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# Ontology-based system for Enterprise 2.0

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***Abstract*—Enterprise 2.0 is mainly focused on answering to people needs and to stimulate flexibility, adaptability and innovation. Ontologies define a common vocabulary to share domain information and are used to state the meaning of terms used in data produced, shared and consumed within the context of Semantic Web applications. In this paper we propose a conceptual architecture where ontologies are used to support the social, open and adaptive views of Enterprise 2.0. We also show how the main elements of the architecture can be exploit in an organizational e-learning scenario.**

***Keywords*-Enterprise 2.0; Ontology extraction; e-learning**

## I. Introduction

The continuous spread of Web 2.0 has dramatically changed the social interaction in the Internet society. Web 2.0 is just the beginning of a transformation to a world of interactivity, collaboration and community. It is easy to see the significance of this new world in the influence and power of social networking sites and online customer reviews for just about every product in existence. This environment will dramatically affect how companies design and implement knowledge management.

In this context the broad emergence of dynamic and interactive technologies in the enterprise arises. These technologies must take advantage of blogs, wikis, RSS feeds, mobile devices, etc. to facilitate user participation in content-enabled business processes, from within the enterprise as well as beyond. The key will be to facilitate collaboration and creativity, without compromising the organization's need, in order to manage user-generated content.

Another important key for the so called Enterprise 2.0, i.e. the enterprise using Web 2.0 tools, which are contributing to new ways of collaborating and proving extraordinarily effective in workgroups, involves stepping up the requirements for security and scalability. This new collaboration idea is not constrained by organizational boundaries. In fact, bringing content-enabled applications to the extranet requires even greater protection to ensure things do not get out of control.

As the enterprise content assets grow to billions of objects, simply knowing what is in there, and how to access it all, is not enough. How it is possible to discover, and use, that information value? Organizations will rely on business intelligence to discover connections between people, processes and data, thus uncovering the buried, implicit knowledge in information. Web 2.0 applications require an even simpler way to expose and manage content services. These applications must be dynamic. Moreover, as with mash-ups, they are even created by the users themselves. Content and business process management systems have already closed ranks. However, with the growing spread of Web 2.0, organizations must look beyond process simulation and optimization, making sure to include collaborative approaches in their process automation. A process is not about performing a sequence of tasks, but about getting work done. It is not practical for the majority of enterprises to move all their data into a single repository. Within the enterprise, the virtual repository has started addressing this constraint. In Enterprise 2.0 repositories can be distributed anywhere, inside and outside the enterprise, in this way the entire "cloud" must now be considered the new virtual repository.

We can identify three models or path towards Enterprise 2.0; namely they are:

- *Social Enterprise*, that is oriented to the creation of new patterns of collaboration, sharing of knowledge and relationship management;
- *Open Enterprise*, which is aimed toward the overcoming of existing Virtual Workspaces boundaries both in terms of access modalities and external actors;
- *Adaptive Enterprise*, which focuses on flexibility and reconfigurability in the context of business processes management.

The *Social Enterprise* model is, actually, the most adopted and represents, at the same time, a great opportunity and a complex challenge for companies. With this term we address the evolution of the "community" concept in creating enlarged virtual environments. Virtual environments are typical

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environments in which people, belonging to different areas, can organize themselves, share knowledge and collaborate to solve problems and create innovation for the company.

Our objective is to define a new architectural vision to support learning activities in the context of Enterprise 2.0. In this paper we propose a conceptual architecture where the ontologies are used to support the social, open and adaptive views of Enterprise 2.0 acting as a bridge between natural language queries and content repositories. We also show how our architecture can be instantiated for an organizational e-learning scenario.

The rest of the paper is structured as follows. Section 2 presents our e-Learning scenario showing the structure of the learning ontologies we used in the proposed architecture. Section 3 describes our architectural vision to embed personalized e-learning activities within the Enterprise 2.0. Section 4 gives the final remarks and explains some future directions.

## II. The e-learning Scenario

In this section we introduce our case study, based on an integrated Semantic Virtual Learning Environment to create and manage personalized e-learning experiences through ontologies.

Before describing the case study, it is necessary to introduce the ontology structure in our system. The main goal of these ontologies is to model the knowledge of disciplinary domains.

