Online Information Review

Developing a domain ontology for knowledge management technologies

Parvin Hashemi, Ameneh Khadivar, Mehdi Shamizanjani,

The current issue and full text archive of this journal is available on Emerald Insight at:
www.emeraldinsight.com/1468-4527.htm

Received 7 July 2016
Revised 24 May 2017
Accepted 15 June 2017

Developing a domain ontology for knowledge management technologies

Parvin Hashemi and Ameneh Khadivar
Faculty of Social Sciences and Economics, Alzahra University, Tehran, Iran, and
Mehdi Shamizanjani
Faculty of Management, University of Tehran, Tehran, Iran

Abstract

Purpose – The purpose of this paper is to develop a new ontology for knowledge management (KM) technologies, determining the relationships between these technologies and classification of them.

Design/methodology/approach – The study applies NOY methodology – named after Natalya F. Noy who initiated this methodology. Protégé software and ontology web language are used for building the ontology. The presented ontology is evaluated with abbreviation and consistency criteria and knowledge retrieval of KM technologies by experts.

Findings – All the main concepts in the scope of KM technologies are extracted from existing literature. There are 241 words, 49 out of them are domain concepts, eight terms are about taxonomic and non-taxonomic relations, one term relates to data property and 183 terms are instances. These terms are used to develop KM technologies' ontology based on three factors: facilitating KM processes, supporting KM strategies and the position of technology in the KM technology stage model. The presented ontology is created a common understanding in the field of KM technologies.

Research limitations/implications – Lack of specific documentary about logic behind decision making and prioritizing criteria in choosing KM technologies.

Practical implications – Uploading the presented ontology in the web environment provides a platform for knowledge sharing between experts from around the world. In addition, it helps to decide on the choice of KM technologies based on KM processes and KM strategy.

Originality/value – Among the many categories of KM technologies in literature, there is no classifying according to several criteria simultaneously. This paper contributes to filling this gap and considers KM processes, KM strategy and stages of growth for KM technologies simultaneously to choice the KM technologies and also there exists no formal ontology regarding KM technologies. This study has tried to propose a formal KM technologies' ontology.

Keywords Ontology, Knowledge management processes, Knowledge management strategies, Growth stage for knowledge management technology, Knowledge management technologies

Paper type Research paper

1. Introduction

Luan and Serban (2002, p. 85) insist the importance of knowledge management (KM) with presentations "Knowledge management is the Holy Grail of the modern company, much rumored but rarely found." Organizations demonstrate a growing interest in KM since they have recognized that effective application of knowledge assets and resources make them more innovative, enable them to meet customers' demands and to help them survive in an ever-growing competitive economy. Several factors are presented as enablers of KM and technology is one of them. In fact, the goal of KM is facilitating the implementation of knowledge processes, and technologies facilitate creation, share and application of knowledge (Luan and Serban, 2002; Tyndale, 2002).

Technologies that can support KM or KM technologies are presented from various aspects. A common approach describes them from the view point of KM processes (Razmerita *et al.*, 2009; Dalkir, 2005). Furthermore, technologies have described as part of KM system architecture

Online Information Review
Vol. 42 No. 1, 2018
pp. 28-44

1468-4527
DOI 10.1108/OIR-07-2016-0177

(Chua, 2004; Benbya and Belbaly, 2005). Sometimes these technologies have been studied from their relationship with KM strategies (Merono-Cerdan *et al.*, 2007; Saito *et al.*, 2007). However, there is no comprehensive framework that has a consolidated approach covering all the factors in KM technologies' classification.

This study presents a new classification of KM technologies based on their support of KM processes and KM strategies as well as the status of these technologies in growth stages of KM technologies whereas the existing frameworks have studied only a limited number of factors to classify the KM technologies. In order to delineate the relationship between these elements, the concept of ontology is applied. "Ontology is an explicit specification of a conceptualization," stated by Gruber (1993). One of its advantages is creation of a platform for sharing knowledge, in particular, domain.

In the classifications proposed for the KM technologies, no formal language has been used. In this study, however, the ontology of KM technologies is delineated via three factors – processes, strategies and growth stages of technologies – in formal language.

Taking improper technologies in implementation of different phases of KM most often wastes time, energy and other resources. Ontology of KM technologies proposes a proper classification of these technologies in different phases, the proposed classifications are compatible with KM strategies. As a result of the formal language used in the ontology, it can be easily developed and updated and also help decision makers on the right choice of KM technology.

2. Literature review

2.1 KM technologies

Today knowledge is perceived as a strategic necessity and the dominant paradigm regards knowledge as a power. In current economy, knowledge has become an asset even more valuable than land, labor and capital (Kumar Agarwal and Anwarul Islam, 2014). Hence, in recent decades KM has gained critical importance. However, there is no universal consensus on a unique definition of KM and researchers have provided definitions from different aspects. Ngai and Chan (2005) regard KM as series of processes that enables organizations to create, acquire, store, conserve and distribution of knowledge within the organization. In the current study, we find Ngai and Chan's definition of more relevance with respect to our methodology.

