Exploiting Semantic and Social Technologies for Competency Management

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Abstract—In an enterprise context, competencies are often dispersed across different teams. A specific need within the enterprise could not be satisfied only because of a lack of awareness about real competencies owned by employees. The aforementioned problem involves two main critical aspects: the difficulty to manage employees’ competencies in order to constantly keep them up-to-date and the ability to agilely share employees’ profiles across the organization in order to support competency finding. This work proposes an approach to relax the above critical points by integrating a semantic web-based educational system within a social network system applied to the enterprise context. The integration glue is provided by using and harmonizing several existing upper ontologies also furthering semantic interoperability.

Index Terms—Distance Learning, Semantic Web, Social Computing, Competency Management, Enterprise 2.0

I. INTRODUCTION

Nowadays, a wide and consolidated use of software for the human resource management is experienced in corporate environments. Typically, this kind of software, namely Human Resource Information System (HRIS), is associated with enterprise systems like Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM). HRIS provide functionalities like organizational management, personnel development, training event management, carrier and salary, etc. that lay upon a competency repository mostly populated through simple data entry activities. Competency repositories updates are performed on the basis of curricula or training activities by HR managers.

According to the aforementioned approach, a HRIS manages a competency hierarchy used to state about all the competencies considered in the specific organization and several profile structures maintaining competencies, and corresponding proficiency levels, of all the employees.

From the technological viewpoint, the information systems for human resource management have to digitally record competency information. As a consequence, specifications and standards are needed to support interoperability between systems. The main specifications and standards for competency management (mostly related to learning-training activities) are in particular: IEEE Reusable Competency Definition (IEEE RCD) specification¹, IMS Reusable Definition of Competency or Educational Objective (IMS RDCEO) specification² and the HR-XML standard³.

The IMS RDCEO specification defines an information model to describe, reference, and exchange definitions of competencies, primarily in the context of online and distributed learning. The IEEE RCD specification describes a Competency Definition as used in a Learning Management System or referenced in a Competency Profile, by making direct reference to the IMS RDCEO specification. HR-XML is a XML schema defined by the HR-XML Consortium in order to support standardized and practical exchange of information on competencies within a variety of business contexts. Although these standards and specifications provide a good framework for interoperability, they produce some problems when both machine searching and processing are needed. This is mainly due to the use of unstructured textual definitions, especially, in RDCEO. Consequently, some drawbacks would have to be faced in order to design innovative and efficient human resource management systems taking into account additional features as the competency management and, in particular, 1) automatic mechanisms to update employees’ competency profiles, 2) interoperability at the semantic level and 3) agile mechanisms to share knowledge about competencies using also horizontal not-hierarchical flows.

Our work proposes an innovative approach able to improve management and exploitation of employees’ competency profiles in organizations, aiming to solve the critical issues discussed above. The proposed approach is based on the definition of a Semantic Layer (section III) enabling cooperation among a Semantic Web-based Educational System, a HRIS and an Enterprise Social Network (section IV). Final remarks will be expressed in section V.

II. BACKGROUND AND MOTIVATIONS

Three main critical lacks have to be faced when competency management is considered:

- Automatic mechanisms to update employees’ competency profiles, that often contain old and invalid information, and to plan training/learning activities within organizations starting from career plans, employees’ competency profiles and organizational strategies.

2http://imsglobal.org/competencies/index.cfm
3http://ns.hr-xml.org/2_0/HR-XML-2_0/CPO/Competencies.pdf
• Interoperability at the semantic level. Specifications and standards like RDCEO and HR-XML only support interoperability at the syntactic level. In this way there is no possibility to exploit external available knowledge and to expose internal knowledge for external uses.

• Agile mechanisms to share knowledge about competencies using also horizontal not-hierarchical flows. Competency information are often used only by a few authorized users. This decreases the possibility to improve processes within the organization.

The approaches to solve the aforementioned issues are essentially based on the use of ontologies to model competency information and to link them to other relevant involved elements within organizations. The authors in [1], consider a competency as: [...] a combination of tacit and explicit knowledge, behaviour, and skills, that give somebody the potential for effectiveness in task performance.

The above cited definition agrees with the traditional view of KSA that considers a competency as a combination of Knowledge, Skills and Aptitudes. Some improvements to IMS RDCEO and HR-XML models by defining a competency ontology are proposed. In [2] the authors define a competency model where a set of job positions is described in terms of objectives (an objective can be an elementary task or a composite task) which are respectively based on resources (knowledge, skill or aptitude) also structured hierarchically. In [3] an ontology (specified in OWL) where a competency is defined through a generic skill applied to a specific knowledge with a certain level of performance is proposed. A competency can be used to annotate resources and can be also specialized in prerequisite competencies, actual competencies and target competencies. The last ones are related to learning objectives. In the work an extensible generic skill sub-ontology and a mechanism to link external domain ontologies in order to support several domains are provided too. The authors of [4] introduce a competency ontological model where competencies are related to other competencies through a subsumption relation and a composition relation. In this model, the competencies are also linked to instructional entities by means of two relations (has objective and has prerequisite).