An e-learning ontology can be represented with a graph in which nodes are relevant concepts within the educational domain of interest and edges are binary relations between two concepts. Our approach foresees different kind of relations: *HasPart* (HP) that is an inclusion relation, *IsRequiredBy* (IRB) that is an order relation, *SuggestedOrder* (SO) that is a "weak" order relation and *HasResource* (HR) that relates concepts with Learning Objects. The restricted set of relations is not a knowledge representation limit, but is a convenient method to improve the computational complexity of algorithms that have to navigate the graph.

Let us illustrate how to model an e-learning ontology. We have to model the educational domain $D$, so we try to conceptualize the knowledge of $D$ and to find a set of terms representing relevant concepts in $D$. The result of this operation is the list of terms $T = C_1, C_2, C_3, C_4$ where $T$ is one of the possible conceptualizations of $D$ ($C$, $C_1$, $C_2$ and $C_3$ are ontology concepts). In order to explain the semantics of *HasPart* relation we can refer to ontology illustrated in Fig. 1 where the three *HasPart* relations $HasPart(C, C_1)$, $HasPart(C, C_2)$ and $HasPart(C, C_3)$ mean, in terms of e-learning, that in order to learn concept $C$ learners have to learn concepts $C_1$, $C_2$ and $C_3$ without considering a specific order. In Fig. 1 we note the existence of elements that are not concepts nor relations. The new elements to introduce are the Learning Objects $LO_1$, $LO_2$ and $LO_3$. The connection

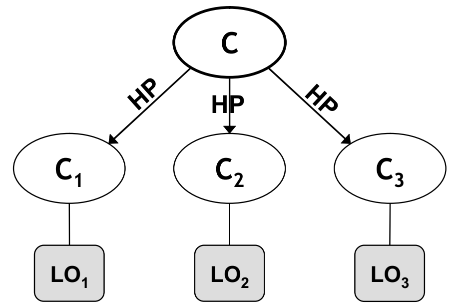


Figure 1. Simple *HasPart* relations for an e-learning ontology.

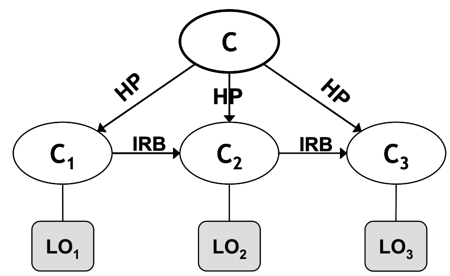


Figure 2. An IWT ontology with HasPart (HP) and IsRequiredBy (IRB) relations.

between a concept and a Learning Object, for instance $C_1$ and $LO_1$, can be interpreted as a *HasResource* (in brief HR) relation. The relation $HasResource(C_1, LO_1)$ means that the educational content packaged in Learning Object $LO_1$ explains concept $C_1$. So, if the Learning Objective is $C_1$ then the correspondent assembled e-learning experience is composed only by $[LO_1]$, otherwise if the Learning Objective is $C$ then the assembled e-learning experience will be composed by one of the plausible permutation of $[LO_1, LO_2, LO_3]$.

Now, consider the ontology shown in Fig. 2. This ontology presents two *IsRequiredBy* relations, that are $IsRequiredBy(C_1, C_2)$ and $IsRequiredBy(C_2, C_3)$. The two relations mean that $C_1$ has to be necessarily learned before $C_2$ and $C_2$ has to be necessarily learned before $C_3$. In this case if $C$ is the Learning Objective, learners have to learn the ordered sequence of concepts $[C_1, C_2, C_3]$ and correspondingly they can join the e-learning experience assembled by the ordered sequence of Learning Objects $[LO_1, LO_2, LO_3]$. Alternative permutations like $[C_2, C_1, C_3]$ will be invalid.

The sequence of concepts useful to reach a pointed Learning Objective is called Learning Path; the operation used to construct the concrete e-learning experience assembling a Learning Object sequence is called resource binding.

We have outlined the foundations of our modeling approach, now we want to refine the approach description. First of all, we state that the same Learning Object can explain more than one concepts within the same ontology.