KM can be considered as a cycle with different phases such as acquisition, creation, codification, sharing, access, usage and reuse of knowledge. Kimiz Dalkir (2005), however, combines different views of researchers about phases of KM cycle, such as Wiig (1993), and Bukowitz and Williams (2000) and provides an integrated cycle with three comprehensive phases:

(1) knowledge capture and/or creation;

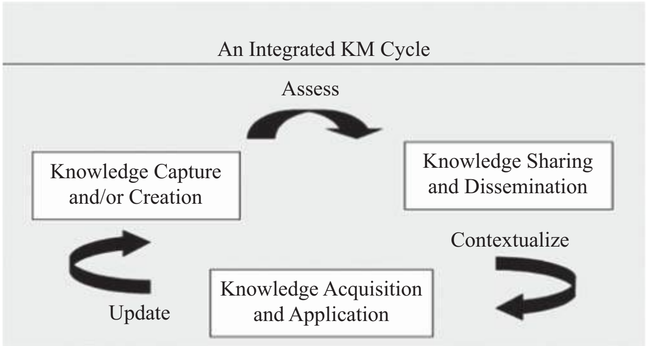
(2) knowledge sharing and dissemination; and

(3) knowledge acquisition and application (Dalkir, 2005).

These phases are shown in Figure 1.

The power of technology to support KM phases is widely recognized. The amount of knowledge and information to capture, store and share, the geographical distribution of resources and consumers and dynamic development of information has the use of technological tools indispensible (Lindvall *et al.*, 2002, 2003; Chua, 2004).

A wide range of technologies that support KM or KM technologies exists, but the problem is the selection of appropriate technology that can have desired effect on KM processes and improve organization's performance. Given a broad range of KM supporting technologies, the choice of the right KM technology is of critical



Source: Dalkir (2005)

Figure 1.
The integrated KM cycle

importance. Researchers have classified KM technologies based on different criteria (Wachter, 1999; Saito *et al.*, 2007).

In the current study, these categories have been presented in five major groups. The most common classification is based on KM processes (Alavi and Leidner, 2001; Tyndale, 2002; Hallouche and Sultan, 2008; Razmerita *et al.*, 2009; Dalkir, 2005; Kevin Sungkur and Ramasawmy, 2014; Kumar Agarwal and Anwarul Islam, 2014; Shafiei Nikabadi, 2014; Yousuf Al-Aama, 2014). In this category, researchers first consider a specific cycle for KM and then assign technologies to each phase.

Another group of researchers classify KM technologies based on the support they provide to KM strategies (Merono-Cerdan *et al.*, 2007; Saito *et al.*, 2007). In this category, researcher first identifies KM strategies – which can be in turn codification, formalization, human-oriented, systems-oriented, aggressive, and conservative, etc. and then classifies technologies based on their support for strategies.

Another group of researchers provides classifications based on heuristic models and spectrums (Binney, 2001; Luan and Serban, 2002; Liao, 2003; Gottschalk, 2006; Hicks *et al.*, 2006; M. Jasimuddin *et al.*, 2014). In such categories, researchers consider the basis for classifying technologies according to distinct factors and their preferences. For example, they introduce a range of applications and then map technologies to those applications or assume steps for technologies, which have different features, or they make categories in terms of manufacturers and their similarities (Binney, 2001; Luan and Serban, 2002; Gottschalk, 2006).

Other group of researchers introduces technologies as part of a KM system (Lindvall *et al.*, 2002, 2003; Chua, 2004; Benbya and Belbaly, 2005). In this case, researchers consider architecture for KM system then allocate technologies based on the layers of this architecture and their functions. Finally, there are researchers who classify technologies based on the support they provide to Nonaka and Takeuchi’s spiral model (Wachter, 1999; Marwick, 2001; García-Ãlvarez, 2014). However, these articles only considered the first phase of KM cycle; in fact, they considered knowledge creation based on the spiral model.

2.2 Ontology

The ontology has been a philosophic concept for years, and according to philosophers, is the science of evaluating creatures and the relations between them (Ikeda *et al.*, 1999). In artificial intelligence and knowledge-based systems, ontology is an explicit and formal description of a shared mental concept (Staab and Studer, 2010). A formal definition of ontology in the field of computer is that Ontology "O" is a multi-arranged $O = <C, R, I, A>$, which includes the following components:

- C, collection of the concepts in the model world;
- R, set of relationships between concepts (taxonomic relations and non-taxonomic relations);
- I, instances for concepts; and
- A, axioms and rules of inference, which is usually expressed in formal language (Kalfoglou and Schorlemmer, 2003).

There are various types of ontologies: knowledge representation ontology, general ontologies, high-level ontologies, domain ontology, task ontology, task domain ontology and application ontology (Gomez *et al.*, 2004). Each of them applied based on the aim and application of the ontology.

Ontology development approaches can be manual, based on ontology engineering tools, automatic and semi-automatic. In the manual approach, a huge volume of knowledge is coded manually by experts. Cyc is an example of an ontology developed via this approach (Lenat, 1995). In recent years, there have been a number of tools designed to support developing of ontologies such as Protégé, Ontolingua and Svetlan. Engineering tools for ontologies that only act as intermediaries do not nullify the need for a human being as the designer of the ontology, but only facilitate the architecture of the ontology. In the semi-automatic approach in developing ontologies, two methods have been introduced: integration and reapplication of current ontologies (Chapulsky *et al.*, 1997). In the automatic approach; tools, extract concepts and the relationships between them from data source, not the users. Tools such as Ontobuilder and Tango take structured data as learning resources for ontologies (Uschold and Gruninger, 1996).

There has been numerous but sporadic efforts in order to develop an explanatory language for ontologies. In 2003, the W3C proposed Ontology web language (OWL) as a standard language for ontologies (Alesso and Smith, 2008). Amongst the three types of OWL, OWL-DL have the highest explanatory power and fully supports calculations (Pan *et al.*, 2012).

Ontology has numerous applications including but not limited to areas such as developing systems to suggest publications to researchers, personalizing advertisements and news, classification of concepts in religious books including the Holy Quran are examples of ontology applications (Maidel *et al.*, 2010; Iqbal *et al.*, 2013; Amini *et al.*, 2015).

