USE OF COMPETENCE ONTOLOGICAL MODEL FOR MATCHING OF QUALIFICATIONS

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Abstract. The ontological representation of competence knowledge about various specialties (from national qualifications frameworks) for their efficient matching and retrieval for the purpose of the European and National Qualifications Frameworks transparency is represented. The structure of atomic competencies is formalized by ontology that can be automatically built by semantically marked Web resources from the Semantic Media Wiki environment. Computer ontologies and methods of their use to ensure the transparency of the European and National Qualification Frameworks are suggested.

Keywords: ontology, competence, qualification, Semantic Web, Wiki.

Introduction

Now such socio-economic and demographic processes as rapid globalization and labor mobility require the development and implementation of methods and tools for integration of national qualifications systems that have to provide transparency of relevant diplomas and certificates of lifelong education. Many European countries implement their national qualifications systems but do not propose common vision of requirements to their integration.

Thus, the development of methods and tools ensuring the transparency of the European and National Qualifications Frameworks is a relevant and actual task.

Therefore, the development of conceptual grounds and methodological aspects of the development and implementation of the national qualification frameworks are being actively discussed by the academic community (Baidenko, 1999; Sukharnikov, 2012).

Tools of establishing the relationship between levels of qualifications frameworks

The European Qualifications Framework[1)] is a meta-structure that provides a comparison of the various national qualification structures. Its importance is caused

by increasing globalization of the labor market and mobility of human resources, academic mobility in the integration processes in the sphere of education, especially in Europe (Bologna and Copenhagen processes).

The European Qualifications Framework has eight interrelated levels of the qualification that are defined according to learning outcomes – the triad of professional qualities: knowledge, skills and competencies. This approach helps to compare qualifications and simplifies their recognition. Suppose that an organization or enterprise in one of the countries of the European Union, for example in Sweden, is not sure about choosing the candidate from another country, for instance from France, for a specific job. This is due to the fact that employers have no idea about the qualifications of the French candidate. However, once the French qualification is compared with the EQF, the Swedish employers who have similar correlations will receive full information about the qualification of the applicant.

The national qualifications are intended not only to describe the qualifications, but also to modernize the system of vocational education and staff training, to ensure wide public access to qualifications. The role of the national qualifications frameworks in modernization is that vocational education should go to learning outcomes. To do this, it is necessary to develop cooperation in the field of work, work out professional standards, new technology for competencies evaluation that form the basis of qualifications and recognize the learning outcomes, regardless of whether they have been achieved in the area of formal or non-formal learning. The role of the national qualifications frameworks in expanding access to qualifications is that owing to the framework everybody who wants has a possibility to determine their own competencies without going through training in the framework of compulsory education programs.

Ukraine has also started the process of developing and implementing a national framework of qualifications.

The process of formation and development of the national qualifications framework in Ukraine is aimed at implementing the policy of learning throughout life and is based on common European principles in the field of education and vocational training. The national framework of qualifications provides the participation of the social partners in the processes that are associated with the recognition of learning outcomes, development, quality assurance and qualification award. Recognition of the learning outcomes is done regardless of the method of their achievement – both by recognition of formal and non-formal or informal education.

The main element of the national system of qualifications is the National Qualifications Framework (NQF) which covers all levels and qualifications subsystems and relates to the European Qualifications Framework through the whole life. The National Qualifications Framework describes levels for all subsystems of qualifications – both formal education qualifications and vocational qualifications.

The comparison of the qualifications with the qualification levels of the NQF is based on the ratio of the learning outcomes of a particular type of qualification with the description of a certain level of NQF. However, there are now a number of challenges that complicate the implementation of the National Qualifications Framework in Ukraine, in particular: (i) existing qualifications of the professional sphere and education standards do not take into account the system of competencies in the NQF and, as a rule, they cannot be compared with the national and European qualifications frameworks; (ii) the modern structure of educational standards is an extremely complex and regulated which significantly limits the abilities of educational institutions with respect to the modification of training programs in accordance with the needs of the labor market; (iii) higher education qualifications are not formally compared with the qualifications of the European Higher Education Area (EHEA); (iv) standards of competence for a significant number of categories and sub-classes of occupations are not formed, so that there are difficulties with the qualification award; (v) the list of directions and specialties of higher education is extremely detailed and does not meet the needs of the labor market.

