

MANAGING CHARACTERISTIC ORGANIZATION KNOWLEDGE IN COLLABORATIVE NETWORKS

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Abstract: Modeling and management of the knowledge/information related to the organizations is fundamental to efficient operation of the Collaborative Networked Organizations (CNOs). Continuous changes in different aspects of involved organizations, is an unavoidable reflection to the dynamic changes in the demands of stakeholders and customers in the market / society. Organizations' profiles, and especially their competency characteristics tailored to the requirements of opportunities emerging in the market, need to be modeled and managed. Furthermore, mechanisms are required for handling the flexible representation and processing of the organizations' knowledge. Both research and practice have shown that the formation of collaborative networked organizations requires pre-establishment of a cluster, also called a breeding environment. In this paper we address the Virtual organizations Breeding Environments (VBEs), which provide the necessary conditions and support for configuration and creation of Virtual Organizations (VOs). Using the ontology engineering approaches, we present an approach for modeling of organizations' knowledge inside VBEs, and specify the ontology for their profiles and competencies. Furthermore, we present the required mechanisms for management of the organizations' knowledge, and specify the functionality required to manipulate organizations' information through the life cycle of VBEs. The paper also addresses the logical design of a database for storage of organizations' information and for the visualization of organizations' profile and competency knowledge.

1 INTRODUCTION

Modeling and management of knowledge that is gathered and generated by organizations is a fundamental driver for organizations' successful operation in the market and society (Balakrishnan et al, 1999) (Caie, 2007) (Afsarmanesh and Camarinha-Matos, 2005). Existing networks/clusters of are now eager to model and manage their knowledge, accumulated across their environment, in order to process and analyze it for discovery of possibilities, and deciding on strategies for future network evolution. In this paper we focus on modeling and management of different organizations' knowledge within the *Collaborative Networked Organizations (CNOs)*. The CNO has provided a new paradigm applied to many emerging domains (e.g. domain of tourism, health care, manufacturing, among others) in the market and society. (Camarinha-Matos and Afsarmanesh, 2006-a) gives the following definition for the CNO: *CNO is an alliance constituting a variety of entities (e.g. organizations and people) that are largely*

autonomous, geographically distributed, and heterogeneous in terms of their: operating environment, culture, social capital, and goals, that cooperate/collaborate to better achieve common or compatible goals, and whose interactions are supported by the computer network. Unlike other networks, collaboration in a CNO is an intentional property that derives from the shared belief that together the network members can achieve goals that would not have been possible or would have had a higher cost if attempted individually.

Supporting the main features of the CNOs, such as scalability, dynamism and geographic distribution, require the need for the ICT-based management of CNOs. In our research we address management of the CNO member organizations' knowledge that constitutes the base for the entire CNO management. We focus on a specific type (Afsarmanesh and Camarinha-Matos, 2007) of CNOs, namely the Virtual organization Breeding Environment. We adopt the following definitions of the Virtual organization Breeding Environment and the Virtual Organization: **Virtual organization**

Breeding Environment (VBE) (Afsarmanesh and Camarinha-Matos, 2005) is a network of organizations and some related supporting institutions that adhere to a base long term cooperation agreement, and adopt common operating principles and infrastructures, with the main goal of increasing their preparedness in advance, towards potential collaboration within Virtual Organizations. **Virtual Organization (VO)** (Camarinha-Matos and Afsarmanesh, 2006) represents a network of legally independent organizations that come together and share resources and skills to achieve common goals, such as preparing a proposal or a bid, or jointly performing the tasks needed to satisfy an opportunity, while using the computer networks and software systems as the base communication/interaction infrastructure.

In VBEs, the member organizations' knowledge is mainly represented by their "profiles" (Afsarmanesh and Camarinha-Matos, 2005) (Ermilova and Afsarmanesh, 2007]. Considering the main aim of collecting knowledge about member organizations', which is to enhance their involvement within VOs, the main element of the profile is the organizations' "competency" (Afsarmanesh and Camarinha-Matos, 2005). In this paper, we provide "extensive" definitions for "organization's profile" and "organization's competency" in VBEs:

Organization's profile consists of the set of determining characteristics (e.g. name, address, capabilities, etc.) about each organization, collected in order to: (a) distinguish and compare each organization with others, (b) analyze the suitability of each organization for involvement in some specific line of activities / operations.