Furthermore, the work presented in [5] illustrates the integration among an e-learning system and a competency management system that makes use of ontologies. The integrated system supports the development of correct learning paths and consequently appropriate competencies acquisition by the employees. The authors also present a competency ontology in which skills are related to learning objects. The last ones are used to enable the employees to reach required skills. The same idea is developed by the ICOPER EU Project [6]. ICOPER aims to define a competency-based educational framework. The authors state that: [...] To change the educational system towards a more competency-based approach, we need to develop technology enhanced learning support that bridges the competency definitions and educational content, e.g. linking competencies to Unit of Learning (UoL).

Hence, while several ontologies, modeling competencies, and competency-based learning approaches are emerging, new research directions go towards the use of Semantic Web technologies to support Educational System. This synergy [7] will also conduct to more adaptive and personalized learning environments and effective information sharing.

Finally, in the last years a paradigm, namely Enterprise 2.0, is arising [8]. Enterprise 2.0 aims to use the Web 2.0 technologies as a support for business activities within organizations. Web 2.0 is mainly exploited to sustain collaboration, information exchange and knowledge sharing. Moreover, Enterprise 2.0 places a high value on the importance of social networks inside and outside the organization.

The present work, starting from the results of past researches and from research directions in the fields of Semantic-based Education and Enterprise 2.0, sets out an approach to improve the management and exploitation of employees’ competency profiles in organizations, aiming to solve the critical issues discussed above.

### III. Definition of the Semantic Layer

In this section we will focus on modeling employees’ profiles and correlating them to a suitable competency model. In our approach we exploit the actual vocabulary and ontologies that can be used to capture metadata about persons and competencies in organizations using Semantic Web methodologies and technologies. This will lead to the application of common machine-readable formats (syntax and semantics) supported by a critical mass of users (low entry barrier, tool support, reuse) as well as enabling technologies (e.g. SPARQL, etc.) in order to implement practical use cases [9].

First of all the ontology space we would like to describe can be divided into two sub-layers: Upper Ontologies and Domain Ontologies. For the first one, we propose FOAF (Friend-of-a-Friend) and ResumeRDF to organize information about employees [9] and the competency ontology provided by Schmidt & Kunzmann (Competency-Oriented Human Resource Development Ontology or SK ontology in brief) [3] to model the structure of knowledge about competencies. The second one will be covered by the definition of all domain terms, and their relations, that are modelled by using SKOS (Simple Knowledge Organisation System)⁷.

FOAF is mainly used to organize information about on-line account of people. The foaf:Person class is crucial for our proposal. By using foaf:Person it is possible to model information about an employee. For instance, we can use foaf:firstName and foaf:surname properties for the employees’ names, foaf:mbox property for their mailbox addresses, foaf:publications property for the documents they produced and foaf:interest for their topics of interest. The FOAF schema is widely used as a backbone to be augmented in order to model information about people

