ONTOLOGY DEVELOPMENT FOR HUMAN RESOURCE MANAGEMENT

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Modern Human Resource Management (HRM) for knowledge-based enterprises must consider competencies of the workforce on a more detailed level of description than in the past. With this more complex description and the requirement to exchange information between different organizations in networked enterprises it becomes necessary to standardize the description of competencies and other related concepts. We have developed an ontology containing concepts of HRM for two different projects: a meta-search engine for searching for jobs in job portals and for a university competence management system. We present the requirements derived from the two projects and describe the design of the ontology. This ontology is characterized by its integration of job descriptions, concepts for evaluating competencies on different levels and evidences for competencies. The definition is also aligned with the HR-XML approach of defining competence profiles.

1 Introduction

Human Resource Management (HRM) or more specifically competence management is an important function of knowledge management because it reasons about an organization's most important resource – the knowledge and skills of its staff. Typically such functions as staffing, project staffing, human resources development and more are supported by competence management, i.e. the reasoning about availability and absence of required competencies both on the level of an organization as well as on the level of individual members of the organization.

Traditionally, in personal management more coarse-grained reasoning was applied. Job postings internally as well as externally contained a job type (e.g. programmer, database manager or accountant) or a certain university degree that is required were used to describe which competencies an applicant should have. The US Office of Personnel Management (1999) reports on fundamental changes in the Human Resource Area and argue that competencies may help organizations to focus on the characteristics their employees must possess in order for them to be successful and that competencies also provide a means to measure employee performance and to align performance with business strategies. Consequently, recent versions of Enterprise Resource Planning (ERP)-systems provide modules for competency management. However, the supported functionality is scarce.

There exist some research on requirements for a more sophisticated competence management for companies. Bergenhenegouwen et al. (1996) investigate the potentials arising

from detailed competence management and Lindgren et al. (2004) derive requirements for competence managements system from several case studies and the cited study.

In many cases information about competencies are exchanged between different organizations. The HR-XML consortium (Allen and Pilot 2001) has defined different XML-Schemes to exchange HR-related information between organizations. These definitions, however, do not include definitions of certain competencies but only a method how to link claimed competencies to an external definition. Therefore competencies should be "standardized" additionally to understand what a certain competence means. In HR-XML the term taxonomy is used and usually taxonomies are only used to describe competency hierarchies. Ontologies are a stronger form of knowledge representation by applying additional relations and constraints between concepts. They are a means to support understanding between communicating partners. An ontology for HRM can define concepts such as "competency", "job" and certain attributes of such concepts as well as the relationships between these concepts. Thus we may define which competencies are required for a certain job and which knowledge and experience is required to achieve a certain level of competence.

We have developed an ontology that supports two different projects: a project on meta-search in job portals (Dorn and Naz 2007) and a competence management system at universities (Dorn and Pichlmair 2007). In contrast to other described ontologies, we support different levels of competencies as well as satisfaction degrees for each level. An evidence for a competency is a concept to show how a competency was achieved. Levels reflect the problem that also the evaluators of certain competencies require a certain competency to evaluate others.

Section 2 of paper is about related work. In section 3, we describe the requirements on an ontology for HRM. Section 4 describes the design of our ontology. We conclude our work in section 5 and also describe our future work.

2 Related Work

There exists some work on taxonomies for describing competencies. On one hand there are taxonomies for job descriptions such as the "Standard Occupational Classification (SOC)" (http://www.bls.gov/soc) of the US Federal statistical agencies with 820 occupations to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data. With the support of the European Commission, a consortium of eleven major ICT companies has described the skills and competencies required by the ICT industry in Europe with the co-ordination of International Co-operation Europe Ltd (ICEL 2001).

For competencies, there are many publications with a generic classification into three to five types of skills, e.g. Tucker and Cofsky (1993) differentiate skills, knowledge, self-concepts, traits and motives. There are only few references to detailed representations. In the KOWIEN project (Dittmann 2003) such a taxonomy for skills was developed. Noda (2006) proposes an ontology for evaluating skill-based human performance.