Ontology has also been applied in designing the architecture of the levels of KM system (Fu *et al.*, 2008) but the only study that provides an ontological description of KM technologies is a research conducted by Saito *et al.* (2007). However, they do not express that ontology with a formal language. In fact, they designed the ontology for human understanding not computers. In their study, the relationships between technologies, KM and strategy are tracked with ontology. This study considers two phases of KM cycle, and the ontology did not express by a formal language. The contribution of the present study is considering three factors: KM processes, KM strategy and the KM technology stage model in the selection of appropriate technology. Furthermore, relationships between these factors are presented by a formal ontology so it can serve as a platform for sharing knowledge among experts in this field in worldwide.

3. Methodology

The methodology applies an applied-developmental and descriptive approach with in terms of the research purpose and data collection, methodology. We have referred to 2000 articles and books, and five different internet scientific databases. Ontology development phase was started when organizing all the information was finalized, as it was told in Section 2, ontology development can follow a manual – application of ontology engineering tools – semi-automatic or automatic approaches. The current ontology has been developed via engineering tools entitled "protégé5." In this study, we have utilized the latest version of software, protégé5. Protégé5 supports creating OWL ontologies in such a way that it can benefit from description power and rich functions of this language to build ontologies (Horridge *et al.*, 2009).

Aside from ontology development approach, several methods have been introduced to construct it: including Cyc, Uschold & King, Sensus, Kactus, Methontology and Noy. Each of these methods includes some steps to create an ontology (Gomez *et al.*, 2004).

There are a number of common steps between them including determining the scope, collecting terms, implementation and evaluation. It is noteworthy that there exists no right methodology in developing an ontology. The decision on the choice of methodology is based on the desired goal of the research. Moreover, integration of methodologies is a very common practice. A number of methodologies are experience based and are designed for a particular project, such as Cyc, Kactus and Uschold & Knig that are applied whenever all the requirements are determined at the beginning. Another group of methodologies propose evolutive prototype models, such as Metontology and another group, provides an iterative approach in developing ontologies. NOY is an example of an iterative approach in this group (Brusa *et al.*, 2006). Sensus methodology starts with developing the territory ontology by defining a very comprehensive ontology: the Sensus ontology. The basis of this approach is confirming the seed terms of the designed ontology to those of Sensus ontology. This is achieved via removal of the irrelevant terms (Gomez *et al.*, 2004). The aim of this research, however, is not expansion of the Sensus ontology but establishing a common platform for sharing the knowledge of the experts in this area to benefit from this database to decide on the most appropriate KM technology for their organization. Given the objective of developing an ontology and also the fact that not all the requirements is obvious at the beginning, the need for an iterative technology and the ease if application of the NOY methodology, this methodology is selected to develop the ontology of KM technologies.

This methodology includes the following steps:

(1) Determination of the ontology scope (domain, reason of use, competency questions).

(2) Considering reuse of existing ontologies.

(3) Enumerating important terms of ontology (Terms, their features and our knowledge about them).

(4) Definition of classes and their hierarchy (as top-down, bottom-up and middle around).

(5) Determining characteristics of class-slots (internal, external, components, other relationships).

(6) Defining the characteristics or the limitations of these slots (procedure).

(7) Production of instances (Gomez *et al.*, 2004). These steps will be further explained in Section 4.

4. Ontology development

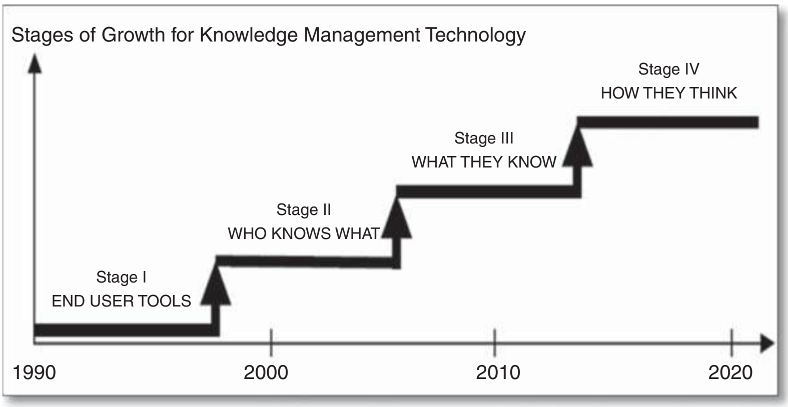
Ontology is an explicit and formal description of a shared mental concept. KM technologies' ontology is the domain ontology. In this study, for the purpose of presenting an ontological description of technologies, 1980 general and related sources in

KM technologies' field from different scientific databases including Emerald, Science Direct, Scopus, Springer and ProQuest were studied and amongst them, 23 articles and one book that were closely related to categorization of technologies were reviewed. From the various categories mentioned in Section 2, KM processes, were considered as an eminent factor in classification of KM technology. Technologies presented in these studies listed for every process according to Dalkir's three-phase cycle. Another factor that was considered in selection of technologies was KM strategy. Generally, two KM strategies have been considered: codification and personalization (Smith, 2004). Next influential factor is extracted from heuristic models. Gottschalk (2006) defines four stages for KM technologies' growth and defines a number of characteristics for each stage with some examples of their technologies. His model is depicted in Figure 2. Technologies that have been listed in the literature review are also embedded in these four stages based on characteristics and examples from the paper.

As explained in Section 3, Noy methodology is applied for this study. In order to create accurate documentation, all steps of the methodology have been conceptualized and have been formalized in the software.

