Semantic e-Learning: Next Generation of e-Learning?

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Abstract. Semantic e-learning aspires to be the next generation of e-learning, since the understanding of learning materials and knowledge semantics allows their advanced representation, manipulation, sharing, exchange and reuse and ultimately promote efficient online experiences for users. In this context, the paper firstly explores some fundamental Semantic Web technologies and then discusses current and potential applications of these technologies in e-learning domain, namely, Semantic portals, Semantic search, personalization, recommendation systems, social software and Web 2.0 tools. Finally, it highlights future research directions and open issues of the field.

Keywords: Semantic e-learning, Semantic Web, Semantic portal, Semantic search, personalization, recommendation systems, social software, Web 2.0.

1 Introduction

In recent years, advances of Information and Communication Technologies (ICTs) and especially the World Wide Web have dramatically affected education. The provision of learning and training over the Web has been widely adopted as a promising solution to lifelong learning and on-the-job training. *E-learning (electronic learning)* stands for all forms of Web-based learning and uses computers and network technologies to create, store, deliver, manage and support online learning courses to anyone, anytime and anywhere [14], [22]. It provides a configurable infrastructure that can integrate learning materials, tools, and services into a single solution for offering training or educational materials quickly, effectively, and economically [58].

Thousands of institutes, universities, organizations, enterprises and schools worldwide have already integrated and are using e-learning applications customised to their requirements, needs and preferences. A particular feature of these efforts is the "on-demand" presentation of learning resources (lessons, exercises, links, etc.) based on multimedia material (text, sound, graphics, video, animation, etc.) and overcoming difficulties in timing, attendance and travelling.

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As the e-learning industry begins to mature, we are seeing products that are far beyond the simple "click-and-read" courses that have characterised the field up to date. Future manifestations of e-learning, including e-learning 2.0 (e-learning based on tools and approaches typical of Web 2.0) [23], will allow reusability and exchanging of learning resources, systematic compilation of online courses from distributing learning content, efficient delivery of learning content in order to enhance learner's knowledge, customization of learning material based on learners' goals, preferences, capabilities, needs, and knowledge, etc. [14]. All these comprise great challenges for the current and future e-learning systems.

To this direction, emerging *Semantic Web technologies* have changed the focus of e-learning systems from *task-based approaches* to *knowledge-intensive* ones [26]. The Semantic Web (SW) is a W3C (World Wide Web Consortium, http://www.w3.org) initiative and according to Berners-Lee et al. [5] comprises *"an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation"*. So, the Semantic Web promises that tomorrow's Web will be a Web of semantics with far greater capabilities than today's Web of text [42]. This means that the documents contain not only content, but also context. The capability of the Semantic Web to add meaning to information, stored in such way that it can be searched and processed and recent advances in Semantic Web technologies provide the mechanisms for semantic knowledge representation, exchange, sharing, reuse and collaboration of e-learning applications [3].

Semantic e-learning is the *"e-learning based on the Semantic Web technologies that can easily provide learning materials in a common format and therefore enhance personalised learning"* [14]. In this context, e-learning systems have the potential to develop descriptions of their processes, as well as rules in order to create content-based and logic-driven information and knowledge value. This ability of representing semantics of knowledge resources (learning objects, lessons, courses, etc.) and their relationship in a standard format can promote the dynamic composition of learning materials and processes and enforce the customization by organizing these resources based on the user's need, such as teacher's preferences or student's profile [30].

The aim of this paper is to argue that Semantic e-learning could be the next generation of e-learning. Firstly, we define Semantic e-learning, explore the literature and all these foundations upon which it is envisioned and demonstrate its close relation with the development of Semantic Web technologies. Moreover, we focus on those directions that support the vision of Semantic e-learning, illustrate the future trends and discuss the open issues in the field.

2 Background

In the majority of past e-learning systems the courses and the educational materials were not dynamic enough, provided a rather restricted feature set or presented complicated structuring and consequently could not respond effectively to the needs and competencies of the learners, resulting in poor online experiences [13]. An answer to this problem that comprises also the current challenge for Web-based learning systems is their enhancement by the integration of adaptive features that allow for the delivery of *personalized learning* [32].

