Towards a Reference Model to Semantic Web-based Educational Systems

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Abstract. *Semantic Web is one of the hottest research and development topics in recent years in the Artificial Intelligence (AI) and Internet community. Moreover, the same have happen to the AI and Education (AIED) community. Recently some initiatives to start so-called semantic web-based educational systems (SWBES) have emerged in the AIED field. This is driven by the hope that the use of SW technologies in educational systems can help the accomplishment of AAAL: Anytime, Anywhere, Anybody Learning where most of the WWW resources are reusable learning objects supported by standard technologies and learning is facilitated by intelligent pedagogical agents. Although there are some initiatives to provide an architecture to SWBES, they do not describe all the roles and/or modules presents in a SWBES. This paper presents steps towards a reference model for semantic web-based educational systems.*

Resumo. *Web Semântica tem sido considerada pela comunidade de Inteligência Artificial e da Internet como um dos grandes tópicos em pesquisa e desenvolvimento nos últimos anos. Além disso, o mesmo tem acontecido com a comunidade de Inteligência Artificial e Educação. Recentemente, algumas iniciativas para iniciar o que está sendo chamado de Sistemas Educacionais baseados na Web Semântica (SEWS) têm emergido no campo de Inteligência Artificial e Educação. Tais iniciativas são dirigidas pelo esperança de que tecnologias da web semântica em sistemas educacionais possa ajudar a alcançar aprendizagem a qualquer momento, em qualquer lugar, para qualquer pessoa, onde a grande parte dos recursos da WWW são objetos de aprendizagem reusáveis suportados por padrões tecnológicos e a aprendizagem é facilitada por agentes pedagógicos inteligentes. Apesar de iniciativas para prover uma arquitetura para SEWS, eles não descrevem todos os papéis e/ou módulos presentes em um SEWS. Este artigo apresenta passos em busca de um modelo de referência para SEWS.*

1. Introduction

Semantic Web in general are becoming popular as tools for user to provide semantic descriptions of the content and machine process of the resources. Roughly speaking, the Semantic Web (SW) extends the classical Web, providing a semantic structure of web pages to give support to human as well as artificial agents to understand the content inside the Web applications. As a result, Semantic Web provides an environment where software agents can navigate through Web documents and execute sophisticated tasks [Bittencourt et al. 2008b].

In addition, the Artificial Intelligence and Education (AIED) community is particularly interested in this area in order to enhance educational systems in this directions. SW itself offers numerous improvements in the context of Web-based education systems contributing to the upgrade of learning quality. This new generation of AIED systems comes from the combination of two broad modalities of web-based educational systems (both take into account web-based approaches), which are e-Learning systems (or Learning Management System) and AIED (Artificial Intelligence and Educational) Systems.

Semantic Web-based educational systems (SWBES) is the name given by the AIED community to the new generation of such systems that use semantic web technologies to generate educational systems that are more personalized, adaptable and intelligent. The main goal is to use resources available on the Web through standards technologies in order to accomplish AAAL: Anytime, Anywhere, Anybody Learning [Bittencourt et al. 2008b]. Indeed, such standards have been proposed and some of them have been accepted by the community, such as RDF, OWL, OWL-S, LOM, and so on.

In fact, some initiatives to provide an architecture to SWBES have emerged in the community [Devedzic 2003, Koper 2001]. However, they do not describe all the roles and/or modules presents in a SWBES. In addition, the interaction between the modules is not described and expressed. For these reasons, it is necessary a conceptual model to drive the specification and construction of SWBES. This paper presents steps towards a reference model for semantic web-based educational systems.

2. Educational Systems

Computers have been used in education for over 50 years, yielding various proposals of computer-based systems to support learning. Computer Aided Instruction and Microworlds were the firsts to interact students with a software system. Basically, the system contains a set of learning objects.

