Application of Ontologies for Knowledge Management

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ABSTRACT

Knowledge management is the deliberate and systematic coordination of an organizational people, technology, process, and structure in order to add value through reuse and innovation. This coordination is achieved through creating, sharing, and applying knowledge as well as feeding the valuable lessons learned and best practices into corporate memory in order to foster continued organizational learning, typically using advanced technology. Ontologies are increasingly seen as a key technology for enabling semantics-driven knowledge processing. Communities establish ontologies, or shared conceptual models, to provide a framework for sharing a precise meaning of symbols exchanged during communication. Many applications benefit from semantically enriched information, including knowledge management and e-business applications. Ontologies have been proven to be really helpful for knowledge management as they are applications for information retrieval, information systems, and system modeling, and they are better ways to store and retrieve knowledge semantically. In this article, we discuss the advantage of using ontologies in the knowledge management.

Keywords: Ontologies, Knowledge Management, Ontology-based Knowledge Management

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1. Introduction

This article is an extension of the original work which was presented in 2017 at the International Conference on Innovation and Knowledge Management. This article explains in more detail about knowledge management process, semantic web and ontologies: principles, methods and applications and using ontologies for knowledge management.

Modern organizations face constant turbulence in their environment. A reduced life cycle of products and services and a highly integrated international market have led to a high degree of competitiveness. Information and knowledge are true assets. In recent years, companies have made significant investments in knowledge management (KM) initiatives (Almeida et al., 2009). Many organizations have collected and stored vast amounts of data. However, they are unable to discover valuable information hidden in the data by transforming these data into valuable and useful knowledge (Berson et al., 1999).

Knowledge resides in many different forms: as explicit knowledge in documents and processes, as tacit knowledge in people and procedures, and in many different forms between these two extremes (Bäck et al., 2003). Managing knowledge resources can be a challenge. These organizations are employing information technology in KM to aid in the creation, sharing, integration, and distribution of knowledge (Silwattananusarn & Tuamsuk, 2012). Among the many techniques utilized, ontologies are an alternative that have been given an increased amount of attention (Almeida et al., 2009).

The vision of the semantic web is to extend principles of the web from documents to data. Data should be accessed using the general web architecture, for example, URIs; data should be related to one another just as documents (or portions of documents) already are. This also means the creation of a common framework that allows data to be shared and reused across applications, enterprises, and community boundaries, to be processed automatically by tools as well as manually, including revealing possible new relationships among pieces of data (W3C, 2009).

Central to the vision of the semantic web are ontologies. Ontologies are formal theories supporting knowledge sharing and reuse. They are used to explicitly represent semantics of semi-structured information. These enable sophisticated automatic support for acquiring, maintaining, and accessing information. In the context of knowledge sharing, we use the term ontology to mean a specification of a conceptualization, i.e. ontology is a description like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents (Wilson & Matthews, 2006).

Certainly, in examining research articles on KM from research databases, we found studies using ontologies for KM applications with KM functionality in business applications, for example, Repository application, Discovery application, Dissemination application, and Collaboration application. This article presents a study case on how ontologies can be utilized for knowledge management in KM systems.

2. Knowledge Management

Knowledge Management (KM) has been an established discipline since 1995. The knowledge movement spawned through managements' realization that what an organization and its employees know is central to an organization's success. In 1995, two Japanese academics, Ikujiro Nonaka and Hirotaka Takeuchi, published the book "The Knowledge-Creating Company". They highlighted the conversion of internalized tacit knowledge into explicit codified knowledge for successful knowledge sharing. They created a model for knowledge conversion called the SECI model (Davenport & Prusak, 1998).

Socialization involves the sharing of tacit knowledge between individuals, emphasizing capturing knowledge through close physical proximity. *Externalization* involves the conversion of tacit knowledge to explicit knowledge into a comprehensible form understood by others. *Combination* involves building explicit knowledge into a more complex set of explicit knowledge. *Internalization* involves the conversion of explicit knowledge into tacit knowledge that is actionable (Nonaka & Konno, 1998). These modes view knowledge as context-specific and dependent on a time, space and relationship with others (Nonaka & Toyama, 2004).