These advanced e-learning applications provide high quality content, efficient structuring, and full support for the varied tasks of all user profiles participating in a typical distance learning scenario. Specifically, depending on the knowledge background of the learner, his strengths and weaknesses, and the preferred learning style and the progress made so far, the system decides what and in which way the content should be presented next. Possible parameters are different learning paths through the content, different ways of presentation of the same content (e.g. with or without audio) or offering a different set of functions which the user interface of the learning system provides to reduce complexity [12], [17].

To achieve this, methods and techniques from various scientific domains and application areas are used. The most well-known are Data Mining, Web Mining, Knowledge Discovery, Knowledge Management, User Modelling, User Profiling, Artificial Intelligence and Agent Technologies, etc. Especially, *Web Mining* is defined as the use of Data Mining techniques for discovering and extracting information from Web documents and services and can be categorised into three areas depending on which part of the Web is mined [27]:

- *Web Content Mining* focuses on the discovery/retrieval of useful information from Web contents/data/documents. Web content data consist of unstructured data (free texts), semi-structured data (HTML documents) and more structured data (data in tables, DB generated HTML pages).
- *Web Structure Mining* focuses on the structure of the hyperlinks within the Web as a whole (inter-document) with the purpose of discovering its underlying link structure. Web structure data consist of the Web site structure itself.
- *Web Usage Mining* mines the secondary data derived from Web users' sessions or behaviours and focuses on techniques that could predict user behaviour while the user interacts with the Web [16]. Web usage data can be server access logs, proxy server logs, browser logs, user profiles, registration data, user sessions or transactions, cookies, user queries, bookmark data, mouse clicks and scrolls, and any other data as the result of interactions.

In the majority of cases, e-learning applications base personalization on *Web Usage Mining*, which undertakes the task of gathering and extracting all required data for constructing and maintaining learners' profiles according to the behaviour of each user (or user groups) as recorded in server logs, as well as on other rules, web site contents and structuring, etc. [37]. The discovered behavioural patterns are usually represented as collections of pages, sessions, items, etc. that are frequently accessed by groups of users with common needs, background, interests, etc. Such patterns can be used to better understand behavioural characteristics of users or user segments, improve the content, organization and structure of the site, create a personalized experience for users by providing dynamic recommendations, etc.

The combination of Web Mining and Semantic Web has created a new and fast-emerging research area of *Semantic Web Mining*. The idea behind using Semantic Web for generating personalized Web experiences is to improve Web Mining by exploiting the new semantic structures [34]. Semantic e-learning uses the power and flexibility of Semantic technologies in order to facilitate large-scale collaboration of e-learning activities and develop tools, standards and environments that support content management, knowledge navigation, experienced-oriented environments, etc.

3 Semantic Web Technologies

In the following sections, we focus on those technologies that define and enable knowledge representation, structure and reasoning, offer exchange mechanisms to allow collaboration and sharing and provide organizations with the means to implement Semantic e-learning. These technologies that underlie the Semantic Web include XML, URIs, RDF, RDFS, Web services, Semantic Web services, ontologies, languages and intelligent agents and promise to incorporate well-defined semantics into e-learning systems.

3.1 XML

Extensible Markup Language, shortened *XML* [8], consists of a set of rules for defining and representing information as *XML documents*, where information structures are indicated by explicit markup. Unlike HTML that controls the way data are displayed, XML facilitates the sharing of structured data and information on the Web. The markup vocabulary and the structures specified for a particular domain create an *XML application*, a formal language for representing information of the domain. The use of XML has extended towards data interchange between software applications.

In e-learning domain, XML technologies seem to provide an open-ended range of solutions. They enable modular creation of learning materials at different levels of granularity, in a way that supports content reuse and sharing and also allow the separation between content and presentation [24]. XML use can be divided into two major categories: the format for data interchange and the format for information assets. The information assets can be further divided into documents and metadata.

