Ontology and Software Components for the E-learning Domain

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Abstract

The high quality software development process can imply in component reuse. Reuse demands appropriate documentation. One of the approaches to document software development uses the concepts of ontology. Our research focuses domain ontology and software component development. It aims to test ideas on the use of OdysseyShare available tools. In this paper we present an e-learning ontology, created and modeled in order to provide support to the development and reuse of software component to be shared with software engineering community. To better expose our approach, Virtual Classroom, one sub sector of the e-learning domain, is presented, and it is pointed out how we developed some components for the described sub sector.

Key-words: E-learning. Domain ontology. Software components.

1. Introduction

Reuse is a promising way to help improving software development. One of the most encouraging reuse techniques available is Component-Based software Development (CBD) (Szyperski et al, 2002). CBD exploits interrelations between preexisting components and reuse of components that have been exhaustively tested to reduce complexity and costs of software development (Braga, Werner and Mattoso, 1999). CDB also promises to expand software quality by re-using existing and well-tested software components.

The activities of CBD process require interaction and cooperation among all the professionals involved. In this sense, a cooperative environment for component development, named OdysseyShare (Werner, C., et alli. 2003), is under construction in the Program of System Engineering and Computer Science (COPPE/Systems/UFRJ), Universidade Federal do Rio de Janeiro. The goal is that the teams generate software devices, as models, diagrams, source code, programs or any other kind of artifact used or produced along the different stages of software development process.

The OdysseyShare activities on e-learning involve the cooperation among researchers of COPPE/Systems/UFRJ, the Research Group of Software Quality, Universidade Federal de Juiz de Fora (NPQS/UFJF) and a third partner, from the Computer Science Department, Universidade do Estado do Rio de Janeiro. In this paper, we detail the construction of the e-learning ontology, show how it was modeled in the OdysseyShare environment and present some software components specifications, already integrated into the component repository. These components were identified using the functionalities and concepts detailed in the e-learning ontology. It is organized as following: section 2 briefly argues domain ontology; section 3 describes the e-learning domain, presenting parts of the ontology; section 4 details the specification models of one developed component; and section 5 reports the conclusions.

2. Domain Ontology

An important issue in software development is the reusability. Ontology can be a useful support for software reuse since it establishes a joint terminology between members of a community of interest. Ontology is generally considered to provide definitions for the vocabulary used to represent knowledge. It can be seen as a schema that provides precise and complete models of particular domains. In the process of building ontology, each term must be defined by means of a formal or informal description, as well as the specification of the relationships among the terms, shaping a semantic net.

According to Fikes (1996):

Adopting reusability as a primary goal for ontologies has a significant impact on the tools and

methodologies that are needed for ontology creation and use. For example, developers need to make their ontologies accessible and understandable to a community of use. So, new techniques are needed for translating ontologies between representation formalisms and for describing the competency of an ontology. Also, when knowledge is encoded specifically for use throughout a community, one would expect there to typically be involvement by that community in the encoding process. So, tools that support collaborative development and evolution of ontologies would appear to be important in achieving desired levels of reusability.

Our e-learning ontology uses the notion of domain ontology that describes precisely the basic concepts found in particular domains. In the OdysseyShare context (Werner et al, 2003), and in the reuse area, the model that specifies the domain terms, shaping a semantic net of terms, is called features model. The features model (Cohen, 1994) captures the general features of available software application in specific domains and allows the insertion of new terms in as domains grow up. To specify the e-learning ontology, we used Domain Engineering (DE) techniques, and we particularly used the domain engineering method called Odyssey-DE (Braga, Werner & Mattoso, 1999), which main purpose is to facilitate software reuse in an application domain.

