independence in the evolution of software, which allows adding new functionalities whatever the underlying LMS version.

Among the possible applications of SOA various approaches should be considered:

- Use SOA to provide information to external contexts. For example, the use of service-oriented architectures for semantic searches of information in a learning platform, as illustrated by the LUISA project [13].
- Small adaptation of learning platforms to other applications, such as authentication services and backoffice and administrative communication tools [14].
- Linkages between platforms and applications in which the integration is completely transparent to users, allowing two-way communication and providing a mode of presentation fully adapted to the LMS. Several specifications are proposed for this, such as IMS LTI (Learning Tools for Interoperability) for transparent integration of applications into platforms, or OSIDs (Open Service Interface Definitions) from the OKI project (Open Knowledge Initiative) [15], which describe ways to communicate with the platform using other tools.
- Mixed adaptations, where applications require communication with the LMS to extract and incorporate information into it, but without having themselves to be incorporated therein, such as mobile clients for learning plat-
forms. Moodbile [16] is a notable example of such integration.

In any case the aim is to provide new functionalities to learning platforms, allowing them to evolve to an evolutionary, scalable and flexible model from a monolithic model, which tends to become obsolete.

3 Web Services in Moodle 2.0

Moodle is an open-source learning platform, meaning it is a free application that educators can use to create effective learning sites online. The new version of Moodle was released in November 2010. This new version was seen as the opportunity to do things differently, to give a radical change to the platform and adapt it to the technologies that are flooding the telecommunications market. Many of these changes include support for external repositories (Picasa, YouTube, Flickr, Wikimedia, etc.), new modules and blocks, changes in the core, etc., and one of the most important changes is the support for Web services. These Web services will greatly expand the possibilities of Moodle, from being a monolithic platform to become a scalable application that can interoperate with users. These services could provide solutions to emerging needs of the users, such as the following:

- The emergence of mobile devices with Internet access, with various interfaces and features. Many of these devices allow navigation through the application, but, due to their physical limitations the navigation can be very complex. Therefore, knowing that the number of these devices is growing, it would be advisable that Moodle facilitates the creation of alternative interfaces adapted to these platforms.

- The number of organizations that rely on Moodle as their e-Learning platform has increased in recent years, leading to changes in the system requirements (scalability) and diversification, as there are continually emerging new needs, such as new functionalities (without corrupting the pedagogical principles of Moodle). It is still necessary to adapt Moodle to the information systems of organizations where it is implemented.

- Backoffice integration. The possibility is provided of creating an application that can interact with multiple systems at once, executing the same action in several places, making it all work together, avoiding having to do the operations several times. For example, you may need to register a user in the platform and in the database of the organization (left side of Figure 1).

"It is important to understand that SOA (Service-Oriented Architecture) is not synonymous with Web services"
By using Web services, the action would have to be done just once using a backoffice tool, which is responsible for carrying out the actions both in the database of the organization and in Moodle, using Web services, without modifying or accessing the code of the platform (right side of Figure 1).

3.1 Architectural Approach

The first step in Web service development was to define an architecture that would ensure interoperability. Therefore, these Web services had to fulfill certain requirements established by the Moodle development team [17]:

- Web services must be accessible from any connection system, now and in future, and they should be able to be invoked regardless of the language used in the request (interoperability).
- The Web services structure must be developed so that even if there are changes in the Moodle core, it is not necessary to make many (or any) modifications to the set of features they provide, i.e. the API (Application Programming Interface).
- The functions in the API should be extensible to encourage contributions.
- The Web service must be adapted to the Moodle system privileges (capabilities) to ensure safety.

According to these requirements, Moodle 2.0 Web services are divided into three basic layers [18], shown in Figure 3. External customers connect with the platform via the connectors that receive the requests, interpret them and call the corresponding functions of the Web services. These are defined within externallib.php files distributed over all the directories in Moodle. These functions are responsible for the access to the database or the invocation of the Moodle functions in order to carry out such tasks.

1. Connectors. So far, the platform can be connected through 5 protocols. Each of these protocols has its own connector, which is responsible for receiving the request from outside, checking if the wanted function exists and checking the permissions of the invoking user. If the user is authorised to use the function, connectors will analyze the data (parsing) and will call the appropriate function. Connectors support plug-ins, so it is easy to add new connectors for external systems to be able to connect with Moodle using protocols different to the ones that come as standard with the platform.

Figure 3: Recovering Information from a Particular User in Moodle 2.0.
2. **Externallib.** This layer consists of a set of files, named externallib.php, that are spread throughout the directory tree of Moodle. These files are called from the connectors and contain all the features offered by the Web services API. That is, they comprise all the Moodle features to deliver them to the outside, trying to reuse as much code as possible from the platform. Naturally, before beginning to perform any of the actions, user permissions are checked with respect to the action to take, and the parameters received or returned are also checked. The parameter check is achieved by having a number of methods that indicate the parameters that the functions must receive and that they should return.

3. **Moodle core.** The Moodle core layer consists of all the libraries that contain functions that may be used by the externallib layer functions, i.e. user-related functions, courses, groups, etc. This layer has been improved in Moodle 2.0 because many of these functions formerly printed error messages on the screen when there was a problem, so they have been rewritten to return exceptions when there is an error. (Until now, Moodle had no API, but due to these changes one is now being generated).

As an example of message exchange and Web services structure, the following picture (Figure 3) shows how to recover information from a particular user.

To be able to retrieve data from a user, first it is necessary to select a connector and pass parameters: the action to perform and the information required to carry it out, in this case the "User Information" and the ID of the user to retrieve. The connector will check the permissions and whether the function exists in the user Web service API. In that API it will check the validity of the parameters and will invoke the appropriate function within the Moodle core. Once the information is retrieved, the answer is built and returned to the client via the connector that was used for the connection.

"The authors of this article have taken part in the definition of the new services-based architecture and have performed several deployments to verify its operation"
3.2 Moodle Web Services Applications

It is obvious that Web services will open a new world of possibilities related to the export of information from Moodle and the integration or interaction with other tools. The authors of this article have taken part in the definition of the new services-based architecture and have performed several deployments to verify its operation:

- **Backoffice tool.** During the development of the external layer of the Web services, it was decided to implement a testing tool that would test if the API functions worked properly, besides their usability. It was necessary to cover as many functions as possible, so a small-scale backoffice tool was created, which allowed an administrator to perform the basic steps in a Moodle platform. Among these steps were those to be able to manage users, courses, roles, logs, etc., and also including elements in order to test each function of the Web services API and all the connectors.

- **Visualization tool.** Adaptation of a logging visualization tool to by using the Moodle Web services [19]. This tool is designed to work with the information about the user activity on learning platforms (so far in Moodle), showing for example: information that allows analysis of the best times to do technical maintenance on the platform; make social studies (allowing visualization of the connections between people existing in the platform, word clouds to see the most used terms, etc.). Web services provided the tool with the logs from the platform without having to access the database directly. In this way the tools developed could be independent from the implementation technology and version of the underlying platform

- **Portable learning components.** Another aspect to consider, for possible exploitation of the new services architecture, is the ability to export functionality of the platform to other contexts, such as informal learning environments, social networks, mobile devices, etc. Exporting this functionality requires a form of representation, which will be by widgets. Widgets are small, portable items that can work in any HTML context, providing interaction, content or the functionality of another web context [20]. There are different types of widgets, as well as engines to generate them. The authors of this paper have recently finished the development of a widget for the forum export. To do this, the Apache Wookie widget engine has been used [21]. An example of the current work with widgets is shown in Figure 4, showing a widget created to manage forums.

4 Conclusions

Learning processes are changing, not only due to the development of new technologies, but also sociological changes such as: the emergence of social trends favoured by 2.0 tools; the new training needs more and more student orientation; the new contexts and situations where students learn; the fact that the receivers of the information have been born in the digital age and therefore use the technology at a level not previously considered; new educational paradigms derived from proposals such as Bologna legislation which advocates for the recognition of both formal and non formal learning; etc.

All this shows the need for the development of tools used in learning processes such as LMS. To do that, SOA architectures are needed. These architectures are an opening to allow the increase in functionality of learning platforms, providing a way to avoid stagnation and paving the way towards new trends such as personal learning environments (PLEs) [22].

Moodle 2.0 and the tools defined for its testing are an example of how a platform can go further and can actually be scalable and flexible thanks to the foundation that Web services provide. By using service-oriented architectures on this well-known LMS, a way to enhance its capabilities, independently of the technology, has been achieved. This type of application will ensure the evolution of the "species", which are the ways students use to learn, such as learning platforms and contexts to which they can be applied.

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References


A Practical Case of Agents and Services Integration in e-Learning Environments by means of Tuple Spaces

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The use of e-Learning standards and distributed service-oriented architectures which provide for the reuse and integration of components introduces the concept of a component-based development process in the implementation of e-Learning systems. This concept enables the development of tools that make use of the synergy effect created by the integration of the different components. This article will show our implementation proposal which follows an approach based on tuple spaces for the integration and communication of distributed heterogeneous components, and makes use of a user environment which implements the corresponding Eclipse plug-ins. As an example, we will show several applications integrated under our approach, which facilitate the continuation of the teaching/learning process in subjects related to programming algorithms.

Keywords: Component-Based Development, Eclipse, e-Learning Environment, Tuple Spaces.

1 Introduction

One of the objectives pursued by the main e-Learning systems standardization committees is to encourage the reuse and to ensure the interoperability of both the systems and the components that constitute them. The aim is to build tools enhanced by the integration of different components and services [1][2][3][4] by following a Component-Based Development (CBD) approach [5].

We are currently witnessing the constant evolution of standards, specifications, reference models and good practices to support this. They make intensive use of software engineering, model analysis, etc. in their definition and specification, with the aim of facilitating the construction of systems that use them. In general, literature refers to all these terms as "e-Learning standards".

However, the implementation of standardized services and reference architectures proposed by the various committees and working groups are not tied to a specific middleware, platform or technology. Nevertheless, selecting the most suitable one is an important task to guarantee integration and scalability. Moreover, an additional objective in our research line is not only to allow service integration, but also to integrate intelligent agents and components that provide support to the whole teaching/learning process, and to do so from heterogeneous processing resources. It will allow us to join up the different pieces that make up a complete and complex e-Learning system with a heterogeneous distributed architecture.

In this article, we will start by presenting the proposals of service-oriented architectures for e-Learning systems and the different middleware that we can use to implement them (Section 2). Next, we will show our proposal based on tuple spaces for the integration and communication between heterogeneous distributed components (Section 3). Then, we will present the model of the system implemented as an example (Section 4), and afterwards we will detail the differen...
In this article we introduce some of the main middleware technologies to develop heterogeneous distributed applications that can be used to build heterogeneous distributed eLearning systems.

2 Reference Architectures and Middleware Technologies for their Implementation

At present, there are several groups working with the aim of achieving a set of specifications that enables reuse, interoperability, scalability and durability principles to be extended in the e-Learning industry. These groups define the standards, specifications and reference models that constitute the framework in which developers and engineers of e-Learning systems must work to achieve interoperability between systems.

From a structural point of view, there is great interest in providing standardization which allows interoperability and reuse in e-Learning environments [1][2][3][4]. Most of the standardized specifications are presented as services that can interact and create interrelationships with each other, which is why there are several Services Oriented Architectures (SOA) proposed for the construction of e-Learning environments. Because most of the standardization committees work closely together, their reference architecture is very similar. They even use the same layers and functionalities. Thus, taking the IMS Abstract Framework [1] as reference architecture, we can offer as an example the application of service oriented architectures as proposed by the JISC ((Joint Information Systems Committee), <http://www.jisc.ac.uk>.

The JICS, far from creating new specifications and standards, tries to use and to reach a consensus on the use of existing standards created by other groups. This characteristic makes its architecture perhaps the most pragmatic. This architecture is comprised of three service layers:

- The User Agents Layer; here we can find the LMS, the e-Learning portals, authoring tools, etc.
- The Learning Domain Services Layer; involves the creation and management of courses, learning activities sequencing, ePortfolio, etc.
- The Common Services Layer; here we find services which are shared with other domains, such as authentication, chats, forums, message exchange, etc.

Due to their service-oriented nature, these reference architectures usually propose an implementation based on Web Services (WS) for communication between services [1][2][3]. However, the standardization groups do not make the use of WS mandatory. In fact, there are several options we can use to implement a system based on Service Oriented Architecture.

One of the best-known middleware technologies is Web Services (WS), <http://www.webservices.org/>. However, WS are too slow because, among other reasons, the communication protocol is based on text transmission rather than a more compact format like binary [6].

WS functionalities can be obtained using CORBA (Common Object Request Broker), <http://www.corba.org/>. However, despite the fact that CORBA makes up for what WS lacks, the truth points to WS as the alternative supported by most of the industry. Baker proposes in [6] a consensual solution to integrate different middleware, so that there is not just one single universal solution but also particular solutions for each problem. Then, by means of bridges between middleware technologies, they can be integrated and interoperated all together.

