

Ontology for Cross-Organizational Communication

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1 Introduction

Industry-academia collaboration and other forms of communication across organizations are a prerequisite for developing science and technology and creating innovations. For example, converging technology, which Western countries are beginning to promote for innovation creation, is an approach whereby heterogeneous sciences and technologies are converged^[3] and cross-organizational communication is essential to the development of such a technology. As the Innovation 25 Strategy Council pointed out, creation of innovations requires not only scientific and technical development, but new business models and new social mechanisms as well. New business models also call for innovative approaches to customers, involving collaboration across different organizations and domains and therefore needs cross-organizational communication.

However, Japanese organizations are said to have a high wall separating science specialists and non-science specialists. Even within the same scientific field, people tend to be shy of interacting across organizational boundaries. A first step to achieve cross-organizational communication is to encourage people to engage in outside communication and to create opportunities for such engagements. This would require a mechanism for supporting such communication and, more importantly, organizational efforts to fully exploit rapidly advancing information technology.

Basic and common examples of information and communications technologies to enable such communication are e-mail and the Web (browser), which are accessible via mobile

telephones and PCs. Recently, social networking services (SNSs) and blogs are attracting attention as new communication tools. They are helping to improve communication devices and their associated operations, making the information being communicated more easily accessible.

This article focuses on ontology as an information technology, that is fundamental to structuring, describing and displaying information as the content of communication. Few people have come up with concepts on how to use information technology to structure or describe the information being communicated, except for basic hardware-oriented approaches such as using a computer's word processor instead of pen and paper. Only recently has ontology become clearly recognized as a fundamental tool for communication^[4].

Ontology contributes to not just person-to-person communication, but more remarkably to organization-to-organization communication as well. In other words, although it is individuals that are engaged in communication, in many cases, the target of communication for each of them exists only beyond the boundary of their respective organizations. To enable such communication, each participant must be aware that the "common sense" of his or her organization may not be applicable to other organizations. Unlike person-to-person private communication, in which both parties can express their thoughts in their own language, cross-organizational communication requires each party to describe the information needed by the other party in a mutually understandable language. For this kind of communication to be achieved, an organizational approach to information structure and usage is needed, therefore information technologies such as

ontology can be useful and effective.

With attention to cross-organizational communication assisted by ontology, this report explains what ontology is, describing its historical background and current situation. There are initiatives for ontology standardization as well as efforts to develop related tools, contributing to the collection of ontology data. Nevertheless, ontology is a technology still in the course of development, and many challenges are expected to surface in areas such as the handling of intellectual property rights and the management of information security, as further progress is made.

2 Historical background of ontology

2-1 *Ontology as a technology and ontology in philosophy*

The term “ontology” does not date back very far. According to the Oxford English Dictionary, the term first appeared in 1721 and was explained as “an Account of being in the Abstract,” which refers to the philosophical aspect of ontology. Therefore, the Japanese translation of “ontology” in the philosophical context is “sonzairon,” which literally means the study of the nature of being. Studies on ontology in Western countries date back to scholastic theology and even to Greek philosophy. The main question of Aristotle’s metaphysics was, “What is the meaning of being?” This question is still being studied today in Husserl and Heidegger’s contemporary philosophy, and can be traced back in the theology of Thomas Aquinas in 13th century, Leibniz in 17th century, and Kant in 18th century who founded modern philosophy.

However, “ontology” as used in the context of this article is in a completely different domain than ontology in the philosophical context, although the same term is used. Ontology in the technical context uses the same questions such as “What kinds of entities constitute the world?” and “What kinds of entities exist in the world?” that have been echoed in the history of ontology in philosophy. The perspective of these questions fall into the computer world (or the Web world), not the human world. By the

way, I should mention here that some people started to reinvestigate and try to connect ontology technology with philosophical ontology recently. Some researchers even advocate that debates from philosophical perspectives should be resumed in order to overcome the limitations of current ontology^[6]. They suggest that cross-organizational communication should be based upon such questions as “What is an organization?” “What is the goal of the organization?” and “What does the organization exist for?”