Organization's competency is the main element of the VBE profile that provides up-to-date information about capabilities and capacities of each organization, as well as conspicuous information about their validity, qualifying it for participation in some specific activities / operations within the VBE, and mostly oriented towards the VO creation.

This paper addresses our approach and mechanism for modeling, specification and management of VBE members' profiles and competencies. Our approach is based on the formal specification of pre-defined ontologies for the organizations' knowledge in VBEs. The research results, presented in this paper, further contribute to the design and development of a *Profile and Competency Management System* (called PCMS) for VBEs, which is outside the scope of this paper, but the topic for forthcoming papers.

Below in this Section, after discussion of the main

motivations for the ICT-based modeling and management of member organizations' profiles and competencies, we address the requirements and the identified research challenges. In *Section 2*, the paper addresses the models for VBE member organizations' profiles and competencies, introduced earlier in (Ermilova and Afsarmanesh, 2007). *Section 3* presents the ontologies developed to support modeling and management of organizations' knowledge in VBEs. In *Section 4*, the paper specifies the ontology-based functionalities designed for management of VBE member organizations' profiles and competencies. *Section 5* presents the designs of both: the database and visual interface, specified for the VBE member's knowledge. Finally, *Section 6* concludes this paper.

As such, the main **motivations** for management of detailed profiles and competencies of VBE member organizations are listed by m-1 to m-8: *for profiles* – (m-1) creation of awareness inside the VBE, (m-2) selection of partners for new VOs, (m-3) evaluation of members by the VBE administration, (m-4) introduction / advertising in the market / society, and (m-5) identifying competency gaps; *specifically for competencies* – (m-6) matching VBE members' competency details against the risen opportunity, (m-7) determination of VO's competency, and (m-8) processing the VBE members' competencies.

Furthermore, the design and development of ICT-based representation and management of the VBE member organizations' profiles and competencies are motivated by the following: **(i)** In medium and large VBEs (i.e. with more than 20 members) as well as in geographically distributed VBEs, the only way for all VBE members to get the up-to-date information about each other is through computer-based representation and distribution of their profiles. **(ii)** Due to daily changes of customer demands in the market and society, the profiles and competencies of VBE members are dynamically changing. In medium and large VBEs, the VBE administration is not able to obtain and analyze up-to-date knowledge about all members with such a high level of dynamism. Thus, there is a need for ICT-based submission and processing of the members' profiles and competencies facilitating the VBE's dynamism.

From our analysis of the VBEs, a number of **requirements** are identified for modeling and management of VBE member organizations' knowledge are listed below by r-1 to r-5: *for modeling* – (r-1) in order to be easily adopted by VBEs operating in different domains (e.g. in domains of tourism, health care, manufacturing, etc.), development of unified/generic models is

needed for organizations’ profiles and competencies; *for management* - (r-2) support for continuous (e.g. daily) updating of profile and competency data, (r-3) handling the confidentiality of profile and competency data, (r-4) support for adaptability of the management approaches to the wide varieties of VBE applications, and (r-5) support for sustainability of the management approaches in dynamic and expanding environments.

Among the **technical challenges** involved in modeling and management of VBE member organizations’ knowledge, the following challenges of c-1 to c-7 are addresses by our approach: *for modeling* - (c-1) support of different abstraction levels from general knowledge classes to the domain-dependent knowledge classes, and (c-2) unification / generalization of different competency representations / models as exists in research and practice; *for management* - (c-3) common understanding of profile and competency models by all VBE members, (c-4) categorization in catalogues of competencies, (c-5) unified naming of the competencies and their standardization, (c-6) formal representation of profile and competency data in order to support their further semi-automatic processing, and (c-7) semantic integration of the different description of VBE members’ expertise submitted to VBEs.

2 MODELING KNOWLEDGE OF ORGANIZATIONS

The model, designed for organizations’ profile and competency knowledge, represents the set of knowledge classes, as well as the relationships among these classes, that need to be collected and managed in VBEs. These knowledge classes are empirically identified through: (a) interviewing and questioning the representatives of running VBEs, (b) study of related work on organizations’ profiles and competencies, and (c) study of existing enterprise models and ontologies (Ermilova and Afsarmanesh, 2007). A subset of classes and their relationships representing the profile and competency knowledge are addressed in Table 1 in the form of a hierarchy, where elements labeled by 1 to 8 represent classes, and each “x.y” represents either an *attribute* of the “x” element (e.g. “3.2”) or another class that is related to “x”, e.g. “3.3”. Please note, that Table 1 provides only the names of the main knowledge classes identified for the VBE member organizations’ knowledge model. The detailed specification of this model is the subject for a forthcoming paper.