M. Henning from ZeroC tries to give an explanation of this support for WS and the marginalization of CORBA in [7]. To do so, he analyses the social, economic and technological factors which have made CORBA a technology relegated to the niche of embedded and real time systems. Henning refers to CORBA in the past and points out that "CORBA was a victim of industry trends and fashion" [7]. Furthermore, he spots the technical complexity, the drawback of certain features such as security and versioning support, the difficulty of building a good event distribution service, the lack of asynchronous support for method dispatching between client-server, and the absence of mapping to programming languages like C# and Visual Basic, keeping CORBA out of the .Net architecture.

To address this situation, ZeroC, <http://www.zeroc.com/ice.html>, developed the Internet Communication Engine (ICE). Its authors had one main objective: "Let's build a middleware platform that is as powerful as CORBA, without making all of CORBA's mistakes" [8]. ICE is an object-oriented middleware for heterogeneous environments, which provides a more efficient implementation than WS in relation to bandwidth, CPU and memory, avoiding CORBA's complexity. In the same way, ICE provides a set of features like security, event distribution service and support for asynchronous method dispatching.

As solutions oriented to specific platforms and programming languages, we have Java RMI (Remote Method Invocation) and the Microsoft .NET platform. The former uses...
Java to build the multiplatform services. However, it is a middleware in which the only programming language admitted is Java, both for implementation and for service specification. However, the .NET platform allows heterogeneous distributed systems to be built using several programming languages such as C# or Visual Basic.Net, but it only works with communication protocols supported by the platform.

Typically, all these technologies are based on providing an environment in which we can register the services and store the objects which implement the services. The middleware is in charge of providing a reference to the object or objects that implement the associated functionalities for a specific service. However, in order to access these objects it is necessary to know their public interface. In this situation, it is difficult to add services that can create added value if they are not previously defined and standardized.

3 Integrating Agents and Services by means of Middleware Technologies based on Tuple Spaces

From an e-Learning systems point of view, it is interesting to allow not only services integration with a well-known and standardized public interface, but also the integration of agents and other services that support the teaching/learning process.

It is in this sense that we must search for architectures and middleware technologies that support both service integration and the ad-hoc aggregation of agents. Typically, these architectures that use agents are based on the use of a communication bus. The components communicate by sending and receiving all the information through the bus. The agents “monitor” all the information that travels through the communication bus. Thus, if the agent is interested in the information, it takes it, manipulates it and creates the corresponding output which is sent through the same bus.

An architecture that can be used to implement a system with these features is that known as blackboard architecture, based on the blackboard metaphor. The “blackboard” is the common knowledge base and it is iteratively read and updated.

While implementing a system, this metaphor tries to take advantage of the synergy effect created by the integration of agents. Little software pieces with a well-defined functionality (agents) use the information that is on the “blackboard” to generate new information that can be used by other agents which also have well-defined functionality.

This metaphor, on which the blackboard architecture is based, is the one used in tuple spaces based systems [9]. The tuple space is an associative shared memory where the information is stored as a set of tuples. The tuple is the main element of the system. The tuple consists of a vector of fields, and each of these fields has a data type and a value. The producers’ agents send data in form of tuples to the tuple space (write on the blackboard), and the consumers’ agents read from the tuple space those tuples that match a concrete template (read from the blackboard the information that they understand).

To manage tuple spaces we have the tuple spaces servers, which are accessible through the network. There are different tuple spaces servers’ implementations. Among them we can highlight TupleSpaces [9], JavaSpaces, <http://java.sun.com/developer/technicalArticles/tools/JavaSpaces/>, TSpaces <http://www.almaden.ibm.com/cs/TSpaces/> and SQLSpaces <http://sqlspaces.collide.info/> [10].

All these servers have a simple set of operations that allows the clients to manage all the information. These op-

Figure 1: Design Model for the System Implemented following the Proposed Architecture.
operations are basically to write, read and take tuples from the shared memory. Some implementations even have a notification mechanism, so that the server informs those clients interested in knowing when a tuple that follows a particular template has been written, updated or deleted.

Thus, the blackboard architecture seems to be suitable for implementing e-Learning systems in cases where it is necessary to perform ad-hoc integration of different components (services and agents). Hence, they allow the expansion, integration and scalability of the system. With this architecture, we can implement the Learning Domain Services Layer and the Common Services Layer that we explained in Section 2.

To implement the User Agent Layer, we propose choos-
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4 Design Model of the Systems

To focus our research work, we have taken as a framework the acquisition of the algorithm programming competence [11]. To give support to the acquisition of this competence, we aim to implement an environment which must provide the following features: a) to facilitate the use of different views; b) to provide a mechanism to extend and improve the tool; c) to use a development environment close to what the students will find in their professional lives.

All these features are available on Eclipse, <http://www.eclipse.org>. This is a widely used integrated development environment [12][13]. It is an open source project in which extensions can be created by means of an API. These extensions are made by means of plug-ins that can be optionally loaded by the users. Furthermore, it is a full development environment for several programming languages, as well as for modelling and validating design models. This provides us with the ideal tool for building our proposal as it allows us to validate our approach with different programming languages and other programming and software engineering issues.

Thus, in our developments, we have built a set of tools and views for the Eclipse development environment in addition to a web-based interface to enable us to analyse the versatility of the proposed architecture.

To implement a complete system based on the specified architecture, we have selected a tuple spaces server that allows us to work with Java language, because it is the one used to implement the plug-ins for the selected user environment. Hence, we have chosen SQLSpaces [10], because it is open source and has multi-language support which provides the system with more integration and interoperability capabilities.

As can be seen in Figure 1, the tuple space server constitutes the system’s central piece. This figure shows how all the elements (agents, services, user applications, etc.) are interconnected by means of this server.

We have implemented three users’ applications in particular. On the right of Figure 1 we can see how two of them have been implemented as Eclipse plug-ins, namely Tuple-LD and COLE-Programming. On the left of the same figure, we can observe how another application has been implemented for web environments, namely Edunet.

By using the tuple space server, all these applications share the same information and communicate with each other. This server will store the user’s session data, the communication messages used in several services (chat, forum,

Figure 4: Several Views for COLE-Programming.
etc.), the information related to the students’ assignments, the sequencing of learning activities, etc.

In the next section we will outline the features and functionalities related to each developed application.

5 Features of the Implemented Tools

Having shown the design model of the system in the previous section, in the next subsections we will outline each implemented tool to support teachers and students.

5.1 Tuple-LD

Tuple-LD (Tuple Learning Design), <http://chico.esi.uclm.es/coala/index.php/Tuple-LD>, is a sequencing engine for instructional designs or learning activities [14]. These instructional designs are specified by means of a tuple-based language. This application includes, on the one hand, the service for setting and launching the instructional designs the users must follow and, on the other hand, a set of tools for selecting the instructional design to run, perform the learning activities and monitor progress. Thus, we have the service and the user interface where students will execute the guided tasks (readings, implementations of algorithms, etc.).

Tuple-LD uses SQLSpaces to store and share all the information related to the instructional designs specification, users, groups, tasks, roles and learning design executions. The Tuple-LD’s user interface is implemented as an Eclipse plug-in with two perspectives:

- The administrator perspective that allows users, groups and tasks to be added, by specifying instructional designs and launching the executions, as can be seen in Figure 2.
- The running perspective that allows instructional designs to be run in the environment. In Figure 3 we can see how this perspective looks like. The user interface is composed of the activity-tree (on the left) where the learning activities are shown by using different colours to indicate the state of the activity (finished, to do, running, etc.), the tasks the users are currently executing (on the right),

![Figure 5: Edunet Player with Enhanced User Interface using Adobe Flash CS4.](image-url)
An architecture that can be used to implement a system with these features is that known as blackboard architecture.

and some progress statistics related to the execution of the instructional design for the user (at the bottom).

Among the learning activities that the student must perform in the environment is that of performing some assignments in a collaborative way. The integration of the necessary services and components to perform these assignments can be implemented in isolation and afterwards integrated into the full system following the exposed proposal and architecture. An example will be seen in subsection 6.2.

The instructional designs engine that Tuple-LD implements is a service that is not restricted to use within Eclipse. The learning activities can also be executed in another environment connected to the tuple space server. An example is shown in subsection 4.3, where a web environment to perform instructional design is explained.

5.2 COLE-Programming

The possibility of performing collaborative tasks so that we can take advantage of the use of the Computer Supported Collaborative Learning (CSCL) is one of the features that we did not want to lose. Thus, we implemented COLE-Programming (Collaborative Learning Programming), <http://chico.esi.uclm.es/coala/index.php/COLE-programming/>. This is an Eclipse plug-in that tries to support collaborative programming tasks within the Eclipse environment.

COLE-Programming implements a set of services and tools (chat, forum and poll) to facilitate the interchange of information among students while they are trying to solve a programming assignment in a group. These tools include the following features:

- Message filtering in forums according to their type (new problem to discuss, solution proposal, criticism, etc.)
- Sharing code, compile error messages, warning messages, etc.
- Visualising collaboration statistics, such as the utilisation level of a user for each particular tool, participation percentages, users that have collaborated together or shared information, etc.

In Figure 4 we can see the chat, forum and poll views, as well as the statistics for monitoring the collaboration. The use of these tools will enhance the students’ programming assignments, allowing them to be used in collaborative learning environments.

COLE-Programming can be used in isolation to perform collaborative programming assignments, or used in conjunction with Tuple-LD. These two alternatives allow us to have a learning environment where, if in at a particular moment during the execution of certain learning design the students must work in groups, they can use COLE-Programming. This scenario of use is possible thanks to the proposed architecture. With this, we can obtain a system built with the integration of both tools, so that it can be enhanced with all the functionalities.

Thanks to the proposed architecture, the e-Learning system is not restricted only to the Eclipse context, but can also be extended by implementing components for other environments. Thus, in the next subsection, we will show how the implemented services can be used by other components and platforms so that they can extend the application scenarios.

5.3 Edunet

The Edunet (Education in Internet) environment, <http://chico.esi.uclm.es/coala/index.php/Edunet>, is intended to execute instructional designs in a web-based environment. It uses Tuple-LD services for the execution of the instructional designs and the chat and forum services from COLE-Programming.

Its main feature is its enhanced user interface to allow easier interaction, leaving behind the Eclipse environment. We have chosen Adobe Flash CS4 to implement it. This has allowed us to build a highly customizable environment (Figure 5). This feature makes the learning process more comfortable for the user. So, Edunet allows:

- Visualising the learning activities to perform in the environment (at the top-left). Those activities can include content visualisation, use of services like chats and forums and use of other tools to facilitate the learning process, such as a simple code editor that allows programming assignments to be performed.
- Visualising and navigating through the learning activities sequencing by means of a learning activities graph instead of the learning activity-tree commonly used.
- Customizing the environment by modifying the size and position of the windows, the colour of the environment, the background, etc. (on the right).

The integration of Edunet in the system allows us to use it in more learning scenarios, facilitating the development of Blended Learning environments, where the users can interact with the system by means of both the Eclipse environment and a web-based environment using a web-browser.
Among the learning activities that the student must perform in the environment is that of performing some assignments in a collaborative way.

6 Summary and Final Comments

In this article we have introduced some of the main middleware technologies to develop heterogeneous distributed applications. These technologies can be used to build heterogeneous distributed e-Learning systems which integrate services and agents out of necessity.

On the one hand, we have explained those services-oriented middleware technologies based on the specification of a public interface known to the rest of the services in the system. Their main disadvantage is that in order to use those services it is necessary to know their public interfaces, hence these public interfaces must be previously defined and standardized. This situation means that the services that constitute the system must be previously known, in some cases preventing the integration of additional services on demand.

On the other hand, we have reviewed the tuple spaces based middleware, which use the blackboard architectural model. This model allows the ad-hoc integration of services that share information by using an associative shared memory accessible through the network. We have shown several middleware technologies to implement this architecture and how they are based on a simple and easy to use set of primitives.

So, we have shown a proposal that makes use of tuple spaces to integrate different heterogeneous distributed components. Furthermore, the proposal includes the use of plug-ins for the Eclipse platform to build an integral and extensible environment where students and teachers will interact. To illustrate the use of the proposal, we have shown a set of tools that support learning to programme, individually or in groups, which are perfectly integrated in the environment thanks to the use of the proposed technologies and architecture.

The objective of our actual research line is to validate our proposal by integrating more services and agents, so that we can use it in more learning scenarios and educational paradigms.

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COLE-Programming can be used in isolation to perform collaborative programming assignments, or used in conjunction with Tuple-LD.
Towards Adaptable e-Learning Services Invocation: Application to Navigation and Fishing Simulator

Valérie Monfort and Maha Khemaja

Many companies aim to use Web services to integrate heterogeneous and/or remote application in SOA (Service Oriented Architecture) contexts. The SaaS (Software as a Service) economic model allows the linking of service consumption and pricing. We aim at considering e-Learning as a set of services, hosted according to cloud computing techniques. Moreover, we propose a solution to adapt tutoring content according to context, based on a specific commercial product.

