Ontologies for the Integration of KM and e-Learning

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Abstract. *Two disciplines are complementary with one another on promoting storage, reuse and dissemination of knowledge in an organization: e-Learning and Knowledge Management (KM). Huge repositories of data are employed, either in corporative portals or distributed learning repositories relying on traditional keyword-based search mechanisms that bring inefficient results due to decontextualization and ambiguity. This paper presents the proposal of a system architecture based on semantic technologies such as ontologies and semantic annotations for more efficient retrieval and authoring of relevant educational and corporate content from the viewpoint of the Semantic Web.*

1. Introduction

The need to store knowledge is part of human nature. Knowledge is passed onto other humans through generations. Throughout the centuries, several kinds of physical support have been used as knowledge repositories until the appearance of databases and removable memories that are now used in the Internet age.

When it comes to large organizations, two disciplines are complementary in facilitating learning with the help of current information and communication technology: Knowledge Management (KM) and e-Learning. Whereas e-Learning focuses on how to support the individual's learning process through pedagogical guidance (e.g. by a tutor organizing the learning process), KM takes an organizational perspective and practices a more naïve, but also more versatile peer-to-peer philosophy of "sharing" and "transferring" knowledge [Schmidt 2005].

It is important to stress that KM is not just a bit advanced information retrieval system of target documents. KM is a dynamic process to capture and manage knowledge evolution in an organization through not only documents but personnel and activities of them. In other words, KM is required to deal with corporate learning as a total process.

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This is a great contact point between KM and with e-Learning.

In the KM domain, Content Management Systems (CMS) have been widely used on corporate portals and intranets. Such tools allow non-technical users to cooperate among themselves and publish their contents. [Uren et al. 2006] points, however, that while much of a company's knowledge can be found in text repositories, current CMSs have limited capabilities for structuring and interpreting documents.

Learning Management Systems (LMS) have become a broadly accepted approach to e-Learning both in universities and corporations to give support for virtual activities in the teaching and learning processes [Geser 2007]. Additionally, Learning Objects (LO) technologies have been adopted on e-Learning projects with the aim of improving the share and reuse of educational contents. LOs are small blocks of instructional contents stored on so-called Learning Objects Repositories (LORs).

A number of studies have been undertaken aiming at the development of LMSs and LORs. Whilst LMSs are used to manage on-line courses, LORs allow the localization, access and reuse of relevant LOs. The growing use of LMSs and LORs gave rise to a more integrated approach, namely Learning Content Management Systems (LCMS) [Cohen and Nycz 2006] [Jovanović et al. 2007].

[Duval and Hodgins 2003] were one of the first authors to suggest the existence of a relationship between e-Learning and KM. They assert that the boundary between LOs and information objects (corporate documents) in general is quite fuzzy in a world where just-in-time learning deals with small granularities that are anchored in the day-to-day context of the learner. Or, put another way, LCMSs and CMSs functionalities have so much in common that an integrated solution can be thought of.

Many a solution applied to these domains, like CMSs, LORs and LCMSs, use large-scale contents repositories for knowledge retrieval. The huge amount of contents makes the search for information a costly, inefficient task, as the search mechanisms are mainly based on keywords, which brings ambiguities and decontextualization for the retrieved information.

In the realm of Semantic Web, the goal is to categorize information and increase the quality of the result of search engines through contextualization and disambiguation of information. Annotations on the contents of documents should be done using semantic information preferably linked to domain ontologies. The outcome are web pages with machine-interpretable mark-ups that provide a valuable source on which semantic web services and agents can operate [Berners-Lee, Hendler and Lassila 2001].

An ontology defines the terms, relations and restrictions that are used on the formalization of a knowledge area. These are usually expressed on logic-based languages such as those recommended by W3C consortium [W3C 2008]: RDF (Resource Description Framework), RDF Schema or OWL (Web Ontology Language). Ontologies help intelligent agents (and humans) to access information as they possess formal semantic and, as such, can be used for reasoning, provide a structured vocabulary or explain relationships between the different terms.