Saito et al. (2007) claimed that the processes of activities in KM vary widely, depending on each author's particular interpretation of what knowledge management consists of. For instance, Nonaka et al. (2001) based their work on the well-known SECI spiral of knowledge creation: socialization, externalization, combination, and internalization, which focuses on interactions among people and emphasizes the social nature of knowledge. Alavi & Leidner (2001), although trying to balance the social and technical aspects of knowledge, chose processes that tend to interpret knowledge as the product: creation, storage and retrieval, transfer, and application. Becerra-Fernandez et al. (2004) adopted a technical slant and emphasized a knowledge engineering approach, proposing the processes of discovery, capture, sharing, and application. Although the technologies listed in those studies are surprisingly similar, the way that they are grouped and organized reflects particular interpretations of KM.

According to the researchers (Rehman & Kifor, 2014; Almeida & Barbosa, 2009; Varma, 2007; Wilson & Matthews, 2006; Jurisica et al., 2004; Bäck et al., 2003 and Davies et al, 2002), in knowledge management research has used ontologies for knowledge management. The three major KM cycles are: 1) *People* (Create, Share/Learn); 2) *Management* (Capture/Acquire, Organize); and 3) *Application* (Access/Search/Disseminate, Use/Discover). In the following sections the intelligent use of ontologies makes a major difference in the knowledge management cycle.

Knowledge Sharing

Ontologies are seen as facilitating knowledge sharing and reuse between agents, be they human or artificial. They offer this capability by providing a consensual and formal conceptualization of a given domain. As such, the use of ontologies and supporting tools offers an opportunity to significantly improve knowledge management capabilities in large organizations. In this process, important metadata are extracted and associated with the community information resource using RDF annotations (Davies et al., 2002; Fensel, 2001).

Knowledge Acquisition

The knowledge acquisition (Liou, 1990) is the process of extracting, structuring, and organizing knowledge from human experts so that the problem-solving expertise can be captured and transformed into a computer-readable form. While constructing ontology for any domain, both

tacit and explicit kinds of knowledge are needed. For explicit knowledge, experts of a domain can be interviewed (Rehman & Kifor, 2014). Kaewboonma et al. (2014) presented that the knowledge acquisition approach by Liou (1990) was adopted for acquiring knowledge from the domain experts. The approach involved four steps: 1) Document analysis to identify the concepts and domain knowledge; 2) Drafting the classification following the concept of categorization, considering both common and different attributes by evaluating the data types and the characteristics of the data using a hierarchical clustering of terms; 3) Interviews with domain experts; and 4) Summarizing the knowledge domain and reconfirming the results with the experts.

Knowledge Organization

Poli (1996) believed that ontology is the general framework within which catalogues, taxonomies, and terminologies may be given an appropriate organization. Kaewboonma et al. (2016) used a qualitative research method to develop the knowledge structure of GMS folksongs. The study was conducted using the following steps: 1) Survey and selection of existing resources; 2) Content analysis of the selected resources; 3) Organizing the knowledge by using the domain analytic approach in order for ontology development; and 4) Clarification and modification of the knowledge organization by consulting with domain experts.

Knowledge Dissemination

Ontologies help in distributing knowledge intelligently. Web crawlers can be used to retrieve the knowledge managed in ontologies. As ontologies deal with annotated documents, therefore while retrieving information from ontologies, a user only gets the concerned information rather than a pool of overwhelming documents that may or may not contain required data (Rehman & Kifor, 2004).

3. Semantic Web and Ontologies: Principles, Methods and Applications

The vision of the semantic web is to offer more intelligent services by facilitating machine understanding of content. Ontologies are an important building block in the future semantic web. Ontologies provide a shared and common understanding of a domain that can be communicated across people and applications. This is also an appropriate vision for knowledge management (Bäck et al., 2003).

