Encyclopedia of Networked and Virtual Organizations

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Ontologies for Collaborative Networked Organizations

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INTRODUCTION

It is commonly agreed that networking, as a new way of collaboration, brings benefit to its members (Camarinha-Matos & Afsarmanesh, 2005). Collaboration implies communication and sharing of knowledge between network participants. However, as the participants may be from different fields or may follow a different problem solving philosophy, it is necessary to introduce a mechanism to share common understanding of the information and to agree on a controlled vocabulary used for communication. An ontology provides a representation of knowledge, which can be used and re-used, in order to facilitate the comprehension of concepts and relationships in a given domain, and the communication between different domain actors, by making the domain assumptions explicit. These actors can be either software agents or people that need to access or share a piece of information (Gruber, 1993).

A collaborative network is an association of a set of participants (profit organizations, non-profit organizations, individuals, etc.) and may include organized and non-organized collaborations. In this chapter we focus on collaborative networked organizations (CNOs) which represents only organized and intentional collaborations. CNOs can be roughly characterized as long-term or short-term associations. A long-term association of organizations is called a virtual organization breeding environment (VBE) and its main purpose is to enable fast creation of virtual organizations (VOs) (Camarinha-Matos & Afsarmanesh, 2003). A VO is a short-term alliance created in order to fulfil a common business goal. In the case of individuals, a professional virtual community (PVC) is a long-term alliance, with the aim to enable dynamic creation of virtual teams (VTs).

An introductory and learning phase for organizations joining a VBE should be as short as possible. Ontologies have proven to be an unambiguous and compact way of knowledge representation enabling mutual understanding, as they provide a basis for sharing information not only among people but also among software agents. If several organizations or individuals, joining a CNO, share the same underlying concepts (for example on the Web or on their intranet), then software agents are able to extract and aggregate information and use it to gather the data and to answer some queries. Such agents can also support a process of VO and VT creation by proposing more or less optimal VOs and VTs based on competencies of their participants. In order to share the same terminology, the participants of the VBE need to agree on the terms that they intend to use for collaboration.

This chapter introduces business ontologies and illustrates the notions on a CNO ontology, implemented in the Protégé ontology development tool (Protégé, 2000). This chapter does not aim at giving an exhaustive overview of the state of the art in ontology research and development, as this is a research area on its own. Instead, the goal is to outline existing business ontologies and to present an ontology development approach applicable in CNOs.

The chapter first gives a brief outline of ontologies, their definitions, different types, possible encodings and structure, focusing on existing ontologies related to the business domain. It then presents a sample,

manually developed CNO ontology implemented in Protégé. Its purpose is to establish the vocabulary used in the domain of CNOs and to identify the main CNO actors and their roles. The ontology can be re-used in different CNOs, and can be further elaborated given the specificities of each type of network.

BACKGROUND: BUSINESS ONTOLOGIES

The most basic type of ontology is a set of terms representing a controlled vocabulary (e.g., a glossary), which are the terms that people agree to use when dealing with a common domain. By providing definitions, an ontology helps people and machines to use the same terminology which enables better mutual understanding. The role of an ontology is not limited to providing information; complex ontologies can also constrain the usage of knowledge by giving axioms or micro-theories and show the relations between the different components.

The content of an ontology depends both on the amount of information and on the degree of formality that is used to express it. Generally, we distinguish two main types of ontologies: lightweight and heavyweight (Gomez-Perez, Fernandez-Lopez, & Corcho, 2004). A lightweight ontology is a structured representation of knowledge, which ranges from a simple enumeration of terms to a graph or taxonomy where the concepts are arranged in a hierarchy with a simple (specialization, is-a) relationship between them. A heavyweight ontology adds more meaning to this structure by providing axioms and broader descriptions of knowledge. As a word can have several senses, knowledge can be also interpreted in different ways, which creates ambiguity in the knowledge base. Axioms and constraints tend to reduce the ambiguity by restricting and constraining the usage of information, for instance by specifying what is possible to do with it and what is not.

The degree of complexity of knowledge expressed in an ontology can vary from one ontology to another. This is also true for the spectrum of knowledge. An ontology may cover one or several domains or even focus on a specific aspect. In all cases, the construction of an ontology involves the choice of appropriate concepts that will best describe the knowledge represented in the ontology. These choices are called "ontological commitments" and are described by the ontology. "We say that an agent commits to an ontology if its observable actions are consistent with the definitions in the ontology." (Gruber, 1993).