2-2 *History of ontology technology*

As mentioned in the previous section, the origin of current ontology technology is not directly related to communication, although philosophical ontology that deeply underpins the technology is, of course, connected to communication. Historically, ontology research and development to date has diverged in two different directions.

One of the roots is an offshoot of knowledge engineering, which seeks practical applications of artificial intelligence research. Ontology research in this direction is aimed at “an explicit specification of a conceptualization” with regard to knowledge, as a commonly used definition by Gruber^[5]. In ontology engineering, an ontology is defined as “a structure of concepts or vocabulary for artificial intelligence systems and theory for such structuring”^[6]. Such ontologies have been used in knowledge engineering applications, such as expert systems, for resolving difficulties associated with corrections and updates of knowledge. In short, such R&D has been conducted to specify the conceptual structure underlying the knowledge base being used and to facilitate the maintenance of the knowledge base.

Another direction of ontology research came from the advances in Web usage. This can be divided into two approaches. The first is Topic Map technology^[7] (explained later in Chapter 3), which originates in index processing for document handling dating from 1991. This technology is based on HyTime (Hypermedia/Time-based Structuring Language), an SGML (Standard Generalized Markup Language)-derived markup language applied to multimedia/

hypermedia. Topic Map has been standardized as ISO/IEC 13250:2000/2003 which is a standard for advanced information exchange which expresses knowledge about the subject of the information being sent. Following the advent of XML (eXtensible Markup Language), a successor to SGML, syntax has been extended to be applicable to XML and the Web. Topic Map data model has also been defined. Current standardization activities include canonicalization, the reference model, compact syntax and graphical notation. Topic Map related standards are also being developed, including ISO 18048 TMQL (Topic Maps Query Language), ISO 19756 TMCL (Topic Maps Constraint Language), and ISO 29111 (Expressing Dublin Core Metadata using Topic Maps). In Topic Maps, subject type, subject relationship (association) type, and subject-resource relationship (occurrence) type are regarded as ontologies.

Another approach in advanced Web usage is the Semantic Web^[8]. This involves tagging, which is a set of techniques to add knowledge to enable advanced processing in the Web. R&D on the Semantic Web started in 1998 with a view to achieving a next-generation Web. Ontologies in this field are also called Web ontologies. This third direction, the Semantic Web, surpasses the previous two in terms of the R&D population and the level of attention. However, ontologies were not emphasized in this field initially.

Tim Berners-Lee, the inventor of the World Wide Web (WWW), published some memos on the Semantic Web in 1998^[9-11]. This has led to ontology development in this field. One of these memos is the text of his keynote speech titled "Evolvability," which was delivered at the Seventh International World Wide Web Conference. In this speech he referred to ontology like this: "Strengthening the logical aspect of schema language requires not only relational databases, but also the cooperation of knowledge processing experts"^[11]. Berners-Lee himself considers artificial intelligence as part of "what the Semantic Web isn't," suggesting his intention to separate the Semantic Web from failed technology tried in artificial intelligence research^[10]. He was looking to things that can "globally" handle knowledge and tried to

eliminate "centralist assumptions," which caused the failure of traditional knowledge base projects. During his keynote speech at XML 2000 in Washington, D.C. in 2000, he also mentioned RDF (explained later in Chapter 3) and Topic Maps as enablers of the Semantic Web and stressed the need for integrating them^[12]. On the other hand, in his paper published in Scientific American in 2001, Berners-Lee defined an ontology as consisting of descriptions of the relationships between concept sets and the inference rules governing them, citing ontologies as the third key enabler of the Semantic Web^[13]. Since then, ontologies have become a prerequisite for the Semantic Web.