Keywords: Adaptability, Cloud Computing, e-Learning, Interoperability, SaaS, SOA, Web Services.

1 Introducción

Economical context impacts on companies and their Information System (IS). Companies take over other competitors or develop new business skills and moving offshore whole or part of their organization and their production. IS are faced with these genuine constraints and have to overcome these changes. Service Oriented Architecture (SOA) [1] provides great flexibility to IS because each application has interfaces which mask implementation details. So, applications have interfaces including services and are seen as black boxes independently connected to a type middleware such as an Enterprise Application Integration bus (EAI) with its connectors and adaptors.

However, this integration solution does not enable heterogeneous applications or infrastructures to be connected like distant IS. This is why Web services (WS) are based on standards and have been, until now, the cheapest and simplest solution to support interoperability between platforms. Based on Web services, Enterprise Services Bus (ESB) [2] is a kind of services Web based EAI and allows loose coupling at a low cost.

Unlike these technologies, the SaaS (Software as a Service) model enables a price to be associated with service consumption. Moreover, cloud computing, closely linked to SOA and SaaS paradigms, enables IT resources to be delivered "on demand" by using the virtualization paradigm.

We are convinced that SaaS and cloud computing are the fitted solutions to be used for an e-Learning domain where any user such as companies, schools, etc. could pay services to train learners via Web services and ESB. We also assume e-Learning applications may be considered as part of a company’s Information System (IS). Moreover, e-Learning applications may be viewed as a set of services deployed on a remote server.

Therefore, we are developing a new kind of e-Learning platform, based on orchestrated services which are used "on demand" according to training needs and learners skills. In particular, training content and process may be adapted according to pedagogical context such as: the learner’s skills, a specific event which may or may not be programmed by the teacher, the learner’s location, etc. This solution aims to address: i) a full-service oriented solution to provide full interoperability between authoring tools based on specific e-Learning standards and any kind of execution platform; ii) full interoperability between training and business processes to facilitate the shift between working and training modes and vice versa; iii) services consumption according to the SaaS model and the cloud computing approach; iv) a simplification of execution platforms, according to which platforms become middleware with an orchestration engine for distant, remote, simple or complex services hosted locally; and v) an adaptation of pedagogical context according to events. Since the background of our research work is industry and the users are learners employed by navigation and fishing companies, we will apply this solution to a real-work problem to train employees on simulators.

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2 Background

2.1 Web Services

Web services (WS) [3], like any other middleware technologies, aim to provide mechanisms to bridge heterogeneous platforms, allowing data to flow across various programs. WS technology looks very similar to most middleware technologies. Consequently, each WS has an interface definition, usually described with WSDL (Web Service Description Language), which is responsible for characterizing the message payload. Web services themselves are accessed with the equally famous protocol SOAP (Simple Object Access Protocol), while data structures are explained by XML (eXtended Markup Language). Very often, WS are stored in UDDI (Universal Description Discovery and Integration) registries. Web services standards are gathered in WSA (Web Service Architecture).

2.2 The SaaS Model

Software as a Service (SaaS) [4] is a model of software deployment whereby a provider licenses an application to customers for use as a service on demand. SaaS software vendors may host the application on their own web servers or download the application to the consumer device, disabling it after use or after the "on-demand" contract expires. The "on-demand" function may be handled internally to share licences within a firm or by a third-party Application Service Provider (ASP) sharing licences between firms. "On-demand" licensing and use alleviates the customer’s burden of equipping a device with every conceivable application. It also reduces traditional End User Licence Agreement (EULA) software maintenance, ongoing operation patches, and patch support complexity in an organization.

"On-demand" licensing enables software to become a variable expense, rather than a fixed cost at the time of purchase. It also enables users to license only the amount of software needed versus traditional licences per device. SaaS also enables buyers to share licences across their organization and between organizations, to reduce the cost of acquiring EUAs for each device in their firm. Using SaaS can also conceivably reduce the up-front expense of software purchases, through less costly, on-demand pricing from hosting service providers. SaaS lets software vendors control and limit use, prohibits copies and distribution, and facilitates the control of all derivative versions of their software. SaaS centralized control often allows the vendor or supplier to establish an ongoing revenue stream with multiple businesses and users without pre-loading software in each device in an organization. The sharing of end-user licences and on-demand use may also reduce investment in server hardware, since the server use is shifted to the SaaS suppliers of applications file services.

2.3 Cloud Computing

Cloud computing [5] is a model for enabling convenient, "on-demand" network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models, such as: on-demand self-service, ubiquitous network access, resource pooling, location independence, homogeneity, rapid elasticity, measured service. Cloud computing brings a new level of efficiency and economy to delivering IT resources on demand. It offers efficiency and agility.

Cloud computing is typically divided into three levels of service offerings: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a service (IaaS). The middle layer, or PaaS, is the encapsulation of a development environment abstraction and the packaging of a payload of services. PaaS offerings can provide for every phase of software development and testing, or they can be specialized around a particular area, such as content management. IaaS is at the lowest layer and is a means of delivering basic storage and compute capabilities as standardized services over the network. Servers, storage systems, switches, routers, and other systems are pooled (through virtualization technology, for example) to handle specific types of workloads from batch processing to server/storage augmentation during peak loads.

3 Towards SaaS and Cloud Computing-Based e-Learning Solutions

3.1 e-Learning Standards and Web Services

e-Learning standards are the necessary vehicle to ensure interoperability between e-Learning platforms and tools. Nowadays there is an increasing tendency to integrate Web services and SOA concepts and principles inside e-Learning standards. Additionally, many of these specifications have a counterpart in the WS and SOA arena.

Many companies aim to use Web services to integrate heterogeneous and/or remote application in SOA (Service Oriented Architecture) contexts
A good example of the integration of WS concepts in e-Learning standards is given by the IMS Learning Information Services (LIS) specification\(^1\). It is a standard addressing some interoperability issues for training (in particular information exchange between student information or human resources systems and learning management systems). The LIS specification is based on the IMS Abstract Framework (IAF) and the IMS-GWS (General Web Services Standards), an IMS specification that allows interoperability between any Web services. The IAF defines the IMS approach to creating SOA-based interoperability specifications that are implemented by Web Services in the form of GWS. End-users benefit from having systems that can be easily integrated with their other student information or Human Resources Systems and learning management systems. IAF consists of layers. The higher layer contains the set of e-Learning applications that can use the framework such as Learning Management System, Assessment System, etc. The application services layer contains a set of core e-Learning application services, such as assessment, class administration, collaboration, portfolio management, etc. The layer below contains the common services such as authentication, authorization, database management, security, etc.

Regarding the similarities between e-Learning and WS standards, these can be made apparent by considering the aforementioned IMS-GWS and WS-IBP (WS-I Basic Profile), \(<http://www.ws-i.org/Profiles/BasicProfile-1.1.html>\). Both of them promote interoperability with Web services. They use the same mechanisms and semantics based on SOAP, WS-Security, \(<http://docs.oasis-open.org/wss/v1.1/wss-v1.1-spec-os-SOAPMessageSecurity.pdf>\) and WS-Addressing, \(<http://www.w3.org/Submission/ws-addressing/>\) and allow referencing a document from SOAP messages.

\(^1\) This and other IMS specifications are available at \(<http://www.imsglobal.org>\).

“"We assume e-Learning applications may be considered as part of a company’s Information System""
A second example is given by comparing IMS-TI (Tools Interoperability) and WS-Federation, <http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsfed>. Both specifications promote interoperability between platforms and/or components. They aim to build a trustable architecture by using WS-Security tokens. IMS-TI uses IBAT tools based on UML meta-modelling and models transformations from one platform to another.

Finally, comparison can be also carried out at the level of more basic standards. For instance, BPEL [3] and IMS-SS (Simple Sequencing) may be compared as far as concerned training tasks orchestration. IMS-SS provides a simple description and the BPEL semantic is broader. Additionally, many other e-Learning standards, which are useful to manage pedagogical contents, are all based on XML so they are Web services compliant.

### 3.2 Limitations and the Shift to SaaS and Cloud e-Learning

Regardless of the interoperability and flexibility issues of the previously described standards, SOA-based e-Learning systems are quite expensive and their maintenance costs and efforts are also significant. However, we have noticed that cloud computing and shared services can help enterprises and training institutions to move towards an open and collaborative environment while reducing the costs of delivering and managing the required services. For example, in virtual computer laboratories, cloud computing and shared pooled services make a significant difference in the

**Software as a Service (SaaS)** is a model of software deployment whereby a provider licenses an application to customers for use as a service on demand.”

![Figure 2: Training Services according to BPMN.](image-url)
Figure 3: General Architecture.

cost structure, service delivery, and user satisfaction.

Moreover, mobile users are now demanding access to an institution’s computing facilities from new, remote access points while expecting it to be delivered with the same security and ease of use that they expect when inside a laboratory. Therefore, the challenge facing training institutions or those enterprises with specific training needs is twofold:

- Enhanced user experience – remote and mobile access, access to latest applications, secure and authorized access.
- Easier maintenance and lower cost – efficient utilization of hardware and software resources, easier management and provisioning of services.

Therefore, enterprises and training institutions could promote business-based e-Learning services as shared services according to the SaaS or IaaS models by using cloud computing facilities such as virtualization of infrastructure and services, automated provisioning of services and increased availability and connectivity with end users.

4 Self Adaptation

Nowadays SaaS and cloud computing are tools for companies to be more competitive. Shared services are attractive to both training institutions and enterprises for at least three key reasons: cost reduction; quality improvement; shorter time-to-market. But, there remain the following pending issues to which we will try to find a relevant solution: how to enhance the learner’s experience by offering a business-like training context, and how to adapt the learning process according to contextual data and events. Let’s introduce adaptation and self-adaptation concepts.

Self-adaptation and adaptation may be used in e-Learning domains to propose new trends and challenges for learning objects configurations and pedagogical systems.

Self-adaptive software aims to adjust various artefacts or attributes in response to changes in the self and in the context of a software system. The whole body of the software is mostly implemented in several layers, while the con-
text encompasses everything in the operating environment that affects the system’s properties and its behaviour [6][7][8].

The context awareness of such applications is the subject of a recent field of studies in pervasive computing called context-aware systems, as discussed in [9]. The works described in [10][11][12] propose four features of context-aware applications: (1) Contextual sensing, which refers to the detection of environmental states and their presentation to the user; (2) Contextual adaptation refers to the adaptation of application behaviour to the current context; (3) Contextual resource discovery is the use of context data to discover other resources within the same context; (4) Contextual augmentation in which the environment is augmented with digital data associated to a particular context.

5 Case Study

In order to illustrate the aspect discussed, we will use a real case-study. We aimed to design and implement a genuine fishing simulator. This software was intended for navigation and fishing schools or fishing fleet owner companies. The partial UML model of Figure 1 shows the different services proposed by the navigation and fishing e-Learning system. This e-Learning platform provides fisherman diploma for students (learners) in fishing schools and certificate for companies. The learner can subscribe, have a course, and receive a diploma after an exam. The teacher may or may not be human. The system can take decisions and can send specific events to complicate lesson if the student has a good level. Figure 2 shows a process where the teacher is preparing training and is sending it to the student who identifies himself by invoking identification and authentication services, linked to the rules manager. While training, the learner may receive specific events during the current lesson to assess the learner’s skills. The learner is assessed at any time.

Figure 3 outlines the architecture of the resulting e-Learning application. This architecture integrates SaaS and cloud computing. The providers’ repositories manage services like business, training supervisor, course virtual management, planning management, collaborative management, subscribing management, time/tracking management, etc.

6 Technical Implementation of Adaptation

6.1 WCOMP

WComp [13] is a prototyping "development" environment for context-aware applications. The WComp Architecture is organized around the Containers and Designers paradigms. The purpose of the Containers is to take into account system services required by Components of an assembly during runtime: instantiation, destruction of software Components and Connectors. The purpose of the Designers is to allow the configuration of assemblies of through Containers. To promote adaptation to context WComp uses Aspect [14] Assembly paradigm. Aspect Assemblies can either be selected by a user or triggered by a context adaptation process. It uses a weaver that allows components to be added and/or suppressed. A container includes a set of beans (components) and each bean has properties, input methods that use received input information, and output Methods to send, for example, output information to another bean. Aspect Assemblies allow links to be defined between beans by using input and output information. WComp uses UPnP (Plug and Play) technology to detect locally whether the device is active or not and to define input methods and sent events for each component. With this architecture WComp allows: i) the management of device heterogeneity and dynamic discovering, ii) events-driven interactions with devices, iii) the management of dynamic devices connection and disconnection (dynamic reconfiguration at run time) in infrastructure. Services are imbedded in the WCOMP platform. Moreover, remote services can be invoked to extend current embedded services.

6.1 Reviewed Architecture

WComp platform can be embedded in our architecture as the execution platform. WComp intercepts all the events coming from I/O middleware (learner interactions with the equipments) and learner interactions with different media as keyboard and mobile phone. According to these contextual parameters it invokes remote services and new service orchestrations.