Indeed, in these system there is just a player which uses a set of educational content and the decisions are made on itself. For this reason, the instruction in these kind of systems was not individualized to the learners' needs. To overcome these lacks, it is necessary to engage students in a dialogue game. As a result, the Intelligent CAI systems were proposed, aiming at providing individualized instruction. From now on, systems as Intelligent Tutoring System and Interactive Learning Environments are presented as an AIED System.

In addition, the most part of research concerning the design of AIED systems rely on interaction between two players, which are: a machine/AIED System (responsible for providing information according to a domain) and a human. In this sense, there is

an interaction process where the main goals are to provide information provided to each player and to help in the decision making. In addition, both machine (specifically, an AIED System) and human agent (often, a student) have a view of the world, which they communicate. Broadly speaking, the interaction process represents the interchangeable messages ($< X >, < Y >$) through a certain protocol. However, each player must make a decision about what and how to interact with the other player. This interaction process may require others agents (or an environment). Also, the same idea must be considered to the other player with regards to educational interactions between students and AIED System as some form of dialogue between agents. Another important point is that the interaction can occur with a set of students.

In fact, the focus hereby is the improve the adaptation to a student or a group of student. For this reason, it is essential a feasible model which interacts with the student mediated by well design resources. In order to accomplish this goal, a rich AIED System is necessary. As a result, the literature [Jennings 2001] has discussed that a multi-agent approaches is necessary to overcome the complexity cited above, as shown in Figure 1.

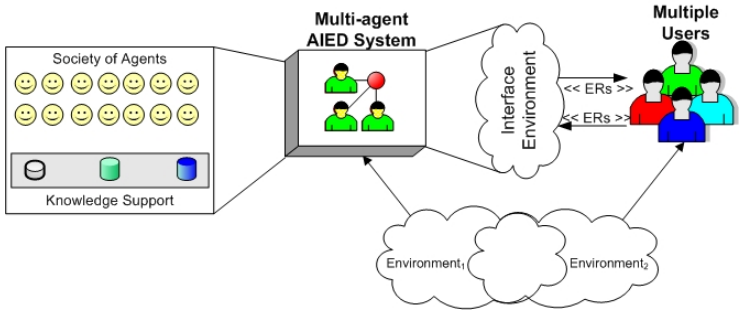

Figure 1. The Multi-agent Approach.

Furthermore, the Artificial Intelligence and Education (AIED) community is particular interested in the combination of two broad modalities of web-based educational systems (both take into account web-based approaches): i) e-Learning systems, which provide interaction between students and teachers through the use of information technology (by using synchronous and asynchronous tools) to ensure this communication, and ii) AIED Systems, which use artificial intelligence techniques to provide personalized interactions, aiming at improving the learning and problem solving processes, as shown in Figure 2.

An Adaptive e-Learning System is a system that changes its configurations in order to improve the learning of the students. In other words, its goal is to provide adaptive interactions to the learners aiming to improve the quality of services. The types of adaptation are described as follows:

- Instructional Model Adaptation: this adaptation form provides to the student different content, activities and services according to the specifications made by the course author. At project time, the author may only specify which attributes a user may have, aiming to receive certain content, activity or access to a service. At execution time, the student model has to be checked for specified conditions agreements in order to decide which content, activities and services will be provided to the student. The referred content, activities and services shall be properly