The history of ontology technology described so far, whether in connection with the Semantic Web or knowledge engineering, tells you that it heavily depends on computer processing. Topic maps, too, were originally developed for document processing, and proceeded for computer-aided knowledge data structuring, such as information management and information searching. However, some new ideas recently propose the direct use of ontological knowledge expressions and structures for human communication rather than computer processing^[4, 14]. Although still technically under development, such communication based on novel ideas may in the future replace current human communication that are bounded in literal words.

3 | Ontology technology development status

This chapter describes the current status of ontology technology development from three perspectives: standardization, tool development and data accumulation.

3-1 *Standardization of ontology description*

Historically, the standardization of ontology description originates in the development of topic maps in the early 1990s. However, this section begins with the Resource Description Framework (RDF), which has a simpler standard format and will therefore make it easier to understand the other standards. Descriptions in RDF use

XML (eXtensible Markup Language) format. XML is a standard format similar to SGML and HTML, and was developed by the World Wide Web Consortium (W3C), a Web technology standardization body. Its first version has become a Japanese Industrial Standard (JIS X 4159:2005) and has been released in Japan.

(1) Resource Description Framework (RDF)

The Resource Description Framework is literally a framework for describing resources on the Web. RDF is primarily considered a model and a description language. W3C recommendations consist of six elements (RDF Primer, RDF/XML Syntax Specification, RDF Vocabulary Description Language: RDF Schema, RDF: Concepts and Abstract Syntax, RDF Semantics, RDF Test Cases), and their specifications are available at <http://www.w3.org/RDF/>.

Although RDF is essentially a framework for handling resources on the Web, it can actually deal with concrete objects residing outside the Web and abstract concepts. It uses Uniform Resource Identifiers (URIs) to refer the resources. The description format for the URI is separately defined as the URI Scheme. In general, URIs use Uniform Resource Locators (URLs) to identify the location of Web resources, and character strings to identify the other objects. A resource is expressed by a triplet: the subject representing that resource, the property (or predicate) and the property value (or object). URI notation usually uses either XML or directed graphs. Elements of these notations rely on character strings called RDF URI references. For objects not existing in the Web, a special notation known as blank nodes is used.

The original purpose of the creation of RDF was to enable machines to process Web resources. XML notation is also designed for machine processing, while graph notation is aimed at helping human understanding. One should note that although RDF describes properties of individual resources, it cannot represent such issues as sets of resources, general relationships between resources, and relationships between properties. These should be specified in the RDF Schema in the RDF vocabulary description language. The RDF

Schema adopts concepts such as object-oriented class, domain and range, which can represent concepts similar to functions in mathematics.

(2) Web Ontology Language (OWL)

OWL is an abbreviation of Web Ontology Language. This is an extension of RDF, and thus an RDF document may be interpreted as an OWL document. OWL has inherited syntax from RDF. OWL functions consist of class descriptions, set operations for classes, and class axioms, which describe relationships between classes. Although there are some additional functions concerning properties and class members, their number is limited because additions to the RDF Schema by OWL are confined to descriptions of relationships between concept sets. Class description is also possible in the RDF Schema, but OWL additionally incorporates relationship descriptions including set operations as a standard.

A notable fact about OWL is that it is part of a large project, namely, the Semantic Web. OWL is becoming recognized as a standard ontology description language even in non-Web related areas, driving moves to create resources for OWL, such as libraries, special search sites, and software tools like description editors and inference engines.

(3) Topic Maps

The development of Topic Maps as a standard began in 1991, ahead of the development of RDF and OWL, as mentioned in Chapter 2. Although originally designed to enable index processing associated with machine-based document processing, topic maps can now handle information on the Web just as RDF and OWL do. Topic Maps are significantly different from RDF and OWL in that they discriminate between the information layer in which information content exists and the knowledge layer for relationship description. A Topic Map description consists of three major elements: topic, association, and occurrence. A topic is a computer-based expression of the subject and has a base name and multiple variant names. The subject of a topic is identified using either the subject locator or a combination of the subject indicator and

the subject identifier. An association, which is roughly equivalent to the property in RDF, is not directional and is specified for multiple topics. Furthermore, topics participating in an association are assigned association roles. An occurrence is a link to information in the information layer and includes a URI to indicate the location of information. There are multiple types of topics, associations and occurrences, each of which is assigned a specific scope. The notion of Published Subject Indicators (PSIs) has been adopted to allow the consistent use of common subjects. The W3C has made a proposal to achieve standardized interoperability between RDF and topic maps^[15].