4.1 Determining the ontology scope

The outputs of this stage are ontology scope, reason of using the ontology and competency questions. KM technologies' ontology introduces different types of technology to support KM processes and also provides a tetramerous category of technologies based on Gottschalk's (2006) model: the end user tools, who knows what, what they know and how they think, and examine technologies in support of KM strategies too. Therefore, it should be able to answer questions such as: what technologies are appropriate for knowledge creation process? What technologies are suitable for the knowledge sharing process? What technologies can be used for implementation of personalization strategy in the knowledge application process? What are the technologies for what they know the stage of Gottschalk model? etc. According to these questions, the ontology should include KM processes, types of technologies in KM, KM strategies and four stages of growth for KM technologies so it can respond to the questions from the combination of these concepts.



Source: Gottschalk (2006)

Figure 2.
Stage of growth for KM technology

4.2 Considering reuse of existing ontologies

Literature review suggests that there is no formal ontology for KM technologies. The only ontology is the one that Saito *et al.* (2007) proposed, which is based on KM strategies, and it has been designed for the understanding of human beings not machines. There are ontology libraries, but the purpose of KM technologies' ontology is to summarize the concepts of KM technologies in various sources. Therefore, there is not any ontology exclusively about KM technologies.

4.3 Enumerating important terms of ontology

To construct ontology, all the terminologies that are going to be in the ontology should be specified. At this stage, existing categories of technologies are investigated. An extensive literature review suggests 241 words. All these terms, including concepts, instances, properties and relations between them, together with their synonyms, acronyms and descriptions have been collected in a table similar to Table I.

Out of the 241 words, 183 terms are technology instances or individuals – that are special software or platforms – which can be used in KM such as Docstoc and Go to meeting. In total, 49 terms are concepts that create ontology classes. eight terms are about the relations between these concepts. Two types of relationships can be defined in ontology,

Name	Synonyms	Acronyms	Description	Type
Discussion board	Discussion group, discussion forum, message board, online forum	–	A discussion board is a general term for any online "bulletin board" where you can leave and expect to see responses to messages you have left, or you can just read the board (http://whatis.techtarget.com)	Instance
Electronic performance support system	–	EPSS	A performance support system provides just-in-time, just enough training, information, tools, and helps for users of a product or work environment, to enable optimum performance by those users when and where needed, thereby also enhancing the performance of the overall business (Raybould, 1991)	Instance
Knowledge capture or creation	Acquisition, discovery, identify, generation, gathering, obtain, produce	–	Knowledge capture refers to the identification and subsequent codification of existing (usually previously unnoticed) internal knowledge and know-how within the organization and/or external knowledge from the environment Knowledge creation is the development of new knowledge and know-how innovations that did not have a previous existence within the company (Tyndale, 2002)	Concept
Knowledge management process	–	KM process	Dalkir (2005) referred to the KM processes as composed of three main steps: capture or creation, sharing and dissemination, application and use	Concept

Table I.
Part of the glossary

taxonomic and non-taxonomic. Two terms are about taxonomic relationships and six terms are about non-taxonomic relationships, and one word is an instance attribute. Instance attribute value might differ for each individual.

In this case, the attribute is KM strategy, which is supported by a specific technology. The value of this property according to literature can be personalization, codification or both. In this way, important terms of ontology are identified.

4.4 Definition of classes and their hierarchy (as top-down, bottom-up and middle around)

Definition of concepts' hierarchy is based on four types of relations: subclasses relationships, separated analysis, complete analysis and partition. Accordingly, KM processes class has been the complete analysis to knowledge capture or creation process, knowledge sharing and dissemination process and knowledge acquisition and application process.

There are two types of taxonomic relationships, one between class and subclass that is identified with "is-a" and the other between class and its instances that is identified with "a kind of." Based on this, 183 instances have been allocated to their classes with this kind of taxonomic relationship.

Based on the literature review, 26 types of technologies were identified. Hence, the numbers of direct subclasses of KM technologies' class are more than one dozen. This situation indicates the need to further classify them into middle classes. Other than categories based on processes, as explained in Section 2, technologies are classified based on KM system architecture, Nonaka and Takeuhi spiral model, strategies and heuristic models.

In order to construct middle classes, subcategories based on KM system architecture is too general and do not provide a good measure for creating middle classes. Spiral model only covers the first phase of KM cycle. Therefore, this category is not appropriate too. However, amongst heuristic models, growth stage model of Gottschalk (2006) is a sound basis for classification. In addition to the characteristics of each stage, that paper provides some examples of different stages' technologies. Based on these attributes and examples, 26 previously identified technology types are further categorized in the form of four stages (shown in Table II). The mapping is a hierarchical subclass.

4.5 Determining characteristics of class-slots (internal, external, components and other relationships)

In this stage, object properties are determined. These relationships include the relationships between technologies and KM processes. To determine which process is associated with which technology, frequency method has been applied.

In fact, if from nine resources about classifying technologies based on processes, six sources allocated a technology to knowledge creation process; this technology is allocated to knowledge creation process in ontology too. In this step, the relationships and concepts that are involved in each of them are gathered; some of which are presented in Table III. Disjoint classes cause incompatibilities in defining relations between KM technologies and KM processes.

In order to avoid inconsistencies due to disjoint classes in linking processes to technologies, we created three subclasses for KM technology classes – technology for knowledge creation, technology for knowledge sharing and technology for knowledge application.