Bizer et al. (2005) claim the development of human resource ontology by the integration of existing standards and classifications. They also claimed about skill sub-ontology that defines concepts representing competencies, derived from KOWIEN ontology and defines the competence level. But they do not discuss the design of the ontology, its attributes and the relationships between sub ontologies.

Harzallah et al. (2002) worked on the project CommOnCv to transform the current website into real Career Networks i.e. virtual places where both job seekers and employers can find relevant and efficient services to meet their respective needs but they do not consider the benefits that can be achieved by using meta-search engines for e-recruitment. They focused only at the semantic search in recruitment process.

Schmidt and Kunzmann (2006) describe an ontology that integrates concepts from skill management and learning. This approach is similar to our approach, however, they do not consider job descriptions composed of required competencies.

Uschold and King (1995) describe a methodology for building ontologies in four main steps and describe guidelines derived from their experience. A methodology for building ontologies is also provided by Lau and Sure (2002). They show how their five-step methodology is used during the introduction of an ontology-based skill management system at a large insurance company.

Sure et al. (2000) describe the redesign of a skill management system to an ontology based skill management system focusing on a matching-algorithm.

3 Requirements on an Ontology for Human Resource Management

Ontologies were first used as a representational means in artificial intelligence where in knowledge representation a separation of taxonomic and assertional knowledge is proposed. The assertional knowledge describes typically certain existing, individual objects and the taxonomic knowledge some kind of blueprint for such objects. In simple applications, a taxonomy of objects is sufficient to represent the conceptual knowledge. However, if the meaning of objects or concepts must be constrained stronger in order to support some kind of understanding, we need an ontology to describe the taxonomic knowledge. In taxonomies we relate described concepts in a kind of inheritance hierarchy. In an ontology further relations are defined in order to constrain concepts stronger against each other. Thus, by this stronger constrainedness it should be clearer how to assign correctly certain individuals to concepts and moreover, to define consistent processing on these concepts.

Typically, some kinds of taxonomies are used in the HR domain for grouping such concepts as competencies, job occupation types and learning objects. With additional relations between steps we support a stronger reasoning resulting in a more robust and trustworthy knowledge base. In the following we identify such relations as well as certain attributes of core concepts of our ontology.

The requirements for ontology stem from two projects: university competence management and e-recruitment with a meta-search for jobs.

3.1 University Competence Management System

"A competency is a specific, identifiable, definable and measurable knowledge, skills and/or other deployment related characteristics which a human resource may possess and which is necessary for the performance of activity within a specific concept" (Allen and Pilot 2001). Resources of competency are knowledge, know-how, and behaviors. Knowledge is something that we learn through education system. It can be theoretical knowledge or procedural knowledge. Know-how is gained through personal experience and by practice. Behaviors are individual characteristics. Behavior conditions the way knowledge and know-how are put into practice.

Competence management systems help on the one hand to describe the grades of the staff's/student's competencies by storing competency profiles and on the other hand to identify gaps and development potentials. For modeling competency profiles we use HR-XML. This standard developed by the HR-XML Consortium describes Human Resource relevant processes and data (www.hr-xml.org, Allen and Pilot 2001).

Modeling such competency profiles has to satisfy three important requirements: comparability, validity and data privacy. For creating comparability, different actors have to use the same words for competencies and use the same scales for measuring. An ontology is an accepted approach to create such a common language (Uschold and King 1995). Validity means that the values of the competence grades are true. Evidences (e.g. digital certificates) or measuring the competence by experts or peer groups can prove the validity.

Competencies are not static: the required knowledge and experience may change over time and the grade an individual person has can change. An algorithm using evidences' values to aggregate the total grade of a competence has to support learning and unlearning. Thus for designing the ontology we have to model the structure of evidences and a kind of objects that are able to increase competency values as well as different levels and rules to describe under which conditions a grade will change.