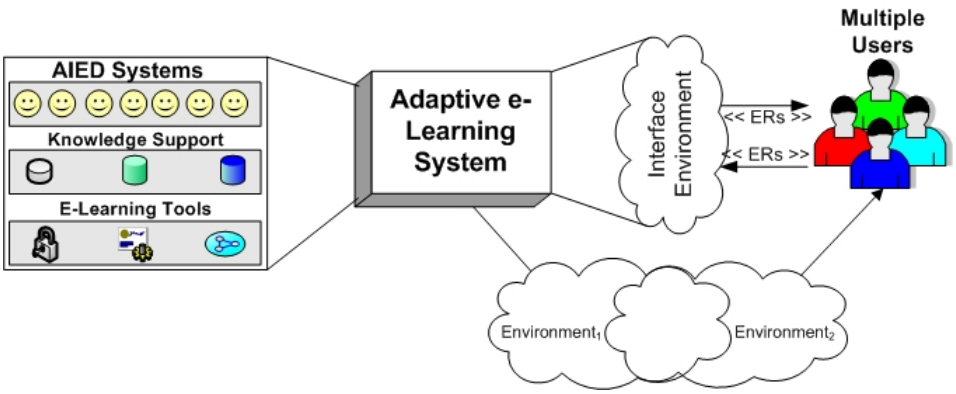

Figure 2. The Adaptive e-Learning Approach.

modeled to apply this adaptation at execution time;

- Adaptive Interactions: this adaptation form provides support to the students whilst they interact in a certain course. This support is addressed to the student and the tutor, possessing several services, contents and activities to work in the interaction. Besides, user support is given considering the information stored in different models, especially the user, group and service models. Intelligent Learning Systems (ILS) originated approaches and Computer Supported Collaborative Learning (CSCL) have been used as a starting point to define such adaptive interactions;
- Presentation Adaptation: aim to presents a different user interface for each student according to his or her model. This adaptation does not refer only to what the user has customized, but also to what the system has learned from previous interactions of that and other users. This is one of the most efficient ways of building the presentation for certain user learning.

Several challenges are related with the construction of such systems [Mizoguchi and Bourdeau 2000, Brooks et al. 2006, Bittencourt et al. 2008a] and with the attempt to represent information on the Web in a way computers can understand and manipulate [Bittencourt et al. 2009]. The research in this field is known as Semantic Web research. As a result, the next section proposes a conceptual framework for developing semantic web-based educational systems.

3. Semantic Web-based Educational Systems

Roughly speaking, Semantic Web (SW) extends the classical Web by providing it with a semantic structure of web pages to give support to human and artificial agents to understand the content. As a result, the Semantic Web provides an environment where software agents can navigate through Web documents and execute sophisticated tasks. SW enables numerous improvements in the context of Web-based education systems contributing to the upgrade of learning quality. Indeed, it can provide personalized learning material for students, collect data related to the interaction between students and the Web environment, find out services according to students needs, make recommendations, among others.

According to [Anderson and Whitelock 2004], the Educational Semantic Web is based on three fundamental affordances. The first is the capacity for effective information storage and retrieval. The second is the capacity for non-human autonomous agents to

augment the learning and information retrieval of human beings. The third affordance is the capacity of the Internet to support, extend and expand communications capabilities of humans in multiple formats across the bounds of time and space. These fundamental affordances can be achieved through some technologies:

1. Ontologies: information on the Web is commonly represented in natural-language for human understanding. However, in order for the computer to understand its meaning, it is necessary to represent the information in a form that can be interpreted syntactically and semantically. Such representation helps the process of analyzing, extracting, and integrating information on the Web, making it easier the creation of solid knowledge bases that intelligent services can rely on to support users' needs. Nowadays, research on ontologies has been considered one of the keys to provide information in a computer-understandable way [Mizoguchi 2004]. According to [Devedzic 2006], the use of ontologies and the advent of intelligent services for developing Web content, Web filters, intelligent search engines, and other applications are transforming the Web of information into the Semantic Web;
2. Learning Standards: the use of standards is fundamental in describing, developing, exchanging, accessing, annotating, combining and qualifying educational resources. Both Semantic Web standards (e.g., RDF, SKOS) and educational resources (e.g., IEEE, IMS) are used in the development of SWBES [Gasevic et al. 2004, Dietze et al. 2007];
3. Semantic Web Services: SWSs provide a number of different activities transforming a static collection of information into a distributed way on the basis of Semantic Web technology making content within the WWW machine-processable and machine-interpretable;
4. Intelligent Agents: they are autonomous software entities which provide several kind of support through the interaction with players according to their roles. In addition, these entities must have the ability of execute and accept new requirements on the fly.