Many ontologies have been developed, covering different domains (medicine, tourism, common-sense knowledge, etc.). The most important ontologies concerning the business domain and enterprise modeling are outlined in the following.

The AIAI Enterprise Ontology

The AIAI enterprise ontology (Uschold, King, Moralee, & Zorgios, 1998) was developed in the scope of the enterprise project whose goal was to provide a set of tools for enterprise modeling. The available enterprise tool set contains a procedure builder, for capturing process models, an agent toolkit for supporting agent development, and a task manager for integration and visualization. The ontology was used in order to ensure a consistent communication between agents (human or software agents). The enterprise ontology built within the enterprise project is not meant to be a complete ontology describing the enterprise domain. It only presents the most frequent terms used in this field. Thus the ontology has to be enriched for each specific business case.

The enterprise ontology is divided into five top-level concepts: activities and processes, organization, strategy, marketing, and time. The organization part contains the terms representing the actors that play a role in an enterprise. They can have legal responsibilities or not, be a human or a machine. These terms are then used to model activities and processes. The activity part includes the concept of resources and skills that are needed and the effects of the activity (i.e., the concept of input-output). The central concept of the strategy part is purpose. Purpose captures the idea either of something which a plan can help achieve, or what an organization unit can be responsible for. Finally, the marketing part describes sales. Sale is an agreement between two legal entities for the exchange of a product for a sale price.

The Toronto Virtual Enterprise's Ontology (TOVE)

The TOVE enterprise ontology was developed in the scope of the TOVE project (Fox, 1992). The TOVE ontology is a formal representation of the enterprise

domain. As the enterprise ontology, it is divided into several top-level concepts to segment the enterprise into general categories: activity, states, causality, time, resources, organizational structure.

In this overview, we focus primarily on the resources and organization parts of the ontology. In TOVE, the resource ontology comprises two sets of assertions. First, the resources are defined in terms of knowledge, role, mobility and divisibility of the resource. Role of the resource represents its nature, for instance, whether it is a product, a tool or a work area. Mobility specifies the possibility of moving the resource from one place to another or not. Divisibility of the resource specifies if the resource can be divided into several resources, without affecting its role in an activity. Each division must be able to be consumed by an activity. Once these basic terms are defined, more complex ones are introduced such as the nature of the resource or its capacity. Nature of a resource means that a resource can be continuous or discrete. Capacity of a resource represents its availability at a certain point of time.

In the organization ontology, an organization-entity can be an organization-individual or an organization-group denoting several people (e.g., board of directors, teams, etc.). Each organization has properties such as organization-role, skills, constraints, and so on. Organization-role specifies the goal that the organization has to achieve. Each role has attached skills, processes, policies, and so on. that are necessary to complete the goal.

The concepts encoded in the ontology are also enriched by a set of axioms that define and constrain the interpretation of these concepts. The ontology is formalized using first order logic, allowing answering questions by using the TOVE reasoning engine.

The Business Process Management Ontology (BPMO)

The primary goal of the business process management ontology (BPMO) (Jenz, 2003) is to provide a stable platform for the semantically rich definition of business processes, in order to better align information technologies with business. The business process management ontology allows to define private and public processes, business entities, business objects and services that implement process activities. It follows the UN/CEFACT modeling methodology (UMM) for business process and information modeling.

The BPMO uses the concept of business entities and business objects for process modeling. Their definitions rely on the UN/CEFACT glossary, which defines a business entity as "something that is accessed, inspected, manipulated, produced, and so on in the business." Business entities are defined for all the terms that are intended to be used in business and thus form a kind-of glossary. Once these entities have been defined, they are generalized under new concepts called business objects.

For instance, business entities customer and supplier may be represented by a business object named party, which is a generalization of customer and supplier (Jenz, 2003). The BPMO also introduces the notion of process task concept type. It describes which role performs a task, the business entities and business documents it is related with, and the resources it consumes.

Currently, the BPMO comprises approximately 650 classes. The ontology is available in the OWL format (McGuinness & van Harmelen, 2004).

Process Specification Language Ontology (PSL)

Process specification language (PSL) (Schlenoff, Gruninger, Ciocoiu, & Lee, 1999) is an attempt to create a formalism for the representation of processes that is common to all manufacturing applications. The PSL ontology is formally defined using first order logic and the KIF language (http://ksl.stanford.edu/knowledge-sharing/kif/) to encode axioms.