One way to represent such grades could be as a percentage. The problem in representing grades is the difficulty to define which conditions must be fulfilled, to reach completeness (our knowledge about a certain topic will almost never be complete). Every other value is dependant on this critical definition. We favor a kind of fuzzy value that represents a dimension of "insecurity". The higher a value is, the more we can say that someone fulfils the competence without demanding completeness.

3.2 Job Meta-search

Job seekers are in search of best suitable jobs and recruiters in search of competent employees. Both face the problems of lack of transparency in the labor market. Recruiters face increased cost for manually pre-selecting potential candidates, increased transaction cost etc. For recruiters there are difficulties to choose the best person as they have a large number of CVs and information. Many companies therefore try to improve the staffing process by asking for electronic applications. To further improve this process "standard-

ized" competency profiles can be used to automatically filter applications that are required. This is partly supported by HR-XML. With HR-XML a CV may be submitted in a standardized manner and it may contain the competencies of the applicant.

Job seekers face the problems to explain about their competencies in their CVs and have difficulties to find job offers, which ideally correspond to their profiles, due to the large number of search engines. Thus electronic support with semantic techniques support the automatic comparison of offered and required competency profiles. Addressing all existing job portals also supports the job seeker. Moreover, if competency profiles are generated already at a university as envisioned in our other project, the job seeker does not have to care about the representation and evidences for their competencies.

We developed a prototype for integrating information of different job portals into one meta-search engine so that people can access more than one job portal at a time. Since different job search engines use different data, concepts and granularities of knowledge, we need a mechanism to translate between different concepts. For example, some offers in job portals describe required competencies; others demand certain university degrees and a third group of portals give job descriptions. In order to find matches we must be able to translate between the three concepts. After collecting the results, duplicate links have to be removed and the results have to be ranked in a single merged list. This has also to be supported by semantic reasoning.

3.3 Derived Requirements

An e-recruitment system may use a competence management system at a university to find capable students by analyzing their competency profiles. A university competence management system may use a meta-search engine to search for appropriate jobs for students. In both cases, the systems need a common language to enable the matching of profiles and preferences of the searching companies and students.

We identified following requirements for our ontology:

- matching job requirements and competency profiles of the candidate and vice versa,
- synonyms of occupations and competencies,
- relating occupations to required competencies,
- concepts for personal attributes,
- scale and measurement concepts for competencies and learning objects and
- dependencies between competencies

4 Ontology Design

The design of our ontology is guided by the requirements described before. We use Web Ontology Language (OWL) for modeling.

The ontology is separated in sub-ontologies for competencies, occupations and learning objects to solve the problems in e-recruitment and competence management. Our ontology is also used for user interfaces. Our aim is to achieve all the benefits of

semantic reasoning for competence management and e-recruitment by developing a competency logic. Fig. 1 explains how our ontology can be used in e-recruitment and university. Our ontology relates competency and occupation sub-ontologies and supports thus matching of demands and offers for both the recruiters and job seekers. It can be used to find the semantic relationships, e.g. synonym and hypernym between job categories of various semantically different job portals (Dorn and Naz 2007).

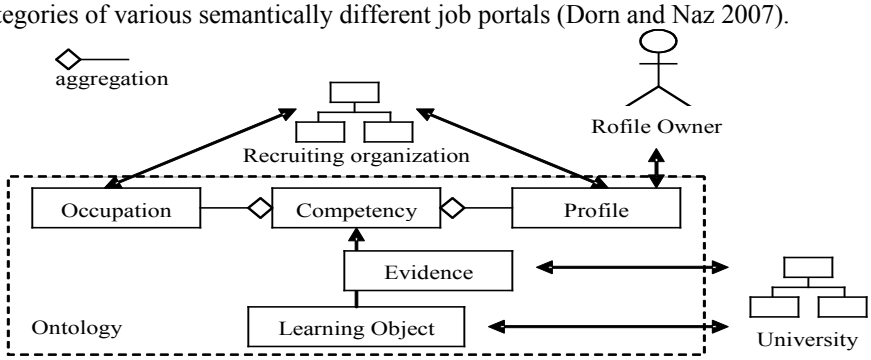

Figure. 1. Ontology for human resource tasks.