3.2 URIs

A *Uniform Resource Identifier (URI)* which *"is a compact string of characters for identifying an abstract or physical resource"* can be used to designate a particular Web resource i.e. *"anything that has identity"* [4]. Furthermore, a URI does not have to map to a real Web address. URIs that refer to objects accessed with existing protocols are known as Uniform Resource Locators (URLs). So, URIs provide a general identification mechanism, as opposed to URLs which are bound to the *location* of a resource. An e-learning system can identify learning objects via URIs in order to retrieve and use them in various learning scenarios.

3.3 RDF and RDFS

Resource Description Framework (RDF) comprises a general purpose language for representing Web information in a minimally constraining, extensible, but meaningful way [10]. It was developed by the W3C and provides a common specification framework to express document metadata in a standardized form that computers can readily process. RDF commonly uses XML for its syntax and URIs to specify entities, concepts, properties, and relations. It is based on the Directed Acyclic Graph (DAG) model. The basic unit of data in RDF is a *triple*, which consists of i) the *subject* (what the data is about), ii) the *property* (an attribute of the subject) and iii) the *actual value*.

RDF Schema (RDFS) is a language for defining RDF vocabularies, which specifies how to handle and label the elements. Generally, the role of a schema as a representational model in the context of Web information is to mediate and adjudicate between human and machine semantics.

The generic structure of RDF makes easier the e-learning data interoperability and evolution because different types of data can be represented using the common graph model, and it also offers greater value for data integration over disparate Web sources of information [56]. For example, RDF can be used to describe e-learning data semantics or an e-learning ontology in order to mediate heterogeneous databases.

3.4 Web Services and Semantic Web Services

Web service is a software system designed to support interoperable machine-to-machine interaction over a network [6]. It is identified by a URL, whose public interfaces and bindings are defined and described using XML. Its definition can be discovered by other software systems. These systems may then interact with the Web service in a manner prescribed by its definition, using XML-based messages conveyed by Internet protocols. The Web service model consists of three entities, the service provider, the service registry and the service consumer [19].

The service provider creates or simply offers the Web service. The service provider needs to describe the Web service in a standard format, which in turn is XML, and publish it in a central service registry. The service registry contains additional information about the service provider, such as address and contact of the providing company, and technical details about the service. The service consumer retrieves the information from the registry and uses the service description obtained to bind to and invoke the Web service.

In order to achieve communication among e-learning applications running on different platforms and written in different programming languages, standards are needed for each of these operations. As Web services technology evolves, the need of locate and use them in an automate way is a challenge. This can be achieved by adding explicit semantics to their descriptions. *Semantic Web services* are expected to enable applications to dynamically locate others that provide particular services, and to facilitate (semi-) automated cooperation with them [11].

3.5 Ontologies

Ontologies define the terms used to describe and represent an area of knowledge. Hendler mentions that ontology is *"a set of knowledge terms, including the vocabulary, the semantic interconnections, and some simple rules of inference and logic for some particular topic"* [20]. Ontologies comprise the backbone of the Semantic Web and offer a way of representing the semantics of heterogeneous Web resources and enabling the semantics to be used by Web applications and intelligent agents. They fulfil the need to specify descriptions for the following concepts: (i) classes (general things) in various domains of interest, (ii) relationships that can exist among things, and (iii) the properties (or attributes) those things may have. In this way, they support knowledge reusability, since they encode knowledge in a domain and also knowledge that spans domains.

The development of the ontology is akin to the definition of a set of data and their structure. In this content, an ontology can formulate a representation of the learning domain by specifying all of its concepts, the possible relations between them and other properties, conditions or regulations of the domain.

Current research has shown the important role that ontologies can play in the e-learning domain. They can be used for realizing sophisticated e-learning scenarios and improving resources' management, for automatic generation of hypertext structures from distributed metadata, for organizing learning material according to different needs of tutors and learners, for more accurate searching, etc. [7].