3-2 Software tools

Notation standardization in ontology technology has promoted the development of software tools to deal with standardized documents. Major software tools has been already developed such as editors for standardized description, tools to integrate and consolidate multiple ontologies after their creation, and inference engines for inference based on relationship descriptions included in ontology data.

Currently, the most advanced area in development and proliferation is for editors, i.e. entry tools for ontology. Protégé (<http://protege.stanford.edu/>), developed by Stanford University, has almost become a de facto standard, with 62,000 registered users (as of April 2007) and international conferences being held every year. Protégé provides two kinds of editors: Protégé-Frames and Protégé-OWL. Protégé editor users can obtain applications and extensions known as plug-ins, as well as ontology data created using Protégé. Plug-ins for diverse areas are available, including biomedical informatics, project management, search and navigation, visualization, import & export, inference & reasoning, Semantic Web, terminologies, software engineering, code examples, and natural language processing. Ontology data sets, which are available as libraries, are accompanied by frame-based data examples, OWL data examples and examples of data in other formats. Protégé is open-source software, which means a

community of registered users is responsible for its development and maintenance.

For inference engines, which the Semantic Web emphasizes, no standard tools like Protégé have been developed. However, several types of engines already exist, with some of them commercially available.

A typical topic map tool is the one released by Ontopia, the Ontopia Knowledge Suite (OKS). Other examples include Topic Maps 4 Java (TM4J), an open-source project^[7].

3-3 Collecting ontology data

More and more people are involved in the creation of ontology data and making them available to others, often through Semantic Web projects. Even an ontology search engine for the Semantic Web, called Swoogle^[16], has appeared. According to its data, as of April 2007, there are about 2 million Semantic Web documents and about 374 million elements. Swoogle extracts Semantic Web documents, which are identifiable by the .rdf or .owl extension, from documents found with the Google search engine, and then reads these documents' ontology structure written in XML to interpret the content. While the current Google engine does not handle such semantic data descriptions, Swoogle's search robot is designed to use the ontology data obtained like this to automatically search through other ontological documents^[17] *1. Stanford University's Protégé Web site mentioned above also offers ontology data sets written in OWL and many other formats.

Such moves have led to standardization under ISO/IEC 19763-3 for ontology metadata registration^[18].

Constructing ontology data, even if their scope is limited, actually involves the cumbersome work of listing all the concepts within that scope and describing relationships between them. Apart from this traditional centralized approach to ontology data construction, a new approach has been proposed which uses a collaborative method that develops ontologies by allowing participants to add tags to freely describe the content. This approach (known as folksonomy) suggests that semi-automatic collection of ontology data may be possible, although their

tags may not be exact conceptual elements nor relationship descriptions for ontology^[21].

3-4 *Science and technology fields actively using ontologies*

One of the science and technology fields eager to benefit from ontologies is genetic research and development (so-called Gene Ontology). However, even in this domain, data and frameworks for ontology description have yet to be standardized. For example, a Web site called “Standards and Ontologies for Functional Genomics”^[19] declares, “Numerous ontologies for human and mouse anatomy exist or are being developed. Each has its own purpose. For the biologist who wants to annotate data with anatomical names this variety is confusing”. To mitigate such confusion, this site intends to provide a place for interaction.

Another Web site, Open Biomedical Ontologies^[20], introduces nine related projects and lists ontology data files in 63 domains, in an attempt to provide links to diverse initiatives by different groups.

Developing an ontology of the knowledge owned by an organization requires substantial efforts and money. This is demonstrated by the College of American Pathologists (CAP) of the U.S., which has created SNOMED-CT, a large ontology consisting of as many as 340,000 concepts and 870,000 terms related to them. The ontology is offered at a licensing fee of US\$32.4 million^[24].