A main objective for our research on knowledge modeling and management is to distinguish among the domain-independent knowledge classes (e.g. common for all VBEs) and the domain-dependent knowledge classes (e.g. related only to a specific domain of activities, e.g. manufacturing). In this paper we introduce the concepts of a “*core-class*” and a “*domain-class*”. As such the knowledge classes represented in Table 1 are the *core-classes*, because they are generic enough to be presented in all VBEs, independent of their domains / business areas. Additionally, some of the core classes (e.g. competency, resource, products/services, etc.) have further domain-dependent sub-classes, i.e. *domain-classes*. For example, within the manufacturing domain the competencies can be classified by the specific manufacturing activities, e.g. “metalworking competency”, “welding competency”, “turning competency”, etc. As such, the domain-classes can be integrated into the generic profile / competency model as the elements labeled by 3.1, 3.2, 3.3.1, 3.3.4.1, 3.3.5.1, 5.1, 6.1, 7.1, and 8.1 (i.e. italicized elements in Table 2). The domain-classes shall be arranged in the form of generalization hierarchies, e.g. the “milling competency” and “welding competency” are subclasses of “metalworking competency” in the generalization hierarchy of competencies for the metalworking domain. Such hierarchies shall also support the categorization and cataloguing of VBE member organizations by their domain related characteristics.

Table 1: Hierarchy of the main knowledge classes in the VBE member organizations’ knowledge model.

Label	Element	Label	Element
1	General data	4	Financial data
2	Contact data	4.1	Annual balance
3	Competencies	4.2	Annual revenue
3.1	<i>Competency class</i>	5	Resources
3.2	Competency name	5.1	<i>Resource class</i>
3.3	Capabilities	5.2	Resource name
3.3.1	<i>Capability class</i>	5.3	Capacities (ref. 3.4)
3.3.2	Capability name	5.4	Conspicuities (ref. 7)
3.3.3	Resources (ref. 5)	6	Products
3.3.4	Raw materials	6.1	<i>Product class</i>
3.3.4.	<i>Raw material class</i>	6.2	Product name
3.3.4.	Raw material name	6.3	Product markets
3.3.5	Standards	7	Conspicuities
3.3.5.	<i>Standard class</i>	7.1	<i>Conspicuity class</i>
3.3.5.	Standard name	7.2	Conspicuity name
3.3.6	Products (ref. 6)	7.3	Issue date
3.3.7	Conspicuities (ref. 7)	7.4	Issuer
3.4	Capacities	7.5	Expiration date
3.4.1	Total rate	8	Associated partners
3.4.2	Available rate	8.1	<i>Associated partner</i>
3.4.3	Available time	8.2	Associated partner
3.5	Conspicuities (ref. 7)	8.3	General data (ref. 1)
		8.4	Contact data (ref. 2)

3 SPECIFICATION OF ONTOLOGY

We have introduced the concept of “VBE ontology” in (Afsarmanesh and Ermilova, 2007). As such, the VBE ontology represents a form of unified and formal conceptual specification of the heterogeneous knowledge in VBE environments to be easily accessed by and communicated between human and application systems, for analysis and evolution purposes. The main objective of the VBE ontology is the provision of support for knowledge modeling and management in VBEs, particularly for: (1) the establishment of a common semantic subspace for VBEs, (2) the development of VBE knowledge repositories, (3) the processing VBE knowledge by software tools, (4) the enabling inter-organizational learning & operation, and (5) the integratability of VBE knowledge.