To solve these problems, we recommend the following steps: (a) to develop characteristics of domestic educational qualifications taking into account the descriptors of the National Qualifications Framework; (b) to perform a formal comparison of the domestic educational qualifications with the National Qualifications Framework (by levels); (c) to compare higher education qualifications with the structure of qualifications of the European Higher Education Area; (d) to take a set of measures for the implementation of competence approach to educational standards and curricula, teaching and assessment practices; (e) to form the professional standards taking into account the descriptors of the National Qualifications Framework and compare professional qualifications with the qualification levels of the NQF; (f) to introduce new approaches to the development of branch standards for higher education recognizing that: (g) Higher Education branch standards are developed by education branches, the list of which is advisable to form in accordance with the International Standard Classification of Education (ISCED) – branch-standard of higher education is a holistic document, which must contain a description of the socio-personal, general science, instrumental and general professional competencies, as well as methods of demonstration and evaluation criteria for learning outcomes; (h) to recognize the ability to determine the professional competencies (learning outcomes) of graduates and build educational and professional training program as the inalienable academic right and responsibility of the higher education institutions.

In our opinion it is important to analyze the development and use of tools to correlate levels of qualifications in order to ensure the transparency of the European and National Qualifications Frameworks.

RCD (Reusable Competency Definition) and SRCM (Simple Reusable Competency Mapping) can be used for these purposes. RCD was developed as a standard for a consistent and structured description of competencies. This standard provides an opportunity not only to describe the competencies, but also to share information about them between different automated systems. However, the competencies described with the use of natural language do not carry the semantic load. There were cases when the two nearly identical competencies were recognized by the system as completely different due to the lack of possibility for their semantic analysis. An alternative to the RCD standard became the SRCM standard which complemented RCD with logical connections. It helped to improve the level of understanding of competencies and their identification. However, the SRCM standard could not guarantee a qualitative analysis without the full semantic content. That is why it is the computer ontologies that are seen as the most appropriate tool of qualifications representation and learning outcomes description.

Use of computer ontologies for semantic representation of competencies

Ontological analysis is widely used as an instrument of formal representation of various subject domains (Gruber, 1991). Computer ontology is a formal explicit description of concepts in the domain (classes), properties of each concept which contains a variety of qualities and attributes of concepts (properties, roles, slots), restrictions that are added to the properties (facets). Ontologies together with a set of individual instances of classes form the knowledge base.[2)] Now the most popular language of ontology representation is OWL (Ontology Web Language). OWL ontology is a sequence of axioms and facts that can be associated by references to other ontologies.

Ontologies help to analyze and reuse knowledge in the domain area. The use of computer ontologies for semantic representation of distance learning domain (Gladun & Rogushina, 2011; Ronchetti & Sant, 2007) and competencies[3)] (Paquette, 2007) is analyzed by many researchers. However, the aspect of their applications as the tool to ensure the transparency of qualifications has not become the subject of a separate study.

Computer ontology as a base of semantic markup of competence descriptions

A lot of applications oriented on Semantic Web use ontologies as a base of domain knowledge that are oriented on semantic markup of various documents (natural language texts, semi-structures and structured texts, multimedia context etc.) by ontological concepts and relations.

Now a lot of descriptions of competencies such as disciplines, specialties of different educational organization are represented by Wiki resources on their Web sites, and many others can be easy transformed to this form (Krötzsch et al., 2006).

Popular representation of information in Wiki resources can be semantically enriched in this way. For example, Semantic Media Wiki provides to users such tools of semantic structuring as categories and semantic properties. Categories help to link Wiki pages with more general terms and group them, and semantic properties allow to define various semantic features and their values of concept linked with some page.

Semantic Media Wiki propose an instrument for building of the OWL ontology by the set of Wiki pages on base of their categories and semantic properties. This ontology can be processed and visualized by Protégé. Unfortunately, there is no logical or semantic restrictions on ontology building in Semantic Media Wiki (Rogushina & Gladun, 2008).

An important open sources of semantically structured domain knowledge are various Wiki-resources (for example, http://isrg.kit.znu.edu.ua ontology of key terms). Their categories and semantic properties can be used as classes and object properties of domain ontology, and names of Wiki-pages – as individuals of ontology. Such domain ontology can be built automatically by special functions of Semantic Media Wiki or by special algorithms according to personal needs of users. Then this ontology can be processed by Protégé (Fig.1).