4 | Ontology for cross-organizational communication

4-1 *Different aspects of ontology*

The idea of using ontologies for the sake of communication is relatively new, as explained in the section on the historical background of ontology, and only recently did researchers begin addressing ontology from this perspective. An example of ongoing projects to develop ontology-based communication tools is Semantic Authoring by Hasida and others at the National Institute of Advanced Industrial Science and Technology, a project that uses a semantic editor^[4, 14].

Roles of ontology for cross-organizational communication are twofold. First, it is a tool to organize or systematize knowledge or to give everyone an at-a-glance picture of the knowledge structure of an organization (“visualization”)^[2]. Second, it is a technology aimed at removing subtle obstacles from linguistic expressions so that cross-organizational communication can be smoothed through the direct use of ontology descriptions which conveys the basis of the information being communicated^[4].

From a different viewpoint, ontology can also be divided as descriptions of the semantic structure of specific information (more exactly, what can be called semantic expressions of information using an ontology, or simply ontology data), and as computer systems to enable such ontology-based expressions and collections of computer processes applicable to such expressions (more exactly, what can be called ontology tools and environments).

4-2 *Explicit representation of an organization’s knowledge*

There have been a number of attempts to achieve the task of clarifying an organization’s knowledge, especially informal, tacit knowledge^[23]. Ontologies can be considered as a technique to explicitly specify such knowledge.

In this context, the knowledge for which an ontology is created is not simple numeric information, but in principle the terminology used in the organization, concepts represented using this terminology, and relationships, especially set relationships between these concepts. For example, the knowledge addressed here does not refer only to numeric information such as output, work in process, and inventory in a production division, or cash flows, sales by item, and profits in an administrative division. An ontology expresses the knowledge representing concepts behind such numeric information and relations between them. A new trend in recent years is using multimedia, such as still images, audio and movie pictures, instead of words, for representing knowledge concepts.

In terms of explicit representation of knowledge, ontology is superior to other

information-related technologies (for example, a technology to create electronic documents including multimedia objects and hyperlinks) in the following respects.

- (1) Ontology explicitly expresses relationships between concepts in graph structure, thus enabling machine processing with no human assistance.
- (2) For ontology, established standard description formats exist, such as OWL and topic maps. Therefore, it allows the mutual exchange, comparison and merging of ontology data relatively easily, providing superior interoperability.
- (3) For their standard description formats and graph structure, ontology data can be translated into other natural languages or environments with different cultures relatively easily.

4-3 Challenges

Ontology for cross-organizational communication still has many challenges to overcome.

(1) Social aspects of the community

Since an ontology incorporates an organization's knowledge, it should primarily be shared among the organization's members. However, taking the possibility of communication across organizations into account, an ontology should address a broader community consisting of everyone associated with that knowledge. Ontologies so far have mostly been indifferent to sociological aspects of such a community because their scope was confined within information technology. However, it is now necessary to address more explicitly the community that consists of all the people related to the organization's knowledge, and the social aspects of such a community, because a number of challenges stem from such a community—including the issues of validating a knowledge structure created using ontology technology, verifying an inference in a graphic relationship description, and changing (evolving) concepts and their relationships.

(2) Intellectual property rights

A knowledge structure expressed using ontology technology can be subject to intellectual property rights. However, fundamental and common knowledge used by an organization or an industry should essentially be disclosed for wider public use. For example, traditional knowledge structures like dictionaries have been protected as publications under intellectual property rights. Since ontologies are supposed to be used for day-to-day operations, their treatment as intellectual property is far more complex than it is for publications. An ontology that explicitly describes an organization's expertise is a source of the organization's value, and therefore should be considered invaluable and in need of strict protection.

(3) Safe sharing

As in the case with any other artificial object, ontologies are not free from errors and defects. In particular, the possibility of machine processing based on ontology data implies that erroneous processing using erroneous ontologies may lead to fatal results. How to ensure the safe use of ontologies is a challenge to be overcome in the future. The sharing of an ontology among different organizations poses particularly diverse risks.