Although KM has a document centric perspective and e-Learning centers on the LO paradigm, both pursue the same core goals, that is, to promote storage, reuse and dissemination of knowledge in an organization. This work promotes an interdisciplinary approach between Semantic Web technologies, KM and e-Learning. In order to support

the evolution of knowledge in an organization, it proposes an integrated architecture to enhance the semantics of the current KM and e-Learning solutions usually employed in a corporate scenario.

This work is organized as follows. Section 2 discusses how semantics is used in traditional approaches of KM and e-Learning and how it can be enhanced by Semantic Web technologies. Section 3 analyzes related works dealing with semantic solutions in developing e-Learning and KM systems. Section 4 proposes an integrated architecture to promote semantics in a corporate scenario and section 5 presents conclusions and future work.

2. Semantic Aspects in Corporate Scenarios

High-level requirements, such as availability, interoperability, accessibility, reusability and durability of knowledge resources are key factors to the success of organizational attempts to provide effective semantics to KM and e-Learning.

For knowledge to be available in an organization, a much more dynamic training approach is required, such as just-in-time learning, which focuses on how to share the right knowledge with the right people at the right time. For this to be accomplished, the contents are modeled according to the individual needs of the employees, considering the compatibility with the strategic challenges of the organization, among other criteria.

To promote just-in-time learning involves a collaborative culture and an intelligent architecture for accessing knowledge in an organization. The technologies to support such an architecture must structure organizational knowledge both syntactically and semantically.

An aspect to be considered on e-Learning is the problem of interoperability. According to [Verbert 2008], efforts on standardization have focused on the interoperability between LOs and LMSs, and among LORs. However, an optimized interoperability between LOS and parts of LOs has been neglected.

Information about documents has traditionally been managed through the use of metadata which can concern the world around the document, e.g. the author and often at least part of the contents, e.g. keywords [Uren et al. 2006]. The accessibility and consequent reusability of resources, such as LOs or business documents, heavily depends on the quality and the availability of its metadata.

Besides, the reuse of a resource is inversely proportional to its size. In fact, as the size of the resource decreases, its potential to reuse increases. Fine-grained components, such as illustrations, tables, definitions, examples and exercises are more likely to be reused than complete courses. [Silveira, Omar and Mustaro 2007] assert that reusability is achieved when a resource has the ideal granularity within a certain context and that coarse-grained resources must be aggregations of fine-grained resources (multi-grained).

[Geser 2007] points out that, in spite of this, LMSs have been used in practice to provide access to coarse-grained resources, influenced by restrictions on the technical standards of interoperability and commercial interests. On an attempt to satisfy the need to reuse a coarse-grained resource, like a complete course, the most common practice has been the good, old “copy-and-paste” process. This method of reuse is possible in any authoring tool, but is limited in several ways: the approach is non-scalable in terms of maintenance, tends to be error-prone, and due to its inherent monotony, easily becomes both bothering and time consuming [Verbert 2008].

[Zouaq, Nkambou and Frasson 2007] believe that the ability to reuse the contents of a document could represent a great opportunity to capture tacit and explicit domain knowledge. Competence development and training could benefit from document reuse by creating LOs from documents fragments. This will avoid building LOs from scratch, which is a very expensive and time-consuming operation. This can also help knowledge dissemination within a community.

According to [Zouaq, Nkambou and Frasson 2007], LORs are static pools of LOs organized in predefined structures, regardless of the learners' knowledge, preferences, learning styles, etc. They believe that Organizational Memory (OM) represents an alternative to static LORs, regarding the aspect of knowledge durability and accessibility.

OM is the part of KM that deals with the explicit dimension of knowledge providing a prosthesis for knowledge objects to be stored and retrieved. Technically it is also a repository, but the idea proposed here is that fine-grained components combined with an ontology-based approach can fulfill the actual need for information retrieval or training through a dynamic aggregation of the resources fragments (components) and the support of a semantic-based adaptive learning platform. An efficient KM policy results on the creation of an ontology-based OM that will provide a platform adaptable to the needs of both the apprentice and the organization.

The Semantic Web proposes annotating document contents using semantic information from domain ontologies. Interoperability is achieved by providing a bridge of common syntax with well-defined semantics, making it possible that heterogeneous resources can operate and ensuring that annotator and annotation consumer actually share meaning [Uren et al. 2006].

