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Evolutionary Development of an Infrastructure Supporting the Transition from CBT to e-Learning

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Abstract: *In the paper an evolutionary approach (DeLC) for a consecutive development of electronic education infrastructure, based on clear differentiation between the concept of CBT and e-Learning is presented. The main development steps of DeLC are explained in some details. Furthermore the adaptation of the infrastructure for Software Engineering Education (eLSE) is shown.*

Keywords: *Software Architectures, CBT, e-Learning, DeLC, e-Services, Mobile Services, Ontologies, Agents, Constraint-Based Services Grid.*

1. Introduction

In recent years the use of Information and Communication Technologies (ICT) in education has become an area of ever growing research and development (R&D) interest as well as a topical application area. Different terms and notions used in the specialized bibliography sources are confusing in many cases and do not fully express the essence of the problems and the complexity of the tasks that must be solved when creating automated means for the support of e-Learning process. In many cases the challenges and the problems are simplified, which hampers significantly the development of effective, added-value, e-Learning systems. The quick solutions offered often are without real benefit for the learning process itself.

Aiming at the development of adequate automated ICT means for the effective support of e-Learning as well as seeking new approaches, models, and architectures that could facilitate it, in this paper we consider consecutive development of an e-Learning infrastructure, based on clear differentiation between two basic concepts. The first concept Computer Based Training (CBT) can be used as a starting point for the development of means for e-Learning support. The second concept e-Learning can be used as a target serving as a reference point for long-term research and

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development (R&D). The e-Learning [33] concept builds on the traditions of CBT but also adds powerful new ingredients drawn from network-centric computing, computer-supported co-operative work, adaptive environments, flexible processås and component-based software reuse [8].

The emerging next generation e-Learning systems will be highly adaptable, where the student and domain modeling and the using of new software architectures (especially service-oriented) play an important role. In the paper the integration of three models (student, domain, and pedagogical models) in the proposed infrastructure is presented.

Our evolutionary approach for successive specification of an appropriate e-Learning infrastructure called Distributed e-Learning Center (DeLC) includes the following development steps [39]:

- Concept Model;
- DeLC Infrastructure Model;
- Expanded DeLC Infrastructural Model;
- Constraint-Based Service Grid (CBSG) DeLC.

Furthermore we present an adaptation of the DeLC for the development of an e-Learning information system for Software Engineering education called e-Learning for Software Engineering (eLSE).

2. A concept model for electronic media and technology education support

The concept model depicted in Fig. 1 is the basis of our research approach to elaborate a suitable infrastructure for the support of e-Learning. In general the two main processes in each automated environment supporting e-Learning is the creation (or generation) and interpretation of an electronic content (e-Content). These two processes must be managed in the context of mainly three models – domain model, student model, and pedagogical model (includes the educator model as well).