Odyssey-DE is composed of four stages: domain viability analysis, domain analysis, domain design, and domain implementation**.** The main objective of the *domain viability analysis* stage is the analysis of the viability of the domain to provide a group of reusable components. This stage is important for the whole process, because it is based on the result of this analysis that domain engineers and specialists decide whether it is worthwhile or not to implement a base of interconnected components for the domain. The *domain analysis* consists in the definition of main domain concepts, standing out similarities and differences among these concepts in a high abstraction level. Models are divided based on main characteristics (i.e., features) of the domain. The main objective of the process is the identification and specification of components that can be reused in domain applications in all levels of the application development. Besides that, the specification of reusable components is done in an incremental and evolutionary process, i.e., as new information is added to the domain, reusable components are developed or adapted based on the acquired information. It is important to notice that the Odyssey-DE process tries to unify the approaches of Domain Engineering, with the purpose of provide reusable software artifacts, with Component Based Development Approaches, such as UML Components (Cheesman, Daniels, 2001), whose main proposal is to provide replaceable components. Odyssey-DE provides models that emphasizes reuse but emphasizes also the detailed component specification, using for that some characteristics from UML Components.

The model of features allows the detailing of the general characteristics – the features – of domain applications. Applications similarities and differences are expounded by means of a hierarchy of features. In Odyssey-DE context, we extended the classic definition of features by introducing deeper detailing into the domain ontological terms (by way of using domain patterns) and from their relationships. Hence, each ontological term is specified as a domain feature, and a detailed description of it (i.e., *Domain Patterns*), and relationships with other ontological terms (features), at different levels of abstraction, are created. We provide also some ontological rules in order to discover new ontological relationships. This set of rules allow the creation of synonym, hypernym and hyponym relationships that domain engineer did not discovered by his own.

As result, the features are expressed with more precise elements: Categories (divided into Sectors and Sub sectors) and Functionality (divided into Sub functionality and Specific Functionalities. C*ategories* embrace the high-level domain characteristics, and *functionalities* contain the most general domain functionalities.

Based on this theoretical background, we created an e-learning ontology. Considering that the Web Based Education is one of the software development domains where reuse must be considered because of characteristics such as distribution, server side services, among others, that are very adequate to a CBD approach (Szyperski et al, 2002), we aim to describe this ontology to reach two goals: provide some semantic to the domain and using it in order to discover components that are most reusable for the domain, display them in a Web repository to share with other software users and developers, and provide search and retrieval mechanism, based on the domain ontology in order to improve the retrieval of the right components for a given. We argue that these characteristics are very important in a CBD approach, once, currently, one of the most promising research areas in CBD is to improve the search and retrieval of components for reuse. We believe that ontologies, as we propose here, and some other web semantic techniques could improve this process.

3. Ontology for the e-Learning Domain

Ontologies are becoming increasingly important in e-learning systems domain, since they provide means for machine-based knowledge sharing and reuse between applications. However, because of their size, their complexity and their formal underpinnings,

ontologies are still far from being a commodity (Smolle and Sure, 2002). Even so, some available works reports the use of ontology in this domain. The literature exposes that, at the moment, there is not a common terminology in use by the researchers and practitioners. In this way, all available proposals to create e-learning ontology are useful.

An interesting use of ontology to supply e-learning information sites is the e-Learning Cybrary. It is an ontology-based collection of annotated links to e-learning sites, news, documents, portals, and other e-learning resources available on the web. In the e-Learning Cybrary point of view, the area covers: Shared learning, Communities of practice, Learning networks, Peer-to-peer e-learning, e-Training, Edutainment, Learning histories, Online coaching, "Open source" e-learning, Digital storytelling, Environments, Learning portals, Collaborative workspace, Virtual university/online campus, Virtual classroom.

According to e-Learning Cybrary the main technologies to support e-learning are: Synchronous communication technologies, asynchronous communication technologies, Authoring tools, Simulation & Computer-Based Training, Visualization Tools, Electronic Performance Support Systems, Intelligent agents of e-learning, Integrated platforms, Learning Management Systems.

Paulsen (2002) categorizes and described some terms related to online education systems. He proposed the following categorization:

- Online Education, E- learning, Online Education Systems, Integrated Online Education Systems, and Standards Specifications.
- Content Creation Tools, Authoring Tools, Assessment Tools, Learning Content Management Systems, and Learning Objects
- Learning Management System, Learning Platform, Virtual Learning Environment, and Learning Service Provider
- Student Management System, Enterprise Resource Planning System, Human Resource Information System, Knowledge Management System, and Competency Management System

Our proposal sketches very similar terms to those presented in related works. One difference of our approach is that it was developed based on a Domain Engineering process, whose main purpose is to develop reusable software artifacts. So, our domain terms were specified thinking in which components could be developed that are related with these terms. For this, the Odyssey-DE process has a set of activities that “links” domain terms and component specifications.