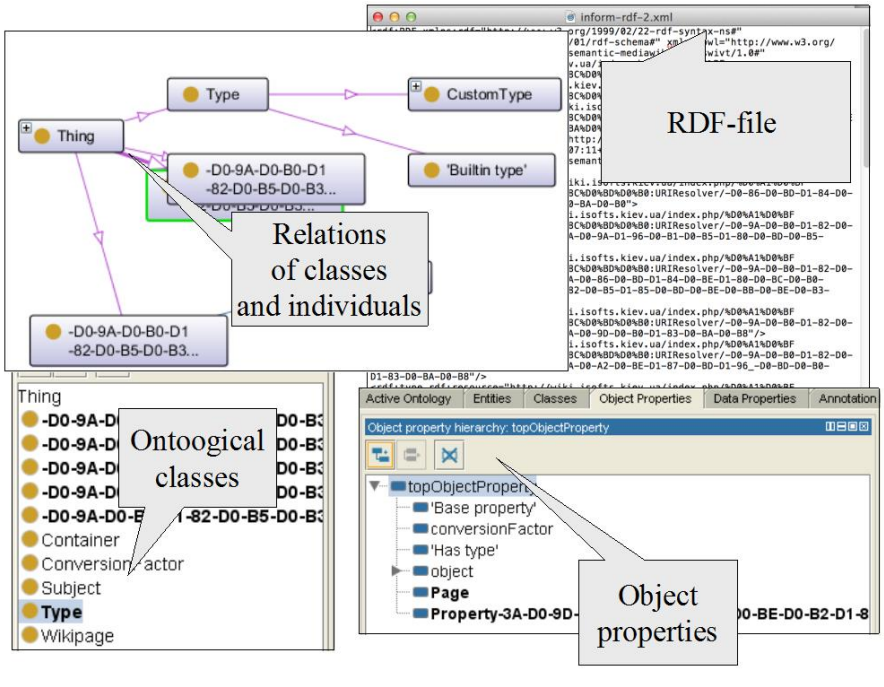

Fig. 1. Structure of competence ontology exported from Semantic Media Wiki

Personal domain ontology – for example, generated by pages edited by some user – can be used as a formalized model of user competencies and defines the sphere of expertise of this person. By comparing of such ontologies we can retrieve experts, tutors or other specialists by analysis of their competencies on semantic level.

Integration of these ontologies with European and National Qualifications Frameworks provides more pertinent matching of different taxonomies with personified information.

Today we don't have any universal ontology of competencies and qualifications that have been harmonized with all national and international approaches. But we can use a set of such ontologies that would be matched one with others.

That's why we propose the following method of competence matching: (1) define the documental content that can be used for description of the set of atomic competencies that define some complex information object (for example, requirements of employer or passport of postgraduate specialty); (2) transform these documents into the Wiki representation; (3) build the ontology that defines relations of atomic and complex competencies, disciplines, specialties, professions etc; (4) semantically marl up these Wiki resources by the concepts of this ontology that can be used as classes and by object properties of this ontology that can be used as semantic properties at Semantic Media Wiki; (5) at last, we can built semantic requests to these resources that are oriented on retrieval of individuals (humans, institutions etc.) with appropriate values of defined properties

We understand that there is no way to realize all these activities by any single organization but some parties of this work can be executed by relevant educational organizations or governmental structures. We propose the approach to knowledge-oriented subtask of this problem – the development of structure of competence ontology and methods of matching of various information objects marked up by the elements of this ontology.

Structure of competence ontology

Competence ontology defines semantic properties and relations of the main information objects deal with qualification of people, possibilities of learning organizations and requests of employers.

We propose to use as a basic element a *competence* $c \in C$. Competencies are divided on *atomic* competencies C_{atomic} and *complex* competencies $C_{complex}$, $C = C_{atomic} \cup C_{complex}$.

$$c \in C_{complex}, \text{ if } \exists c, c` \; c` \neq c, c` \in C, c` \subseteq c.$$

Atomic and complex competencies are the classes of competence ontology. Both of then are the subclasses of class "competence".

Other important classes of this ontology are: (i) discipline; (ii) specialty; (iii) person; (iv) organization.

All subclasses of class have some general properties. For example, all subclasses of "person" have properties "name", "year of birth", "residence" etc. These classes are made more concrete by their subclasses and various semantic object properties.