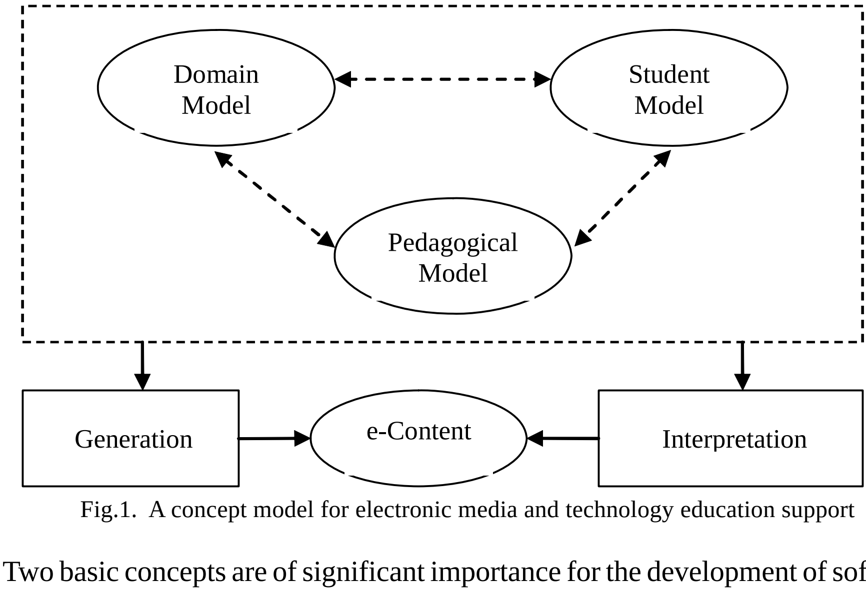

Fig.1. A concept model for electronic media and technology education support

Two basic concepts are of significant importance for the development of software for the support of learning process. CBT is an attempt to automate education, replace an educator, and develop self-paced learning. The CBT focus is primary on electronic recorded education. So this kind of learning is time/place/content predetermined learning. e-Learning has its origins form CBT. The focus of e-Learning is not only on education, but also on education without barriers of time and distance, and customized to users and business' needs [4]. The e-Learning is just-in-time/at-work-place/customized/on-demand process of learning [25]. It is essential to understand that the differences between CBT and e-Learning are not just semantic.

In order to make the e-Learning a reality, a number of research challenges need to be addressed as for example new architectures, multi-communication access to information sources, agent-based approaches, knowledge technologies, dynamic profiling, use of existing standards, etc. It is envisages that two types of emerging e-Services-oriented architectures can provide the needed flexibility: *Semantic Web architecture* and *Grid architecture*. The main challenge in transition from today's *Web* to the *Semantic Web* is in relation to the engineering and technology adoption nature of the problem rather than to the scientific one [4, 44]. Partial solutions to all-important building blocks of the Semantic Web exist already, e.g. knowledge management systems, business-to-business e-Commerce and business-to-consumer applications, intelligent and personal agents. At present, the main problems are: the integration, the standardization, the development of supporting tools, and the adoption by users of all these rational solutions. GRID has emerged as a distributed computing infrastructure for advanced science and engineering [12]. The real and specific problem that underlies the Grid concept is coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations [13]. The establishment, management, and exploitation of dynamic, cross-organizational virtual organization relationships require new technologies. The open Grid architecture organizes components into different layers where components within each layer share common features but can build on capabilities and behaviors exposed by any lower layer. The specification of the various layers follows the principles of the "*hourglass model*" [27]. By definition, the number of protocols defined at the neck must be small. In the Grid architecture, the neck of the hourglass consists of *Resource and Connectivity protocols*, which facilitate the sharing of individual resources. The Semantic GRID [9] is an extended architecture in which additional layers are integrated. The new layers enhance the GRID for powerful processing of the information semantics. In respect to computation and semantics there are close relationships [10].

3. DeLC infrastructure

Established as a collaborated project between the University of Limerick and the University of Plovdiv, the Distributed e-Learning Center (DeLC) [37] aims to provide a distance e-Learning / e-Teaching facility available at any place and at any time to individuals and groups of students / educators both in synchronous mode (on-line) and asynchronous mode (off-line). The DeLC project focuses at the development of a common concept for the creation of e-Learning information systems and a theoretical and conceptual base of service-oriented e-Learning infrastructure for the integration of e-Services. A significant part of this project is dedicated also to the development of a suitable technological environment and architecture that is independent from the embedded e-Services. Three models build the basis for the implementation of the