"Ontology" is the term used to refer to the shared understanding of some domain of interest. An ontology necessarily entails or embodies some sort of world view with respect to a giver domain. The world view is often conceived as a set of concepts (e.g., entities, attributes, and processes), their definitions, and their inter-relationships; this is referred to as a conceptualization (Uschold & Gruninger, 1996). In artificial intelligence (AI), according to Tom Gruber, an AI specialist at Stanford University, an ontology is "the specification of conceptualizations, used to help programs and humans hare knowledge." This seems to be one of the most, or even the most quoted definition for an ontology. In this meaning, an ontology consists of specified concepts that are defined to create an agreed-upon vocabulary for information exchange. Knowledge in ontologies is mainly formalized using five kinds of components: classes, relations, functions, axioms and instances.

Ontologies themselves can be classified into the following groups: 1) Knowledge Representation ontologies; 2) General/Common ontologies; 3) Meta-ontologies, also called Generic ontologies or Core ontologies; 4) Domain ontologies; and 5) Task ontologies.

Knowledge Representation ontologies capture the representation primitives used to formalize knowledge in knowledge representation paradigms. The most representative example of this kind of ontology is the Frame-ontology, which captures the representation primitives (classes, instances, slots, facets, etc.) used in frame-based languages.

General/Common ontologies include vocabularies related to things, events, time, space, causality, behavior, function, etc.

Meta-ontologies, also called *Generic ontologies* or *Core ontologies* are reusable across domains. A representative example of a Meta-ontology may be a mereology ontology, which includes the term "*part-of*".

Domain ontologies are reusable in a given domain. They provide vocabularies about the concepts within a domain and their relationships, about the activities that take place in that domain, and about the theories and elementary principles governing that domain.

Task ontologies provide a systematized vocabulary of the terms used to solve problems associated with tasks that may or may not be from the same domain. These ontologies provide a set of terms by means of which to generically describe how to solve one type of problem. They include generic names, generic verbs, generic adjectives and others in the scheduling tasks. Domain-Task ontologies are task ontologies reusable in a given domain, but not across domains.

On the other aspects, Jurisica *et al*. (2004) classified the concepts used for knowledge representation into four broad ontological categories: 1) Static ontologies describe static aspects of the world, i.e. what things exist, their attributes and relationship; 2) Dynamic ontology, on the other hand, describes the changing aspects of the world in terms of states, state transitions, and processes; and 3) Intentional ontology encompasses the world of things that agents believe in, want, prove, or disprove, and argue about. Finally, Social ontologies cover social settings– : agents, position, roles, authority, permanent organizational structures or shifting networks of alliances and interdependencies.

3.1. Methods for developing ontologies

There are many methods for developing ontologies, and each one has strengths and weaknesses. Gruninger & Fox (1995) proposed that this methodology is based on the experience in developing the TOVE project ontology within the domain of business processes and activities modelling. The steps proposed are as follows: 1) Capture of motivating scenarios; 2) Formulation of information competency questions; 3) Specification of the terminology of the ontology within a formal language; 4) Formulation of a formal competency question using the terminology of the ontology; 5) Specification of axioms and definitions for the terms in the ontology within the formal language; and 6) Establish conditions for characterizing the completeness of the ontology.

Uschold & King (1995) envisaged a comprehensive "A Skeletal Methodology" for developing ontologies to include the following: 1) Identify purpose; 2) Building the ontology (ontology capture, ontology coding and integrating existing ontologies); 3) Evaluation; and 4) Documentation.

METHONTOLOGY (Gomez-Perez *et al.*, 2003) has been used by different groups to build ontologies in different knowledge domains, such as Chemistry, Science, Knowledge

Management, e-Commerce, etc. METHONTOLOGY proposes a task set for capturing domain knowledge. These can be divided into three groups of tasks.

The first group would be steered to enclosure and structure the domain by means of tasks - 1 to 4: Task 1 - Build glossary of terms; Task 2 - Build concept taxonomies; Task 3 - Build ad hoc binary relation diagrams; and Task 4 - Build concept dictionary.

The second group of tasks, from 5 to 7, would help to document the acquired knowledge from the previous tasks: Task 5 - Describe ad hoc binary relations; Task 6 -Describe instance attributes; and Task 7 - Describe class attributes.

Finally, METHONTOLOGY proposes others tasks, from 8 to 11, to complete domain knowledge: Task 8 - Describe constants; Task 9 - Describe formal axioms; Task 10 - Describe rules; and Task 11 - Describe instances.