For example, class "person" has subclasses "student', "employer", "tutor", "researcher", "postgraduate student" etc. Such subclasses are different by some properties: "student" has properties "place of training", "specialty", "year", and "postgraduate student" has properties "scientific adviser", "theme of research work" (Fig.2).

An important characteristic of proposed approach is the fact that all main classes have semantic object properties with value from class "competence" that define their semantic aspects deal with competence analysis.

This approach is compatible with different formal knowledge-oriented models of qualifications. For example, eight levels of qualification of the European EQF standard can be represented by subclasses of class "qualification" with numerical values of data property "level" from 1 to 8, value of data property "qualification system" equal to "EQF" and with object properties "Knowledge", "Skills" and "Communication" with values from class "Competence".

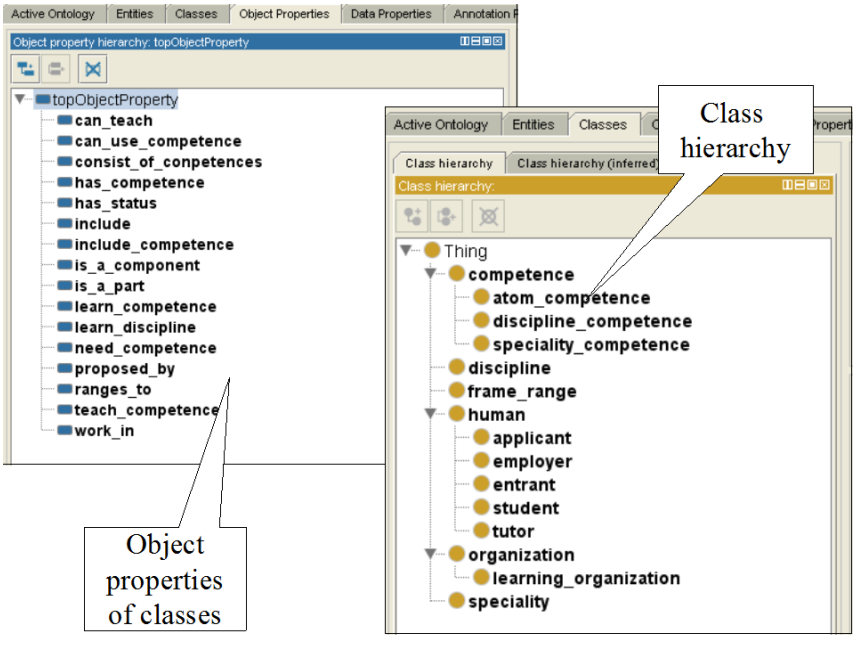

Fig. 2. Classes and object properties in competence ontology

Every individual of class "Qualification" that has data property "qualification system" equal to "EQF" obligatory has unique value of data property "level" from 1 to 8 and three nonempty sets of object properties "Knowledge", "Skills" and "Communication" with values from class "Competence".

The simplest model of qualifications on base of competence ontology can be formally represented by triple

$$q \in Q = \langle Iq, Lq, Compet = Kn \cup Sk \cup Com \cup \ldots \cup Compet_p \rangle, p = \overline{0,r},$$

where $iq_j \in Iq, j = \overline{1,n}$ – the identifier of qualification system; $Lq = \bigcup_{j=1}^{n} \{lq_{i_1}, \ldots, lq_{i_{s_j}}\}$, where $lq_{i_{s_j}}$ is a number of various levels in classification system iq_j ; Kn is a set of atomic competencies that characterizes the knowledge of appropriate qualification; Sk is a set of atomic competencies that characterizes the skills of appropriate qualification; Com is a set of atomic competencies that characterizes the communications of appropriate qualification; $Compet_p$ is a set of atomic competencies that characterizes the p-th set of appropriate qualification (hear we don't concretize the criteria of building of these sets that deal with specifics of different national and international qualification systems).

Various sets $Compet_p$ can be used in different qualification systems, but we state that two qualifications $A \in L$ and $B \in L$ are equal if their sets of competencies are identical:

$$A \in L \equiv B \in L \Leftrightarrow Compet_A \equiv Compet_B .$$

If some identical qualifications have different sets of competencies in different qualification systems, then we have to refine the set of atomic competencies or rules of transformation from complex competencies into the set of atomic ones.

Specialties and disciplines are modeled similarly.