DeLC – the Infrastructural Model, the Service Model and the e-Learning Node Model. The DeLC Infrastructural Model specifies the basic building blocks of the DeLC. Furthermore it characterizes all the possibilities for integration and management of e-Services within the defined clusters. An initial DeLC infrastructural model was proposed in [35, 36] consisting of DeLC Nodes established and supported by real administrative units offering a complete educational cycle (e.g. laboratories, departments, faculties, colleges, universities). The enhancement of the DeLC for the provision of mobile services improves organizing and functioning of the entire e-Learning/e-Teaching process within a University Campus. An initial outline proposal for this was given in [14, 15]. We plan to develop the DeLC architecture as a consumer-oriented one in line with the trend in mobile communication services based on the *Consumer-based Business Model (CBM)* [28, 29]. This model will be a much more pro-active business driver for the evolution of next fourth generation (4G) wireless world vision [30], which will provide for users access network choices, price-performance choices etc. to enable an always best connected and an always best served (*ABC&S)* wireless networking. When applied to e-Learning/e-Teaching, the CBM will provide flexible opportunities for reach m-Learning/m-Teaching environment. The CBM eliminates the disadvantages of the *Subscriber-based Business Model (SBM)*, which is widely used today but seems not suitable for future 4G mobile communications where users will want to act more as consumers seeking better value for their money and not as restricted (as regards the access and services) subscribers. In CBM the users get services much like shoppers entering this or that shop, buying goods and paying by their credit cards. A key element is that the CBM model separates out the administration and management of consumers' one-stop-shop authentication and accounting system from the business of supplying services, and locates it with a third-party AAA SP[1] (institutions, such as present day credit card companies).A ready-made application is mobile wireless access to full e-Learning education. Our pilot system development would start with InfoStations (free & wideband on universities campuses!), then expand into 2G, 2.5G and 3G systems, then through an integrative and a re-structuring process described herein effect a transition to "consumer-driven" environment of integrated heterogeneous networks. For this the DeLC network model first has to be extended to a 3-tier structure by an introduction of additional entities (e.g. *InfoStations, Intelligent Redirectors, Profile Managers, Intelligent Agents* acting as personal helpers for users, etc) needed for the provision of intelligent mobile services. This will effectively be a pilot infrastructure providing to the user efficient seamless and ABC&S wireless e-Learning services delivery. We suggest that research and development should be made on the basis of intelligent (especially from a communications viewpoint) mobile terminal, which is matched by intelligent service provider (e.g. an intelligent DeLC in the pilot scheme proposed here).

4. Expanded DeLC infrastructure

In order to support also mobile e-Services a so-called Expanded DeLC Infrastructural Model is developed [16, 17], which has a 3-tier structure (shown in Fig. 2), consisting of:

[1] Service Provider of Authentication, Authorization and Accounting services.

• *Mobile Devices* – such as: cellular phones (e.g. GSM[2] [18], GPRS[3] [19], UMTS[4] [41]); Personal Digital Assistants (PDAs); laptops/notebooks; vehicle communication terminal systems (VCTS).

• *Information Stations (InfoStations)* – deployed on the University key points and providing network access (e.g. WLAN[5] [45], Bluetooth[6] [5], UWB[7] [42]) for mobile users with wireless devices. The InfoStations accept requests from mobile devices and forward them to an InfoStations' center for further processing. The InfoStations are used for urgent messages downloading, Internet caching, synchronization of off-line e-Learning process with on-line e-Learning system (e.g. tracking of a learner's progress, sending of asked off-line questions to educators, receiving of answers, sending of other relevant off-line information, such as test scores, time spent on task etc.). The InfoStations obtain all updating information from an InfoStations' center.

• *InfoStations' Centre* – implemented as a server module in one of the DeLC nodes. This centre controls all InfoStations and provides updating and synchronizing information. It contains also Intelligent Redirectors (e.g. needed to redirect a message or incoming phone call to the current user location and most appropriate user terminal used at the moment as specified in the user profile) and corresponding Profile Managers.

The DeLC Service Model serves the development of the system managing the e-Service invocation, which will be a constituent part of the DeLC node's run-time module. The Service Model is open for extensions including new values of already specified dimensions or entirely new dimensions. In order to separate the DeLC