The first step of work was to define and validate the notion and boundaries of e-learning systems.

To Kaplan-Leiserson (in Paulen 2002), e- learning covers a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. It includes the delivery of content via Internet, intranet/extranet LAN/WAN), audio- and videotape, satellite broadcast, interactive TV, and CD-ROM.

E-learning also can be Internet-enabled learning. Components can include content delivery in multiple formats, management of the learning experience, and a networked community of learners, content developers and experts. (Cisco Systems in http://www.learnframe.com/aboutelearning/glossary.asp)

We defined e-learning as the use of the Web and other Internet technologies to enhance the teaching and learning experience. It usually embraces: (a) online activities to study online learning resources; (b) online tests to self-assess their own understanding of the subject; (c) online discussions to maintain a seminar discussion over a longer period of time; and, (d) collaborative learning activities for students to work together on projects without necessarily being in the same room (http://www.e-learningcentre.co.uk/eclipse/Guides/eLearninginHE.htm). The terms "online learning" and "web-based learning" are often used interchangeably with the term "e-learning".

We constrained the scope of the E-learning ontology in order that it only involves the infrastructure offered by the Web to create and delivery teaching and learning tasks. We classified the domain in two comprehensive sub domains: Web-based instruction (WBI) and Computer-supported cooperative learning (CSCL).

We stand out that these sub domains are complementary and in many cases interdependent approaches. However, our classification is based on a remarkable difference: WBI incorporates the main features of e-learning area, but it does not emphasize the cooperative learning activities. In the other hand, CSCL focuses basically the cooperative side of the educational process, and does not highlight the instruction delivery.

WBI concerns basically the use of the Web platform to delivery didactic material, to provide students support, and to offer access to a large range of communication tools. It refers to providing a learning environment that is mediated and supported via the Internet/Intranet and connected to a computer with hyperlinks to resources outside the instructional domain. The instruction can be as simple as using the system as a "page turner" for information, to as complex as an integrated system which logs learner inputs and responses, provides interactions with video, animation, imagery, forms, examinations, or software. Not only can learning occur through interactions with the materials but through a community of learners using chat, threaded discussion, e-mail, whiteboards.

CSCL supports and promotes shared experience, peer exchange, interaction, shared purpose, common practices of interaction and communication. A spirit of co-operation not only provides the right atmosphere for learning, however; it also promotes the development of good personal relationships, the two of which are intrinsically linked. The purpose of CSCL is to scaffold or support students effectively in learning together. It is based on the promise that computer supported systems can support and facilitate group process and group dynamics in ways that are not achievable by face-to-face, but they are not designed to replace face-to-face communication. CSCL are systems typically tailored for use by multiple learners working across networked machines.

To represent the e-learning ontological terms, we specified a model for the domain. The domain model gathers together terms and functionalities, commonly used by the community. Relating software components to the domain terms allows the software developers to retrieve and select components to be reused in their further applications, as the selection is based on the most commonly described domain terms. Based on the features model and on the different kinds of software for e-learning, we identify common functionalities and started the process of modeling software components for this domain. During the process, we count on domain experts and developers to validate and to confirm sub-domains, sectors, sub sector and their functionalities.

In the OdysseyShare context, the features model was subdivided into two models: concepts and functionalities. In the e-learning area, the conceptual model is called model of categories, since this term is closer to the characteristics of the domain. We defined two sub-models:

Categories embracing the main concepts related to the domain, and

Functionalities, joining the general functionalities of the domain.

The most specific concepts were organized in a decreasing order, in Sectors and Sub sectors, and the Functionalities, in Sub-Functionality and Specific Functionality. The domain encloses two great sub domains: Web-based instruction, and Computer-Supported Cooperative Learning.