From the viewpoint of KM, semantic interoperability between learning contents can be obtained through the definition of a standard scheme, over an appropriate vocabulary, that is agreed inside a virtual group or community, having collaborative purposes [Pimentel de Sousa et al. 2003] or through the use of Semantic Web technologies, like RDF based languages, ontology merging and rules.

In an organization, for KM to benefit from semantic web technologies, it is necessary to merge a large number of different technologies and tools so as to provide semantic interoperability in a corporate environment. E-Learning tools are also included in this fusion.

The semantic annotation is the crucial process on this task as it is the base for the other processes to work properly. Its main goal is to promote an interoperability among different types of documents and provide a more efficient search [Uren et al. 2006].

[Warren 2006] points out that the new vision of the Semantic Web as a knowledge management environment introduces new requirements, including the ability to semi-automatically learn ontologies and extract metadata by using statistical techniques and linguistic analysis. He adds that it is desirable that semantic information be extracted in an almost transparent way by the interface through its continuous use by the user without distracting him/her from his/her work.

A number of authors, [Dehors 2007], [Zouaq, Nkambou and Frasson 2007], [Kohlhase and Kohlhase 2008], proposes the integration of Semantic Web technologies with the fields of KM and e-Learning and aspects of structuring resources to provide

semantics and interoperability in e-Learning and KM systems. Tools have been developed to promote and ease the search and retrieval of significant and contextualized contents. Ontologies favor this process with models and techniques to represent, share and reuse organizational knowledge. Next session presents some state-of-the-art related works.

3. Related Work

The KIM platform [Kiryakov et al. 2004] is particularly interesting because it uses Natural Language Processing (NLP) and text mining techniques for automatic annotation, indexing, and retrieval of documents. KIM is based on the General Architecture for Text Engineering framework (GATE) and produces metadata in the form of named entities (people, places etc.), which are defined in the KIMO ontology.

[Silva and Palazzo 2004] describe how Semantic Web technologies were applied to the Adaptive Hypermedia System AdaptWeb®[1], an application profile of the Learning Objects Metadata Standard (LOM) based on RDF biding. In order to implement a powerful adaptation mechanism in AdaptWeb®, ontologies were employed to achieve personalization and reuse of the educational contents, interoperability at the semantic level and reasoning support.

[Waperchovsky, Souto and Palazzo 2006] present six techniques for metadata retrieval of LOs in an automatic and semi-automatic way for the context of the AdaptWeb® environment. The main goal is to retrieve as much metadata as possible with minimal user intervention, hence making the author's task easier, guaranteeing quality and consistency to data and enabling efficient search, retrieval and reuse of LOs.

[Silveira, Omar and Mustaro 2007] discuss architectural aspects for the adequate implementation of a completely interoperable LOR containing adaptable LOs. An LOR with a well-defined structure for indexation/metadata and multi-grained LOs can be used to hand tailor the learning process accordingly with the needs of the apprentice.

[Jovanović, Gašević and Devedzić 2006] present the Tangram system, an integrated environment for Intelligent Information Systems that uses ontologies to automatically annotate LOs. Tangram enables automatic generation of LOs components by using content mining algorithms and specific heuristics. It also employs an ontology to model the contents structure so as to decompose an LO into smaller units of contents.

[Nunes and Fileto 2007] explore the use of ontologies and semantic annotations to cope with the problem of precision and recall in the domain of jurisprudence. They present an application architecture for semantic-based information extraction from documents and make a comparative analysis of tools for generating semantic annotations.

The Knowledge Puzzle Platform [Zouaq, Nkambou and Frasson 2007] is another approach based on ontologies where (semi) automatic annotations are made on contents of documents at component level. The ontological model presented is composed of five ontologies: a domain ontology, a document structure ontology, an instructional role ontology, an organization ontology and a competence ontology. NLP tools are used to annotate content into concept maps and support the evolution of the domain ontology. One innovative idea is the storage of semantic annotations in an OM. Once the OM is populated, it is used as a knowledge base for KM and training integrated environment.

[1] http://sourceforge.net/projects/adaptweb

Based on the symbiosis of KM and e-Learning in an organizational environment and taking into account the role of semantics in this interplay, the next session presents an architectural proposal to integrate such functionalities.