4. Reference Model to Semantic Web-based Educational Systems

In general, a broad question concerning SWBES is the one involving the interaction among, at least, two players, which are: a machine/Educational System (responsible for providing information according to a learning context or learning domain) and a user (with a specific role). Figure 3 describes a reference model of a Semantic Web-based Educational System [Bittencourt et al. 2008b].

Each module concerning Semantic Web-based Educational Systems is discussed in the following subsections.

4.1. Roles

Several educational activities are involved on Semantic Web-based Educational systems, such as teaching, learning, cooperation, collaboration, authoring, and so on. Moreover, these activities are distributed according to roles of each player. They are discussed as follows:

- Teacher's Role: teachers are required to monitor learners' interactions (problem solve, assessment, etc), configure learners' strategies;

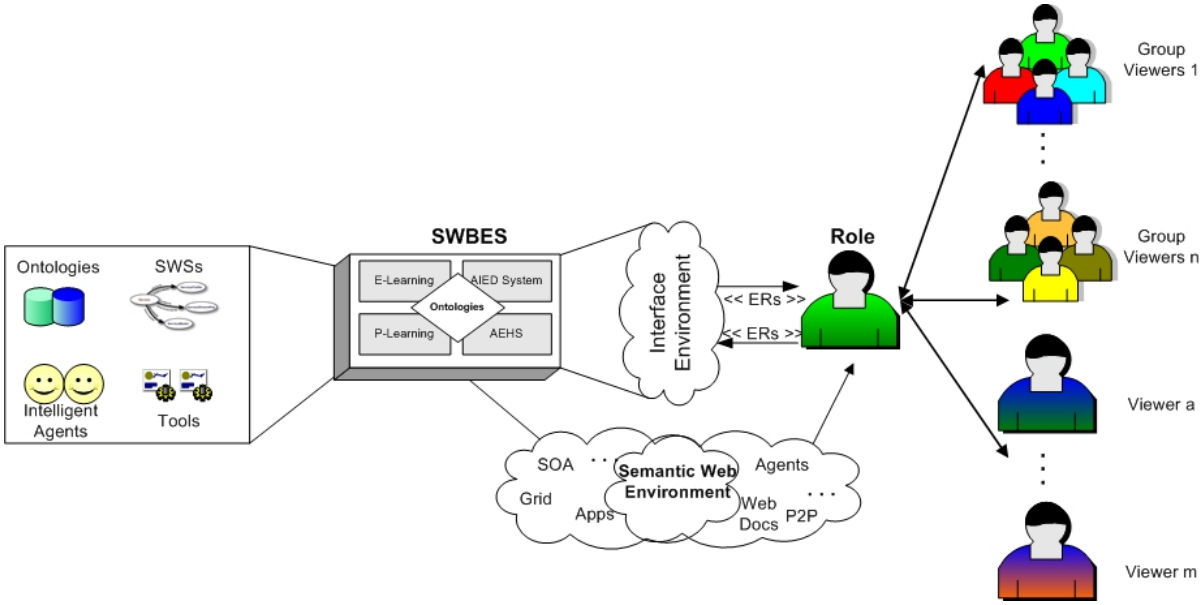

Figure 3. Reference Model to Semantic Web-based Educational Systems.