Noy & McGuinness (2001) described an iterative approach to the ontology development process that includes the following steps: step 1: determining the domain and scope of the ontology; step 2: consider reusing existing ontologies; step 3: enumerate important terms; step 4: define classes and class hierarchy; step 5: define properties of classes; step 6: define facets and step 7: create instances.

Kaewboonma *et al*. (2014) proposed the ontology design and methodology for data integration. The process involved five steps: 1) Identify Purpose; 2) Ontology Modeling; 3) Ontology Development (Setting the Scope, Enumerate Terms, Defining the Class and Class Hierarchy, and Creating Instances); 4) Ontology Implement; and 5) Evaluation Ontology.

However, Noy & McGuinness (2001) have said that "there is no one correct way to model a domain, ontology development is necessarily an iterative process, and Concepts in the ontology should be close to objects and relationship in your domain of interest." Ontology development should be based on the objectives of each application, characteristics of data, role and context of the information system and the feasibility of reuse in the future.

3.2.Ontology Development Tools

There are a number of ontology editors available on the Internet (W3C, 2015). The important ones are: Protégé, NeOn Toolkit, SWOOP, Neologism, TopBraid Composer, Vitro, Knoodl, Anzo for Excel, OWL GrEd, Fluent Editor, Semantic Turkey, and VocBench.

For example, Protégé was developed by the Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine. Protégé system is a free, open-source platform that provides a growing user community with a suite of tools to construct domain models and knowledge-based applications with ontologies.

Protégé Desktop supports creation and editing of one or more ontologies in a single workspace via a completely customizable user interface. Visualization tools allow for interactive navigation of ontology relationships. Advanced explanation support aids in tracking down inconsistencies. Refactor operations are available, including ontology merging, moving axioms between ontologies, renaming multiple entities, and more.

WebProtégé is an ontology development environment for the Web and fully supports the latest OWL 2 Web Ontology Language. The highly configurable user interface creates the perfect environment for beginners and experts alike. Collaboration features abound, including sharing and permissions, threaded notes and discussions, watches and email notifications. RDF/XML, Turtle, OWL/XML, OBO, and other formats are available for ontology upload and download.

Another interesting tool is the Hozo Ontology Editor. Hozo was developed by the Institute of Scientific and Industrial Research, Osaka University. Hozo (http://www.hozo.jp) is an environment for building/using ontologies based on the ontological theory of role: 1) It provides sophisticated user interfaces with some characteristic functions such as dynamic "*is-a*" hierarchy generation; 2) and divergent ontology exploration; 3) so that the users can build well-organized ontologies according to appropriate viewpoints. Various ontologies and ontology-based applications are developed and built using Hozo and its API.

4. Using Ontologies for Knowledge Management

Ontologies are increasingly seen as a key technology for enabling semantics-driven knowledge processing. Communities establish ontologies, or shared conceptual models, to provide a framework for sharing a precise meaning of symbols exchanged during communication. Many applications benefit from semantically enriched information, including knowledge management and e-business applications. Next-generation knowledge management systems will likely rely on conceptual models in the form of ontologies to precisely define the meaning of various symbols (Maedche et al., 2003).

Knowledge management is concerned with the representation, organization, acquisition, creation, use and evolution of knowledge in its many forms. To build effective technologies for KM, we need to further our understanding of how individuals, groups and organizations use knowledge. Given that more and more knowledge is represented in computer-readable forms, we also need to build tools that can effectively search databases, files, websites and the like to extract information, capture its meaning, organize and analyze it, and make it useful (Jurisica et al., 2004).

Typical knowledge organization software can be divided into two types: content staging that includes content characterization, indexing, metadata creation, concept extraction, categorization, and summarization; and content delivery that includes data visualization, retrieval, broadcasting, and packaging. Ontologies help in organizational knowledge management in several ways both in content and information staging as well as content deployment. Ontologies act as repositories to organize knowledge and information based on a common vocabulary. They provide access to and optimize knowledge retrieval as well as support the mechanisms for communication and, therefore, the exchange of knowledge. They also help in reusing existing knowledge and facilitating reasoning and inferences on existing knowledge.