4. The Proposal of a Semantic-Based Architecture for Corporate Scenario

This work continues a previous work of a proposal for a system architecture that integrates Semantic Web, KM and e-Learning [Rios et al., 2008]. The institutional context is represented by the Tribunal Regional Eleitoral do Ceará (TRE-CE), the Brazilian Electoral Tribunal of the State of Ceará. The aim is to extend the current KM and e-Learning environments [Araújo 2007] with semantic technologies in order to support the retrieval of the information stored in distributed repositories of the Brazilian Federal Electoral Justice (JE).

The main goals of the new architecture, called Semantic TRE, are:

- Make it easy to reuse the educational and corporate resources;
- Improve the search of legacy contents throughout JE network;
- Allow refinements and inferences on the results of the queries;
- Be totally integrated and compatible with the existing platform;
- Be expansible to other e-Learning platforms of the JE;
- Allow the integration to other systems/applications as customized via an application programming interface (API);
- Create a global organizational memory (OM) of the JE with educational contents that is sensitive to the context of the apprentices and the organization;

Figure 1 presents an overview of the architecture, showing the relationship between the repositories, business logic components and actors.

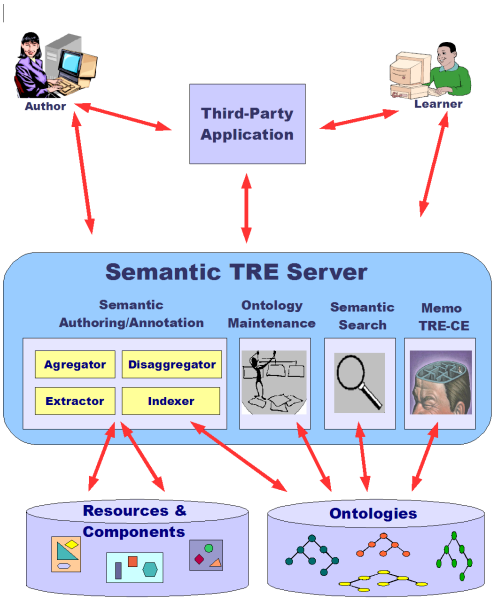

Figure 1. Architecture of the Semantic TRE

The components of the Semantic TRE Server must be based on existing open-source platforms, specialized on three different domains: RDF repositories, information

extraction and information retrieval. To guarantee easy maintenance, extension and encapsulation of other systems, an abstract layer on the implementation of some components is specified so as to make the configuration with other components more flexible. Three layers are used, as described in the next sections.

4.1. The Data Layer

The educational and corporate contents are stored in the Repository of Resources and Components (multi-granular fragments of resources) and the semantic annotations are kept in the Repository of Ontologies. Aiming at supplying more semantics to the system, the architecture is based in the use of ontologies represented in OWL, in order to perform inferences on them. On this model, the ontologies play different roles to promote semantic interoperability.

Component-level reusability allows the optimization of costs and effort for the authoring of a new resource. In order to achieve this level of reusability, the quality of the metadata must be improved via the combination of multi ontological approaches. The ontological model is composed by six ontologies and can be augmented accordingly with the organizational needs:

- Domain Ontology. Describe concepts and relationships among concepts of the specific domain of Brazilian Federal Electoral Justice, such as voting, party, coalition, major election, proportional election etc;
- Structural Ontology. Describe the parts of resource contents, indicating its logical structure, such as chapters, abstract, sections, tables.
- Instructional Ontology. Describe the instructional role of an educational resource, like demonstration, procedure, explanation, questions, answers, cases, conclusions, definitions, examples etc.
- Organizational Ontology. Describe the aspects of an organization, like the distribution of business units in the organizational organogram, job positions, hierarchy and attributions;
- Competence Ontology. Describe employees skills and abilities, professional learning opportunities, competence scale, level and catalog necessary for each professional specialty;
- Intellectual Property Ontology. Describe copyright licenses for resources throughout the Brazilian Federal Electoral Justice, based on *Creative Commons*[2].