- Learner's Role: the main interest of learners is to interact with the system based on personalized and adaptable educational content in order to improve their knowledge and fulfill their learning goals. In addition, these players can be artificial agents on which interacts with the system as learners. Exemples of these kind of agents are companion agents, co-learning, personal intelligent agents, and so on;
- Author's Role: authors are responsible for structuring the educational content. And also, the authoring activities can be divided in i) educational content, ii) instructional process, and iii) adaptation and personalization [Aroyo and Dicheva 2004];
- Group's Role: several applications take into account the learning process through groups. They are interested in collaborative learning, interaction with others students in order to reach personal goals, sharing cognitive, meta-cognitive, motivational, and emotional functions with others learners;
- Developers's Role: they are responsible for developing and adding new functionalities to the SWBES. Moreover, several efforts have been done for building ontology in order to specify as methodologies as scripts to deploy the applications.
- Auditing's Role: they are responsible of gathering data about the effectiveness of the system in general, specific tools, and also about the others players (taking into account their roles). In addition, the agent responsible for evaluating the effectiveness of a specific component can be as an artificial agent (support and controller agents) as an human agent (tutors, students' parents, etc);
- Administrator's Role: they are responsible for managing the system as a whole. Moreover they cover the entire life-cycle of the educational environment administration from registration (of students, authors, agents, services, and so on) and follow-up to termination. In fact, these players can also artificial agents, such as controller agents (which allow another agent to enter in the society).

4.2. Educational Resources

Educational resources represent the learning objects concerning a specific educational system, such as examples, problems, counter-examples, units of activities, and others.

According to [Devedzic 2006], in the context of Educational Semantic Web, most of the practical implementations and usage of standards is related to learning object (LO) annotation, which creates a number of additional requirements for the successful use of standards. The development of simple methods and tools for LO annotation, differentiation between objective and subjective metadata, combination metadata sets and schemes from multiple sources, seamless integration of production and annotation, introduction of formal semantics into existing standards, and a flexible and dynamic association of metadata with LOs, are some of the challenges that the standards have been dealing with.

4.3. Interface Environment

It represents the communication interface between a player with a specific role and the Semantic Web-based system. In addition, the context and the type of educational resources are important aspects that need to be considered when selecting the technology to be utilized in the environment. Another important point is that the Interface Environment has to support the different roles, thus providing specialized interfaces of the authoring tools, mobile tools, development/framework environment, etc. The interface environment can be a browser, Digital TV, Mobile Desktops, Phones, PDAs, and so on.

4.4. SWBES

It supports the numerous users in an effective way to guide and help them to reach their goals. Thus, it represents the new generation of Web-based Educational System that aims at providing several improvements on the Quality of Services (QoS) through the use of Semantic Web technology. Indeed, the semantic web resources can be used in several educational systems, such as Intelligent Tutoring Systems, Learning Management Systems, Virtual Learning Environments, Adaptive Educational Systems, Pervasive Learning Systems, Educational Systems to Digital TV, and others[1]. The components of Semantic Web-based Educational Systems are described in the next subsections.

4.4.1. Ontologies

They are attempts to more carefully define parts of the data world and to allow interaction between data held in different formats [Shadbolt et al. 2006]. Additionally, ontologies have been addressed by the community as an important requirement to assure interoperability between educational systems. In the context of SW and education, ontologies have been applied to solve a variety of complex problems, such as knowledge representation in intelligent systems, knowledge sharing and reuse among applications, annotation and search of learning objects, personalization of learning content, beside many other challenges [Bittencourt et al. 2008b].

Furthermore, notable results in developing and using ontologies to augment web-based learning experiences including both technological and theoretical aspects have been

[1]Several examples about SWBES are found in recent SWEL (Semantic Web Technologies for e-Learning) workshop series

reported in [Dicheva and Dichev 2007, Mizoguchi et al. 2007]. By technological aspects we mean the use of ontologies to enable browsing, sharing and reuse of educational content that is possibly located in different repositories allowing the interoperability and integration of different educational applications. By theoretical aspects we mean the use of ontologies to support the flow of knowledge from theoreticians to authoring practitioners by a comprehensive methodology in which knowledge is created, discovered, shared, and efficiently presented to be used during both authoring of educational content and learning. It is crucial for any intelligent educational application in the era of SW to rely on well-designed and shareable knowledge to support effective learning. The kind of ontologies that can be developed and/or used in the systems are