Table 1 represents the sectors and sub sectors of the sub domains.

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Table 1. E-learning Sub domains

SUB DOMAINS	
Web-based Instruction (WBI) WBI concerns basically the use of the Web platform to delivery didactic material, to provide students support, and to offer access to a large range of communication tools. It refers to providing a learning environment that is mediated and supported via the Internet/Intranet and connected to a computer with hyperlinks to resources outside the instructional domain. The instruction can be as simple as using the system as a "page turner" for information, to as complex as an integrated system which logs learner inputs and responses, provides interactions with video, animation, forms.	Computer-Supported Cooperative Learning (CSCL) CSCL supports and promotes shared experience, peer exchange, interaction, shared purpose, common practices of interaction and communication. Its purpose is to scaffold or support students in learning together effectively. It is based on the promise that computer supported systems can support and facilitate group process and group dynamics in ways that are not achievable by face-to-face, but they are not designed to replace face-to-face communication. CSCL are systems typically tailored for use by multiple learners working across networked machines.
Sectors e Sub sectors	
Integrated and Distributed Learning Environments Course Management systems Courses authoring systems Virtual classroom Online learning systems Distance courses Online didactic material Web-based contents Educational Web sites Educational Portals Virtual Libraries Virtual Universities WBI Models	CSCL Environments Forums-based systems MOO-based systems Solving problems environments Project-based learning environment Text discussion-based environments Co-authoring environments Concepts learning-based environments CSCL Tools Synchronous tools Asynchronous tools Virtual Learning Communities Chat-based communities Virtual worlds communities

The next step is to describe the terms of the domain. In this paper, we only describe the term of the sub-domain Web-based Instruction (WBI).

A) Sector: IDLEs

Client/server applications that use the standard Internet protocols and are designed specifically for educational applications. They take the stand-alone synchronous and asynchronous collaboration capabilities of the Internet. These tools are primarily being used not only for the delivery of entire courses to remote learners (distance education), but also as enhancements to classroom-based education.

Sub sector: Course management systems

IDLE. Software that automates the administration of training. The CMS registers users, tracks courses in a catalog, records data from learners; and provides reports to management. A CMS is typically designed to handle courses by multiple publishers and providers. It usually doesn't include its own authoring capabilities; instead, it focuses on managing courses created by a variety of other sources.

Sub sector: Course authoring systems

IDLE: Multi user environments that provide support resources to write, revise and publish courses. Available tools allow: Web pages edition, multimedia features, glossary tool, hyperlinks to useful resources, supplemental resources, course materials, lecture notes, lists of URLs, syllabus, Interactivity including practice and feedback, Access to email, listserv, mural, chat, discussion forums, and/or computer conferencing, FAQ, search machine.

Sub sector: Virtual classroom

IDLE. Multi user environments in where online resources are used to facilitate the learning process among students, between students and instructors, and between a class and wider academic and non-academic community. It also can be defined as a teaching and learning environment located within a WBI system.

Sub sector: Online learning systems

IDLE. Multi user environments composed of a set of tools to provide quick and easy training courses. The systems allow delivering contents by means of several kinds of electronic media: Internet, intranets, extranets, audio and video tapes, interactive TV, real time chat, e-mail, forums, electronic library, and CD-ROM, to promote CBT.

Sub sector: Distance courses

IDLE. Multi-user site or system to deliver Web-based educational contents. It can include multimedia features, syllabus, educational goals, online tutoring and assessing resources and communication tools.

Sub sector: Web-based material

IDLE. Multi user Web site with complementary didactic material, textual or not textual, normally used to complete classroom courses.

B) Educational Sites

Web site that joins a set of educational resources (texts, images, educational software library, communication tools, search engine for contents, bookmarks, software for download, links for supplementary online resources).

C) Educational Portals

Collection of sites that joins, in a same virtual space, selected information on specific subject or knowledge area. It can also include communication tools, search engine for contents, FAQ and bookmarks.

D) Virtual Library

Set of organized links on the Internet with access to electronic educational material on the Web, providing navigational support and customization capabilities.