4.6 Defining the characteristics or the limitations of these slots (procedure)

At this stage, the domain and range of object properties are determined. The domain and range of facilitates and enables relations are presented below:

Relation: Facilitates

(1) End user tools	(2) Who knows what	(3) What they know	(4) How they think
Video related tool (including video editing tool, video recording tool)	Knowledge community/profile capturing technology	Collaborative writing technology	Artificial intelligence technology
Mind mapping and diagraming tool	Co-browsing, screen sharing and remote support technology	Content creation technology	E-learning technology
Web/multimedia presenting tool	Collaborative visual reviewing technology	Content management technology	Event scheduling technology
Communication and collaboration tool	Expertise profiling technology	Document sharing- wiki technology	
	Group communication, private social network technology	Groupware technology	
	Networking technology	Large audience webinar technology	
	Social networking technology	Project management technology	
	Virtual 3D immersive collaboration technology	Social content technology	
		Web conferencing technology	
		White boarding technology	
		Work grouping/team collaboration workspaces technology	

Table II.
Mapping technologies to stage of growth for KM technology

Table III.
Describing some non-taxonomic relationships

Relation name	Source concept	Target concept	Inverse relation
Supports	TechnologyForKnowledgeCreation	KnowledgeCreation	IsSupportedBy
Facilitates	TechnologyForKnowledgeSharing	KnowledgeSharing	IsFacilitatedBy
Enables	TechnologyForKnowledgeApplication	KnowledgeApplication	IsEnabledBy

Inverse relation: IsFacilitatedBy
Domain: (TechnologyForKnowledgeSharing)
Range: (KnowledgeSharing)
Relation: Enables
Inverse relation: IsEnabledBy
Range: (KnowledgeApplication)
Domain: (TechnologyForKnowledgeApplication)

4.7 Instance production

In this step, 183 instances and their attributes are identified and allocated to 26 technology classes. In this study, support for KM strategy is an instance attribute that its value can be personalization, codification or both. These instances – and their capabilities – which are extracted from literature are checked one by one for the level of support they provide for KM strategy. A table on details of instances characteristics has been prepared. In this table, instance name, the name of the class which the instance belongs to, instance attribute, value type and attribute value is specified for each instance. Table IV is a small part of this table.

By presenting the mentioned tables, conceptualization of KM technology ontology is finalized and formalization stage or implementation in software begins. In this study, protégé5 – which is an open-source tool – and OWL language are used. Protégé has two versions: desktop version and web-based one. The ontology that is made in desktop protégé can be easily uploaded on the web-based version of the software. The ontology that is uploaded to the web allows users from different locations online access to the ontology. This access is limited to certain permissions and engages users in completing and applying the ontology. In Figure 3, examples of the subclass relationships and object properties in OWL language are presented. In this way, classes, object properties, data properties, annotations including labels, synonyms and descriptions are determined in protégé. In description section, definitions of terms are presented based on literature. Figure 4 presents a view of ontology that is created in protégé5. In addition non-taxonomic relations between KM processes and KM technologies that support them are shown in Figure 5.

Table IV. Details of instances characteristics

Instance name	Concept name	Instance attribute name	Value type	Attribute value
Twitter	SocialNetworkingTechnology	Supports-KM strategy	String	personalization
WhoIsWho	ExpertiseProfilingTechnology	Supports-KM strategy	String	personalization
Basecamp	ProjectManagementTechnology	Supports-KM strategy	String	personalization /codification
skyDrive	FileSharingTechnology	Supports-KM strategy	String	codification

```
<!-- http://Ontology#VoIP -->

<owl:Class rdf:about="&Ontology;VoIP">
    <rdfs:label>VoIPTechnology</rdfs:label>
    <rdfs:subClassOf rdf:resource="&Ontology;Groupware"/>
</owl:Class>
```

```
<!-- http://Ontology#Enables -->

<owl:ObjectProperty rdf:about="&Ontology;Enables">
    <rdfs:range rdf:resource="&Ontology;KnowledgeApplication"/>
    <rdfs:domain rdf:resource="&Ontology;TechnologyForKnowledgeApplication"/>
</owl:ObjectProperty>


<!-- http://Ontology#Facilitates -->

<owl:ObjectProperty rdf:about="&Ontology;Facilitates">
    <rdfs:range rdf:resource="&Ontology;KnowledgeSharing"/>
    <rdfs:domain rdf:resource="&Ontology;TechnologyForKnowledgeSharing"/>
</owl:ObjectProperty>
```