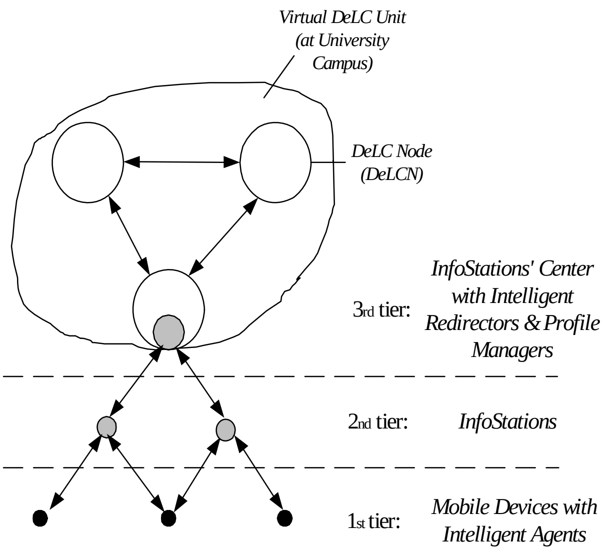

Fig. 2. The 3-tier DeLC Infrastructural Model

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[2] GSM – Global System for Mobile communications (2G – 2nd generation of mobile communications).
[3] GPRS – General Packet Radio Service (2.5G – 2.5 generation of mobile communications).
[4] UMTS – Universal Mobile Telecommunications System (3G – 3rd generation of mobile communications).
[5] WLAN – Wireless Local Area Network.
[6] Bluetooth – an industrial specification for wireless Personal Area Networks (PANs).
[7] UWB – Ultra-Wide Band.

architecture from the offered e-Services, the Service Model is developed as an infrastructure-independent one. The Service Model consists of two main components: e-Services characteristic space (*meta-model*) and *subject models*. The characteristic space classifies the DeLC e-Services within an *n*-dimensional discrete hyperspace. For the moment four characteristic dimensions are defined: *content/nature*, *invocation*, *mobility*, *standard-conformance* (e.g. SCORM [1,22], ARIADNE [2], AICC [3], IEEE LTSC [19, 31], IMS [20, 21], and CEN/ISSS [11]).

In the DeLC concept the nodes are the main components needed for the configuration of any e-Learning system. These nodes are models of real organizations/ institutions certified to provide education. The main task of the DeLC nodes is to provide different services to users/consumers of a system. A DeLC node has to support the integrated e-Services and solves the following problems: analysis and management of the users requests, localization of the required services and their mapping to the actual user request, service customization and personalization, service activation, control over service processing and execution (single services and transactions), sending back the results ect. Currently we develop a concept for the creation and support of clusters, within which an integration and remote invocation of e-Services will be possible.

5. CBSG DeLC

In order to bring more power and flexibility during the run-time we are going to look for possibilities to extend the DeLC infrastructure. A first notion about the new infrastructure, called Constraint Service Grid Architecture (CSGA), is shown in

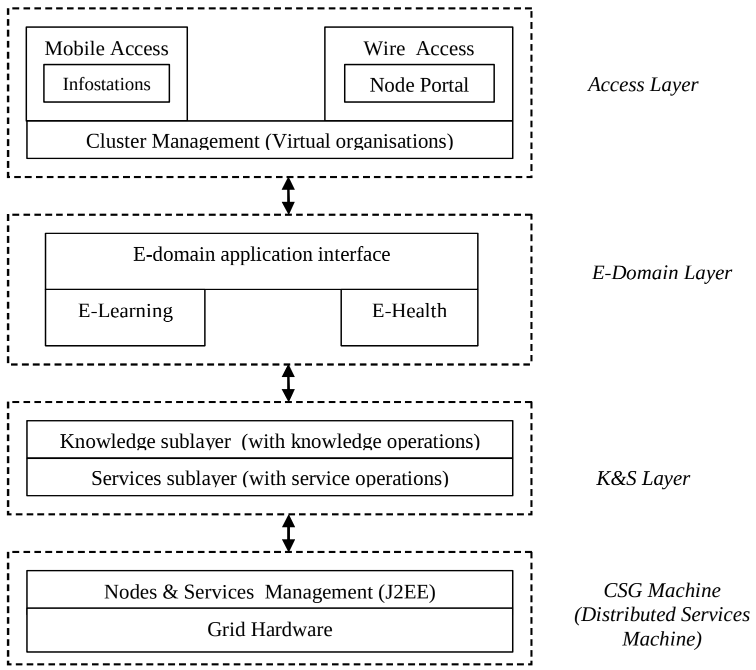

Fig. 3. CBS-Grid Architecture

Fig.3. The kernel of the intended extension builds the theory and the model for Constraint-Based Services described in [6, 34, 47]. This model aims to support the development of an integrated and practical approach for the compositional specification, design and analysis of data-intensive constraint-based Service Grid. Fundamental to the approach is service integration and its run-time validation in the presence of constraints along temporal, uncertainty and error dimensions. The approach will be supported by a Grid-based software toolset for run-time validation of service integration [46].