The **structure** of the VBE ontology consists of four levels of abstraction and ten partitions constituting sub-ontologies of the VBE ontology, as also illustrated in Figure 1. The *four levels of abstraction*, including the “meta” level, the “core” level, the “domain” level, and the “application” level, reflect the reusability of the VBE ontology at different VBE domains and application environments. For example all VBE applications from the same domain share the ontology defined for all the above levels and differ only at the application level. However the *ten ontology partitions*, such as the “VBE profile and competency sub-ontology”, the “VBE history sub-ontology”, the “VBE Bag of Assets sub-ontology”, etc., mainly refer to the knowledge about the fundamental entities and concepts in VBEs as being addressed by different VMS sub-systems (Afsarmanesh et al, 2007). Please also note that in Figure 3, the number/symbol represented inside the parenthesis next to each ontology level represents the cardinality of instances for this VBE ontology level, e.g. there is only one VBE meta level ontology and one VBE core level ontology common to all VBEs, while N and M both represent “many”, e.g. addressing the fact that there are many different domains / business area ontologies for different VBEs and each VBE domain / business area may in turn also have many VBE application ontologies. Furthermore, the decomposition of this ontology structure into levels and partitions supports the incremental development of the VBE ontology, and the developed parts of the ontology can be reused by VBE management subsystems for different VBEs.

VBE ontology aims at providing the specifications for all VBE knowledge classes

through presenting the following properties for each classes: (i) a definition of the concept, represented by this class, (ii) a set of synonyms for the concept, (iii) an abbreviation for the class’s name, (iv) a set of subclasses of this class, and (v) a set of attributes / relationships of this class.

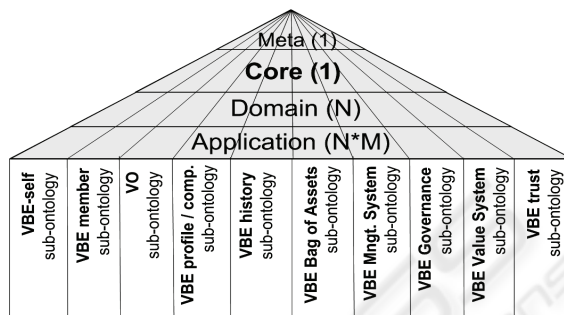


Figure 1: Structure of the VBE ontology.

While the meta and core VBE ontology levels are specified and constructed manually, the domain and application VBE ontology levels must be constructed on demand for each specific VBE domain and application. The VBE core level represents ten separate OWL (OWL, 2007) files that were constructed using Hozo (Sunagawa et al, 2004) and Protégé (Protégé, 2007) editors.

To support the modelling and management of VBE member organizations’ knowledge, we use the core and domain levels of the “VBE profile and competency sub-ontology” as addressed below:

- **VBE core profile and competency sub-ontology** (Figure 2) represents the core/generic profile and competency model, as addressed in Table 1. The main **purposes** and **usage** of the VBE profile and competency core sub-ontology for the modelling and management of organization’s knowledge in VBEs includes the following: **(1)** Support of the R&D in the VBE field through providing means for the evolution of the organizations’ profile and competency model by being an extensive, uniform and sharable representation of these models. **(2)** Support for the common understanding of the structure of the profiles and competencies through providing the extensive definitions of the related concepts. **(3)** Support for semi-automated design and development of a database for organizations’ knowledge (Guevara-Masis et al, 2004). **(4)** Support for automatic structuring of the profile and competency knowledge for its representation in a GUI.

- **VBE domain profile and competency sub-ontology** is a form of representation of the domain classification for the organization’s profile and competency model. The VBE domain profile /

competency sub-ontology can be further partitioned into several specific “sub-sub-ontologies” depending on: a specific core concept (e.g. only for domain resources), or a specific domain / business area (e.g. only for welding). Figure 3 illustrates a sub-ontology developed for the classification of standards/practices and capabilities/processes in the metalworking domain. The **usage** of the VBE profile domain sub-ontology includes the following: (1) Support of the representatives of the VBE member organizations with the definition of their domain-specific profile and competency related data (e.g. identification of classes of the domain-specific business processes performed within an organization). (2) Support for representation of the “standard names” and the “standard relationships” for the domain-dependent profile and competency knowledge that can be further facilitate the software-based matching/processing of the knowledge. (3) Support for automatic structuring of the domain-dependent profile and competency knowledge in a GUI.

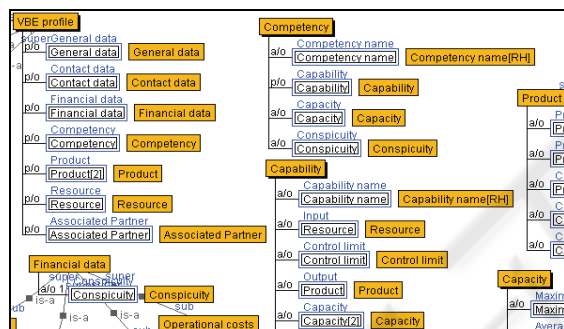


Figure 2: Example partial screen-shot from the profile core sub-ontology constructed in Hozo.