The model of specialties on base of competence ontology can be formally represented by triple

$$s \in Sp = \langle Is, Ls, Compet = Compet_1 \cup \ldots \cup Compet_m \rangle,$$

where $is_j \in Is, j = \overline{1,n}$ – the identifier of classification system of specialities; $Ls = \bigcup_{j=1}^{n} \{ls_{i_1}, \ldots, ls_{i_{s_j}}\}$, where $ls_{i_{s_j}}$ is a number of various levels in classification system of specialities is_j; *Compet* is a set of atomic competencies that characterizes the appropriate competencies of specialities.

The formal model of disciplines based on of competence ontology can be formally represented by triple

$$d \in Disc = \langle Id, Ld, Compet = Compet_1 \cup \ldots \cup Compet_m \rangle,$$

where $id_j \in Id, j = \overline{1,n}$ – the identifier of qualification system; $Ld = \bigcup_{j=1}^{n} \{l_{i_1}, \ldots, l_{i_{s_j}}\}$, where $l_{i_{s_j}}$ is a number of various levels in classification systemof disciplines id_j; *Compet* is a set of atomic competencies that characterizes the appropriate competencies of disciplines.

Other concepts deal with competencies can be modeled on base of classes of proposed competence ontology in a similar way.

For example, formal model "employer" that is the subclass of person can be represented as an element e of Emp,

$$e \in Emp =< Ie, Name\_e, Adress\_e, Type\_e, Country\_e, CE = \{Compet_1, \ldots, Compet_x\} > ,$$

where $ie_j \in Ie, j = \overline{1,n}$ – the identifier of employer; $ne_j \in Name\_e, j = \overline{1,n}$ – the name of employer; $ae_j \in adress\_e, j = \overline{1,n}$ – the address of employer; CE is a set of competence sets where $Compet_y$ is a set of competencies that employer requires from y-th employee.

Relations of these concepts are visualize on Fig. 3.

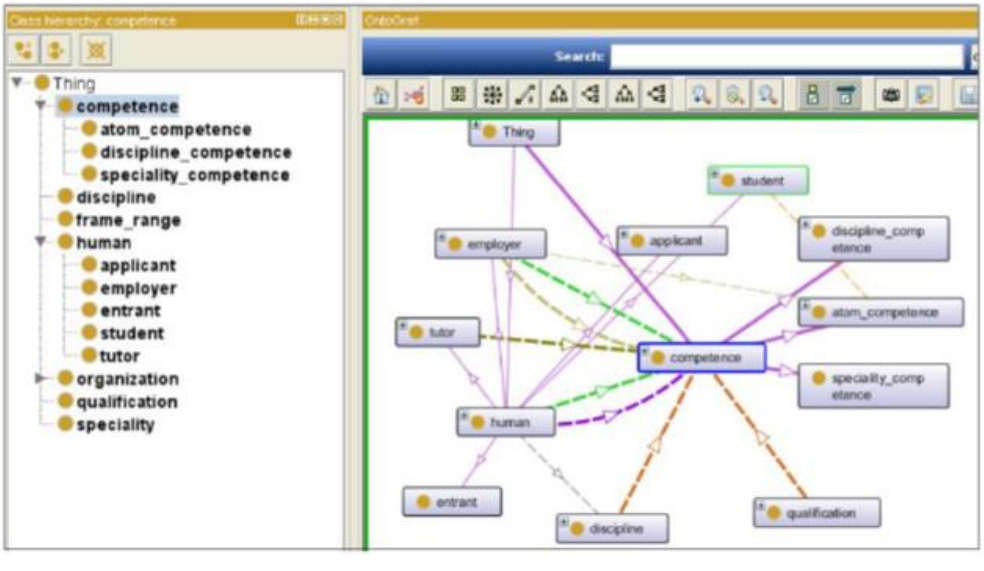

Fig. 3. Relations of competence ontology concepts

Matching of semantically marked up information objects

All these models contain the sets of competencies and can be matched by these components.

Availability of common provides the possibility of easy semantic comparison of different information objects where the set of competencies of one object is matched with the set of competencies of other object taking into account the meanings of these sets. We have to consider that one information object may contain more then one set of competencies. For example, the information object of class "tutor" has the sets of competencies "know", "can teach", "have certificate on teaching" etc.

We can build semantic requests to semantically marked up information objects that are represented by Semantic Media Wiki.

`For example, we can find all organizations from category "learning organization" where disciplines with proposed set of competencies are learned and show important information about these organizations.