In relation to this model we propose a four-layered architecture which originates from the DeLC infrastructure. The new architecture consists of three standard layers and a domain-oriented layer. The access layer of the original architecture is extended with a cluster management module. In order to operate as constraint-based service machine the DeLC node management and run-time will be transformed. In this layer we intend to include the AnaTempura run time module proposed in [48].

There is a fully new layer (*Knowledge & Service Layer*) which will be developed and included in the new architecture. The layer will be decomposed into two separate sub-layers. The *services sub layer* will mainly implement the mentioned above model. The second layer will manage larger knowledge-oriented structures build on the services proposed in the first layer. In order to evaluate the proposed architecture we intend to adapt the standard layers to different applications by help of the *e-Domain layer* which will include appropriate application interfaces dealing with explicit presentations of the domain semantics (probably as corresponding ontologies).

In the Access Layer we intend to use a de-centralizing network management, i.e. by distributing network management functions across multiple management entities (*agents*) many such problems can be solved [32]. The agents work together to coordinate themselves in such a manner as to complete network management tasks. In addition the agents can also work autonomously in whichever environment they are situated in order to complete their own objectives. This agent autonomy means an agent controls its own actions and state, and acts on its own behalf without outside intervention (i.e. other agents or users).

Our InfoStation-based system is implemented by using a multi-agent approach, i.e. through the use of intelligent agents that communicate and cooperate to satisfy user requests for intelligent mobile services. As described previously some agents are installed on the users' mobile devices and work as users' Personal Assistants. Others are deployed in the InfoStations and in the InfoStation Center itself.

The multi-agent approach was chosen as it offers more adequate model for the implementation of the InfoStations architecture than the one supported by the object-oriented approach, satisfying the following requirements:

- *Distributed control* – the user session control must be distributed across the three tiers of the network architecture in such a way so the agents have shared responsibility for the session execution;
- *CC/PP conformance* – the agents must operate in conformance to the uniform format "Composite Capability/Preference Profile" (CC/PP) [7], which was chosen for the implementation of the user/service profiles.

By having intelligent agents deployed in the mobile devices [38, 49], one could take advantage to the InfoStations intermittent, yet high-rate coverage. An intelligent agent may request a service while within the range of an InfoStation, and then pass out of the coverage range. The intelligent agent will however continue to work autonomously, until it eventually comes back into the coverage area of another InfoStation. Essentially, during the time when the mobile device is out of range, the intelligent agent adopts the functionality of the service agent, until the user is finished with the service. Once the intelligent agent is back within the range of an InfoStation, the updating and synchronization of the service can proceed.

The multi-agent communication will be accomplished by help of DAML-S, which structure is divided into three separate sections, each dealing with a different aspect of the agent:

- **Service Profile:** for advertising the service abilities (i.e. what it can do); up-to-date service profiles are kept in the InfoStation Center, and copies of these are periodically delivered to all InfoStations.
- **Process Model:** gives a detailed description of the operation of the service.
- **Grounding:** provides details of how the agent can interact with the service.

When combined, these three parts create a description/ontology, which allows intelligent agents to discover and use e-Services.

DAML-S (OWL-S) offers a good opportunity for the realization of flexible software architecture and offers a suitable environment for the support of the intelligent mobile services considered in this paper. We treat the DAML-S (OWL-S) specification in a distributed fashion, where the exact scheme of distribution depends on the chosen model.

6. eLSE Project

On one hand, the project is implementing to demonstrate our approach for an application domain. On the other hand, we intend to transform the learning material created in the JCSE project [23] to an e-Learning environment. The proposed development environment consists of two main parts (Fig. 4):

- Domain Model – the Software Engineering Domain Model is created as an appropriated ontology by means of Protégé tools;
- eLSE Environment – the desired e-content can be generated by a three-step process which includes editing of the in the SE-ontology saved structures (SELBO editor), transformation of the created internal content (TRANSF), and generation of the final SCORM-compliant e-content (GEN).