In general, the *HasResource* relation is represented by a function $HasResource(LO_1; \{C_1, C_2, ..., C_n\})$ meaning that $LO_1$ explains all concepts $C_1$, $C_2$, ..., $C_n$. Otherwise, it is possible to have more than one Learning Object explaining the same concept. We can have, at the same time, the relations $HasResource(C_1, LO_1)$, $HasResource(C_1, LO_2)$, $HasResource(C_1, LO_3)$, etc. Finally, let us suppose to have a $SuggestedOrder$ relation between concept $C_1$ and concept $C_2$ that is $SuggestedOrder(C_1, C_2)$, this relation states that the modeler claims that is preferable to explain concept $C_1$ before concept $C_2$ (this is not mandatory).

We investigate the problem of ontology extraction in the context of real e-learning activities, building personalized and contextualized learning experiences based on explicit knowledge modeling, and exploiting ontologies in order to represent disciplinary domains.

The learning experience definition process is based on ontologies built in the process of knowledge extraction from available text documents of a specific domain.

We have developed an advanced e-learning system that, on the basis of the extracted ontologies (representing the disciplinary domain of interest), can be used to define the sequence of concepts needed (by a learner) to acquire a satisfactory knowledge of learning objectives identified (by a teacher) as target concepts of the given ontologies.

A complete description of the overall e-learning system is beyond the scope of this article. We introduce just the structure of our e-learning ontologies that has been used in the ontology extraction subsystem described here. The reader can find a more detailed dissertation in [1] and [2].

## III. Architecture

Our aim is focused to inject personalized e-learning processes within the enterprise 2.0.In order to achieve the aforementioned purpose we propose an architectural vision that exploits ontologies as a glue between collaborative work activities and e-learning activities in the enterprise 2.0 environment. The importance of these issues has been widely highlighted by various researches (see for example [3] [4] and [5]).

In the next section we will describe an element of a system that concretizes part of the proposed vision.

The architectural vision will be defined through:

- the description of how e-learning fits into the three enterprise 2.0 *dimensions* (see the previous section) establishing three access types for the enterprise 2.0 environment
- the description of how to exploit ontologies in order to support the semantic annotation of data produced and accessed using the aforementioned environment
- the description of an e-learning scenario leveraging the enterprise 2.0 tools and methodology (e.g. blog, forum, wiki, etc.) and becoming part of them.

Figure 3 shows the details of our proposed architectural vision. Contents are the foundation of the system and we can consider four different kinds:

- *learning object*, i.e. a learning content (or a packaged aggregation of learning contents) that can be delivered through a common Web browser.
- relationships between users of the system and external ones.
- all data created by the community, i.e. discussions, posts, tags, uploaded pictures etc.
- documents, created and stored in the system.

We use ontologies as a substrate between different types of user's accesses and the underlying contents. E-learning ontologies allow to associate domain specific concepts to the learning contents that explain them. Relationships between different users of the community can be easily mapped with the FOAF (Friend of a Friend) ontology. FOAF [6] is a machine-readable ontology describing people, their activities and their relations to other people and objects. It allows sharing personal information across different platforms. We will use an extension of FOAF, detailed in [7], that allows to also keep track of each user cognitive state and proficiency. Other community contents can be mapped using SIOC (Semantically-Interlinked Online Communities) [8] and MOAT (Meaning Of A Tag) [9] and taxonomies help in documents classifications.

There are three different kinds of access to the system, that reflect the three different views on Enterprise 2.0. In our vision the system offers a support for collaborative work, following the principles of the Social Enterprise vision. With a Social Enterprise approach companies may exploit the same benefits of social networks: all the individuals involved work together, share information and create networks of people with similar interests. This can increase cohesion among workers, especially in large companies where people working together are often physically distant from each other. Moreover, as McAfee points out [10], in some cases this type of information sharing, lowers the total time required between having an idea for a contribution and the actual application of this idea. Choosing this approach means not only offering support for social networking, but also allowing employees to acquire knowledge through the Web. This knowledge is obtained using RSS feeds, document management systems and also blogs, wikis and forums.