Ontology in KM contributes directly to the application functionality. It has helped in all three fundamental knowledge management processes, namely, Communication, Integration, and Reasoning. One ontology has been created that serves as a base for communication, thus facilitating knowledge transfer. To do this, it provides precise notation for queries on the domain of interest (Varma, 2007).

Ontology-based Knowledge Management

Maedche et al. (2003) presented integrated enterprise-knowledge management architecture for implementing an ontology-based knowledge management system (OKMS). The Figure 1a presents the Ontologging OKMS architecture, and the system's front end is organized into several different applications, each targeted at different user groups. The ontology management GUI provides the facilities that system administrators need to set up and to evolve the ontology. All GUI applications are realized on top of the core integration layer, which coordinates the interaction of various system components. This layer also hosts a set of intelligent services and agents that improve user interaction with the system by tracking the user's behavior. The core integration layer is realized on top of two other systems (the ontology server and the document server). However, the documents are annotated using the "Ontologging" domain ontology, and then the ontology server stores this information.

In the process of ontology-mapping, Maedche et al. (2003) used a five-step process (Lift and normalization, Similarity extraction, Semantic mapping, Execution, and Post processing) to address methodological issues in ontology mapping.

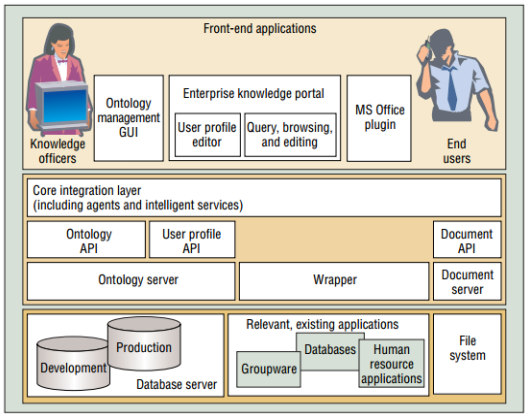

Figure 1a. The architecture of the Ontologging Ontology-based knowledge management system (Maedche et al., 2003).

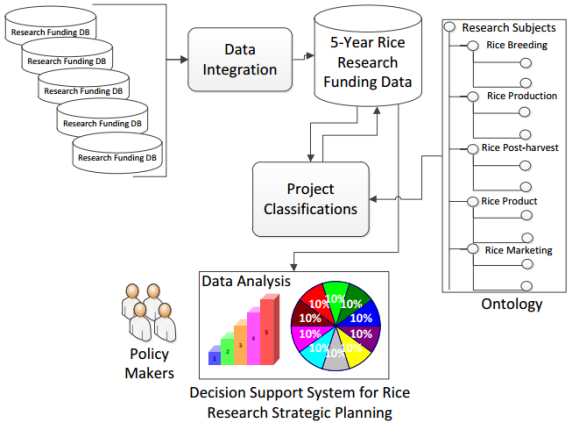

Figure 1b. A conceptual architecture for rice research DSS development (Buranarach et al., 2011).

Buranarach et al. (2011) presented a framework and a decision support system development (Figure 1b) to support a national policy planning for rice research. The framework utilizes ontology as a key component to model the standard data schema and to support development of the related information systems. By utilizing the ontology-based framework, the knowledgebase can be shared and reused across the systems. The ontology development process in this project involved four domain experts in defining classes for five major rice research areas based on the rice supply chain, which are rice breeding technology, rice production technology, rice post-harvest technology, rice product technology, and rice marketing and economic affairs. This project mainly focuses on the development of a decision support system to collect and analyze past research funding data. The development process involved ontology development, data collection, data cleaning, project classification and data analysis processes. The data analysis results were used as a key input for the experts in developing the strategic plan and policy recommendations.

Fensel *et al.* (2000) proposed an ontology-based tool environment to speed up knowledge management when dealing with the large numbers of heterogeneous, distributed, and semi-structured documents typically found in large company intranets and the World Wide Web. *On-To-Knowledge* is developing an associated methodology for ontology-based knowledge management. The input on this subject includes existing European research results, such as the *CommonKADS* approach to knowledge engineering and management; experiences from knowledge-based software engineering and tool development, ontology composition, and information retrieval techniques; and feedback form industry case studies. The methodology will also cover how to develop the business case for ontology-based knowledge management. The desired results of this project included: 1) A toolset for semantic information processing and user access; 2) OIL, an ontology-based inference layer on top of the World Wide Web; 3) An associated methodology; and 4) Validation by industrial case studies.