6.2 Implementation

In an example concerning the implementation details, Figure 4a outlines the result of modelling the casting off manoeuvre using the WComp modelling tool. Figure 4b
shows a fragment of the code generated from this model. Our example uses a Boat bean which makes it possible to represent the manoeuvre. Lines 46 and 47 show the assembly definition between beans Boat and checkbox1 in the container. This assembly is carried out with the help of EventHandler, which captures the event emitted by checkbox1 and invokes a suitable method received as a parameter in the constructor. Lines 48 to 49 are the definition of the assembly between the component beans Boat and label1 in the container.

7 Related Works
Several e-Learning research works [15][16][17] use Web services to get interoperability. The Sakora project is an instance of such works. This project aims to integrate Student Information Systems (SIS) with the course.

The SAKAI Management System is strongly based on web services, but this solution still needs custom developments to encompass the entire integration needs of educational institutions. Unicon and oracle are also working together on LIS and SAIP (Student Administration Integration Pack), <https://confluence.sakaiproject.org/>, to integrate the SIS and the LMS to offer a complete solution to the marketplace. The other well known project is Cornerstone OnDemand, <http://www.cornerstoneondemand.com>. This project aims to provide on-demand talent and learning management services as well as on-demand delivery of training content among LMS software and services.

None of the previously described works uses adaptability with SaaS and Cloud paradigms that are the genuine architecture aims of Web services for the industry. Moreover, we based our research works on a concrete industrial project that is reaching a successful conclusion.

8 Conclusion
In this paper, we propose a Web services-based e-Learning architecture. We used SaaS and cloud computing paradigms to implement a navigation and fishing simulator. The main advantages of this architecture are:

- The interoperability of the platforms and the applications. Applications are considered as black boxes offering services, without considering the way they are coded or which platform they are on. Interoperability is promoted by Web services XML based standards.
- To take into account new needs in terms of new lessons, and to add or modify lessons (flexibility).
- Lessons and exercises may be accessible via Intranet, Extranet, Internet, also with mobility via different media as lab top, PDA, mobile phone, …
- This e-Learning architecture is fully distributed, and each knowledge component may be supported by one server independently.

"Nowadays SaaS and cloud computing are tools for companies to be more competitive"
Based on previous research works, we now aim to propose technical architecture and solutions for context awareness such as weather changes during training. We have started by exploring context-awareness solutions based on IA, semantic Web and specifically Semantic Web Services, always in accordance with SaaS and Cloud models. Results of these trends will be published in future papers.

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References
A Pervasive Learning Design Methodology

Jihen Malek, Mona Laroussi, Alain Derycke, and Henda Ben Ghezala

A methodology to design innovative pervasive learning scenarios is essential since pervasive learning is a very innovative field and most pedagogical designers and teachers are unaware of its key concepts and utilities. Such a methodology requires radically new thinking about how and when using new mobile and pervasive technologies can enhance learning and teaching. We can present the challenges of designing pervasive learning on three levels: (1) the proposition of a modeling language; (2) the specification of a design process; and (3) the development of a supporting tool. Our research seeks to provide solutions at all three levels and proposes an innovative pervasive learning design methodology that aims to support pedagogical designers and teachers to model, generate and simulate pervasive, context-aware and adaptive learning scenarios. Our methodology is model-driven, iterative and incremental.

Keywords: Pervasive Learning, Adaptation, Context-Aware, EML - Educational Modeling Language, IMS-LD, MDD - Model-Driven Development, Technology-Enhanced Learning Design.

1 Introduction

Learners have changed radically with the arrival and rapid evolution of wireless networks and mobile technologies in the last decades of the 20th century. Nowadays students are no longer fitting into the classical educational system. Now, they spend most of their time surrounded by and using laptops, smart phones, video games and the toys and tools of the digital age as well as the pervasive environment in which computing systems are seamlessly integrated into their lives. It is now clear that as a result of this pervasive environment, nowadays students or digital natives [1] think and process information in a fundamentally different way from their predecessors.

If teachers really want to reach the new learners of today, they must take into account their new skills and need to reconsider both their methodologies and the content of their courses. Teachers need to be thinking about how to teach future content and adapt materials to the language of those new learners. But unfortunately a review of existing educational modelling languages - MISA [2], IMS-LD [3][4][5][6], EML [7][8], CPM [9] and their content authoring tools MOT+LD [10], RELOAD [11][12], LAMS [13] - shows that none of them supports pervasive and mobile computing related concepts. Our proposed methodology aims to help pedagogical designers and teachers invent, model, generate and simulate (without necessarily having the knowledge and skills of IT programmers) innovative context-aware adaptive, challenging and pervasive learning scenarios with an added value from a pedagogical standpoint.

Those new scenarios aim to ensure learners’ autonomy, motivation and challenge by experiencing various learning scenarios indoors and outdoors. They also aim to enhance interaction and collaboration through collaborative and chal-
lenging context-aware learning activities that take place in different locations and at many stages and levels. Our methodology is model-driven, iterative and incremental. It is based on three components: the CAAML language, the pervasive learning design process, and the supporting tool (ContAct-Me).

This paper is organized as follows. Section 2 introduces a case study. Section 3 describes the levels and meta-model of the CAAML language, while the steps of the proposed pervasive learning design process are summarized in section 4. Section 5 presents the supporting tool ContAct-Me (CONText and ACTivity Adaptive Modeler for Malleable Learning Environments) while the evaluation of our work is described in section 6. Section 7 concludes the paper and suggests future research directions.

2 A Case Study

In order to illustrate how pervasive learning can be applied in a realistic scenario, we will start by introducing a case study.

A French high school decides to raise the awareness of pupils on the effects of pollution on the environment by organizing a trial as a follow-up to the pupils’ educational curriculum in the field of “Education about the environment”. This trial enables pupils to learn through factual cases and to experience various scenarios using pervasive and mobile technologies.

The physical settings of this trial, the where activities take place, are the school’s laboratory and an ecological zone in a nearby industrial area.

In order to boost intra-group competition, students were divided in three groups under the supervision of their coach and each group consisted of six pupils. Additionally, each group was divided in two subgroups of three students each, where one subgroup was working indoors in the laboratory of the school while the other group was outdoors in the field. The ultimate goal behind this clustering was to reinforce teamwork and collaboration within the individual subgroups. Only one group was conducting this activity at a time, which makes it a collaborative and challenging game that takes place in different locations and in four stages as follows:

- Plant sample picking and identification.
- Water treatment (the measure of pH and conductivity rates and the collection of water samples in appropriate containers).
- Soil analysis (soil sample gathering and identification).
- Plant characteristics analysis (verification of presence of toxic gases such as CO and CO₂) and plant preservation in the laboratory.

The outdoor subgroup was equipped with an iPhone with a GPRS connection. The indoor subgroup was equipped with a laptop computer and a Wi-Fi connection.

At the beginning of each of the first three stages, the outdoor subgroup had to identify and take a photo of a QR-codeâte stuck to a tree. Instantly, a text adapted to the pupils’ level and pictures that visualize and describe the activities to accomplish in the current stage were displayed on the iPhone. To accomplish these activities, indoor and outdoor subgroups had to collaborate together. For example, in the first stage, the outdoor subgroup could take a photo of a plant and send it to the indoor group for identification through internet research.

After a pre-defined time of each stage, the subgroup would receive a stage-adapted quiz via an automatic text message. Pupils needed to write an answer using their iPhone and submit it. If the answer was correct, the system sent the instructions describing how to reach and identify the next QR-code of the next stage. If the answer submitted by the group was not correct, the system sent an alert to the coach informing him/her that pupils needed some support. The coach had to send them some hints.

Having completed the stages described above, the indoor subgroups received a list of activities for the fourth stage and were joined by their corresponding outdoor subgroups that were to hand over the picked plant samples.

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1 A QR-code is a specific matrix barcode (or two-dimensional code), readable by dedicated QR barcode readers and camera phones. The code consists of black modules arranged in a square pattern on a white background. The encoded information can be text, URL or other data.
Those new scenarios aim to ensure learners’ autonomy, motivation and challenge by experiencing various learning scenarios indoors and outdoors.

The indoor team had to run experiments on those samples with a view to investigating the presence of toxic gases such as CO and CO₂. They also had to preserve the samples under suitable temperature conditions. If the temperature were not appropriate, the system would interact with the smart object in which the plant sample was preserved in order to adjust it to the required experimental temperature.

At the end, each of the three groups had to draw their own conclusions and present the outcome of their study about the effects of pollution on the environment.

The following sections outline an approach that enables the development of this kind of pervasive e-Learning systems.

3 The CAAML Language

In a previous work, first we defined the notion of context as a set of evolutive elements appropriate to the interaction between learner and pervasive learning applications including the learner and the applications themselves. This set of contextual elements comprises the context of the interaction that can be divided into two classes: learner context and activity context [14]. Then, we proposed to widen the notion of adaptivity to take into account all possible interactions between context and learning activity, because they influence each other in learning processes [15]. This "bijective adaptation" or "co-adaptivity", which is a useful designation we have taken from the field of biology [16], aims to make things easier for the learner and create an adequate learning environment which helps him/her to concentrate better on his/her learning tasks.

The core of our proposed methodology consists of an Educational Modelling Language called CAAML (Context-aware Adaptive Activities Modeling Language). It is a visual modelling language that takes into account the concepts of context and co-adaptivity to provide a framework of elements that can design pervasive learning scenarios in a formal manner.

3.1 The CAAML Levels

CAAML is made up of four levels, where each level requires, extends and incorporates the previous one:

1. Resources Creation Level contains: Learning resources (document, course, file...), tools (smart object, sensors, mobile devices and their physical and software characteristics) and services (E-learning, M-learning and P-learning Services);

2. Components Creation Level includes the main components of the scenario: Contexts (static or dynamic) and their acquisition sources (sensors), roles, persons, outcomes and activities (Learning or coaching activities) and each activity must refer to its outcome and relevant contexts;

3. Scenario Creation Level contains the core of the CAAML Meta-Model: the Pervasive Learning scenario Description (Community, objectives, pre-requisites, outcome) and the coordination between the components like learners, coaches, activities, outcomes and contexts. This simply provides a series of context-aware learning activities to be performed by learners or coaches using Pervasive Learning Resources;

4. Co-adaptivity Level adds up better control and adaptation through the use of Co-adaptive rules allowing the adaptivity of activities to context and vice-versa. This level offers also the opportunity for more sophisticated learning designs through notifications (messaging), which allow for notification of new activities to be triggered automatically in response to events in the learning process. For instance, a coach may be notified by email that a pupil needs some support if his submitted answer is not correct. The coach should send him/her some hints.

3.2 The CAAML Meta-Model Structure

The CAAML meta-model describes a learning scenario as being a composition of several phases. Each phase includes role-parts (activities and their relevant contexts) as shown in Figure 1.

The context can be:
- Static: does not change during interaction (e.g., season, student’s name);
- Dynamic: changes during the interaction (e.g., noise level, temperature...). A dynamic contextual element can be directly acquired through "embedded environmental sensors" or "mobile device sensors".

The CAAML meta-model defines two classes of "co-adaptivity rules": rules for adaptivity of context to activity and rules for adaptivity for activity to context. A rule is based on a context to trigger the appropriate co-adaptivity actions. Rules have the basic format:

Our methodology is model-driven, iterative and incremental.
IF [expression] then [show, hide, change-context value or notify someone]

The expressions are mostly defined in the context of the interaction between application and learner. An action is performed according to the success (true) or failure (false) of the condition. The action is to show or hide activities, change context value or notify someone.

With notification it is possible to send a message to a role based on certain events:
- The completion of a certain activity;
- The completion of a certain phase;
- When an expression in a certain condition is true;
- When a certain context value has been changed.

The CAAML meta-model also defines components related to pervasive learning environments such as "smart objects", "sensors" and "mobile or pervasive services".

4 A Pervasive Learning Design Process

The proposed learning design process organizes the design of pervasive learning scenarios into three steps (specification, modelling and simulation) and each includes a variety of tasks that take place during the process.

4.1 Specification

The specification of new pervasive learning scenario is done through a top-down approach containing three levels of abstraction and consisting of breaking down a scenario to gain insight into its compositional phases. Each phase is then refined in yet greater detail, into many learning activities. And for each level (scenario, phase and activity), the pedagogical designer must extract the required structure, resources, components and co-adaptive rules. This specification is done first through a textual description and then through a UML activity diagram.

4.2 Modelling

This includes two major tasks: design and CAAML/IMS-LD models transformation:

Task 1: Design. The major steps of this task are:
1. Creation of a learning design (specifies the title, learning objectives, prerequisites and outcomes of learning scenario);
2. Creation of different levels of the CAAML language (resources, components, scenario structure and co-adaptivity rules);
3. Generation of an exploitable description of the CAAML model in XMI format.