Figure 3. Syntax for defining subclasses and object properties in OWL

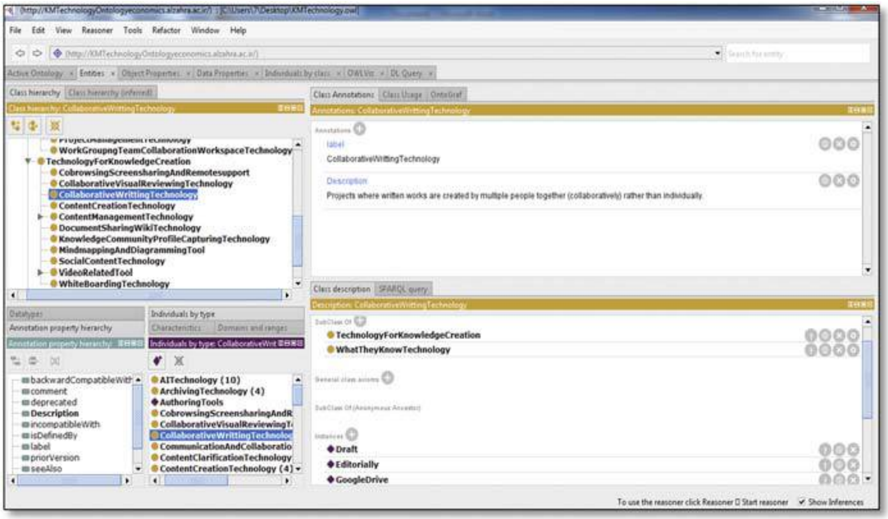


Figure 4.
Schema of KM technologies ontology in protégé5

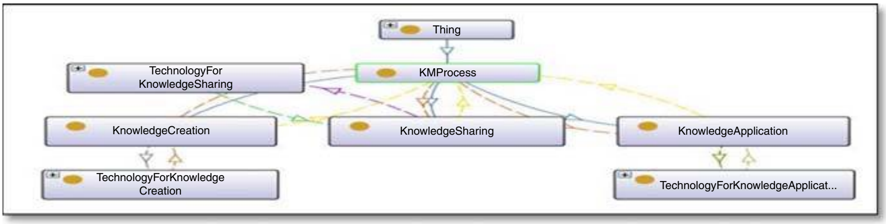


Figure 5.
Non-taxonomic relations between KM processes and technologies

5. Ontology evaluation

Ontology evaluation is a necessity to determine ontology's suitability for a particular domain (Yu *et al.*, 2007). Various methods have been proposed to evaluate ontologies that can fit in the four general categories: evaluation based on golden standard, data-driven evaluation, evaluation by human and evaluation by application (Brank *et al.*, 2005).

In this perspective, ontology is evaluated based on certain quality criteria. The aim of KM technologies' ontology is to store the words of the field and enabling to search appropriate technology according to organization's KM processes and KM strategy. Therefore, consistency and abbreviation have been considered for evaluating KM technologies' ontology. We also evaluated knowledge retrieval of KM technologies which is conducted, through query by experts.

5.1 Consistency

Consistency implies that ontology has no paradox or does not result to paradox rise. Contradiction in definitions of ontologies will lead to inconsistency in ontology. Consistency check is one of the standard services that provided by Reasoners. Some of the concepts in a domain are defined as disjoint classes in ontology. Defining common partial classes of disjoint classes and also sampling from them lead to inconsistency in ontology. If such an incorrect definition is provided in ontology, it will be identified by Protégé. These concerns have been considered in definition of all classes in KM technologies' ontology.

5.2 Abbreviation

A succinct ontology does not accommodate unnecessary and unused definition. It means there is no explicit redundancy in definitions of ontology, and no deduction from these definitions. Since in this, only the essential concepts are defined, the abbreviation enables the ontology to reuse. In modeling the KM technologies, this criterion has been tried to cover too. Before constructing the ontology, all concepts are identified and then defined as ontology classes. In addition, for creating communication between classes, a set of general relations between the concepts are established. Furthermore, the properties arising from those relations are also specified. These properties help to infer implicitly other required concepts and relationships. On the other hand, determining the domain and the range of properties in the ontology will prevent any unnecessary inference of knowledge.

One form of redundancy in ontology is when there exist numerous classes with the same definition but different names in ontology. In order to resolve this redundancy, the distinction between classes needs to be specified. One of the capabilities of OWL ontologies is provision of the ability to define necessary and sufficient condition or description of "Equivalent to" for each ontology class. In KM technologies' ontology, this capability is used to avoid redundancy.

5.3 Knowledge retrieval of KM technologies

The accuracy of the search results depends on several factors such as exact definition of technologies in ontology and execution of right queries. In the current study, ontology is applied to store and display knowledge of KM technologies; however, in addition to storage capability, ontologies have search mechanism and ability to update the storage. Today, numerous studies are conducted on the subject of knowledge retrieval based on application of ontologies (El Khoury *et al.*, 2008; Figueiredo *et al.*, 2012). Each of these research studies has special methods for representation and knowledge retrieval of its ontology. In this study, KM technologies are expressed in the form of OWL ontology. To retrieval the knowledge about this kind of ontology due to the nature of the issue, different languages may be used for different conditions. W3C organization proposes SPARQL language for running query on ontologies which is also compatible with protégé. However the problem with SPARQL is that it cannot extract implicit relations.

Protégé has DL query tab too, and it provided the ability for running query with Descriptive Logic language. DL query language does not have SPARQL problem, and it can identify implicit relations in ontology. However, this query language is not without limitations in execution of complicated queries which result into confusion in the query phrase. Therefore, it should be considered, which method can be effective based on the complexity of the issue and the limitations and capabilities of each query language.

In order to ensure that KM technologies' ontology for choosing technology based on KM processes and KM strategy is suitable or not? Seven experts of the field as potential beneficiaries are asked to run DL queries from ontology in the scope of competency questions like what technologies are appropriate for knowledge creation process? What technologies are suitable for the knowledge application process? What technologies can be used for implementation of codification strategy in the knowledge application process? What are the technologies for what they know the stage of Gottschalk model? etc.

Considering the proposed question, level of the answer can be any of the level determined in the software such as subclass, superclass, direct class, instances, etc. For example, as can be seen in Figure 6, the expert requested that the technologies applied in the knowledge creation phase and also provide support to the personalization strategy be depicted at the instance level.