3.6 Other Languages

There have been several research efforts to build on RDF and RDFS with knowledge representation languages such as OWL, Simple HTML Ontology Extensions (SHOE), Personal Ontology (Personal-Ont), Ontology Inference Layer (OIL), DARPA Agent Markup Language – Ontology Language (DAML-ONT), DARPA Agent Markup Language + Ontology Inference Layer (DAML-OIL), etc.

Especially, *OWL* that stands for *Web Ontology Language* has been standardized by the W3C as a knowledge representation language for the Semantic Web. It is designed for use by applications that need to process the content of information instead of just presenting information to humans, like e-learning ones. It provides additional vocabulary for describing properties and classes: among others, relations between classes (e.g. disjointness), cardinality (e.g. "exactly one"), equality, richer typing of properties, characteristics of properties (e.g. symmetry), and enumerated classes. OWL documents represent domain ontologies and rules, and allow knowledge sharing among agents through the standard Web services architecture [46].

3.7 Intelligent Agents

Intelligent agents are *"software entities that carry out operations and process information on behalf of a user or another program with some degree of independence or autonomy, directed by some awareness of the user's goals or needs"* [42]. There are various types of agents e.g. for searching, shopping, site management, etc. that have the intrinsic ability to communicate, cooperate, coordinate, negotiate and the ability to learn, as well as the capability to evolve through their interactions with other agents [29].

In the context of the Semantic e-learning, intelligent agents are able to organize, store, retrieve, search, and match information and knowledge for effective collaboration among various participants [46]. So, they can be used for knowledge management to support various learning activities e.g. to discover content that satisfies user's requirements and preferences.

4 Semantic e-Learning Applications

The Web provides an existing and highly available infrastructure for supporting e-learning while the Semantic Web enhances this environment by representing semantics of knowledge resources and their relationships in a standard format. In this section, we focus on how semantics can improve e-learning as well as potential applications that Semantic e-learning will greatly impact.

4.1 Semantic Portals

Web portals serve as integrated gateways through which millions of users can access information, services, and other available applications. However, traditional and current approaches often fail to provide users with the type of information or level of service they require. Limitations concern the ability to create, access, search, extract, interpret, process and maintain information resources. These in their turn lead to high maintenance costs and overheads, limited ability for third parties to reuse the information, problematic nature of adding new types of information, etc. The Semantic Web technologies have the potential of overcoming these limitations and enabling the design and implementation of semantic portals.

Semantic portals are considered as the next generation of Web portals and allow improved information sharing and exchange for a community of users. The resources of these portals can be indexed by using domain ontologies. This allows navigation, search, query and reasoning to fully utilize both textual and semantic information leading to more precise results. Moreover, it supports the easy update of portal's structure, and offers possibilities for sharing and reuse since it separates portal content from structure and provides rich structural links [43].

To this direction, semantic e-learning agents can render support to students, assisting them to successfully organize and perform their studies. For example, they can observe student behaviour (e.g. assessment results, interactions with a virtual experiment, etc.) and provide feedback and links to suitable learning material [38]. Other cases are to answer questions regarding the regulations of study (e.g. does a student possess all requirements to participate in an examination or a course?, is a student allowed to register for his/her thesis?) [18], or to provide a student essay system and a question-answering component that searches for answers in different resources such as ontologies and documents on the Web [39]. All these services and more can be parts of an e-learning semantic portal [28], [31], [52].

4.2 Semantic Search

Semantic Web technologies can make search engines more powerful and effective. The traditional keyword search can be enhanced by adding semantic information based on metadata and ontologies [14]. In this way, simple Web pages are transformed to intelligent, semantically annotated Web pages where searching for a particular information, course, lesson, test or practice is comprehensive and precise. *Semantic search engines* applied in e-learning systems can choose the suitable services to manage the queries, match these queries to learning objects or other knowledge resources metadata and then produce improved results [47], [54], [59].