This request is based on the function "ask".

{{#ask:
[[Category:learning organization]]
[[Discipline::Programming]]
[[Competence::C++]]
|?City
|?Country
|?Rating
|?Adress
|format=broadtable
}}

Request can contain some more complex components. For example, we can define the range of level and time of working, merge some requests into one by disjunction of conditions.

{{#ask:
[[Category:learning organization]]
[[Discipline::Programming||Software design]]
[[Competence::C++||Java]]
[[Level::>3]]
[[Level::<5]]
[[Is learned from::<2005]]
|?City
|?Country
|?Rating
|?Adress

|format=broadtable
}}

The results of such requests are represented on the relevant Wiki-pages and can be used a base of competence analysis. Such approach supports the semantic search (Fazzinga & Lukasiewicz, 2019) of information about disciplines, specializations, persons and organizations and provides matching of various information objects on the competence level. Proposed approach was used for design of the site of postgraduate study of the Institute of Software Systems of National Academy of Sciences of Ukraine.[4)]

Types of competence matching

We differ three types of competence matching: (i) *exact* correspondence of A and B – if $a \in A$ then $a \in B$; if $a \in B$ then $a \in A$; (ii) A is *subset* of B – if $a \in A$ then $a \in B$; (iii) *nonempty intersection* – $\exists a, a \in A, a \in B$.

Exact correspondence is the most appropriate result of retrieval but in practice this variant is very rare.

Incomplete correspondence where A is subset of B can be processed by finding of all subsets that satisfy B. This situation has two variants: (1) terms of request are the subset of its result; (2) result of request are the subset of their terms.

First situation usually does not cause any problems – for example, if employer needs a specialist who knows C++ but find somebody who knows C++, C# and Java or applicant needs in institute to learn software engineering but finds some organization that propose software engineering, parallel programming and semantic technologies.

However, if the results of matching are incomplete and multiple we need in facilities of their comparison. The measure of relative correspondence is proposed:

$$r(A,B) = \frac{|A \cap B|}{|A|},$$

where $A \subseteq B$ and $|A|$ is a number of elements in the set A. This function characterizes the proximity of A and from the viewpoint of A.

The second variant of incomplete correspondence causes the advanced retrieval – we have to form the collection of incomplete sets that in general cover the set B.

If $A_i \subseteq B, i = \overline{i,n}$ then we try to fins the set $\{A_i \subseteq B\}, \bigcup_{i=1}^{n} A_i \supseteq B$. For example, if employer needs in em employee with the fixed set of competencies $C_e = \{c_j\}, \overline{j = 1,m}$ but any of potential employees have not all of these competencies:

$$\forall s_k \exists c_j \in C_{emp}, c_j \in C_{spec_k},$$

where C_{spec_k} is the set of competencies of k-th specialist.

In this situation it is necessary to find the group of persons where we can find the specialist with relevant competence $\forall c_j \in C_{emp} \exists c_{spec_k}, c_j \in C_{spec_k}$ for all required competencies.

Ontological knowledge for these analysis can be built by semantic Wiki resources as proposed by Rogushina (2016).

Conclusion

Described above competence ontology can be used for practical tasks deal with qualifications frameworks. It should be noted that the features of Protege-OWL editor allow integrating of other existing ontologies with this one. For example, competence ontology can be integrated with the ontology of other qualifications frameworks or the ontology of branch educational standards (curricula) which makes the developed ontology scaled and dynamic.

An approach proposed in this work is based on use of competence ontology and provides competence-based matching of various information objects for effective mechanism to ensure transparency of the European and National Qualifications Frameworks. It allows semantic comparison of various levels of qualifications that facilitates the integration of qualification systems. Software realization of these methods would be convenient for user and enable all social partners to use computer ontologies of the European and National Qualifications Frameworks for better access to qualifications.

In the future we plan to expand the scalability of the competence ontology, enrich it either by knowledge about information objects from other OWL ontologies or by information about individuals of competencies and specialities from various open resources of the Web.

Also we plan to develop the methods of automatic acquisition of this information from the various semi-structured and natural language documents.

NOTES

1. http://ec.europa.eu/eqf/compare_en.htm
2. http://protege.stanford.edu/publications/ontology_development/ontology101.pdf
3. http://www.eife-l.org/publications/proceedings/ilf07/Contribution110.doc.pdf
4. http://phd.isofts.kiev.ua/

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