Task 2: CAAML/IMS-LD models transformation. In order to ensure the interoperability of the designed activities across different learning platforms, this module transforms models represented in CAAML language into executable models represented in the IMS-LD standard [4].

4.3 Simulation

Through this module, the teacher should perform the following tasks:
The core of our proposed methodology consists of an Educational Modelling Language called CAAML (Context-aware Adaptive Activities Modeling Language)

1. Generate an automatic mobile interface for each phase of the pervasive learning scenario based on the generated CAAML model or the IMS-LD model.
2. Model the execution environment of the simulation.
3. Place smart objects and sensors (defined in the CAAML model) in the appropriate zones of the pervasive learning environment.
4. Launch the simulation of the execution of the pervasive learning scenario in run time thanks to co-adaptivity rules defined in the CAAML model. The simulation shows interactions and co-adaptivity between the generated mobile interfaces and the context (the surrounding pervasive learning environment).

5 Supporting Tool: ContAct-Me
ContAct-Me (CONText and ACTivity Adaptive Modeler for Malleable Learning Environments) is a pervasive learning design tool based jointly on the CAAML language and the proposed process. It is implemented through an MDD approach (Model-Driven Development). It aims to help pedagogical designers to model and simulate context-aware adaptive learning scenarios using friendly interfaces.
To implement ContAct-Me, we used:
- Domain-specific modelling Eclipse Tools (EMF and GMF) to develop the graphical modeller.
- The ATL transformation language to transform the CAAML generated models into IMS-LD models.

Figure 2: ContAct-Me Architecture.
XSLT and XHTML-MP to generate mobile user interfaces.

The context simulator DIASIM and the DiaSpec language to simulate the execution of the modelled malleable learning scenario: we integrated this simulator in ContAct-Me.

The architecture of ContAct-Me includes three interrelated modules (see Figure 2): the graphical modeller, the CAAML/IMS-LD models transformation module, and the simulator of pervasive learning scenarios module [16].

5.1 The Graphical Modeller

Through this module based on the CAAML meta-model, the teacher or the pedagogical designer can:

- Model different levels of the CAAML language (resources, components, scenario structure and co-adaptivity rules). Figure 3 shows a snapshot of the tool concerning the edition of a co-adaptivity rule related to the case-study.
- Generate a CAAML model in XMI format. Figure 4a shows an example concerning the resources section for the case-study.

5.2 The CAAML/IMS-LD Models Transformation Module

This module transforms models represented in CAAML language into executable models represented in IMS-LD. This is done such that IMS-LD complexity is hidden by the use of concepts related to context-awareness.

IMS Learning Design (IMS LD) is a specification for a meta-language which enables the modelling of learning processes. The specification is maintained by IMS Global Learning Consortium [4].

Regarding the technical details, in ContAct-Me the CAAML meta-model is represented in ECore, while the transformation from CAAML to IMS-LD is encoded in the ATL transformation language. Thus, the transformation module is composed of a set of ATL rules (see Figure 4b). Each rule defines the way an input element (that is a given type of entity of the input model) is transformed into a target element (that is a given type of entity of the output model).

5.3 The Pervasive Learning Scenarios Module Simulator

Based on the CAAML models generated by the graphical modeller, this module allows the teacher to perform the tasks (described in Section 4.3) of the simulation step.

Figure 5 shows a snapshot of a simulation scenario concerning the case-study. In order to enable such a simulation, we generated corresponding mobile interfaces for each phase of the pervasive scenario. Then we defined the parameters of the simulation, which enabled us to execute such a simulation.
6 Evaluation

As pervasive learning is a very innovative field and most pedagogical designers and teachers are unaware of its key concepts and utilities, in order to assess the ContAct-Me system, we chose teachers with extensive experience in using e-Learning platforms and in creating learning activities in accordance with the IMS-LD standard through different authoring tools.

At the beginning, we briefed the pedagogical designers and teachers on pervasive learning and its basic concepts such as sensors, smart objects, QR code, context and co-adaptivity...and described the proposed scenario. They were then allowed to explore different modules of the ContAct-Me system while being provided with assistance. The goal was to evaluate the system from the graphical, ergonomic and functional point of view.

![Excerpt from the XML Encoding concerning Resources; (b) Some Rules of the CAAML/IMS-LD ATL Transformation.](image-url)

Figure 4: (a) Excerpt from the XML Encoding concerning Resources; (b) Some Rules of the CAAML/IMS-LD ATL Transformation.
By going through the graphical modeller, the teachers appreciated:
- The user-friendly graphical interfaces as well as the workflow of the different steps, from resource creation to CAAML model generation.
- The creation of context-aware activities.
- The structure of the scenario creation, based on phases allowing the creation of game-oriented learning scenarios.
- Their involvement in the specification of adaptivity in design time, unlike other authoring tools which are not based on context-aware activities.
- The possibility to export the CAAML model into IMS-LD format in a very smooth manner.

From the simulator standpoint, they appraised the model-driven automatic generation of mobile interfaces that corresponds to different phases without necessarily having the knowledge and skills of IT programmers. Furthermore, they enjoyed the output of the simulation run of their own designed works.

Along this experience, the teachers did not feel comfortable with the high number of new concepts that are not in common use and the necessity to get assisted to run the system.

7 Conclusion and Further Works

In this paper, we proposed a pervasive learning design methodology to support pedagogical designers and teachers, and to model, generate and simulate pervasive, context-aware and adaptive learning scenarios.

Our methodology is based on three components: the CAAML language, the design process, and the supporting tool ContAct-Me. The latter is based on an MDD (Model-Driven Development) and takes into account context and co-adaptivity rules.

In order to ensure the interoperability of the designed activities across different learning platforms, this tool transforms models represented in CAAML language into executable models represented in IMS-LD in such a way that the IMS-LD complexity is hidden by the use of concepts related to context awareness.

As the IMS-LD standard does not yet support mobility and its players do not allow the execution of mobile activities in real time, the community of researchers actively working on this standard should find effective solutions to accompany the great steps forward made in mobile and pervasive learning.

Finally, in future works we will attempt to boost the game approach in learning as recommended by the teachers and designers that assessed the ContAct-Me system.

References


Green IT

Green IT: Data Center Power Consumption Effectiveness.
A Case Study

Francesco Merlo

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This paper was first published, in its original Italian version, under the title "Green IT: efficienza nei consumi energetici dei data center - Il caso ENTER", by Mondo Digitale (issue no. 4, December 2011, pp. 81-86, available at <http://www.mondodigitale.net/>). Mondo Digitale, a founding member of UPENET, is the digital journal of the CEPIS Italian society AICA (Associazione Italiana per l’Informatica ed il Calcolo Automatico, <http://www.aicanet.it/>.)

This case study presents the experience of the Italian company ENTER, an innovation solutions provider, in the context of the ENERG-IT project with the aim of rationalizing the levels of use of resources in data centers and optimizing energy consumption. A full methodology is presented, analyzing the three basic steps of Analysis, Optimization and Innovation. Results show that the incremental evolution of a data centers in SMEs is competitive compared to a full redesign, in terms of economic investment, payback time, and power savings.

Keywords: Green IT, Data Center Energy Optimization, Data Center Resources Rationalization, Incremental Data Center Evolution, SME Data Center.

1 Introduction

The case study discussed in this article describes the IT rationalization solutions aimed at increasing the effectiveness of power consumption that the Italian company ENTER has tested in the context of the ENERG-IT project. ENTER has been involved in technology research and innovation guided by two fundamental objectives: i) the need of reducing energy consumption of the data center and ii) the rationalization of resources utilization levels. The operational levers that ENTER has adopted are based on the innovation of the data center infrastructure and the logical architecture of information systems. This case study analyzes the core business of ENTER, the competitive context and the impact of the rationalization solutions adopted on the effectiveness of power consumption.

ENTER is an Innovation Solution Provider, a company that designs, develops and manages services and solutions oriented to connectivity, data center facilities, telephony, and digital communication. Born in 1996, and merged in 2002 with the Y2K Communication group, in the last years ENTER has shown a continuous growth becoming the first Italian "digital hub", providing its customers with services spanning from network connectivity to complete data center hosting solutions and content development.

The core of the solutions provided by ENTER is its own network, supported by a data center located in the technological hub of Milano Caldera. Taking advantage of these assets, ENTER provides services oriented to con-

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nectivity, telephony, hosting, mail and collaboration, and digital asset management.

2 A Methodology Oriented to the Rationalization of Power Consumption for Data Centers

Nicola Sciumè, CEO of ENTER, has well described the philosophy that drives the approach to energy consumption rationalization of its company during the final presentation event of the ENERG-IT project:

"A problem is a situation that should be exploited for improvement. When we realized that power consumption monitoring and management in our data center was a priority, we made a clear choice: monitor the problem, optimize the resources, and apply technological innovations, since we wanted to solve the problem, not just delay it".

This concept, which has been defined in collaboration with the other partners of the ENERG-IT project, is based on the adoption of a methodological approach to address the problems and challenges related to the rationalization of power consumption.

Mariano Cunietti, Technical Manager at ENTER, says that "the mission of our company is to provide to its customers computational power, disk space and network connectivity. In other words, servers". This leads to the need of managing a data center to host the technological devices and provide adequate infrastructures to ensure power, cooling and safety to servers. "We built a home for our servers", continues Cunietti, "in order to provide services to our customers: electrical power, UPSs, cooling systems. The number of servers in our data center has been growing together with our customers".

The management of server growth and the evolution of infrastructural services need to be addressed by means of an adequate planning, otherwise, several criticalities may be introduced in the data center ecosystem which are difficult to address a posteriori. "Step by step", says Cunietti, "our apartment became a big building, with increasing energy requirements: This made clear that energy management was a criticality that had to be addressed as soon as possible". As Cunietti says, it is clear that this priority is perceived; however, he also notes that a first issue is the approach to adopt in order to quantify the total energy consumption, and how to split the cumulative value into its parts related to the data center subsystems. "The first step that we adopted was to pay attention to the direct energy cost from the energy supplier. We analyzed our consumption and checked the offers from different suppliers, in order to choose the most convenient one. The adoption of a green profile gave us the guarantee that the energy used by our data center was produced by renewable sources".

The choice of adopting green suppliers for electrical power is a first step towards sustainability; however, it is not able, alone, to rationalize the power consumption. In other words, it is fundamental to assess the effectiveness level of power consumption, and not only its volume.

Based on this perspective, ENTER and the other partners of the ENERG-IT project chose to design, develop and test a methodological approach to the
rationalization of power consumption, based on three fundamental steps:
- Analyze
- Optimize
- Innovate

The analysis of the problem is a first and basilar aspect, since it allows quantifying the variables and provides a numeric consistence to the problem itself. Although this may be considered as a trivial aspect, there are many logistic and technological issues that may introduce several unattended complexity levels that must be addressed. For example, considering the power consumption of a data center, the first issue stems from the number of devices that have to be included in the monitoring program. The deployment of an infrastructure that is capable to monitor the power consumption of all the servers and other technological devices of a data center is not trivial. A proper design of the power infrastructure may help, since it may allow to monitor power consumption directly from electrical panels, providing (aggregate) measures related to racks and other devices.

A second issue is then related to the storage of monitored data. Provided that the monitoring infrastructure is actually deployed, an automatic storage system should be implemented: for example, existing Configuration Management Systems may be extended with adequate functionalities. A third issue is related to the capability of access and analyze the data monitored and stored, which is typically addressed by means of analytical dashboards. Building such systems may not be trivial, since complex data warehouse systems may be required, depending on the volume of collected data.

Figure 1 provides an example of the analytical dashboard developed by Beta80 (one of the partners of the ENERG-IT project) that allows the analysis of power measurements of ENTER’s data center.

Optimization is a step that can be addressed only after having properly measured the variables involved in the problem. It is critical to be aware of all the aspects of the problem under analysis, since otherwise solutions may even lead to an intensification of criticalities, rather than to an optimization. A trivial solution to the optimization of a data center power consumption, as confirmed also by Cunietti, is that "the only green server is an unplugged server". However, it is evident that this solution is not admissible. As a consequence, it is necessary to address the trade-off between the need to provide reliable services to customers, and the need to minimize energy consumption.

The solution tested by ENTER in its...
The choice of adopting green suppliers for electrical power is a first step towards sustainability.

data center has required the modeling of the data center and the simulation of alternative scenarios to search for the best placement of servers and computational loads in order to maximize resources utilization and minimize power consumption. This complex optimization problem is addressed with a tool developed by the Department of Electronics and Informatics of the Politecnico di Milano (shown in Figure 2), which allows the collection of required data and the exploration of alternative solutions that have higher effectiveness in the consumption of electrical power.

Innovation is a cross-cutting aspect to analysis and optimization, since it may be applied differently in the two steps. Introducing innovation means that new elements and/or changes are applied to the product or process under analysis in order to enhance its performances. Considering the rationalization of power consumption of a data center, innovation may be introduced by means of i) utilization of new technologies or ii) adoption of completely new approaches to solve the problem. The ENERG-IT team has approached the problem by considering both perspectives.