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⁷[http://www.foaf-project.org/](http://www.foaf-project.org/)
⁴[http://www.w3.org/2004/02/skos/](http://www.w3.org/2004/02/skos/)
living in digital environments, where it is needed to manage social networks. This last issue is accomplished by using the foaf:knows property to link two FOAF persons. In our case we need to augment FOAF using ResumeRDF and SK ontologies. ResumeRDF is a RDF metadata vocabulary used to describe professional capabilities of workers gleaned for example from CVs or resumes. The main ResumeRDF class is cv:CV that is a container of information about a specific person (cv:Person), his (her) education (cv:Education class), his (her) work history (cv:WorkHistory), and so on. ResumeRDF also provides a class useful to model skills (cv:Skill class). Although ResumeRDF is very detailed, its cv:Skill class is not compliant with the most accepted definitions of competency (see section II). Hence, we need to extend ResumeRDF with the SK ontology. In the SK ontology, the employees are modelled by using sk:Employee linked to sk:Competency through the sk:has-competency property. sk:Competency is related to its elements (sk:CompetencyElement) by means of sk:consist-of-element properties. Specialized elements are modelled with sk:Skill and sk:Knowledge classes. Competencies (instances of sk:Competency class) are also associated to competency levels that have competency scales. The figure 1 illustrates a significant fragment of the Upper Ontologies sub-layer filled with the harmonized use of FOAF, ResumeRDF and SK ontologies. In order to bridge different ontological schemas, some extensions (in OWL) have been provided, using the my namespace. In particular, we propose to relate instances of foaf:Person and cv:Person by using the owl:sameAs property and adding the my:hasCompetency property to relate zero or more competencies to instances of cv:CV class. With respect to the SK ontology, competencies are linked to both organizational entities and instructional entities. For instance, we can state that in order to cover a specific role (sk:Role is a specialization of sk:OrganizationalEntity class) an employee has to own one or more specific competencies with assigned competency levels. On the other side, we can state that in order to acquire a specific competency an employee has to learn by a specific learning activity (sk:LearningActivity is a sub-class of sk:InstructionalEntity class) that is possibly a learning object, a sequence of learning objects, etc. The SK ontology also suggests that two self-relations for the sk:Competency exist. Thus, the catalog of competencies should be organized in taxonomies (sk:subsumes property) and in partonomies (sk:is-composed-of property). In our proposal the modeling of domain-specific competency catalogs, skill taxonomies and concept maps (used to organize documents, learning objects, tasks, activities, and so on) is realized through the Domain Ontologies sub-layer. We also propose to define this layer by using the Simple Knowledge Organisation System (SKOS). SKOS allows to describe general terms and concepts and to define many useful properties of such terms like declaring whether a concept is broader/narrower than another, preferred and alternative labels in multiple languages for terms, as well as related terms. SKOS facilitates sharing and representing terminologies that may not extensively require the expressive power of other languages such as OWL and where a strict hierarchy such as definable by rdfs:subClassOf cannot be imposed. Skill Taxonomies can be modelled in SKOS without further extensions. The following code lines show how to represent a fragment of the Paquette’s Skill Taxonomy [3] using SKOS.

```reasoning
my:produce rdf:type skos:Concept;  
  skos:prefLabel "produce";
my:self-manage rdf:type skos:Concept;  
  skos:prefLabel "self-manage";
my:analyze rdf:type skos:Concept;  
  skos:prefLabel "analyze";
my:synthesize rdf:type skos:Concept;  
  skos:prefLabel "synthesize";
my:construct rdf:type skos:Concept;  
  skos:prefLabel "construct";
my:skillTaxonomy rdf:type skos:ConceptScheme;  
  skos:hasTopConcept my:produce;  
  skos:hasTopConcept my:self-manage.
```
The skos:ConceptSchema class is used to organize concepts in catalogs. We propose this solution in order to provide an accessible entry point for managed catalogs. In fact, we can assign a URI to my:skillTaxonomy schema and make it simply accessible by both humans and software agents. Moreover, in order to model a specific competency catalog we need to exploit the skos:broader property to represent the is-a relation for taxonomies. Furthermore, we extend the skos:related property to provide the my:hasPart property and to build partonomies of competencies. The following code shows how to model part-of relations between competencies with SKOS:

```xml
ex:hasPart rdfs:subPropertyOf skos:narrower.
```

Finally, when we want to build concept maps able to organize documents, learning objects, learning activities, tasks, etc. we need at least two relations: part-of and prerequisite. In SKOS, we could use the above defined my:hasPart property and extend again the skos:related property providing the new my:isRequiredBy property. The following code illustrates how to model prerequisite relations in SKOS:

```xml
ex:isRequiredBy rdfs:subPropertyOf skos:related.
```

Now, we only need to correlate Upper Ontologies and Domain Ontologies to complete the Semantic Layer definition. This link could be set through the use of the skos:related property. For instance, it is possible to create individuals for sk:Competency class and then link them with a SKOS concept:

```xml
my:evaluate-project-feasibility-Ref rdf:type sk:Competency.
my:evaluate-project-feasibility rdf:type skos:Concept;
skos:prefLabel "Evaluate projects feasibility".
```

### IV. COMPETENCY LIFECYCLE

Once the Semantic Layer is defined, we are able to explain how a suitable competency management improves human resources related processes and, in general, the enterprise processes. The figure 2 illustrates an overview of the proposed approach.

For instance, when a specific role in the enterprise has to be assigned to an employee, this one needs to own one or more specific competencies according to the relation between sk:Role and sk:Competency, defined in the Semantic Layer (see figure 1). A gap analysis is performed using information coming from the HRIS (that is used by the corporate) and organized in the Semantic Layer. The gap analysis will exactly return those missing competencies. Starting from the last ones, a learning plan is defined and a set of learning and assessment activities are executed by the involved employee. At the end of the learning process, the employee’s profile is updated in the Semantic Layer and synchronized with the HRIS data structures (competencies digital records). Typically, the described process is performed with a few software automatisms. In order to improve the process, we firstly proposed a semantic envelope of competencies information (see section III). Hence, a mechanism to automatically define competency-driven learning paths is required.