Organizing data which come from the Social Web with technologies of the Semantic Web is not a completely new concept [11] [12] [13] [14]. Many different ontologies have been created to represent single aspects of the Social Web and a complete representation of social networks could be created by using existing ontologies as building blocks. We propose the use of SCOT (Social Semantic Cloud of Tags) [15] Tag Ontologies and MOAT to implement the tag modeling, the resources of social networks and synonyms

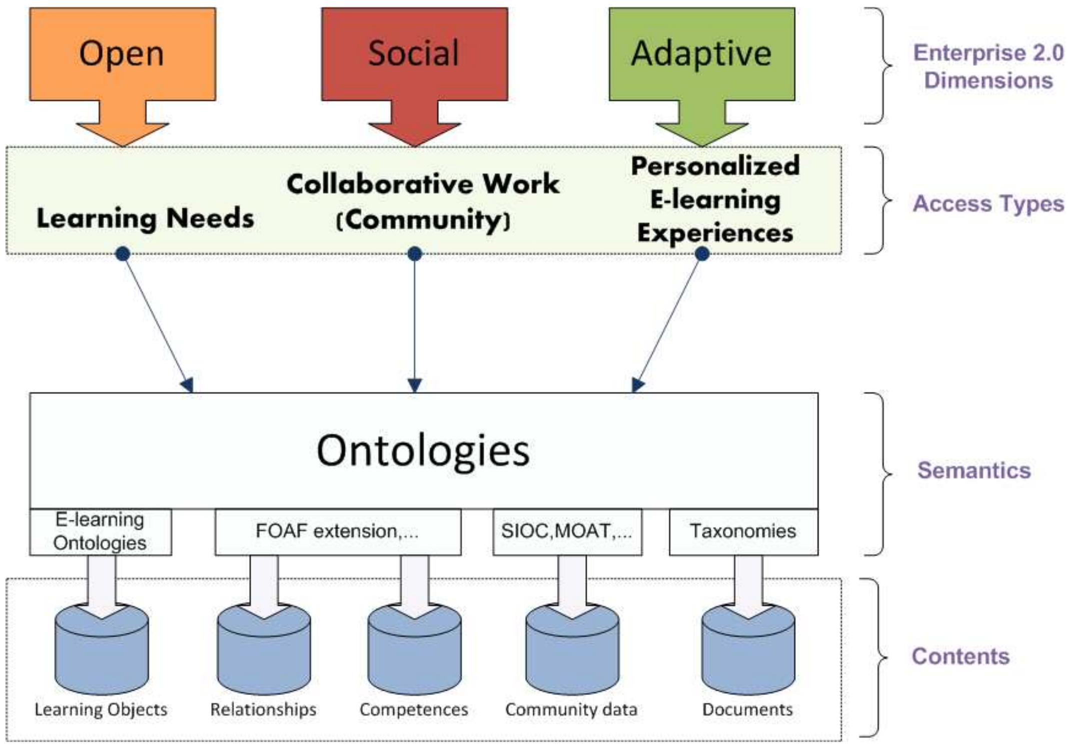


Figure 3. Embedding e-learning in Enterprise 2.0: The proposed vision.

handling for tags.

This approach has many benefits: first of all, we provide a unique tag space populated by several contents and knowledge managing processes. In addition, ontologies could help solving Enterprise 2.0 *Identity Problem* [16]. Especially in a professional environment, credibility and trustability emerge as key issues, but until now, there is no standard identity model and users have to register themselves every time they access a Web site. This is a critical issue, because companies should be able to identify people that write on their platform. With the use of FOAF, users can be identified across multiple platforms. As for the other cited technologies, SCOT is an ontology created with the purpose of enhancing tag sharing and interoperability among different social communities [17]. The tagging activity is represented as a ternary relation between users, tags and resources. SCOT's model is based on three existing Ontologies: it reuses FOAF and SKOS [18] for mapping users and tags and uses SIOC to represent resources.

The second type of user access, implemented in our system, the *Personalized Experience*, is the heart of the Adaptive vision. Personalization of information and content flows is one of the features provided by the Semantic Web technologies. In this context, ontologies are used in order to model knowledge about educational domains (e-learning ontologies).In [19] there is an example of the *Adaptive Enterprise* approach applied in an e-learning environment. The authors created a personalized e-learning system that solves the problem of information overloading by presenting to users only what is relevant, according to their cognitive state and their learning preferences. It is important to remember that the presented approach to the Personalized Experience is specific for the e-learning context but could be used also to support the personalization of general informative content.