E) Virtual University

Web-based environment for the delivery of courses for internal staff and external users. Courses can be taken live, directly from the web server or downloaded to the user desktop. It can join administrative resources, didactic resources (online courses, syllabus, encyclopedia, thesis repository, papers repository, newsletters, technical journal) and communication tools.

F) WBI Models

Instructional models to create e-learning systems and site. There are at least three models: Publishing (Library model; Textbook model, Interactive instruction mode; Web seminars; Hands-on course); Communication (computer mediated communication) and Hybrid (Publishing + Communication).

As example, in this paper, we only represent the functionalities, sub functionalities and specific functionalities of Virtual Classroom, sub sector of the sector Integrated and Distributed Learning Environments. For legibility reason, the ontology terms are represented in table 2.

We show up that we only represent those terms related to the components already specified. However, all the terms had been shaped and detailed using the Odyssey infrastructure, as a first step for the specification of domain components.

4. The Specification of E-learning Software Components

The ontology representation and the specification of its sectors and sub sectors (tables 1 and 2) portray that some software functionalities are common to many e-learning systems. For example, the simplest and even so typical e-learning software support embraces teacher and student communication tools. For this reason, we selected four communication tools to be the first components to be developed: chat, forum, bulletin board and webmail.

Table 2. IDLEs: Sectors and Sub sectors

Sector: Integrated and Distributed Learning Environments
IDLEs are client/server applications that use the standard Internet protocols and are designed specifically for educational applications. They take the stand-alone synchronous and asynchronous collaboration capabilities of the Internet. These tools are primarily being used not only for the delivery of entire courses to remote learners (distance education), but also as enhancements to classroom-based education.

Sub sector: Virtual classroom
Client/server applications, running under the Internet protocols, designed to educational applications. Multi user environments in where online resources are used to facilitate the learning process among students, between students and instructors, and between a class and wider academic and non-academic community. It is also can be defined as a teaching and learning environment located within a WBI system.

Functionalities	**Sub Functionalities**	**Specific Functionalities**
Administrator Tools Set of functionalities that allow the system administrator to manage the system the whole system and its individual tools.	Management system tools	Authorization tools Security access Different security levels Remote access tools Crash recovery tools
	Course management tools	Student support tools Instructor support tools Variable level of security Online registration Guest account creation Users access politics System installing tools Course fault retrieval tools Resource monitoring
Instructor Tools Set of functionalities that allow the instructor to plan, to develop, to revise and to publish Web-based courses.	Course planning	Instructional designing (topics, teaching units) Models of course -Publishing (Library model; Textbook model, Interactive instruction mode; Web seminars; Hands-on course) - Communication (computer mediated communication)
	Course development	Syllabus facilities Course materials editing tools Multimedia features Automated glossary tool Automated index tool Importing/exporting capabilities Links to supplemental resources capabilities Presenting information tools Previewing courses resources
	Course managing	Course managing tools Course monitoring resources Fast course revising capabilities Customization of student curriculum resources Student monitoring tools Student tracking tools
	Students assessing	Assessing tools: -Kinds of assessment: Formative, Summative, Peer evaluation, Self-evaluation, Peer review. -Instruments of assessment: Online testing, Essays, *Portfolios,* Reports, Tutorial. -Automated grading tools - Customized feedback facilities
	Forms of communication	Asynchronous communication -Threaded discussion tool -Discussion forums -Internal E-mail -Bulletin board Synchronous communication -Real time chat -Conferencing tools -Whiteboard Synchronous - asynchronous communication -Threaded discussion tool