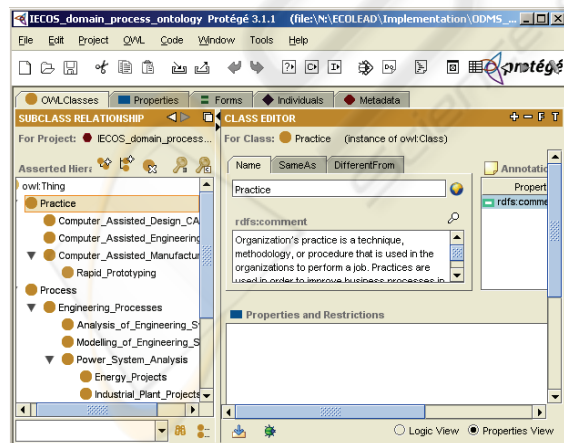


Figure 3: Example screen-shot from the ontology for metalworking capabilities constructed in Protégé.

4 MANAGEMENT FUNCTIONALITIES

Management of VBE member organizations’ profiles and competencies takes place through the entire VBE life cycle (i.e. from the VBE creation stage to the VBE dissolution stage). In this paper we introduce eleven main functionalities identified for the organizations’ profiles and competencies management, as illustrated in Figure 4. All functionalities are activated at different VBE life cycle stages. In Figure 4, these activation times are indicated next to each functionality’s name as follows: [C] for the VBE creating, [O] for the VBE operation, [E] for the VBE evolution, [M] for the VBE metamorphosis, and [D] for the VBE dissolution. Detailed description of the functionalities, as well as of their support by the VBE profile and competency sub-ontology, is addressed below:

- 1. Uploading of Core Profile and Competency Model.** This functionality supports the uploading and installation of the core profile and competency model in the form of the VBE core profile and competency sub-ontology and adaptation of the database to this model (see Section 5 for more details).
- 2. Customization of the Core Profile Competency Model.** This functionality supports modification of the organizations’ profile and competency models.

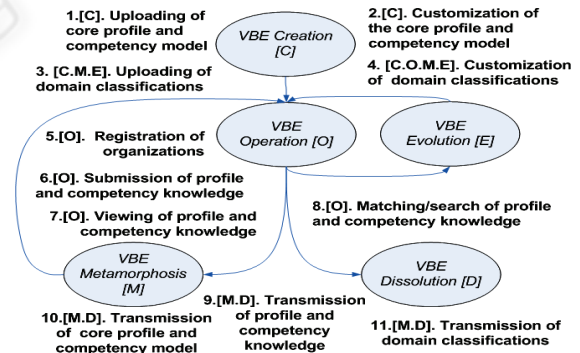


Figure 4: PCMS’s life cycle functionalities.

- 3. Uploading of Domain Classifications.** This functionality supports uploading and installation of generalization hierarchies of specific domain classes of profile and competency knowledge in the form of VBE domain profile and competency sub-sub-ontologies.
- 4. Customization of Domain Classifications.** This functionality supports updating of the generalization

hierarchies of domain classes, for example through adding new domain-dependent profile knowledge classes needed in a specific VBE application.

5. Registration of Organizations. This functionality supports registration of VBE member organizations in the system and thus creation of their profiles.

6. Submission of Profile and Competency Knowledge. This functionality supports uploading of profile and competency knowledge from each member organization. For each “piece” of knowledge, the class of this knowledge needs to be indicated in the VBE profile and competency sub-ontology.

7. Viewing of Profile and Competency knowledge. This functionality supports viewing the profile and competency knowledge accumulated in the VBE. The viewing scope shall address both: single profile knowledge and the collective profile knowledge of the entire VBE. The structuring of the knowledge in the GUI (see Section 5 for more details) shall mimic the VBE profile and competency sub-ontology.

8. Matching/searching of Profile and Competency Knowledge. This functionality supports both: the search for specific profile elements and the matching of the profile and competency descriptions of a group of VBE member organizations against the detailed descriptions of the new collaborative opportunities arisen in the VBE. In case there is no “direct” search results for some specific knowledge classes, “alternative” results for “other” knowledge classes shall be suggested, based on the closeness of knowledge classes in the VBE profile and competency sub-ontology.