The Intelligent Web Teacher (IWT) [10] is a commercial Semantic Web-based Educational System able to automatically assemble and deliver personalized and contextualized learning experiences including resources, services and available tools. IWT exploits ontologies, annotated learning objects and learner profiles in order to perform its tasks. In IWT, the personalized learning experience definition process starts from the identification of one or more target concepts (e.g. subjects, skills or competencies) over a concept map in which concepts and relations are defined according to the modelled educational domain. IWT is able to extract from the concept map a learning path (made up of the due ordered sequence of concepts) oriented to the acquisition of identified target concepts, to bind the extracted learning path to a sequence of learning activities (in the simplest case a learning activity is a learning object) and to personalize the learning activities sequence according to the considered learner profile (cognitive state and learning preferences). IWT also provides user-friendly tools for the authoring of ontologies and learning objects. Further details about IWT techniques and algorithms are better illustrated in [11] and [10]. IWT handles the learning experience execution phase as well. The involved learner accesses the personalized ordered sequence of learning activities and executes a final exam in order to assess his/her knowledge, skills or competencies. Subsequently, IWT can update the proper learner’s profile. The IWT model can be used in the proposed approach in order to fulfill the Learning Plans Definition and the Learning Activities and Assessment Execution steps of the process depicted in figure 2. The table I illustrates the correspondence between IWT knowledge and data structures and the Semantic Layer defined in this work.

The last brick of the proposed approach consists in exploiting social networking techniques to foster the knowledge sharing in the enterprise context. Our purpose is to define an Enterprise Social Network (a social computing software like Facebook used in a corporate domain following the Enterprise 2.0 paradigm) useful to publish employees’ profiles, communicate/collaborate with co-workers, etc. In this way, the employees can build and manage their relationship networks, follow people, publish their status or their current work activity and so on. Once a new competency is added to the Semantic Layer this is suddenly reflected by the Enterprise Social Net-
work. Users connected with or following the employee who has acquired the new competency are notified about the event. The Enterprise Social Network will foster communication and collaboration between co-workers also improving their work activities by sharing their knowledge. The question who can help me with this problem? will be agilely answered by exploiting the collective intelligence with the social computing paradigms. The integration between the Semantic Layer and the Enterprise Social Network is realized by using accepted Semantic Web ontological schemas like FOAF [9] able to model a network of user profiles and a wide accepted RDF query language like SPARQL. In figure 3 an employee decides to follow a colleague by using a mechanism like Twitter9. When a new competency is added to the profile of A a SPARQL9 query returns the new competency provided by the Semantic Layer. The retrieved information is mapped in RSS that is a suitable representation for data that are exchanged on the Web 2.0. The RSS Aggregator page of B simply reads the updated RSS feed (follows A) showing the new information.

V. Final Remarks

This work proposes an approach to develop and sustain effective competency management in the enterprise context by exploiting competency-based learning (the benefits of which are based on developing new methods to foster the sense of belonging of workers in the knowledge organizations [12] and on sustaining the Double-Loop [13]) supported by social and semantic techniques. The improvement is achieved by defining a Semantic Layer supporting the integration of a Semantic Web-based Educational System, an existing Human Resource Information System and an Enterprise Social Network software. At the moment we are planning to develop the integrated system using Microsoft Sharepoint (a widely adopted enterprise portal framework with several social networking and collaborative features) and to evaluate the proposed approach in ARISTOTELE Project (co-funded by European Community in the context of FP7 - framework programme for R&D 2007-2013). Main advantages of the proposed approach are the automatization of competency profiles updates (a feature already available in IWT) and the simplification of knowledge sharing about existing competencies (due to the introduction of the Social Networking paradigm). The possibility to use common query languages, like SPARQL, enables the realization of new user scenarios like, for instance, searching people with specific competencies (User Queries in figure 2). Furthermore, the use of FOAF, ResumeRDF and SKOS also enables the sharing of enterprise explicit knowledge and the interoperability with other semantic softwares. Finally, the acceptance of the Linked Data [14] vision and the correlation with external open data set (e.g. DBPedia) will enable the execution of competency finding also on external social networks.

References


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TABLE I

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<td>target concepts</td>
<td>target competencies (SKOS concepts)</td>
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<td>learners’ profiles</td>
<td>employees’ competency profiles (ResumeRDF, FOAF, SK, SKOS)</td>
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<tr>
<td>learning activities</td>
<td>learning activities (instances of sk:LearningActivity)</td>
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![Fig. 3. Enterprise Social Network and Semantic Layer integration.](image-url)