4.3 Personalization

Personalization features as one of the most promising approaches to alleviate the information overload problem and to provide online users with tailored experiences. In other words, it means *"gathering and storing information about web site visitors* *and analyzing this information in order to deliver the right content in a user-preferred form and layout."* [9]. Recent Web technological advances help e-learning systems to acquire individual learner's information in real-time and with low cost. Based on this information, they construct detailed profiles and provide personalized e-learning services [17], [21], [32], [34], [35], [37], [50], [52]:

- *Personalised content*: Typical adaptations are optional lessons' explanations, personalized recommendations, driven presentations, and more. Used techniques include adaptive selection of Web page (or page fragment) variants, fragment colouring, adaptive stretch-text, adaptive natural language generation, etc.
- *Personalised structure*: It refers to changes in the link structure of hypermedia documents or their presentation. Deployed techniques comprise adaptive link sorting, annotation, hiding/unhiding, disabling/enabling, removal/addition. These adaptations are widely used for producing adaptive recommendations (for lessons, tests, information or navigation), as well as constructing personal views-spaces. Systems attempt to provide pathways through materials by matching domain ontologies with dynamically evolving user models.
- *Personalised presentation and media format*: In this type of personalization the content ideally stays the same, but its format and layout changes (from images to text, text to audio, video to still images). These adaptations are used for Web access through PDAs, mobile phones, sites that cater to handicapped persons, etc.

4.4 Recommendation Systems

Recommendations systems (RSs) comprise the most popular forms of personalization [1]. They have emerged in the middle of 1990's and from novelties used by a few Web sites have changed to important tools incorporated to many applications, especially in the e-commerce domain e.g., Amazon.com, eBay.com, CDNow.com. Specifically, these systems take advantage of users' and/or communities' opinions/ratings in order to support individuals to identify the information or products most likely to be interesting to them or relevant to their needs and preferences. Using RSs in the e-learning environment can help both tutors to improve the performance of the teaching process and learners to find their suitable online materials.

Semantic Web technologies are foreseen to greatly affect these systems. Next generation personalization and RSs integrate semantic and ontological knowledge into the various steps comprising personalization process i.e. data acquisition, data analysis and personalized output [25], [45], [48], [53]. A characteristic example can be the following: the e-learning system could recommend alternative educational resources based on student searching and studying patterns. In a formal setting, it could query the syllabus and timetable to recommend a plan of study.

4.5 Web 2.0 and Social Software

A significant number of Web-based services, applications, and tools that demonstrate the foundations of the *Web 2.0* concept [40], are already being used to a certain extent in e-learning. These include chat rooms, instant messaging, social networks, blogs (weblogs), wikis, tags and tagging, social bookmarking, multimedia sharing services, content syndication, podcasting, RSS feeds, social search engines, mash ups, social gaming, etc. Most of this software, commonly called *social software*, bases on the fact that human communication and interaction have become as important in the virtual environment as they are in the actual one. Social software is relatively mature, having been in use for a number of years, although new features and capabilities are being added on an e-learning basis [2].

Recently, the *social Semantic Web* has emerged as a paradigm in which ontologies and social software have been combined. Ontologies can provide an effective mean of capturing and integrating knowledge for feedback provisioning, while social software can support pedagogical theories, such as social constructivism [51]. Other areas whereas developments in Semantic Web and social software are beginning to be explored are:

- *Semantic wikis*. It allows users to make formal descriptions of things (similar to Wikipedia) and also annotate these pages with semantic information using languages such as RDF, OWL, etc. [41]. A number of engines are being developed to support this concept including Platypus and SemperWiki [2].
- *Semantic blogging*. It can be used to distribute machine-readable summaries of their content and thus facilitate the aggregation of similar information from a number of sources [15]. For example, RDF semantic data can be used to represent and export blog metadata, which can then be processed by another machine. In the long run the inclusion of this semantic information, by instilling some level of meaning, will allow queries such as “Who in the blogosphere agrees/disagrees with me on this point?” [2].