The ontology is organized into two main layers:

- PSL-Core that comprises concepts that are common to all manufacturing applications
- A set of extensions that provide the resources in order to express other concepts that are not present in PSL-Core

PSL-Core is composed of four basic classes: activities, activities occurrences, timepoints, and objects. An activity occurrence is a limited, temporally extended piece of the world. A process can then be defined as: one or more activities that occur over a period of time in which objects participate.

In addition to the core theories comprised in PSL-Core, the ontology can be extended with additional sets of definitions (e.g., activity extensions, resource roles, resource sets). The definitions can be grouped and form extensions to PSL-Core.

The Yahoo! Business Ontology

The Yahoo! business sector data (Yahoo!, 2005) provides structured information on business. Despite the fact that this is not an ontology in the sense of providing a commonly agreed terminology and categorization of the business domain, it does provide a useful structuring of company data.

The data consists of textual descriptions of 7,107 companies in terms of their competencies. In Yahoo!, companies are structured into 12 sectors, which are further divided into 102 industries.

For example, the healthcare sector is divided into four industries: biotechnology and drugs, healthcare facilities, major drugs, and medical equipment and supplies. The number of industries in each sector and the distribution of companies per sector are shown in Table 1.

AN ONTOLOGY OF COLLABORATIVE NETWORKED ORGANIZATIONS

In this section, we present an ontology of collaborative networked organizations (CNOs) and focus on organizations that collaborate in a virtual organization breeding environment (VBE). Its purpose is to provide a common understanding of the structure and functions of a VBE and a VO, and more generally of the terms that are used in such an environment. The ontology provides general knowledge that can be used in different VBEs and VOs, and which can be further elaborated with the specificities of individual networked organizations. An approach that follows a general methodology for building ontologies (Noy & McGuinness, 2001) is included, along with the actual implementation of the ontology in Protégé.

Methodology

For every ontology, its domain and scope should be determined first. This includes the specification of the domain, and the potential use of the ontology. A set of questions an ontology should answer can also help determining the level of detail. First there are some general questions concerning the newly introduced terms, and later some questions concerning the real cases—instances—of those and related terms.

The questions one can ask in the context of a collaborative networked organization are the following:

Table 1. The Yahoo! sectors, industries, the number of industries and companies (per sector)

Sector	**Industry**	**Industries**	**Companies**
Basic Materials	Gold and Silver, Iron and Steel, …	11	429
Capital Goods	Aerospace and Defense, …	7	361
Conglomerates	Conglomerates	1	29
Consumer Cyclical	Footwear, Tires, …	12	318
Consumer Non-Cyclical	Beverages, Crops, …	8	232
Energy	Coal, Oil & Gas, …	4	310
Financial	Insurance, S&Ls/Savings, …	10	1212
Healthcare	Facilities, Major Drugs, …	4	860
Services	Advertising, Restaurants, …	25	1486
Technology	Hardware, Software, …	11	1578
Transportation	Airline, Railroads, …	6	150
Utilities	Electric, Water, …	3	142
Total		**102**	**7107**

- What is a CNO?
- What is a VBE?
- What is a VO?
- What is the difference between a VBE and a VO?
- What form can the following actors take (e.g., a person, a company, etc.) and what are the tasks of: a VBE administrator, a VBE adviser, support institutions, a VBE partner, a VO broker, a VO planner, a VO coordinator?
- What is a business opportunity?
- How is a business opportunity handled when it arises?
- Does a VBE administrator have to be a member of the VBE?
- Who was the broker of "VO1"?
- How many times was person "X" a VO broker?
- Can a VO broker be also a VO coordinator?
- Is it necessary for a VO Support Provider to be a VO partner?
- Is it necessary for a VO partner to be a VBE member?