4.1 Competencies

We considered two types of competencies: *functional competencies* and *behavioral competencies* as shown in the Figure 2. Functional competencies are expressed in terms of knowledge, skills and abilities. They are also called hard, job related competencies or technical competencies. Behavioral competencies (also called soft competencies) define the personal behaviors or attitudes. An example of behavioral competency is leadership i.e. the ability to guide, motivate and influence personnel to meet the organization goals. We focused on the computer and business related functional competencies. We identified different major, minor and sub-groups for functional and behavioral competencies. We also maintain the abilities, skills and knowledge connected with a job that someone requires to perform a job effectively.

In OWL, "attributes" of classes (concepts) are represented by OWL data type properties and "relationships" between classes are represented by OWL object properties. We have to represent general knowledge how a certain competency is related to other concepts and we need attributes that are used to store certain values of an individual person. We identified following attributes and relationships to define a competency in our ontology.

- "has_knowledge_level", OWL object type property to record the knowledge-level of the competency.
- "has_experience_level", OWL object type property to record the experience-level of the competency. It has further three sub-properties i.e. h*as_computer_experience_level*, *has_business_experience_level* and *has_behavioral_experience_level*.

- "has_grade" OWL object type property to record the satisfactory level for knowledge and experience levels. It has further two sub-properties *has_experience_grade* and *has_knowledge_grade*.
- "synonyms", OWL data or object type property to maintain synonyms of competencies.
- "requires", OWL object type property to describe that one competency B is necessary to reach a grade of another competency A.
- "influences", OWL object type property to describe that one competency B influences the grade of another competency A. B is not necessary to reach a grade of competency A.
- "has_evidences", OWL object type property to describe the evidences for a competency of an individual person.

Competencies at experience level have sub properties but not at the knowledge level because both of them are evaluated in different ways. Experience level determination varies from subject to subject. Knowledge, experience and grade levels are given in more detail in section 4.2. We also identified that there is part-type relationship between competencies. For-example C++ is a part-of Object Oriented Programming.

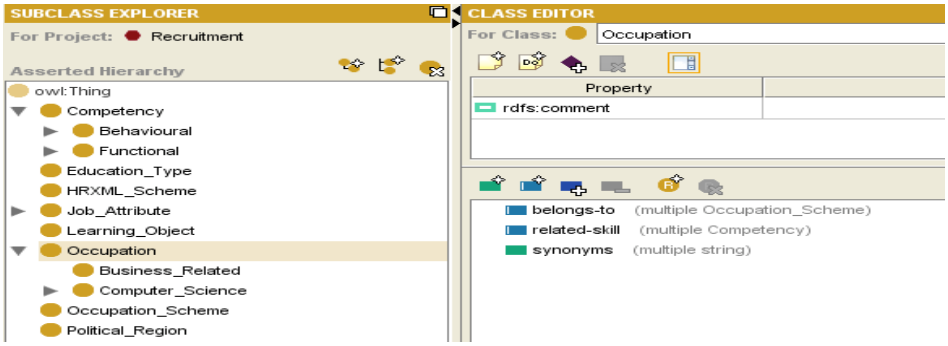

Figure. 2. Ontology with Competencies, Occupations and Learning Objects.

4.2 Levels and Grades for Competencies

Competencies are associated with competency levels to describe different degrees of an abstract competency type. For our ontology, we defined levels to measure computer science, business, and behavioral competencies as shown in Table 1.