What is SELBO? SELBO is an editor, specialized in creating e-Learning content which can generate SCORM 2004 compliant content using ontologies (via the core API of Protégé [50]) to help content creators in designing their electronic lessons. There is provision that in SELBO are integrated JADE [51] agents to help content developers. Design goals of the editor are the following:

- Generation of standard e-Lessons;
- Easy to use by non-professionals in computer science;
- The user works with the terms in his domain of occupation and doesn't have to have any knowledge of SCORM or HTML.

Why SCORM? SCORM is international standard for e-Learning. It not only standardizes the means of generating, packaging and playing the e-Lesson, but also has a means for defining sequencing and navigation of the content on per-student basis.

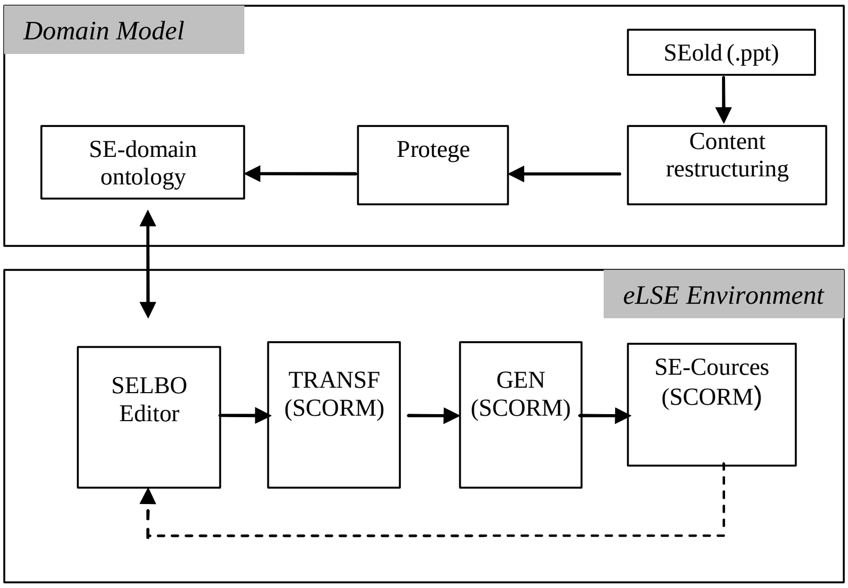

Fig. 4. The eLSE Development Environment

Why HTML? HTML is a mature standard for visualization of multimedia content. HTML pages can be visualized with any modern browser – no need for special third party client applications. If desired, it is possible some part of a page to be generated by third party HTML editor.

Why Agents? An agent is an intelligent autonomous piece of software. It can track content developer's actions, guess his intentions and offer assistance. An Agent may search for a given concept in the ontology on behalf of the developer. It may even communicate with other agents to gather extra resources on the topic of the e-Lesson.

SELBO (Fig. 5) is an open source project written in Java 1.5 and easily interoperates with the core Protégé library and JADE agent container. SELBO's HTML editor is a slightly modified version of Ekit – an open source HTML editor, also written in Java. *HTML editor* is the main widget user will operate with. Every e-Lesson consist of multiple HTML pages (SCOs in the terms of SCORM). Every HTML page can contain multiple multimedia objects like text, pictures, videos, sounds, flash, presentations, etc. (Assets in the terms of SCORM). HTML editor is a WYSWYG style widget, eliminating the need for the user to have any knowledge of HTML. It features easy to use point-and-click toolbar command interface. Also supports drag & drop and copy-paste for easy insertion of text and other multimedia. *Content tree explorer* represents the hierarchy of the e-Lesson. Every leaf node of the tree is bound to one HTML page. The leaf nodes represent the lowest abstraction level of the e-Lesson – pages. The non-leaf nodes itself represent higher grouping levels such as chapters and lectures. *SCORM rules editor* can define rules for navigating the content. Such rules may govern whether the student may advance to the next topic, or visualization of different content based on the student's progress, etc. These rules are translated internally into SCORM 2004 Sequencing and Navigation behaviors. *Ontology explorer* shows the content of the ontology, the user is working with. Every