4.2. The Application Layer (Semantic TRE Server)

The architecture of the Semantic TRE Server is composed of four sub-systems that represent the visible parts of the API. These modules interact with the Repository of Ontologies and the Repositories of Resources and Components. The following is a more detailed view of the sub-systems:

a) Semantic authoring and annotation

In this module, each resource is viewed as an aggregate of several contents components which can be classified according to their types and levels of granularity. This way, the creation of a new resource resembles an assembly line where the author can use new

[2] http://www.creativecommons.org.br/

contents (by uploading them) and/or reuse existent resources and components. This component possesses the following four modules:

Extractor - The extraction process implements the (semi)automatic recognition of the entities of the text of the original document and associates these entities with the corresponding classes on the myriad of existing ontologies. The semantic annotations of the resource and its components are generated at contents level and kept apart from the annotated contents. An API is provided to manage the semantic annotations.

Disaggregator - At the moment when a document is uploaded to the repository, the Disaggregator activates the Extractor so it can proceed with the automatic extraction of the semantic annotations. Next, the document is decomposed into smaller units (Components), according to the annotation of the Structural Ontology (the first indexation step) and the remaining ontologies of the system. The aim of this process is to make of each component a directly accessible unit in order to facilitate the reuse.

Aggregator - When the author of an educational contents requests the creation of a new resource, the Aggregator assembles it by joining components that already exist on the environment. The semantic annotation of the new resource is carried out by taking into account the semantic annotation of the related components.

Indexer – This module is activated whenever a semantic annotation is generated. The resources are indexed in multiple levels, in conformity with each ontology of the system. First, there is an instantiation step in accordance with the structural ontology and several other phases of semantic indexation, one for each ontology of the system. Therefore, the indexing is simply done by associating a resource instance with other related indexing instances for the same resource. The output of this phase is an RDF file representing the resources index.

b) Semantic search

The Semantic Search component may work with the mapping of the ontologies and/or the use of inference rules on the RDF graphs (indexes) provided by the Repository of Ontologies. It can, for instance, find contents of the type “definition” (defined on the Instructional Ontology), that deal with “party affiliation” (Domain Ontology) and is addressed to the “IT Department” (Organization Ontology) through the mapping of the involved ontologies. The index created by the Indexer in the form of an RDF file can be queried by SPARQL, which is recommended by the W3C [W3C 2008].

c) Ontologies maintenance

Besides providing such basic operations as inclusion and deletion of ontologies, the Ontologies Maintenance component gives support to the controlled evolution of the ontologies. An ontology evolves each time a new entity is associated to the ontologies. As each new document included into the Repository of Resources and Components has a semantic model with the entities associated to the ontologies of the system, the incremental union of all the semantic model related to the documents in the Repository of Ontologies has an influence on the evolution of all the ontologies of the system.

d) MemoTRE

In order to provide a more student-tailored educational experience as a just-in-time learning, the MemoTRE was conceived. This component takes into account the level of expertise, learning needs and profiles and other preferences of the student through the

mapping of several ontologies of the system. The indexation of the resources by contents and its automatic composition form the basis for MemoTRE´s adaptive learning platform.

4.3. The User Interface Layer

The architecture front-end tools must be integrated in the context of the user every day work environment (for example via *plug-ins*). Semantic annotations must be semi-automatically extracted through a transparent and sustainable process.

5. Conclusions and Future Work

To empower, enhance and better use all the knowledge generated by an organization, groups or individuals, it must be structured and normalized both syntactically and semantically. The ontologies help this process by providing models and techniques to store, share, represent and reuse knowledge.

The Semantic Web envisages technologies which can make it possible to generate a kind of "intelligent" document. Semantic web and ontologies can bring an answer to this need and are starting to be widely used in e-Learning and KM communities. We believe that the combination of several ontologies in a given domain can avoid the inconsistencies of the traditional methods.

The main contributions of this work are the analysis of the desirable characteristics of an intelligent architecture for the expansion of the existing e-Learning platform and the specification of all the related processes to enhance semantics in a corporate arena, and also the proposal of an integrated solution for e-Learning and KM through the creation of the MemoTRE, an Organizational Memory for educational and corporate contents whose purpose is to promote a just-in-time continuing learning.

This architecture may be improved by the development of some of the hereby proposed ontologies and the reuse of other existing ontologies, the study of open-source solutions that will implement the back-end and front-end components of the architecture, and the development of the Semantic TRE Server.

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