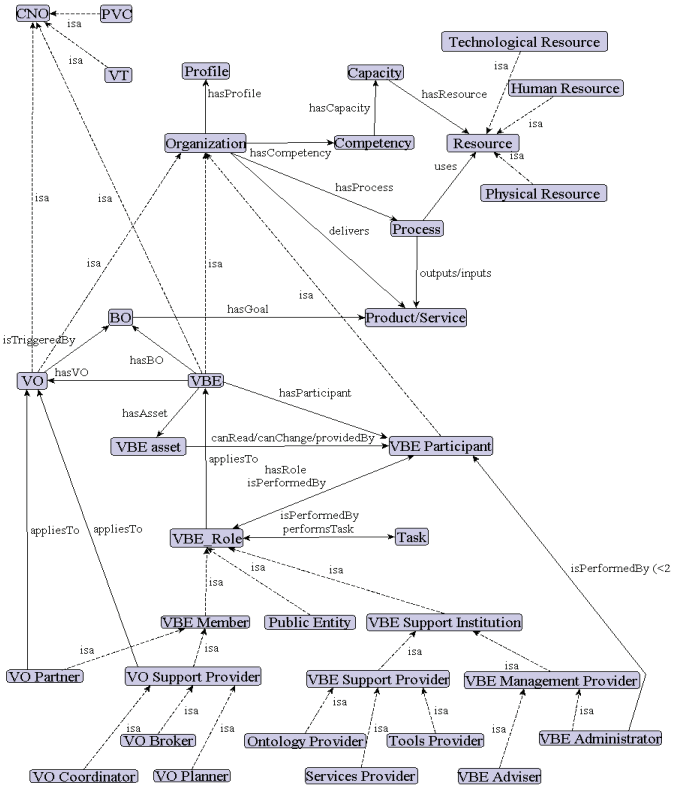
These questions show the level of detail in the operational phase of a CNO. From the questions we can also see how different parts of an ontology emerge:

- The general part, about the structure and function of the CNO,
- The part describing roles of participants of VBE and VO, and
- The part of the ontology describing organizations' competencies, resources and their availability.

The CNO Ontology

The ontology (shown in Figure 1) is based on the concepts developed in the ECOLEAD integrated project (European Collaborative Networked Organizations Leadership Initiative project FP6.IP 506958, 2004-2008), as well as on the entity-relationships and concepts for virtual organizations developed in the SolEuNet project (Mladenić, Lavrač, Bohanec, & Moyle, 2003).

Figure 1. The CNO ontology, with a detailed elaboration of VBE and VO (without any detail on PVC and VT)



In the ontology of Figure 1, the two top concepts are collaborative network organization (CNO) and organization. All organizations have their profiles, competencies, can perform one or more processes, and deliver some products and/or services. Special types of organizations are virtual organization (VO), virtual organization breeding environment (VBE) and VBE participant. VO and VBE are also special types of collaborative networked organizations, since they represent alliances of companies. A VBE participant represents an entity collaborating with other entities in the VBE and VO. A VBE is a long-term alliance, which responds to business opportunities by forming VOs. On the other hand, a VO is a short-term association with a specific goal of being active in fulfilling a business opportunity (BO). A business opportunity is an occasion in time with favourable combination of circumstances that is suitable to start a business. The partners of the VO are selected from the VBE participants according to their competencies and availability to deliver products or services required to fulfill a BO. To facilitate the processes within the VBE, the participants have access to several assets, such as business rules, software tools, specifically developed for the VBE. These assets are called VBE Assets and are kept in the so-called VBE Bag of assets.

Implementation in Protégé

A page containing more details about the concepts that were chosen and used in the ontology is available in the Protégé ontologies library (Protege, 2000). The version of the ontology implemented with the Protégé tool can be downloaded from http://kt.ijs.si/software/CNOntology. It can be used, redistributed, and modified under the terms of the GNU general public license. A screenshot in Figure 2 shows the Protégé description of the CNO concept, and Figure 3 the description of the VBE concept.

FUTURE TRENDS

Ontologies have an important role in the next generation of the World Wide Web, called the Semantic Web. An ontology gives a formal meaning (semantics) to documents on the Web by using descriptions encoded in languages such as RDF (Beckett, 2004) and OWL (McGuinness & van Harmelen, 2004). These descriptions then supplement the contents of Web documents and enable their processing by machines. Thus, different resources (such as documents, databases, knowledge bases) become Web and machine accessible which facilitates their integration and interoperability.

In the context of collaborative networked organizations, the ontology of a CNO should be integrated with the VBE management system and various resources provided by its participants. This leads to the issues of how to connect networked ontologies (between themselves and with other resources), how to map between them, how to support collaborative development of ontologies, and how to use them in different contexts. Another role of ontologies is their use in describing Web services: what are their properties and capabilities, and how to discover, orchestrate and monitor them. All these are open research issues, addressed by several current research projects.