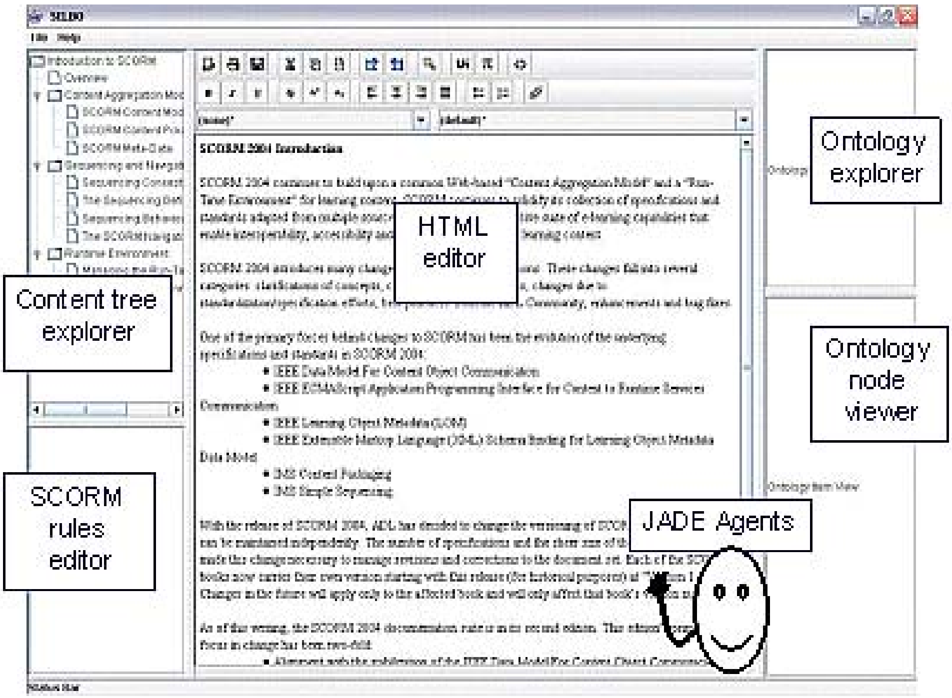

Fig. 5. SELBO GUI

node (object) of that ontology describes a concept from the knowledge domain that the ontology covers. There can be some predefined routes passing through given nodes that can assist content creators in creating sensible e-Lessons. *Ontology node viewer* contains the description of the concept, represented by the selected ontology node. In general it contains text that can be pasted in the HTML page. As well, it can contain pictures and other multimedia. Also there may be examples and useful URL links.

Why Ontologies? Recently, domain and student modeling researchers have begun to adopt technologies, applications and standards from Semantic Web and e-Learning communities to solve the problems of user adaptation [40, 43]. The modern trend is to use semantic web ontology language such as the Resource Description Schema (RDFS) [52] or Web Ontology Language (OWL) [53] for the implementation of this model [44, 24, 26]. The approach has the advantages of formal semantics, easy reuse, easy portability, availability of effective design tools, and automatic serialization into a format compatible with popular logical inference engines. Ontologies are a good way to represent the knowledge (in some domain) as set of objects and their interrelations. They could play an important role in the e-Learning (in our domain: Software Engineering) because they: represent a source of strictly defined terms that can be shared between different applications (information systems or intelligent agents); represent a clearly defined shared knowledge in the discussed domain; give a full description of the objects pertaining to the domain (terms, definitions and meanings) and all the relations between them.