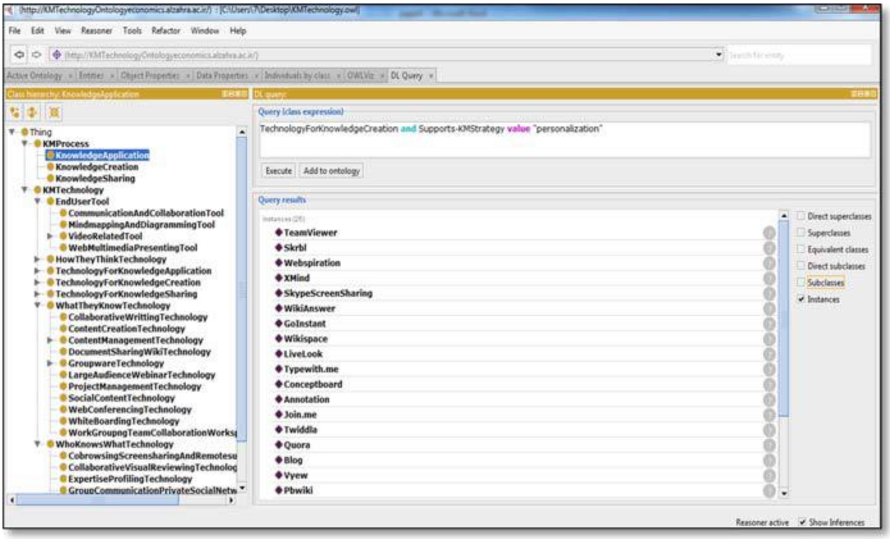


Figure 6.
A sample DL query in protégé5

Based on the findings, experts are asked to answer this question on the Likert spectrum (very poor, poor, medium, high and very high): "how would you judge the performance of the KM technologies' ontology in technology selection with respect to KM processes and KM strategy and stage of growth for KM technology?" Five of the seven experts responded very high and the two of seven answered high. Based on this, we can say KM technologies' ontology can help decision makers choose the appropriate technology based on KM processes and KM strategy. Therefore, this ontology can be applied for developing decision support systems. Moreover, by the help of tools such as web-protégé, experts can easily utilize the ontology in web environment and be able to update it. In fact, the ontology can be provided as a knowledge-sharing platform to those interested in the field including the experts.

6. Conclusion and future research

Previous studies on KM technologies' category only consider one or two factors in their classification. They also do not provide any presentation of a formal language of classifications. For example, Saito *et al.* (2007) offer KM technologies' ontology based on strategy; however, this ontology is designed for human understanding not machines. Kumar Agarwal and Anwarul Islam (2014) map KM technologies to KM processes, but they do not perform the formalization, neither Tyndale (2002) classify technologies based on KM processes but do not present them with a formal language.

In the current study, KM strategy, KM processes and KM technology stage model are considered for categorizing KM technologies, and ontology is applied to create communication between these concepts. Furthermore, this ontology is provided with a formal language so it is also understandable for computers.

In a number of other studies, methods such as Fuzzy Logic are applied in the evaluation of the KM technologies which in particular have been the focus in the Expert and Decision Support Systems (Ngai and Chan, 2005; Hamundu *et al.*, 2009). The ontology of KM technologies compared to these methods, benefits from a number of advantages including but not limited to the ability to define non-taxonomic relations; the application of an explanatory robust language in the ontology that enables writing annotations; defining features and self-evident principles; ease of updating the ontology in a web-based environment by the experts and considering multiple factors in the choice of the appropriate process.

With suggested ontology, choice of KM technology is simplified. In addition, in this area, there was formerly no common understanding of technologies based on KM processes and KM strategy. Constructing this ontology creates such a common mental understanding because one of the advantages of ontologies is creating a common understanding in a specific domain.

KM technologies represent solutions for execution of KM processes. However, decision making on the choice of technology and the logic behind these decisions have not been precisely documented and widely shared. Therefore, a considerable amount of knowledge is wasted. Considering the importance of sharing knowledge, this study provides the conditions that domain experts can exchange knowledge on a shared platform regardless of geographical constraints. As a result, they can play an effective role in development of this ontology. From this point of view, KM technologies' ontology is applied as a communal source of knowledge. This ontology provides a shared understanding of concepts of KM technologies for domain experts. However, the main challenge for domain experts is unfamiliarity with representation of formal knowledge languages and also the ontology editing tools. This major challenge, hinder the expert's participation in development of knowledge in this field. Thus, an infrastructure needs to be provided for interaction between experts. Ontology editing software such as Protégé by providing a suitable interface has largely resolved this problem. Protégé has a web-based version that the ontology built-in desktop protégé is easily loadable on the web-based Protégé provides the opportunity to share the knowledge about this field in the web.

Therefore, it can be said that making formal KM technologies' ontology provides a platform for sharing the knowledge of experts on this field from around the world and ontology tool support for knowledge modeling eliminates the need for experts of ontology.

Applying this ontology, organizations that want to select technologies for execution of KM processes will have the option to choose from a wide range of technologies and select the most appropriate one based on their KM strategy. If an organization adopts a specific KM strategy, it can get query from this ontology and finds the appropriate technologies in line with its strategy. However, in the real world selecting a technology is affected by a number of factors including but not limited to existing infrastructure, budget, and time limitation and so on.

Future studies can consider more factors in the selection of proper technology in this ontology like budget, time or infrastructure. In addition, application of fuzzy ontology is proposed. In fact one technology can be related to more than one process but with different membership degrees. On the other hand, adding more technology classes or instances to the ontology is always an option.

References

Alavi, M. and Leidner, D.E. (2001), "Review: knowledge management and knowledge management systems: conceptual foundations and research issues", *MIS Quarterly*, Vol. 25 No. 1, pp. 107-136.

Alesso, H.P. and Smith, C.F. (2008), *Thinking on the Web: Berners-Lee, Godel and Turing*, John Wiley and Sons, NJ.