		-Discussion forums -Internal E-mail -Bulletin board -Real time chat -Conferencing tools -Whiteboard
Student Tools Set of functionalities that allow student to take Web courses.	Communication tools	-Threaded discussion tool -Discussion forums -Internal E-mail -Bulletin board -Real time chat -Conferencing tools -Whiteboard
	Cooperation Tools	Threaded discussion tool Discussion forums Internal E-mail Bulletin board Real time chat Conferencing tools Whiteboard Portfolio Specific group work tools Knowledge representation tools Workflow machine Schedule tool
	Productivity Tools	Bookmarks Calendar Progress Review Orientation/Help Search tool for course content Student involvement tools Self assessment Student community building Student portfolios Help online Online testing File download and upload
Forms of communication	Asynchronous communication Synchronous communication Synchronous - asynchronous communication	
Forms of cooperation	Asynchronous communication Synchronous communication Synchronous - asynchronous communication	
Communication tools	Threaded discussion tool Discussion forums Internal E-mail Bulletin board Real time chat Conferencing tools Whiteboard	
Cooperation tools	Threaded discussion tool Discussion forums Internal E-mail Bulletin board Real time chat Conferencing tools Whiteboard Portfolio Specific group work tools Knowledge representation tools Workflow machine Schedule tool	
Coordination tools	Online monitoring tools Software agents Bulletin board	

The components specification was supported using the Odyssey-DE development process with reuse (Braga et al. 1999). As mentioned, Odyssey-DE handles the domain models and component specification in different levels of abstraction. The infrastructure Odyssey (Werner et al, 2000) automates the models construction. Previous works with Odyssey-DE and Odyssey (Werner et al., 1999; Procaci et al, 2002) point out that the Odyssey support was stronger in the initial stages and a little limited in the stages of the specification of components.

At present, the Odyssey infrastructure already offers automated support for components specification (Teixeira, 2003) and Odyssey-DE was improved, as stated before, in order to include component specification phases. The main difference between Odyssey-DE and CBD approaches, notably UML Components, is the importance of reuse. UML Components (Cheesman and Daniels, 2001) is mainly worried with the development of components for one application. The reuse of previous developed components is not stressed. Odyssey-DE uses the features model to guide the users in the reuse process, enlightening the best components for a given context, since the domain terms are connected with components specification.

We use also the notion of use case, which is derived from features model main functionalities. It is not our objective in this article to detail Odyssey-DE. Details of the approach is provided on www.cos.ufrj.br/~Odyssey

In this paper, we detail the domain use cases related to the component Bulletin Board, showing the linking of the use cases to the implemented component. The definition of the component interfaces was based on the Chessman and Daniels (2001) proposed steps and the use cases reveal that they are deeply interlinked, and are part of the same process, besides to be interdependent. For this reason, they had been grouped in two interfaces IBulletinBoard (Administrator/Instructor) and IBulletinBoardStudent. Based on this and other previous experiences, we started to use the notion domain use case, which is derived from features model main functionalities. We believe this is a better approach than using conventional use case, as proposed by Cheesman and Daniels, in order to derive components interfaces and specification. In our features model, we have the term Bulletin Board. Using a domain use case, we detailed the main functions of a Bulletin Board and, using the conventional use cases, we detailed its provided interfaces.

5. Conclusions

In this paper, we described and illustrated the process of structuring an e-learning ontology and its application in the definition and possible search and retrieval of software components, which are under development, to compose a component repository. It also presented the main stages of the development process, detailing the documentation and the development of components. We used the Odyssey Share and the Odyssey-DE methodology in the diverse stages.

Our main contribution is to provide an ontology connected to component specification that helps in the identification of components of greater importance in the domain and must be specified in the domain, and to provide a domain ontology that guides a reuser in component search in the domain.

Our work is a cooperative research, aiming to develop reusable software components. we adopt the notion of domain ontology, linking the features model to component specifications. The extension of the features model allows to shape and to represent the ontology as well as to describe the domain terms and functionalities, with appropriate level of granularity, making it able to point out priorities for components development. OdysseyShare component repository is in constant evolution.

With the aid of our partners, we are defining innovative interest areas, to choose, develop and detail new components.

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Glossaries of e-learning terms:
e-Learning Cybrary:
http://www.co-i-l.com/elearning/about/
Learning Center:
http://learningcentre.co.uk/eclipse/Guides/eLearninginHE.htm
Learn Frame:
http://www.learnframe.com/aboutelearning/glossary.asp
What is Web-based Instruction?:
http://www.proofofconcepts.com/web_guide/What_is_Web.htm
CSCL Theories -
http://www.edb.utexas.edu/csclstudent/Dhsiao/theories.html