1. Educational Ontologies: these ontologies are responsible for specifying and validate knowledge concerning a specific feature of the educational system, such as Domain Module Ontologies, Student Module Ontologies, Pedagogical Module Ontologies, Adaptation Ontologies, task ontologies, and so on;
2. Interaction Ontologies: these ontologies have the knowledge about the components of an educational system, such as ontologies to specify the agents, semantic web services, and the tools;
3. Context Ontologies: they are responsible for describing the SWBES as a whole in order to ensure the communication and the publication of the educational system on the web. As a result, educational environments (through their agents) can require and interact between them.

4.4.2. Tools

An educational environment can offer a number of tools, in a wide range of interactivity and sophistication at any time. In addition, a system must provide a tool according to the kind of user, the purpose of the user and the device (mobile phone, PDAs, browser, etc). The kind of tools that can be developed and/or used in an educational systems are:

1. Educational Tools: these tools play an important role in the learning process of each student. In others words, the most sophisticated and the most interactive educational environments provide tools for synchronous and asynchronous communication in order to train and to guide students in a learning session and in real time. Indeed, tools from the Web 2.0 are examples which can be described as an educational tool. The integration of theses tools with semantic web technologies provide new possibilites to the system through the Social Semantic Web approach. In addition, several tools can be provided according to the role of the user, for instance, authoring tools, teacher tools, auditing tools, semantic wiki tools and so on;
2. Tools to SW Support: some tools are necessary to make to public semantic web cames true. These are with regards to semi-automatic features on which users provide support to intelligent agents, for instance, tools for ontology mapping, ontology annotation, social semantic web, ontology visualization, ontology engineering, and so on;
3. Administrative Tools: they are important to configure the environment with regards to roles, users, authenticity, and others.

4.4.3. Semantic Web Services

Semantic Web Services (SWS) are used to provide to the users, agents and tools a service-oriented access to the features according to the interest of each one of them. Another important point is the research conducted by the SW community regarding semantic web services as an option for automating the integration of activities through creation, automatic discovering, and automatic composition [Brambilla et al. 2007, Al-Masri and Mahmoud 2007]. The kind of Semantic Web Services which must be available are:

1. Educational SWS: they provide key features to assure the goal of an educational system. In other words, they facilitate some educational activities, such as integration of content, discovery of educational resources, evaluation and comparison between educational applications, personalization of educational content and interfaces, collaboration, recommendation, problem solving, diagnostic, and others;
2. Support SWS: several activities in which do not take into account educational purpose are present within every educational system, such as conversions, search, mining, and others. For this reason, support SWSs are important to such systems.

4.4.4. Intelligent Agents

Agents play an important role in Semantic Web-based Educational Systems. In fact, they are the responsible to ensure the automatization of the activities, dynamic evolution of the requirements, and so on. The kind of agents are described as folows:

1. Tutoring Agents: these agents ensure the interaction between the features of the system and the users (mainly students) according to their roles. Examples of these are to discovery new knowledge about the users, interoperation content between applications, personalization of the content to different users, and so on;
2. Support Agents: they support the others agents to ensure the accomplishment of their activities. Examples of these agents are support agents for mining the web;
3. Controller Agents: they are important to administrative activities, such as verify the performance of the agents and semantic web services, provide access to agents in the system, identify untrustful agents, etc.

4.5. Semantic Web Environment

It represents the interaction environment available (to SWBESs and users) to discover, browse, select, and invoke resources on the Web according to several technologies and architectures semantically described.

5. Conclusion and Future Works

This paper presented steps towards a reference model to semantic web-based educational systems. In addition, a discussion about the interactions and the settings for SWBES were provided in order to clarify the modules and roles presents and the conceptual model. As future works, is intended to identify the features present in each SWBES (ITS, ILE, LMS, Digital TV, etc) and to describe a methodology for building such systems.

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