On one hand, in ENTER technologies have evolved, introducing advanced virtualization techniques and migrating systems to blade servers and dedicated storage systems. Thanks to these technological innovations, ENTER has been able to reduce the number of physical servers (previously underutilized) and concentrate the computational loads in a small number of high-density servers. The introduction of dedicated storage led to the simplification of cabling layout, easier management procedures and a rationalization of the data center physical layout. Besides the innovations applied to IT devices, ENTER has also introduced new cooling systems in order to replace the classical Computer Room Air Conditioners, CRACs, deployed in the data center rooms. In particular, ENTER has tested a new rack-level cooling system that prevented the hot and cold air flows to mix, thus enhancing the effectiveness of the overall cooling system.

On the other hand, radical new approaches to the rationalization of power consumption have been explored. Particular attention has been devoted to the analysis of the optimal disposition of the servers into the data center under the assumption of keeping the infrastructural systems already deployed, in order to improve the energy utilization efficiency without a complete restructuration of the data center. In this case, the idea was based on the intuition that the physical disposition of servers inside the data center influences the dynamics of hot and cold air flows, creating different operating conditions to the cooling system.

If the temperature is kept homogeneous throughout the whole data center, less physical work is required to the cooling system in order to refrigerate the air, and thus less power consumption is required as well. Hot
The second scenario required an investment of 200,000 € and led to an overall reduction of power consumption of 83%, cutting the total amount of energy consumed to only 10 kW.

Spots (areas where the operating air temperature is particularly high) induce in fact anomalies in the air flows inside the data center rooms, increasing the global power consumption of the cooling system that needs to face such fluctuations of the air temperature.

3 Results of the Methodology

The experimental setting of ENTER on its data center has been driven by two objectives: i) quantify the increment of efficiency of power consumption that can be achieved through the adoption of radical new technologies and ii) quantify the returns that derive by applying incremental ameliorations to a data center, while keeping in place the infrastructural systems.

The ENERG-IT team addressed both objectives by applying a methodology inspired in the three steps described in the previous section, that is: Measuring the variables involved (i.e., power consumption, number of devices, efficiency of the infrastructure, etc…), analyzing the data collected by means of an analytical dashboard developed by Beta80, and optimizing the data center configuration with the optimization tool developed by the Department of Electronics and Information of the Politecnico di Milano.

The results achieved in the project are based on the analysis of operating costs reductions considered in two different scenarios: a) the "revamping" of the existing data center by means of changing the physical layout of servers, and b) the introduction of new technologies, such as the rack-level cooling system.

Analyses have been conducted on a test context comprising 10 racks disposed in two parallel lines with hot-cold aisles, filled with 130 physical servers consuming on average 57 kW of electrical power, which corresponds to 70,000 € per year (with an energy cost of 0.14 €/kWh).

In the first scenario, we considered the possibility of replacing the existing servers with new models, and applying a virtualization with a 2:1 ratio. Moreover, we considered the possibility of placing the physical servers in different locations based on the suggestions provided by the optimization tool in order to improve efficiency of the cooling system. This scenario required an investment of 160,000 €, and led to an overall reduction of power consumption of 65%, cutting the total amount of energy consumed to 20 kW (corresponding to 24,000 € per year).

In the second scenario, we tested the adoption of a precision cooling system, using new blade servers and dedicated storage systems. We also applied a more aggressive virtualization ratio of 10:1.

This scenario required an investment of 200,000 € and led to an overall reduction of power consumption of 83%, cutting the total amount of energy consumed to only 10 kW (corresponding to 12,000 € per year). Figure 3 provides an overview of the results of this test.

Beyond the numerical results, the text carried out at ENTER’s data center has been significant for all the partners of the ENERG-IT project. For example, ENTER has now the capability of monitoring and collecting data related to the power consumption of its devices, which is considered a great help in facing issues such as the choice of energy providers.

4 Conclusions

From the case study presented in this review it is clear that the use of new technologies (both infrastructural and IT) may lead to consistent improvements to the efficiency of power consumption of data centers.

In particular, the solutions tested by ENTER on its own data center demonstrate how it is possible to rationalize the consumption of electrical power, but also provide important data and knowledge to gain competitive advantage over competitors. Moreover, we have demonstrated that also from the perspective of a SME it is possible to implement alternative solutions to the complete restructuring of the data center, by adopting an incremental approach to the existing data center configuration and infrastructural systems.

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Entrepreneurship

Digital Entrepreneurs:
A Winning Big Idea for the Digital Agenda
Interview with Emmanuel Carraud and Roman Tolic

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One of the "Big Ideas" that received an award on October 25 2010, the "Digital Agenda Stakeholder Day" held in Brussels, Belgium, was the "Digital Entrepreneurs" one, presented by Roman Tolic and Emmanuel Carraud, who had set up the "12 Entrepreneurs movement" barely two months ago. Now, as a few more months have gone by, this is a good moment to interview Roman and Emmanuel about those topics with a little more perspective.

Keywords: Digital Agenda for Europe, Digital Entrepreneurs, Entrepreneurship, European Digital Talent Fund, Digital Valley for Europe, Future Digital Economy, Innovative Ecosystems, Silicon Valley, 12 Entrepreneurs.

A few months after the new strategy for the Digital Agenda of the European Commission was published¹, Commissioner Neelie Kroes invited major European stakeholders to attend a meeting aimed at discussing and organizing the implementation of the 101 recommended actions announced in the strategy.

On Stakeholder Day, Monday 25 October 2010, ideas previously submitted on the Web were selected and refined in several rounds of ever growing groups until the selection was whittled down to a few "refined" ideas which were hailed as the "winning" ideas to be prioritized in the Digital


The Interviewees

Roman A. Tolic is a visionary entrepreneur who is the founder and CEO of Tolikas Media Company and Hercules Filmnetwork. For 22 years Roman has worked in the field of media (13 years as a TV journalist, director and producer for the Austrian Broadcasting Corporation - ORF - as well as 9 years as CEO and independent film producer of Tolikas Media Company). He has conducted various international expert workshops (EBU - European Broadcasting Union, Content for Broadband, media literacy) and is the initiator of numerous collaborative media productions (ORF Goes to School, Clip 2000, etc.) as well as having won several national and international awards (UNICEF, European Union Parliamentarian, Council of Europe, Austrian film, etc.). Between 2006 until 2009 Roman was president of the Austrian platform "Content Industries", promoting digital content, services and applications for broadband communication. In 2010 Roman was chosen for the Initiative "Go Silicon Valley" – for a business program at the technology park and business accelerator "Plug and Play Tech Center" in Sunnyvale, CA, USA where, with Emmanuel Carraud and 10 other entrepreneurs, he founded the "12 Entrepreneurs" movement and initiated "Digital Entrepreneurs", which in Brussels on 25 October 2010 was chosen as a "Big Idea for Digital Agenda" – Europe’s new strategy for the digital economy. In 2011 the United Nations Industrial Development Organization (UNIDO) sent Roman on the official United Nations Mission to the Caribbean as Expert Innovation & Entrepreneurship for UNIDO-UNDP Joint Programming. In 2012 (after several years of R&D) Roman plans to launch the Digital Film Factory "Hercules Filmnetwork" – an online platform for connecting film with Internet crowds. <roman.tolic@tolikas.tv>

Emmanuel Carraud is a visionary entrepreneur who is co-founder and CEO of MagicSolver.com Ltd. MagicSolver develops innovative iPhone applications and brings magic to your mobile phone with over 2,500,000 customers across 90 countries. Sudoku Magic, FaceShift, Christmas Advent Calendar and World Cup Calendar 2010 are among MagicSolver’s main successes.
Agenda implementation”. Later, in the afternoon, those ideas were presented to the plenary (and the Commissioner).

The organizers of the event probably arranged it deliberately so that the last presentation went straight to a very critical point for the future of the European economy: innovative and entrepreneurial activity boosters and facilitators. Roman Tolic and Emmanuel Carraud, on behalf of a very young organization called ”12 Entrepreneurs”3, attracted the audience’s attention with an appealing video which ended with the following slogan: ”Bring the spirit of Silicon Valley to Europe”.

In recent months the Digital Entrepreneurs idea promoters have been more and more active ahead of the next event in the Digital Agenda development: the first Digital Agenda Assembly4.

UPGRADE and Novática have talked with them in depth about their conceptions, developments and aspirations.

How did the idea of setting up the 12 Entrepreneurs movement come up? Why did you call it ”12 Entrepreneurs”?

Roman Tolic: We met thousands of miles away from our homes, at the startup-coliseum ”Plug and Play Tech Center”, in the heart of Silicon Valley. Emmanuel (an entrepreneur from Cambridge) and I (an entrepreneur from Vienna) came to pitch for our companies but very soon we discovered Europe in Silicon Valley. Together with 10 other visionary entrepreneurs we created the new movement ”12 Entrepreneurs”. It became a movement for next generation entrepreneurship and innovation in Austria, France, Spain, Germany, Britain, Romania, Poland, Portugal, Norway, Belgium, Italy, Czech Republic, Centrope Region, Sweden, Hungary, Greece, USA, Russia, Israel, Serbia, Bosnia, (F.Y.R.) Macedonia, Turkey and many other countries of the world. Emmanuel gave it the name ”12 Entrepreneurs”.

Emmanuel Carraud: 12 is the symbol of perfection and completeness. The flag of Europe consists of 12 golden stars. 12 means no fewer than 12 million entrepreneurs. The 12 Entrepreneurs do not represent any single organization, rather an ideal of open innovation and inter-supportive entrepreneurship for the coming decade. Our identity is the identity of innovators making Europe and the world a better place for entrepreneurs!

Your intro video which is entitled ”12 Entrepreneurs. The Comeback” concludes with a slogan, written with the map of Europe as the background image, which says: ”Bring the spirit of Silicon Valley to Europe”. Does this really sum up the main objective of ”12 Entrepreneurs”?

Roman: Our goal is to improve the system of innovation in Europe and to improve the position of digital entrepreneurs globally. We started as a European project but we have become a global movement.

Let’s talk about your background. Could you please tell us something about your experiences in Silicon Valley? What is it like to be an entrepreneur there?

Roman: I was a traditional film-maker and then I moved into ICT (information and communications technology), because I understood that the traditional film industry was going to change rapidly. Seven years ago I started to think about the power of collective intelligence and collaboration, connecting film with Internet crowds and creating a new digital film factory in the cloud. Today, through Internet and digital media, the film industry is facing the greatest shift in its over 100-year history. Don Tapscott (one of the world’s leading authorities on innovation, media and technology) proclaimed the beginning of a new age: ”Film 2.0” - the global transition of film to Web 2.0 and the inclusion of Internet communities into the film creation process. Our startup ”Hercules Filmnetwork Film 2.0” is a digital film factory that offers millions of low-to-no budget filmmakers and digital AV storytellers, media practitioners and their fans what they most require: crowd funding and collaborative filmmaking including production resources, film networking, online cinema and online shop. It is something like ‘Social Hollywood’ made in Europe. Today we have a full product ready, proof of concept, and 600 beta testers worldwide. Hercules Filmnetwork looks for funding / investment capital for the release version, market entry and internationalization. Last year my startup was selected by a US jury for a several

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4 <http://www.youtube.com/watch?v=uiWXWFoQ7o>.
months business initiation program "Go Silicon Valley" of the Austrian Chamber of Commerce - at the technology park and business accelerator "Plug and Play Tech Center" in Sunnyvale. There I met Emmanuel and other world-class entrepreneurs including Lou Covey, our American colleague and one of the 12 Entrepreneurs co-founders, who said "What is good for Europe is good for the United States" and brought the discussion about the Valley to the point: "Silicon Valley is both a place and a state of mind. It is not a place for failing or succeeding but finding a better way to the future."

Emmanuel: My entrepreneurial background is also atypical. I started out as a Marketing Food Manager for Danone and Auchan/Alcampo in France and Latin America. Then, after an MBA at Cambridge University, I started my iPhone company in the UK, and won a prize, "Silicon Valley come to Cambridge", which opened the door to the USA for me. It was a great experience to meet and interact with World Class Entrepreneurs in the Valley. I also met many European Entrepreneurs looking for the Eldorado there. I realize it was also a missed opportunity for Europe, which could do much better to retain and nurture its talents.

In Europe we are probably behind in terms of technology development, innovation and technological entrepreneurship. What are the main reasons for this gap?

Emmanuel: Europe doesn’t believe in its own assets, Europe is not a risk-taker; there are multiple barriers to capital and growth for European entrepreneurs and no culture of failure.

Roman: Recently my former boss from the Austrian Broadcasting Corporation, Helmut Kletzander, said to me: "In Europe, ideas grow, and then people have to emigrate with their ideas because they will not find fertile ground for their vision. In Europe the 'capitalists' unfortunately see their money primarily as personal wealth and not as a means to do good, or at least not substantial good. The fact that this wealth has been created by others is unfortunately far away from their thinking."