9. Transmission of Profile and Competency Knowledge. This functionality supports the transition of VBE member organizations’ profile and competency knowledge to a special format in order to support its transmission to other VBEs, external institutions, or further VBE-related activities in the market and society.

10. Transmission of Core Profile and Competency Model. This functionality supports transmission of the customized core profile and competency model of one VBE to the format of the VBE core profile and competency sub-ontology in order to support its usage by the R&D organizations working on the evolution of the generic/core VBE profile and competency model.

11. Transmission of Domain Classifications. This functionality supports transmission of customized

generalization hierarchies of domain classes of one VBE to the format of the VBE domain profile and competency sub-sub-ontologies in order to support its inheritance by other VBEs from the same domain or by the R&D organizations working on the evolution of these generalization hierarchies.

5 DATABASE SCHEMA AND VISUAL INTERFACE

The design of the **database** for the VBE member organizations’ knowledge aims to support both structuring of members’ profiles/competencies based on the VBE profile and competency sub-ontology, and dynamic customization of the profile and competency model, i.e. through dynamic creation/deletion of knowledge classes and instances. As the DBMS, the PostgreSQL (PostgreSQL, 2007) has been initially chosen because it represents a strong free-ware system, for which the needed drivers and documentation are available. A number of logical/physical database designs have been considered and evaluated. However, the approach, where one physical table in the relational database corresponds to one class of the profile knowledge has been rejected. The main reason for the rejection is the need to support the dynamic creation/deletion of database tables, resulted from the requirement of dynamism in profile knowledge classes. Such dynamic operations with tables are however problematic in PostgreSQL. Instead, we chose for a more object-oriented design of the database with only one generic table for all knowledge classes. Thus, all operations with classes simply represent the operation with the records in this table. The final database schema consists of seven tables/relations (as illustrated in Figure 5). The main four tables include: (a) the “class” table for representing the profile knowledge classes; (b) the “instance” table for representing the profile knowledge instances (i.e. real data from VBE entities); (c) the “class_relation” table for representing different relationships among the classes; and (d) the “instance_relation” table for representing the relationships among the instances. The other three tables are meta-data defined above these four tables.

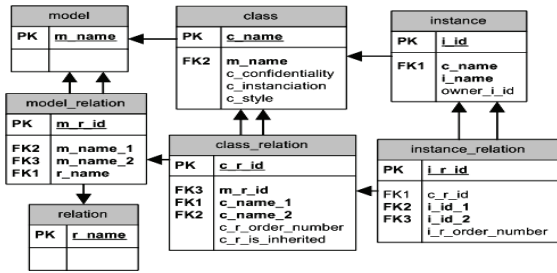







Figure 5: Database schema.

Suitable user-friendly **graphical user interface** of the profile and competency knowledge is required to support their navigation, understanding and “digestion” by human users. The more complex the knowledge is the more difficult it is to specify proper form for its visualization. Below we introduce some “*catalogue*” forms for the profile knowledge visualisation. Each catalogue mimics the visualization of an acyclic graph including the knowledge “classes” (representing both: core classes and domain classes) and their “instances” as its “nodes”, and three types of relationships as its “edges”. These relationships include: (1) the generalization relationship (called “has subclass”) defining classes and their subclasses, (2) the aggregation relationship (called “has attribute”) defining classes and their attributes, and (3) the instantiation relationship defining classes and their instances. Two types of catalogues, namely the PKCC and PKIC that are described below, are designed for representing the VBE member organizations’ profile and competency knowledge.

In relation to illustrations of PKCC and PKIC, addressed in Figures 6 and 7, please notice that in both catalogues described and illustrated below, the **bold entries** represent knowledge classes. The image , located next to a class, indicates that this class is a sub-class of its upper-level class. In the PKCC, absence of this image next to a class indicates that this class is an attribute of its upper-level class. In the PKIC, the *italicized entries* represent some instance’s data for attributes, also called “records”. The image  in the PKIC indicates a record. In both catalogues, the smaller-font entries next to the class entries, e.g. “14 attributes”, “2 subclasses”, “2 records”, represent the summary for the class definitions. The clickable images  and  support expanding and collapsing the catalogue items. A radio-button  next to each entry supports the selection of an entry to perform some operations on it (e.g. creation of a new subclass, a new attribute, or a new instance).