Finally, *learning or educational communities* possess important place in the e-learning domain. They involve a domain of knowledge defining a set of issues, a community of people who care about this domain, and the shared practice that they develop to be effective in their domain [55]. These communities are typically categorized as communities of purpose, with the purpose being learning and require advance tools to support their communicative needs. The introduction of online communities has proved to be a quite promising concept, allowing the improvement of both the quality of online courses and the attractiveness of Web-based learning environments. Ideally, within the context of a learning community, knowledge and meaning are actively constructed, and the community enhances the acquisition of knowledge and understanding, and satisfies the learning needs of its members. Moreover, communities can counteract the isolation of the independent learner and the associated dropout quota. Members of a learning community may be students, lecturers, tutors, researchers, practitioners and domain experts [36].

5 Future Trends

Semantic e-learning is not a single solution, but a cluster of technologies, techniques, protocols, and processes. Such systems are too complicated to be implemented in the current stage. However, we argue that the next generation of e-learning is Semantic e-learning. To this direction, a number of issues and challenges that still remains unclear should be overcome before Semantic e-leaning vision becomes a reality.

First of all, interoperability features as an extremely important requirement for future e-learning. Interoperability is the ability of ICT systems and of processes they support to exchange data and enable information and knowledge sharing. It appears as the mean for accomplishing the inter-linking of information, systems, applications, and ways of working. Three interoperability levels need to be considered: syntactic, communication and semantic. One step forward to fulfil interoperability is Web services deployment. Despite the several efforts to extend emerging Web services with new features such as composition and content mark-up, full semantic interoperability is not provided yet.

Furthermore, researchers argue on e-learning ontologies' design. This task is not trivial or straightforward and requires the involvement of experts, who have an abstractional thinking and deep knowledge of the domain to be described, in order to provide a shared and common understanding of it. The selection and definition of the concepts and the relation between them, as well as the level of detail is a costly and time-consuming task, since the more analytical the ontology is the more complexity and difficulty it imposes. Moreover, their development and maintenance cost can be prohibitive [57]. It often happens that the ontological decisions embodied in the design of the data repositories may not correspond to those of the user. This is the case for many e-learning environments, where the differences of the various notions may often be indistinguishable. A solution to this can be the use of multiple ontologies, one for each user profile, instead of a single universal ontology [36].

Another issue refers to information sharing that should comply with personal data protection principles, laws and regulations [33]. Generally, it involves the following tasks: digital data collection, storage, processing, transfer, and sharing. This, in its turn, affects the way e-learning architectures are designed and implemented. Moreover, the user privacy threats in an electronic environment are so many that a single solution does not exist. The future challenges and research in the direction of delivering adaptive e-services without jeopardising -but in fact protecting- privacy relate to: standards support, intelligible disclosure of data, disclosure of methods, provision of organizational and technical means for users to modify their user model entries, servers that support anonymity, and adapting user modelling methods to privacy preferences and legislation [49].

Finally, other obstacles that hamper Semantic e-learning are the following: (i) E-learning systems use various terminologies and vocabularies. It is important to detect differences, overlaps and gaps appeared in learning processes and resolve conflicts. (ii) Learning components interact with different ways. The used protocols and how they are integrating in processes comprise critical challenge of the field. (iii) Each e-learning system has its own processes running within and across its environment. This can cause interoperability problems.

6 Conclusion

In recent years, the focus of ICTs is shifting to the applications to help universities, businesses, governments, and other organizations improve and transform their current practices. In this direction, new methods and the technologies supporting those methods are widely adopted. Among the emerging technologies in this competitive digital economy is Semantic e-learning. Its vision is to enable ICT architectures and technologies to support information and knowledge transparent exchange among collaborating e-learning systems. XML-based languages, RDF, ontologies, Web services and other related technologies are utilized in order to accelerate this attempt. Even though research on Semantic e-learning is just beginning, these technologies have the potential to provide a number of benefits over the traditional approaches including improved performance, effective representation and reasoning, maintaining and sharing of learning resources. Finally, there are still a lot of issues that need to be addressed before effective e-learning applications developed (interoperability, security, privacy, other obstacles). Future research activities will focus on these challenges.

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