Do you think that in America people have some personality traits which make them more prone to entrepreneurship than European people?

Roman: It is not about personality, it is about culture and the eco-system which will generate a startup explosion, including world-class technology and world-class universities. America was founded on entrepreneurship.

Emmanuel: It is true that on average, Americans are bigger risk-takers, as the country was built by emigrants who took the risk of leaving their home country to succeed. But Europe also has a great past of adventurers and inventors. Europe’s entrepreneurs need to learn from their past successes to reinvent their future.

Given what we can see, we might say that American (Silicon Valley) investors and business angels are usually more knowledgeable about technology which makes it possible to create more fluent relationships and build a climate of trust between investors and entrepreneurs. Do you agree with that?

Roman: Yes, we need a climate of trust between investors and entrepreneurs. But first we need an explosion of investors in European startups and high-growth companies and, especially, more visionary investors for the digital economy. At the moment, compared with Silicon Valley, the European Venture Capital (VC) market is a Mickey Mouse market.

Emmanuel: Secondly, we also think that the current VC situation in Silicon Valley needs to be optimized. VCs are more and more becoming private bankers, taking less and less risk, expecting 5M members, 5M revenue, minimum $1B market opportunity from entrepreneurs, and for them investing in a European company is very exotic.

Roman: What we need in Europe is a new Go-to-Market Bridge and new Booster for internationalization and commercialization. We need the European Digital Talent Fund (EDTF) – that is one of our main big ideas.

Emmanuel: The EDTF is a new model of startup funding, a social venture capital to invest in technology startups in Europe and help them to expand globally through a network of offices and advisors.

Many people state that regulations in Europe would have to be reviewed in order to boost innovation and entrepreneurship. What do you think about?

Roman: Very true! Investments in qualified digital start ups, especially during the seed and early stages could be stimulated by providing tax benefits to investors. A lot of things need to be deregulated and optimized for small enterprises – for example the 7th Research and Development ICT Framework Programme has a budget of over 9 billion euros but only a small number of projects go on to commercialize their results and access the market. It means that many new innovations, products and services never reach the market and the private equity community. The European Commission for Digital Agenda intends to change this. We, "12 Entrepreneurs" and winners of Big Idea for Digital Agenda "Digital Entrepreneurs", can help the Commission change this and turn big ideas into innovation.

It is common knowledge that startups tend to group together into clusters. On the other hand, it is said that your physical location doesn’t really matter when it comes to developing innovation in the Internet era. How can these opposing trends be reconciled and made to work to our advantage?

Roman: This trends are not opposite, actually are very compatible trends that create opportunities to develop local cluster initiatives globally. Collaboration is power: at all levels - local and global!

Emmanuel: Clusters are very important to create emulation between entrepreneurs and create an ecosystem. Each European country has a few successful clusters (Cambridge, Oxford, London in the UK, Paris, Grenoble, Sofia-Antipolis in France, while Barcelona, Berlin and Vienna are also becoming increasingly dynamic clusters too). Of course, none of these clusters has the critical mass of the Silicon Valley. However, it is a chance for Europe to build its strength on a network of clusters. Collaboration between Euro-
pean clusters and European entrepreneurs everywhere is power as Roman described it, but it is also new ideas, innovation, creativity, value and common wealth.

You said that "12 Entrepreneurs" intend to create a new European entrepreneurial identity. What would that new identity consist of?

Roman: Entrepreneurship doesn’t only mean generating financial growth – it also means exploring the unknown, self expression, and creating identities. Digital entrepreneurs are the pillars of European development, carriers of new business approaches, the new philosophy of business, which will result in the creation of next-gen jobs, social and economic growth, the strengthening of European solidarity and European and global innovation.

On the route to achieving that new identity you are proposing to create a "European Digital Talent Fund". What would be the main features of such a fund? How could it be managed to make sure that it is investing in good talent? What kind of talents should be fostered?

Emmanuel: The European Digital Talent Fund (EDTF) is a new Go-to-Market Bridge and Booster for internationalization and commercialization of digital startups across Europe. The EDTF is a new model of startup funding, a social venture capital fund with 6 Ps: Public–Private Partnership, People, Planet and Profit – to invest in European technology start ups and help them expand globally through a network of offices and advisors.

Another of your goals is to create a "Digital Valley for Europe". What would that Digital Valley be like?

Roman: One goal is the Network (social media platform) connecting and federating existing clusters, incubators and initiatives for the digital economy and next generation entrepreneurs. Another goal is an entrepreneur and innovation Village like, for example, the one anchored in the heart of Europe - Pannonia (Centrope) region - on the border of Austria and Hungary: "Dreamicon Valley" - it is in the early stage including TedXPannonia, Future Lounge, Web-TV for entrepreneurs and infrastructure for the Next Generation Technology Park. The vision: digital university, technology-parks and business accelerators empowering European entrepreneurs in sharing, funding and realizing business projects.

We would say that Europe is very diverse. So, how do we combine European cultural and economic diversity with the creation of such a shared entrepreneurial valley for Europe?

Roman: Exactly. The idea is not to copy Silicon Valley in Europe. This will not work. We have to create Europe’s special Digital Dream Icon.

Emmanuel: Success in Europe will only happen with a collaboration between European entrepreneurs and European clusters of entrepreneurs.

Europe itself is a huge, broad market. As far as I understand, you are proposing to dynamize this broad market for the sake of entrepreneurs, too. What is your vision on that desirable dynamization process? How could "12 Entrepreneurs" contribute to the process?

Roman: Recently we met Dimitris Tsigos, President at YES - European Confederation of Young Entrepreneurs representing 40,000 entrepreneurs <www.yes.be>. We want to cooperate and initiate a cross-sector roundtable with two commissioners: Vice-President Neelie Kroes (Digital Agenda) and Vice-President Antonio Tajani (Enterprise and Industry) and connect: (1) Digital Agenda for Europe (2) Research & Innovation CSF (3) Innovation Union. We digital entrepreneurs are the missing link of the flagship initiatives "Digital Agenda" and "Innovation Union".

Emmanuel: Selma Prodanovic, the Initiator and Chairwoman of "Incredible Europe" (which connects the most influential innovative and creative changemakers) to "Think Europe 2049 - Act now!") and a member of our movement posted: "Entrepreneurs are the new rock stars - translating the needs of the people into a language everybody can understand: Yes, we will!"

Your long-term vision includes the creation of a new entrepreneurial eco-system by 2020. What would that new ecosystem be like? Would it be a European ecosystem or a global ecosystem in which European stakeholders have a leadership role?

Roman: The vision is of a global ecosystem where visionary entrepreneurs and innovators have a leadership role.

Emmanuel: Europe is not isolated as a fortress and should be open and welcome talents and entrepreneurs from the whole world.

So far, you have worked on the design of a 10-year roadmap to reach your intended goals <http://ec.europa.eu/information_society/events/cf/dae1009/document.cfm?doc_id=15672>. According to that roadmap you are now in the "preparation" phase. Could you please describe the "preparation activities you are carrying out at this point?

Roman: Getting the support of stakeholders and authorities, building up our community of digital entrepreneurs, drafting the roadmap until 2020 and executive summaries for big ideas, presenting a keynote address to "International B2B Software Days" in Vienna in front of several hundred entrepreneurs from Europe, taking part in the European Mediatech Investment Forum in Barcelona, social networking via LinkedIn, Facebook, Youtube, Twitter, Xing, DAE, cooperation talks with "European Tech Tour Association", "peacefulfish" and "Tornado Insider", etc.

Emmanuel: We worked with Cambridge University Entrepreneurs, the business organizations CUTEC in the UK, ESSEC in France, Visiting Digital Village ("Dreamicon Valley") in Centrope, bilateral contacts at Mobile World Congress in Barcelona.

Roman: We were also invited to Berlin by the German Federal Ministry for Economics and Technology to "DAE German Stakeholders Day"; cooperation talks with DAE Austrian national point of contact, Federal Chancellery of Austria; we are in contact with media adviser of French Government, we participated in various surveys including "European Digital Innovation" (BEL), "Media" (EC), etc.

Emmanuel: The United Nations Industrial Development Organization

Roman: Annik Bouquet, Technology Attaché of the Government of Flanders, Belgium said, that we are "capable of building significant and sustainable job creation over time on both sides of Atlantic".

On 25 October, 2010, at the Digital Agenda Stakeholder Day, your idea “Digital Entrepreneurs” was elected as one of the best 7 ideas from the Digital Agenda stakeholders to be developed with the support of the European Commission. What has been the impact of this fact on your activities or your influence as a group, so far?

Roman: It gave us publicity and high-level contacts.

Emmanuel: We became a serious factor. We are an important part of the workshop “Future digital economy” which is about the efficient framework for financing between entrepreneurs, all industry sectors, financing providers and policy makers in the context of the "First Digital Agenda Assembly” and takes place on 17 June in Brussels. <http://ec.europa.eu/information_society/events/cf/daa11/item-display.cfm?id=6000>.

In your roadmap phases 2 and 3 you have planned activities under the title "Going Global with DAE". Does this mean that you aim to receive support from the European Commission for your "globalization" activities? Do you think that through your planned globalization activities you could help the European Commission spread the objectives and benefits of the European Digital Agenda?

Roman: Exactly! Going global with Europe’s Digital Agenda: first stop is Silicon Valley. One-day major conference on “Europe in Silicon Valley” planned to promote the Digital Agenda, mobilize the European business community in the San Francisco Bay Area, and spur investment in the European Digital Talent Fund (EDTF).

We can help the Commission to spread the idea and connect the leaders. Additionally, we are planning to organize a road show - promotional tour for DAE and EDTF meeting influential US and European companies, CEOs and decision-makers. The third goal is the opening of the first European Pavilion in Silicon Valley and subsequently in Hollywood, which would help European companies to grow and get access to capital in the US and Europe.

Emmanuel: The European Pavilion would also help US-companies regarding internationalization in Europe.

I notice that you have two different stages for your planned “going global” activities: 1) Silicon Valley; 2) Shanghai, Bangalore, Sao Paulo, Kuala Lumpur.

Outcomes: Global Innovation Hub and Next-Gen Jobs.

You have declared that you are an open group in which every IT stakeholder can take part. Besides, as yours is such an attractive idea, it stirs up a lot of enthusiasm among IT stakeholders (I am a good example of this, I must confess). What might be the role of the different IT stakeholder groups in “12 Entrepreneurs”? Are you considering setting up specific working / discussion groups to deal with different aspects of your initiative?

Roman: German writer Knigge once said: “Without inspiration (enthusiasm), which fills the soul with a healthy warmth, nothing great can ever be brought to pass." We are open to every suggestion, everyone can contribute via "12 Entrepreneurs" social networking groups on Facebook and LinkedIn or via winning big idea "Digital Entrepreneurs" on DAE (Digital Agenda for Europe) Commission’s site. Come to our next workshop "Future Digital Economy" in the context of the "First Digital Agenda Assembly" which we mentioned before.

The “12 Entrepreneurs” movement was set up in September 2010 so you are a very young organization. Are you satisfied with your first six months of life? What do you consider to be your main achievements so far? Looking forward to the near future, what will you be putting emphasis on in the next months?

Roman: Our movement has a strong story starting thousands miles away from our homes, discovering Europe in Silicon Valley and winning Big Idea for Digital Agenda in Brussels. We are coming from the “garage” (basement), not from the “top этаж” (top floor). Entrepreneurs join our movement, because they see that we are bottom up, full of energy and new approaches, open and different from many other similar initiatives. We achieved in several months more than some initiatives in several years, without funding, even without a website, but by having global linkages to world-class entrepreneurs, government representatives, service providers from Europe and the US and high level contacts to the European Commission and United Nations. Government of Flanders, Belgium and Vienna IT Cluster (former VITE) supported us from the beginning and helped us directly. Belgium (at that time EU Presidency) covered the costs of our foundation conference. Vienna IT Cluster invited other cities, countries and organization to support our initiative. Our goal is to operationalize our big ideas until 2020. For that we need funding. We are negotiating with the EU Commission and we are looking for a sponsor: company, city, region, organization, wealthy entrepreneur.

Emmanuel: We are interested in connecting with entrepreneurs, investors, individuals, public and private organization, and NGO who would like to contribute to European entrepreneurial success and make Europe a better place for entrepreneurs and innovators.

Thank you very much for your kindness and your contribution.
Cloud Computing Security and Privacy Issues - CEPIS Statement

CEPIS publishes a Cloud Computing Security and Privacy Statement that explores the security and privacy implications associated with Cloud Computing. It examines areas such as the loss of control over data and dependence on the Cloud Computing provider and outlines the related issues. Within this statement, CEPIS provides 15 recommendations on measures that should be taken to deal with the risks and privacy invasion factors of Cloud Computing.

Keywords: CEPIS LSI SIN, Cloud Computing, control over data, data confidentiality, data protection, privacy invasion factors, risk factors, risk management, security issues.