The development of the *Software Engineering domain ontology (SE-Ontology)* will allow to share and reuse all the knowledge accumulated till now in the JCSE

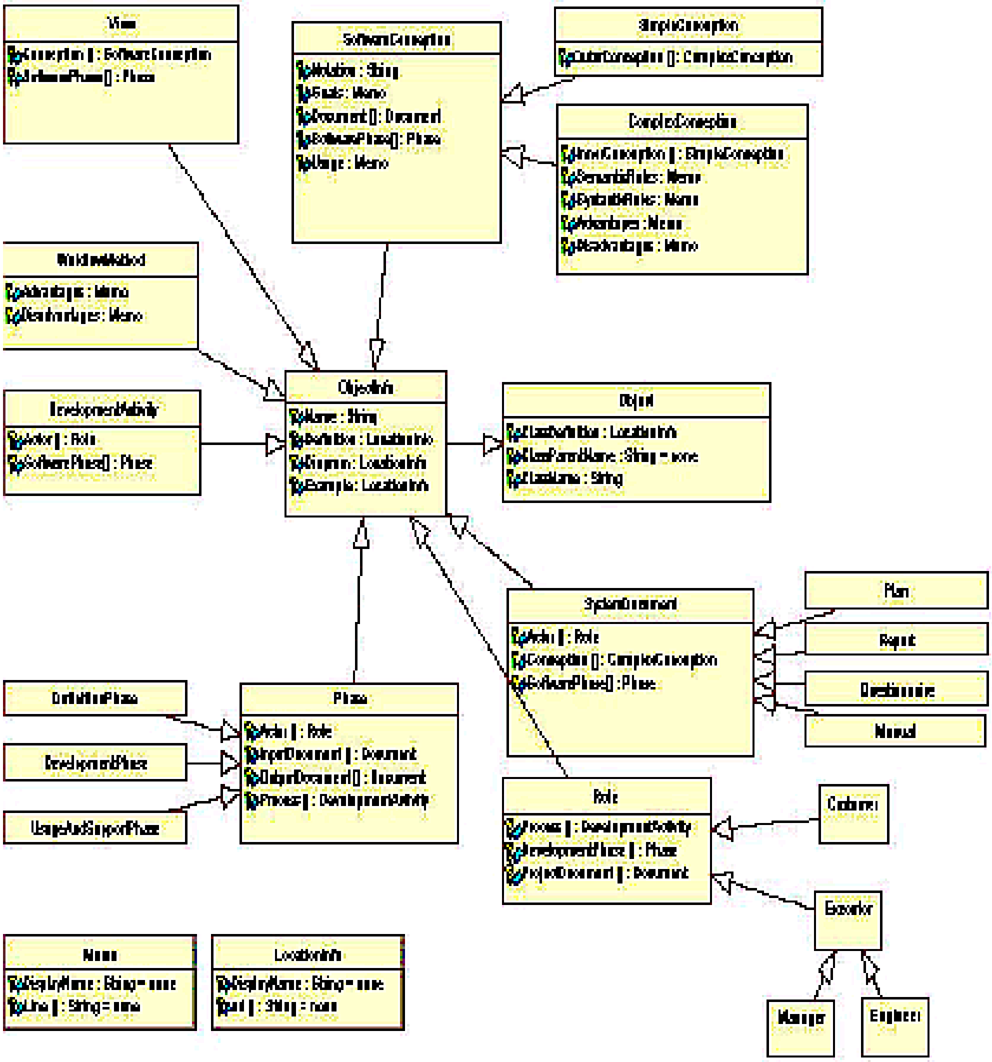

Fig.6. eLSE Ontology

Project and to realize an automatic interpretation of this knowledge, using information systems or intelligent software agents (i.e. our editor – SELBO).

Objectives of the SE-Ontologie are: to analyze the contents of the Software Engineering discipline, define the base objects and classes (terms, definitions and meanings); to specify the relations between objects as some kind of “network”; to provide read-only access to the software engineering body of knowledge; to visualize the created ontology – full hierarchy view and detailed object representation and to allow extraction of the object’s content only with drag & drop operations. The kernel of the current version of the eLSE domain model is the ontology shown on Fig. 6.

7. Conclusion and future work

The current developmental phase is focused on the basic modules of the DeLC object-oriented version, the SELBO editor and the corresponding SE-Ontology. The tools are implementing in a J2EE [54] compliant development environment. Additionally planning of the re-engineering process for transition to the agent-oriented version has commenced. A fundamental point is a possible distributed treatment of the DAML-S protocol [55] which supports the communication between intelligent agents and e-Services.

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