The *Profile Knowledge Class Catalogue (PKCC)* represents an acyclic graph including the profile knowledge classes as the nodes, and the

relationships among these classes as the edges. The root of PKCC is represented by an abstract class called “Profile knowledge”. The relationships among the classes represent two types of the “has attribute” relationships (e.g. a competency definition has a capability definition as an attribute) and the “has subclass” relationships (e.g. the manufacturing capability has the welding capability as a subclass). An example illustration of the PKCC is addressed in Figure 6. This Figure illustrates the list of the top-level classes of profile knowledge such as “General data”, “Contact data”, “Resource”, etc. The representation of two classes, namely the “General data” class and the “Resource” class are also expanded, so that the fourteen attributes of the “General data” class, as well as one attribute and four sub-classes of the “Resource” class, can be viewed.

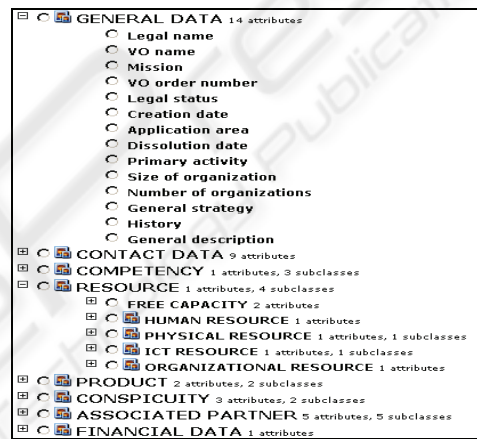


Figure 6: An example illustration of PKCC.

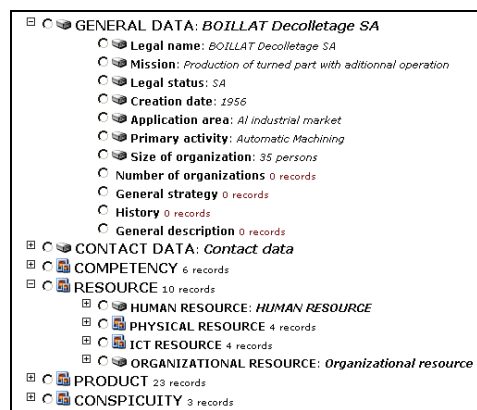


Figure 7: An example illustration of PKIC.

The *Profile Knowledge Instance Catalogue (PKIC)* represents an acyclic graph that includes the profile knowledge classes and the profile knowledge instances as the nodes, and the relationships among these classes and instances as the edges. Please note

that the relationships among classes in PKIC represent only the “has subclass” type, the instances are not connected among each other directly, while the main types of the relationships in this models represent the relationships between classes and their instances. An example illustration of the PKIC is addressed in Figure 7. This Figure illustrates a list of classes for the profile knowledge and some existing records for these classes from a member organization of Swiss Microtech (SMT) - a VBE from Switzerland. In this Figure, the record for the “General data” is expanded, so that the records for its attributes can be viewed. For example, the record for the “Creation date” is “1956”. It also illustrates that the “Resource” class does not have direct instances/records, rather it has records only through one of its sub-classes, e.g. through the “Human resource” class.

6 CONCLUSIONS

This paper addresses an approach for ontology-based modeling and management of characteristic knowledge collected from organizations/companies collaborating in CNOs and specially in VBEs. Each organization is presented in VBEs by its “profile” and specifically by its “competency” - a fundamental element of the profile. This paper starts with the definitions of organizations’ profiles and competencies. It addresses the motivations, requirements, and technical challenges for ICT-based modeling and management of organizations’ profiles and competencies in VBEs. It introduces the “VBE profile and competency sub-ontology” to support modeling and management of organizations’ knowledge in VBEs. Furthermore, the functionalities for profile and competency management are presented that are based on the ontological representation of the organization’s knowledge model. As steps required for specification and development of the Profile and Competency Management System (PCMS) for VBEs, the designs of both: the database and the GUI for profile and competency knowledge, are addressed. More details about specification and modeling of organizations’ competencies as well as about the PCMS’s development fall outside the scope of this paper, and are the topics for forthcoming papers.

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