Table 1. Levels to measure competencies

Competencies	Knowledge Level	Experience Level
Computer Science	Elementary, Intermediate, Advanced	Basic, Advanced
Business		Beginner, Competent, Professional
Behavioral		Basic, Professional, Corporate

For some computer science skills i.e. programming, we added one more *Intermediate* experience level. It is to be noted that level determination is not based upon time in the job and few competencies have influence on others. For example, communication competency has influence on presentation competency and vice versa. Written communication skill has effect on the text of slides and oral communication skill has effect on the talk during presentation. Competencies can be uni- or bidirectional dependent.

We distinguish grades for knowledge and experience level. Grades value can be between 0 to 1. Grades for levels can also be interpreted as satisfactory level. For example, we can say that if a person has an intermediate knowledge level programming skill then grade assigned is 0.5 and if a person has advanced experience level programming skill then grade assigned is 1. The competency of a grade issuing authority (expert/professor) issuing the grade, must be at least one level higher than the competency of the person to be evaluated. For example, the presentation technique can be evaluated by a computer science professor/teacher at the lowest level. Higher level experts in communication training must be the evaluators of presentation skills. Thus a professor at a computer science department may evaluate programming skills on a higher level than a professor in a business management department.

Moreover, if one person has the highest grade issued by a secondary school authority and another has the highest grade issued by a university authority, then the representation must state that a person with university grade is at a higher competency level then the person having a secondary school grade.

4.3 Evidences and Measurement of Competencies

Evidences are necessary to prove that a person has reached a certain competency grade. Describing evidences the ontology contains:

- "knowledge_value", OWL data type property to describe the value used by the algorithm discussed in 3.1 to aggregate the knowledge grade of a competency
- "experience_value", OWL data type property to describe the value used by the algorithm discussed in 3.1 to aggregate the experience grade of a competency
- "knowledge_level", OWL data type property to describe the knowledge level
- "experience_level", OWL data type property to describe the knowledge level

To achieve valid grades for competencies we have to store and aggregate different evidences. Measurement values are one kind of evidence. Typically competencies are

evaluated by an expert or by a person at a higher competency level, but in some cases also a peer evaluation is useful. Moreover, someone on the highest level can only be evaluated by people reached at least the same level.

Different persons can evaluate on different levels as defined above. Such values are not so valid as values measured by one person on different levels. Regarding the example students are doing a peer evaluation concerning the competency "presentation techniques" we can be sure, that they have less experience and tend to give higher values near 1, because they do not realize lacks an expert could. If a student gets the maximum value it does not mean that he or she is an expert, it just means, that he or she reached the same level as his or her peers reached, because a difference cannot be identified.

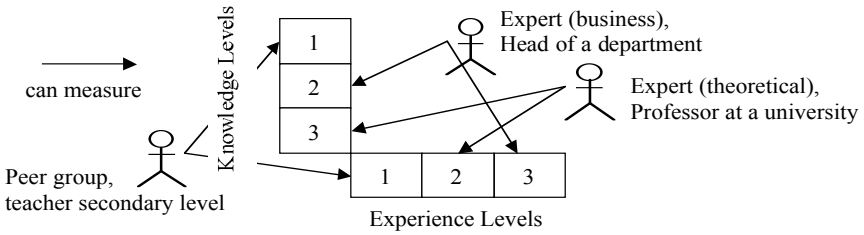

Figure. 3. Measuring competencies on different levels.

Figure 3 shows how measurement and assessment works. Different groups of persons are able to measure in different levels. So there is a big scale where different parts of the scale are shown to different measuring people. To get valid values it is important that peers can just give grades up to their level. If a person is at level two he or she can just measure grades up to this level.