(4) Emergence of new forms of communication

It is true that a general debate should be held on which direction ontology-based communication should develop in order to achieve more efficient communication, but there is a possibility that ontology evolves to a completely new form of communication that complements traditional natural language communication. Even today, some people speculate that youth, now deeply reliant on messaging via mobile phones, are lacking in the ability to communicate in traditional language. This leaves a question to be answered in the future: Can ontology-based communication enable more efficient and less misleading communication by making it possible to omit the interpretative process in traditional natural language communication, or will it weaken

natural language communication?

4-4 *Status of cross-organizational communication in Japan*

As explained in Chapter 1, in Japanese organizations, there is a high wall between science specialists and non-science specialists, and people tend to shy away from interacting across organizational boundaries even when they focus on the same scientific field. This is said to have a harmful effect in many ways.

As an example, take iPod, a portable music player. There is a view that in spite of Japanese companies' competitiveness in the development of components and the availability of all the necessary components, including music distribution systems, in Japan, it was not a Japanese company but Apple that was able to integrate these components across conventional industry sectors and organizations to create iPod^[1]. Another example is the weakening of the competitiveness of the once-dominant Japanese semiconductor process industry, which is partly attributed to a delay in integrated accumulation of knowledge on and expertise in semiconductor production systems. One researcher argues that the Japanese semiconductor process industry has lost its competitiveness because at the time when it was vital for semiconductor manufacturers to share knowledge among many stakeholders in production-related divisions, (so that knowledge conversion could be achieved quickly and autonomously where needed), the industry failed to share knowledge and keep the traditional operation that the knowledge is acquired and used by limited individuals^[2].

Another study attributes the lack of cross-organizational communication in Japanese organizations to, in addition to technical shortcomings, the absence of the willingness to initiate such communication and a trait characteristic of Japanese organizational culture that tends to deny such communication. In other words, Japanese organizations lack certain necessary mindsets for cross-organizational communication^[25].

Although ontology as a communication technology is not able to directly influence this lack of certain mindsets, the act of expressing

an organization's knowledge using ontology may motivate its members to actively compare their organization with others', for example, through a comparison of their ontology with another organization's ontology. For example, in a project to develop a software system, the system developer needs to fully understand the needs of system users. This would require cross-sectional communication, but in reality, such projects often fail to deliver the best possible system due to misunderstanding^[26]. There are attempts to solve this problem by describing the knowledge of system users by using ontology so that the developer can fully understand it and effectively perform high-level processes in system development.

In Japan today, where experienced and highly intellectually skilled workers are retiring in large numbers, some organizations are making attempts to ensure that their existing business knowledge is maintained and passed on to the next generation of workers by explicitly representing such knowledge through the use of ontology technology^[27]. In a sense, these attempts are aimed at achieving communication across time rather than across organizations.

5 | Conclusion

This article focuses on ontology because the author believes that ontology helps Japanese organizations to foster cross-organizational communication, which is currently one of their weaknesses. However, the idea of using ontology for the sake of cross-organizational communication is relatively new.

Cross-organizational communication can open up many new possibilities, such as the convergence of technology for innovation creation, more effective high-level processes in software system development, and delivery of business knowledge across generations. For these possibilities to become a reality, there are several challenges to be overcome concerning ontologies, including their intellectual property rights, safe sharing, and the social aspects of the communities supporting them.

In the future, ontologies may also be utilized for man-machine communication. Ontology R&D

and utilization may even lead to a grand challenge to pass the current human knowledge on to later generations and possibly to extraterrestrial life.

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Glossary

*1 Unlike other emerging search engines, such as the one developed by Powerset for semantic interpretation of queries, Swoogle mechanically processes the semantic structure of information contained in the documents being searched. Although this is not as "semantic" as human understanding, the technology holds the possibility of achieving equivalent capability.

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