The Open Enterprise approach focuses on the concept of *open affiliation*. It lets people feel part of enlarged dynamic circles instead of a single organization. Of course, for the "Open" philosophy, in order to work it is necessary to restrict access to crucial information that should be left private. It is important for workers or external partners to be able to express information needs (also called *learning needs*) through the use of natural language rather than navigating resources catalogues. In this way all contents are accessible even by people who do not have the level of business knowledge required to find what they want manually. This task can be simplified if resources are represented using ontologies that partially fill the gap between natural language requests and contents. With this technology we can express the semantic contents in a machine-understandable way. This leads to a more advanced similarity techniques to match natural language queries with learning or informative content.

Therefore, we focus on two main directions. The first one, which has been already illustrated, foresees the formulation of needs in natural languages. Moreover, the second one permits the broadcasting of an unsatisfied need through a community or a network of experts (inside or outside the enterprise boundaries). The need can be understood by one or more experts that can answer to it by populating the enterprise repositories and notifying the answer to the worker that has originally expressed the need.

In order to better understand how the proposed architectural vision works, we will describe a typical scenario:

- **Step 1**. Researchers and teachers engage in collaborative work through the community. They create learning contents in forums and blogs that are stored using SIOC and tagged using MOAT. They also create documents that are organized hierarchically using taxonomies.
- **Step 2**. One of the company workers has a particular learning need (e.g. he/she needs to learn the foundation of Java programming language). He/she accesses the platform and expresses his or her needs in natural language.
- **Step 3**. E-learning ontologies are used to fill the gap between the request in natural language and the underlying content. Relationships among the concepts of each ontology are exploited to generate a personalized e-learning experience that includes the content created on *Step 1*. The system keeps track of the worker personal information and her cognitive state using an extension of FOAF.
- **Step 4**. Domain experts have to refine the personalized learning path created on *Step 3* and create new contents if the solution does not completely satisfy the learning needs. In this step the system identifies the users that have the necessary expertise to perform the task by examining documents, posts and publication of each teacher and finding who has published contents on the same topics. The system can easily keep track of each user's publications with the `foaf:publication` property and `foaf:maker` property and competencies are accessed with the `foaf:capabilities` property. Using the FOAF ontology the system can access information produced by its users on external platforms because each member has a list of `foaf:holdsAccount` properties that indicates her accounts on all the communities she is involved with. FOAF is also used to contact external people (i.e. people that are not registered to the platform) who have links with registered users. Links between users are mapped using the `foaf:knows` property. All the people identified in this step receive a request (via email or through the platform, depending on each account setting).
- **Step 5**. Teachers, researchers and experts, identified on *Step 4*, answer to the request. Registered users analyze the personalized e-learning experience created on *Step 3* and identify which parts of the users learning needs are still unsatisfied. Following the previous example, one of the company experts on Java programming could notice that in the user learning path (for Java learning) there is no material explaining the use of developing environments. Experts create new learning contents, blog posts or documents and submit them to the system. External users can participate to this activity too. For example a Computer Science researcher who has friendship links with one of the platform researcher, but is not part of the company, receives the request and decides to answer. The company could think of a way to reward external contributions or could pay for external consulting.
- **Step 6**. The worker receives a notification indicating that new content related to his or her learning needs has been added.
- **Step 7**. All new contents created on *Step 5* are integrated with existing information and enrich the knowledge base of the platform.

The explained process can also be useful to identify people needs and to accordingly alter the knowledge production. The company learning manager could discover frequently requested topics and create new courses or standard learning paths.

## IV. Conclusion

Recently Enterprise 2.0 raises as an important part of Web 2.0. Enterprise 2.0 contributes to new kinds of collaboration, proving extraordinarily effective especially in workgroups.

In this paper we briefly analyze the three dimensions of Enterprise 2.0 proposing a conceptual architecture where the ontologies are used to support all Enterprise 2.0 views.

We are now implementing the different components of the proposed architecture in an integrated system using the ontology structure we used in other projects [19]. Moreover we are defining a set of experiments in order to tests the results of the system. We plan to show the validity of the tests in terms of two straight forward evaluation measures derived from information retrieval community, namely *Precision* and *Recall* [20].

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