1 Background
Cloud Computing is not a very new concept in IT, in fact Cloud Computing is a more advanced version of the Data Processing Service Bureaus that we had 40 years ago. Nevertheless, the best known companies in the IT field offer or will shortly offer Cloud Computing services to a range of customers from organisations of all sizes to individuals. The biggest and best known Cloud Computing providers include Amazon with EC2 [5], Microsoft with Azure [6] and Google with GoogleApps (e.g. Gmail, Google Docs, Google Calendar) [7]. The paradigm of Cloud Computing can be described in simple terms as offering particular IT services that are hosted on the internet, the most common ones being Platform as a Service (PaaS), Infrastructure as a Service (IaaS) and Software as a service (SaaS).

Cloud Computing is often marketed as an efficient and cheap solution that will replace the client-server paradigm. The paradigm shift involves results in the loss of control over data as well as new security and privacy issues. For this reason caution is advised when deploying and using Cloud Computing in enterprises. After all, the first big issue in data protection in Europe arose at the end of the 1960’s, when a Swedish company decided to have its data processing done by a service bureau in Germany and the data protection legislations in both countries were not alike.

With Cloud Computing rapidly gaining popularity, it is important to highlight the resulting risks. As security and privacy issues are most important, they should be addressed before Cloud Computing establishes an important market share. Many IT and important research agencies are aware of these risks and have produced reports and analyses to document them [1][2][3][4].

2 Concerns
There seems to be no area of ICT that is not affected by Cloud Computing. Two main issues exist with security and privacy aspects of Cloud Computing:
1) Loss of control over data and
2) dependence on the Cloud Computing provider.

These two issues can lead to a number of legal and security concerns related to infrastructure, identity management, access control, risk management, regulatory and legislative compliance, auditing and logging, integrity control as well as Cloud Computing provider dependent risks.

Typical issues due to the loss of control over data are:
1) Most customers are aware of the danger of letting data control out of their hands and storing data with an outside Cloud Computing provider. Data could be compromised by the Cloud Computing provider itself or other competitive enterprises which are customers with the same Cloud Computing provider. There is a lack of transparency for customers on how, when, why and where their data is processed. This is in opposition to the data protection requirement that customers know what happens with their data.

2) Many Cloud Computing providers are technically able to perform data mining techniques to analyse user data. This is a very sensitive function and even more so, as users are often storing and processing sensitive data when using Cloud Computing services. This holds especially true for social
media applications that encourage users to share much of their private life, e.g. private photos.

3) Mobile devices, in particular with their limited storage and computing capabilities are drivers for having services provided by Cloud Computing instead of using software on individual computers. Even data that are only to be transferred from one mobile device to another (local) device, are often transferred via the cloud, when cloud oriented applications on the mobile devices are involved. Therefore users often put themselves at risk without noticing this, as they assume that the data is transferred locally.

4) Since Cloud Computing is a service, it has to be accessed remotely. The connection between the Cloud Computing provider and customer is not always adequately protected. Security risks that threaten the transfer line include eavesdropping, DNS spoofing, and Denial-of-Service attacks.

5) The paradigm shift in Cloud computing makes the use of traditional risk management approaches hard or even impossible. Irrespective of the fact that control over data is transferred to the Cloud Computing provider, risk management and compliance issues are split between the Cloud Computing provider, Internet provider and customer. However, compliance can be seen as one of the important trust factors between the Cloud Computing provider and customer. Regulatory and legislative compliance is also problematic. Cloud data centres can be geographically dispersed. Therefore legislative compliance is not currently adequately defined.

6) As all technical control is given to the Cloud Computing provider, customers often want to have an external audit of this provider. Therefore logging and auditing information has to be stored and protected in order to enable verification. Appropriate logging could provide the possibility for forensic investigation in cases of incident.

7) Concerns also exist with regard to deletion of data: It is difficult to delete all copies of electronic material because it is difficult to find all copies. It is impossible to guarantee complete deletion of all copies of data. Therefore it is difficult to enforce mandatory deletion of data. However, mandatory deletion of data should be included into any forthcoming regulation of Cloud Computing services, but still it should not be relied on too much: the age of a "Guaranteed complete deletion of data", if it ever existed has passed. This needs to be considered, when data are gathered and stored.

8) Data Protection and Privacy legislation is not even similar in many countries around the globe yet Cloud Computing is a global service of the future. Consequently the problems and risks that affect data protection rules in Europe must be considered properly when Cloud Computing platforms are located on servers in non-European countries.

9) Cloud computing depends on a reliable and secure telecommunications network that assures and guarantees the operations of the terminal users of the services provided in the cloud by the cloud computing provider. Telecommunications networks are often provided separately from the Cloud computing services.

Typical issues with regard to the dependence on the Cloud Computing provider are:

1) A major concern regarding dependence on a specific Cloud Computing provider is availability. If the Cloud Computing provider were to go bankrupt and stopped providing services, the customer could experience problems in accessing data and therefore potentially in business continuity.

2) Some widely used Cloud Computing services (e.g. GoogleDocs) do not include any contract between the customer and Cloud Computing provider. Therefore a customer does not have anything to refer to if incidents occur or any problems arise.

3) Cloud Computing is a service similar to other more "traditional" services and utilities (e.g. telecommunication, transaction banking, electricity, gas, water, etc.) Both Cloud Computing services and traditional services and utilities tend to be offered by large providers dealing with smaller customers. Therefore the customers usually depend on the providers because it is difficult to change providers if it is possible at all. Consequently traditional services (e.g. telecommunication, transaction banking, electricity, gas, water, etc.) are usually regulated with regard to the functionality range (e.g. mandatory functions, coverage), pricing, liability of the provider, and reliability.

Cloud Computing corroborates a trend that ICT security is no longer a purely technical issue but an issue between individuals and organisations and thus includes both human and organisational aspects such as management, contracting, and legal enforcement.

3 Recommendations

In particular the following points need to be considered.

1) Risk management and (legal) compliance issues must be well defined in the contract between Cloud Computing provider and customer and should enable transparency with regard to the processing and storage of data, e.g. the physical location of data storage. In this way the trust between the Cloud Computing provider and customer can be strengthened.

2) The service provided shall be compliant with the regulation and legislation that the customer needs to follow, and also customers should be enabled to be compliant with the respective regulation and legislation.

3) The problems and risks that affect data protection rules in Europe must be considered properly when Cloud Computing platforms are located on servers in non-European countries.

4) The communication line between the Cloud Computing provider and the customer has to be adequately protected to ensure confidentiality, integrity, authentication control and further to minimise the risk of denial-of-
service attacks. An open and clear specification of the measurements taken to ensure the security of the communication line should be obligatory for any Cloud Computing provider and should be based on open and transparent standards and technologies.

5) The Cloud Computing providers should be obliged to ensure data confidentiality.

6) Mandatory deletion of data should be included into potential regulation of Cloud Computing services, but it should not be relied upon too much.

7) The fact that there is no guaranteed complete deletion of data needs to be considered, when data are gathered and stored.

8) In order to guarantee the availability of data, local backup of essential data by customers should be considered.

9) Development and better promotion of software that enables local data transfers between devices should be encouraged.

10) The telecommunications network that supports the cloud computing services should be secured and protected against malware and DOS attacks.

11) Adequate logging and auditing should be provided. An external audit can be beneficial for the reputation of the Cloud Computing providers as well as for strengthening the trust with the customer.

12) Non-professionals (e.g. the usual user) should be educated with regard to the new paradigm. Education should prepare them to make competent decisions on using Cloud Computing services including what information should be transferred into the Cloud and under what circumstances.

13) Professionals should be skilled to manage the new types of risks.

14) Given that some regulation will be needed in the future, e.g. to balance the power between providers and customers of Cloud Computing services, it would be wise to consider its weaknesses and issues before Cloud Computing becomes a critical service or infrastructure. It needs to be checked which of the dimensions of conflict and regulatory potential will be relevant (e.g. the guarantee and liability with regard to confidentiality and integrity of processed data). In particular when a Cloud Computing provider becomes part of a critical information infrastructure some regulation or limitations concerning their possible takeover by another party may be appropriate.

15) Research on the basic concepts and issues in informatics, security, and privacy and their consequences and trade-off’s with regard to Cloud Computing should be encouraged. Also issues concerning the possible impact of Cloud Computing platforms on the validity of certification of applications that are certified according to criteria (e.g. Common Criteria, European Privacy Seal, etc.) may need to be investigated.

References


Invitation: Help Develop a pan-European Framework for ICT Professionalism in Europe!

CEPIS and the Innovation Value Institute (IVI) at NUI Maynooth are asking IT practitioners throughout Europe to contribute to a ground-breaking research project on attitudes to structures of professionalism within the field of IT.

CEPIS and IVI have been tasked by the Directorate-General Enterprise and Industry of the European Commission, to contribute to the development of a European framework for ICT professionalism, which is ultimately aimed at fostering the competences and the mobility of IT practitioners across Europe.

CEPIS would like to invite ICT professionals to take part in the ICT Professionalism survey, which will look to develop a clearer understanding around the following issues:

- The need for, and structure of, an ICT Professionalism framework.
- The impact of certification programmes on job mobility and career development.
- How competence frameworks are and can be used to develop ICT professionalism.
- What training and education is best suited to developing the CIO / IT Manager of the future.
- The ethical considerations for an ICT profession.
- The Bodies of Knowledge (BoK) currently being used by ICT practitioners.

Please, take the ICT Professionalism survey at: <https://www.surveymonkey.com/s/ICTProf>.

The closing date for completing the survey is early June 2011.

ICT Managers: How Green is your Organisation? Take the CEPIS Green ICT Survey!

The CEPIS Green ICT Taskforce has been created to carry out specific strategic objectives such as raising awareness of Green ICT issues to European institutions and to promote the good practices of Green ICT in Europe. The Task Force is composed of a group of experts from various CEPIS Member Societies across Europe.

Taskforce members have created a new survey on Green ICT to examine the awareness and behaviour of ICT managers regarding energy consumption and energy efficiency of ICT equipment and policies within organisations. This was influenced by the work that our Greek Member society, Hellenic Professionals Informatics Society (HePIS) presented at the 45(10) Council meeting in November of last year.

The results will provide useful business information on organisations’ ICT usage and green ICT practices, and will enable ICT Managers to determine how ‘green’ they are compared to organisations in other countries <http://www.surveymonkey.com/s/CEPISGreenICTSurvey>.

Computer Experts from across Europe on the Vital Importance of Developing e-Competences and ICT Professionalism

CEPIS Member Society representatives from 22 European countries gathered in Malta recently to provide their valuable expertise on developing ICT professionalism and identifying e-competences in Europe and other usual Council matters. Almost two dozen informatics associations participated to discuss the importance of professionalism in IT and other key CEPIS strategic activities that help promote the development of the information society in Europe.

With the support of its Member Societies, representing over 350,000 professionals in Europe, CEPIS’ broad network incorporating the expertise of European industry, academia and individual professionals will develop the professionalism domain. In conjunction with IVI, CEPIS has undertaken the ICT Professionalism and e-skills project <http://cepis.org/index.jsp?p=827&n=940> funded by the Directorate-General Enterprise and Industry. Europe’s future as a competitive and digital economy can only succeed when its ICT professionals are equipped with the right skills to be able to fill new jobs. Keynote speaker at the 46th CEPIS Council, Mr. John Ambrogio from the eSkills Alliance Malta, also stressed the importance of matching skills to jobs.

To get a real view of the actual competences held by ICT professionals in Europe today, CEPIS is conducting a pan-European Professional e-Competence project <http://cepis.org/index.jsp?p=636&n=639&a=3546>, which analyses the digital competences of ICT professionals and how they comply with labour market requirements. To date 2,000 professionals from across Europe have participated, and the first draft country-level report...
was presented in Malta to the acclaim of all of the ICT experts in attendance. A pan-European report will be compiled to provide analysis of the competences needed at a European level and will provide a clearer picture of the reality of ICT professionals in Europe today, help identify the gaps and provide the first pan-European picture of Europe’s ICT professionals.

How the CEPIS Women in ICT Award Helped a Senior Programmer in her Career

At the closing event of European e-Skills Week last year, CEPIS launched a new award to encourage young women to take up and stay in ICT-related education and thus careers. University graduate, Louisa Luciani from Sweden, won a €500 educational grant sponsored by CEPIS.

This CEPIS grant supported Louisa in successfully completing a week-long course at the University of Utrecht’s Summer School in The Netherlands. Since completing her third-level education last year, Ms. Luciani is now working in the area of software development with Accenture, a leading global management consulting and technology services company.

As a Senior Programmer, Louisa is very busy with a project on web-portal development, and has recently spent time working in India on related business. The CEPIS-sponsored course has equipped Louisa with necessary tools in her current career; she said, "The course I was able to undertake with the support of CEPIS’ educational grant has definitely helped me in my current career..." adding that it has had a direct and positive impact where she has been able to use the valuable knowledge gained in real-life situations at work.

Louisa’s experience shows that the CEPIS Women in ICT award has successfully enabled one young woman to undertake a promising career in ICT.