Measurement (or evaluation) is a special form of an evidence. It inherits attributes and relations from the *evidence* concept. For measurement the ontology contains the following:

- "scale", OWL object type property to describe the measurement scale

4.4 Occupations Ontology

During integration of job portals, we found that different job portals are representing the job categories in different ways. Some job portals contain different names for representing the job category and some contain the generic concepts or specific concepts. For the unified user interface of job MSE, we have to translate the job categories to one meaningful and appropriate standard format. We integrated the computer and business related occupations from widespread used standard, Standard Occupation Classification (SOC) and skill from International Co-operation Europe Ltd, into one meaningful and appropriate format and maintained it in our ontology. Our domain ontology can be used to translate the concepts related to job categories from the job portals, according to the integrated format. The translated concepts are used on the unified interface of job MSE. We identified following attributes and relationships for the job ontology.

- "related_skill", OWL object type property maintains the relation between occupation and competency ontology.
- "synonyms", OWL data or object type property to keep the similar terms for occupations.
- "belongs_to", OWL object type property maintains the relations between occupation schemes i.e. SOC or scheme by International Co-operation Europe Ltd's

By using the related-skill attribute from our job ontology, we can find the related competencies for a particular job and is useful for our meta-search engine for job search.

4.5 Learning Objects Ontology

The term "Learning Objects" is well known in e-learning concepts (LOM). The expression is usually used for digital or non digital entities that are used for learning, education and training (IMS). We understand a learning object as a unit whose goal is to create competencies. Using this definition, we consider books, projects in enterprises or persons having a trainer's function as learning objects. Figure 4 shows a structure of Learning Objects.

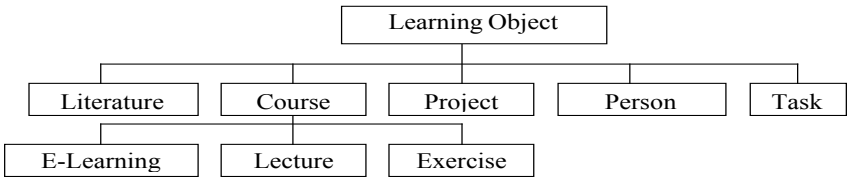

Figure. 4. Learning Objects in the Ontology.

Learning Objects are part of the ontology. The modelling is not focused on the general data of learning objects but more on the following:

- "time_needed", OWL data type property to describe the time needed to get evidences from the learning object.
- "mode", OWL data type property to describe the learning mode (e.g. alone, lecture, groups, e-learning)
- "preconditions", OWL object type property to describe the required competencies
- "creates_evidence", OWL object type property to describe the evidence created by the learning object

Every instantiated learning object has effects on the competency's grade and causes evidences in the person's profile. Some learning objects will have fewer effects on the aggregated value than others. For example: If a person is reading a book the learning object "book" is instantiated and causes an evidence in the person's profile. Different learning objects have different effects on different levels.

5 Conclusion and Outlook

In this paper we have presented an ontology model with competencies, learning objects and occupations for e-recruitment and competence management systems. We identified

attributes describing functional and behavioural competencies more thoroughly and also some attributes for occupations. Our modelled ontology can be used for comparing competency profiles of certain individuals with those of expected competencies in job offers and for finding differences between given goal profiles and those of certain individuals.

We focused on the design of the ontology. This ontology was created in several steps. A first ontology was developed in a course with about 60 students each describing his/her competencies with HR-XML and then extracting common competencies into an OWL ontology. In a second step, two supervisors refined the ontology by more expertise. In a third step, the ontology was revised due to the second project on meta-search. It is assumed that next extensions will be required if we consider competence management in enterprises and the alignment of strategic enterprise competencies with the aggregation of competencies of all staff members. A further alignment may be necessary if we integrate theory and practise of e-learning courses as well as other learning objects.

Trust into claimed competencies seems to be an important aspect of successful competence management. On one side, there must be evidences that proof the existence of a certain competency. On the other side, there must be trust in evaluators. Thus it would be an interesting approach to extend such a framework with the possibility to evaluate additional given assessments. This could lead to new forms of evaluation of teachers as well as for whole schools. Data privacy is a topic also not discussed here. Profile owners must have full control over their data and be able to specify which data can be seen by which user groups. We use encryption of XML to support this (Dorn and Pichlmair):

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