Lau & Sure (2002) presented a methodology for application-driven development of ontologies that is instantiated by a case study, vis-a-vis the introduction of an ontology-based skills management system at Swiss Life and the lesson learned from the utilization of the methodology. Therefore, the methodology has a strong focus on development ontologies. This approach focuses on the application-driven development of ontologies during the introduction of ontology-based knowledge management systems. They cover aspects from the early stages of setting up a knowledge management project to the final rollout of the ontology-based knowledge management system. The steps of this project are sketched out in Figure 2a.

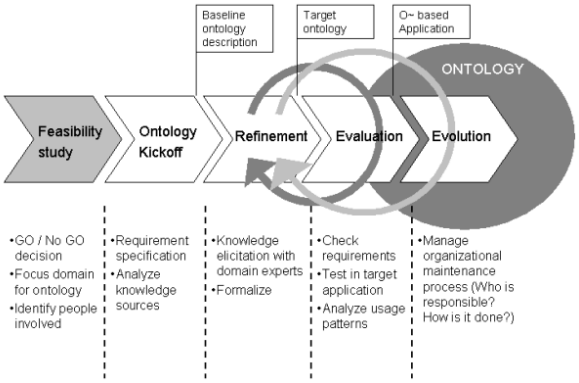

Figure 2a. Steps of the OTK Methodology (Lau & Sure, 2002).

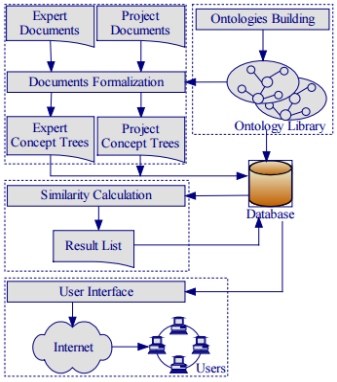

Figure 2b. The ontology-mapping process (WU, 2005).

The process model contains five major steps, vis-a-vis a feasibility study, kick-off, refinement, evaluation and maintenance. The interesting point in the kick-off phase is to capture requirements in an Ontology Requirements Specification Document (ORSD) describing what an ontology should support and sketching out the planned area of the ontology application; for example, 1) Domain and goal of the ontology; 2) Design guidelines to ensure a consistent development; 3) Available knowledge sources; 4) Potential users and use cases; and 5) Applications supported by the ontology. Through analysis of the available knowledge sources, *baseline ontology* is gathered. Typically, the most important concepts and relations are identified on an information level. Domain experts are the very important knowledge sources. This case study also heavily relied on domain experts for the ontology development.

WU (2005) proposed a framework of ontology-based KMS (Figure 2b), which mainly focuses on performing the activity for projects and matching domain experts. In project management, it is not easy to choose an appropriate domain expert for a certain project if experts research areas and the contents of the projects are not known ahead of time. It is also difficult work when the number of projects is much higher. So there is a great need for effective technology that can capture the knowledge involved in both domain experts and projects. The proposed ontology-based KMS tries to solve this problem. The ontology-based KMS encompasses four main modules, which are: Ontology Building, Document Formalization, Similarity Calculation, and User Interface.

5. Conclusions

In this paper, we have reviewed existing studies describing an ontological approach that supports knowledge management and knowledge processes. Ontology can be used to share and retrieve knowledge. Ontologies offer researchers the ability to cope with heterogeneous representations of web resources. The domain model implicit in an ontology can be taken as a unifying structure for providing information, common representation and semantics. Ontologies are being used in a different domain for knowledge process. The major processes are: Knowledge Sharing, Knowledge Acquisition, Knowledge Organization, and Knowledge Dissemination, and KM systems based on ontologies have been useful for a firm to take advantage of supporting data integration for analytics, supporting interoperation of applications, reducing the time and cost of application development, and improving data quality from their knowledge.

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