Figure 2. Description of the CNO concept

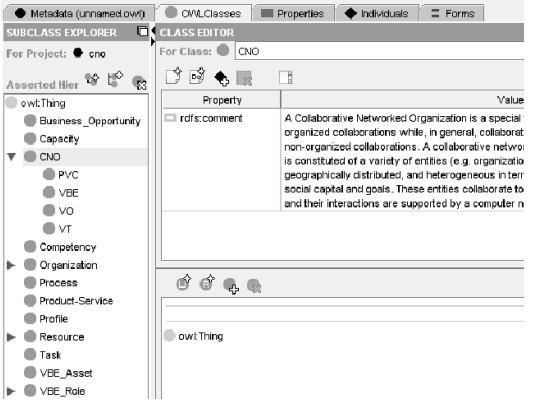
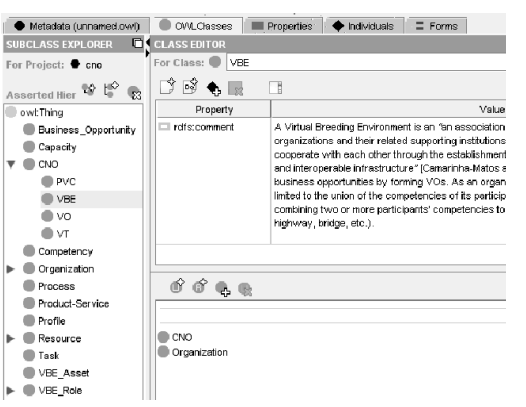


Figure 3. Description of the VBE concept



CONCLUSION

This chapter gives an informal introduction to ontologies, an overview of business ontologies and defines an ontology of terms and concepts used in collaborative networked organizations. The proposed CNO ontology is implemented in Protégé and is freely available for further refinements and improvements. This suggests to the reader to download the ontology and learn how to modify and adapt it for her or his specific needs. The intention is for the ontology to be refined and instantiated for individual types of CNOs and specially VBEs and VOs, depending on the sector and domain of their operation. Such refined and specific ontologies should be an integral part of each individual VBE information infrastructure, providing support for the whole VBE life cycle, and specifically for facilitating VO creation and management tasks.

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KEY TERMS

Collaborative networked organization (CNO): A special type of collaborative network comprising only organized collaborations while, in general, collaborative networks include both organized and non-organized collaborations. A collaborative network (Camarinha-Matos & Afsarmanesh, 2005) is constituted of 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. These entities collaborate to better achieve common or compatible goals, and their interactions are supported by a computer network.

Ontology: A formal representation of a domain under consideration. It consists of individuals and classes or concepts (sets of individuals), their properties (attributes) and relations between them (roles). Usually it is represented in a formal language based on first-order logic. For the Web, the standardized languages are RDF **(**Beckett, 2004**)** and RDFS (Brickley, 2004), and their follow-up OWL (McGuinness & van Harmelen, 2004), all using the XML syntax.

Organization: A company, corporation, firm, enterprise or institution, or part thereof (whether incorporated or not, public or private) that has its own function(s) and administration that supplies products or services to other organizations.

Professional Virtual Community (PVC): The combination of virtual community and professional community concepts. Virtual communities are defined as social systems of networks of individuals who use computer technologies to mediate their relationships. Professional communities provide environments for professionals to share the body of knowledge of their professions such as similar working cultures, problem perceptions, problem-solving techniques, professional values, and behavior (Camarinha-Matos & Afsarmanesh, 2005).

Protégé: An ontology editor and knowledge-base framework which supports the development of ontologies and their export into standard formats including RDF(S) (Brickley, 2004) and OWL (McGuinness & van Harmelen, 2004). It is free, open-source software, supported by a strong community of developers and users.

Virtual Organization (VO): Comprises a set of (legally) independent organizations that share resources and skills to achieve its goal, but that is not limited to an alliance of for-profit enterprises. A Virtual Enterprise is therefore a particular case of a VO (Camarinha-Matos & Afsarmanesh, 2005).

Virtual Organization Breeding Environment (VBE): An association (also known as cluster) or pool of organizations and their related supporting institutions that have both the potential and the will to cooperate with each other through the establishment of a "base" long-term cooperation agreement and interoperable infrastructure (Camarinha-Matos & Afsarmanesh, 2005). A VBE responds to business opportunities by forming VOs. As an organization, it has also competencies but not limited to the union of the competencies of its participants. The VBE competencies are the result of combining two or more participants' competencies to realize more complex projects.

Virtual Team (VT): Also known as a geographically dispersed team (GDT), is a group of individuals who work across time, space, and organizational boundaries with links strengthened by means of communication technology. They have complementary skills and are committed to a common purpose, have interdependent performance goals, and share an approach to work for which they hold themselves mutually accountable. Geographically dispersed teams allow organizations to hire and retain the best people regardless of the location. A virtual team does not always mean a team of tele-workers. Tele-workers are defined as individuals who work from home. Many virtual teams in today's organizations consist of employees either working at home or in the office at different geographic locations.