Amini, B., Ibrahim, R., Othman, M.S. and Nematbakhsh, M.A. (2015), "A reference ontology for profiling scholar's background knowledge in recommender systems", *Expert Systems with Applications*, Vol. 42 No. 2, pp. 913-928.

Benbya, H. and Belbaly, N.A. (2005), "Mechanisms for knowledge management systems effectiveness: an exploratory analysis", *Knowledge and Process Management*, Vol. 12 No. 3, pp. 203-216.

Binney, D. (2001), "The knowledge management spectrum-understanding the KM landscape", *Journal of knowledge Management*, Vol. 5 No. 1, pp. 33-42.

Brank, J., Grobelnik, M. *et al.* (2005), "A survey of ontology evaluation techniques in proceedings of conference on data mining and data warehouses (SiKDD 2005)", Ljubljana.

Brusa, G., Caliusco, M.L. and Chiotti, O. (2006), "A process for building a domain ontology: an experience in developing a government budgetary ontology", Proceedings of the second Australasian Workshop on Advances in Ontologies, Vol. 72, Australian Computer Society, Inc., Hobart, pp. 7-15.

Bukowitz, W. and Williams, R. (2000), *The Knowledge Management Fieldbook*, Prentice Hall, London.

Chapulsky, H., Hovy, E. and Russ, T. (1997), "Progress on an automatic ontology alignment methodology", ANSI Ad Hoc Group on Ontology Standards, available at: http://kslweb.stanford.edu/onto-std/hovy/index.htm

Chua, A. (2004), "Knowledge management system architecture: a bridge between KM consultants and technologists", *International Journal of Information Management*, Vol. 24 No. 1, pp. 87-98.

Dalkir, K. (2005), *Knowledge Management in Theory and Practice*, Chapter 2, Elsevier Inc., Mcgill University, p. 43.

El Khoury, P., Mokhtari, A., Coquery, E. and Hacid, M.-S. (2008), "An ontological interface for software developers to select security patterns", 19th International Workshop on Database and Expert Systems Application, Turin, IEEE.

Figueiredo, A.M., Dos Reis, J.C. and Rodrigues, M.A. (2012), "Improving access to software architecture knowledge an ontology-based search approach", *International Journal Multimedia and Image Processing*, Vol. 2 Nos 1/2, pp. 124-149.

Fu, R.-x., Xin, Y., Ming, S. and Xin, Z.-h. (2008), "An architecture of knowledge management system based on agent and ontology", *The Journal of China Universities of Posts and Telecommunications*, Vol. 15 No. 4, pp. 126-130.

García-Ãlvarez, M.T. (2014), "Analysis of the effects of ICTs in knowledge management and innovation: the case of Zara Group", *Computers in Human Behavior*.

Gomez-Perez, A., Fernandez-Lopez, M. and Corcho, O. (2004), *Ontological Engineering – with Examples form the Areas of Knowledge Management, e-Commerce and the Semantic Web*, Springer, Heidelberg.

Gottschalk, P. (2006), "Expert systems at stage IV of the knowledge management technology stage model: the case of police investigations", *Expert Systems with Applications*, Vol. 31 No. 3, pp. 617-628.

Gruber, T.R. (1993), "A translation approach to portable ontology specifications", *Knowledge acquisition*, Vol. 5 No. 2, pp. 199-220.

Hallouche, F. and Sultan, A. (2008), "Knowledge management: assessment of strategies and innovative technologies", *Proceedings of the World Congress on Engineering and Computer Science*, *San Francisco*, *June*.

Hamundu, F.M., Siregar, L. and Budiarto, R. (2009), "Evaluating the best of knowledge management technology for small medium enterprise based on fuzzy analytic hierarchy process", *Third Asia International Conference on Modelling & Simulation*, *25-29 May*, *IEEE, Bali*, pp. 200-205.

Hicks, R.C., Dattero, R. and Galup, S.D. (2006), "The five-tier knowledge management hierarchy", *Journal of Knowledge Management*, Vol. 10 No. 1, pp. 19-31.

Horridge, M., Jupp, S., Moulton, G., Rector, A., Stevens, R. and Wroe, C. (2009), "A Practical Guide to Building OWL Ontologies Using Protégé 4 and CO-ODE Tools Edition 1. 2." The University of Manchester, Manchester.

Ikeda, M., Hayash,i Y., Lai, J., Chen, W., Bourdeau, J., Seta, K. and Mizoguchi, R. (1999), "An ontology more than a shared vocabulary", *Proceeding of AIED99 Workshop on Ontologies for Intelligent Educational Systems, Le Mans*.

Iqbal, R., Mustapha, A. and Mohd. Yusoff, Z. (2013), "An experience of developing Quran ontology with contextual information support", *Multicultural Education & Technology Journal*, Vol. 7 No. 4, pp. 333-343.

Kalfoglou, Y. and Schorlemmer, M. (2003), "IF-Map: an ontology-mapping method based on information-flow theory", *Journal on Data Semantics I, Part of the Lecture Notes in Computer Science book series, (LNCS)*, Vol. 2800, pp. 98-127.

Kevin Sungkur, R. and Ramasawmy, M. (2014), "Knowledge4Scrum, a novel knowledge management tool for agile distributed teams", *VINE*, Vol. 44 No. 3, pp. 394-419.

Kumar Agarwal, N. and Anwarul Islam, M. (2014), "Knowledge management implementation in a library: mapping tools and technologies to phases of the KM cycle", *VINE*, Vol. 44 No. 3, pp. 322-344.

Lenat, D.B. (1995), "CYC: a large-scale investment in knowledge infrastructure", *Communications of the ACM*, Vol. 38 No. 11, pp. 33-38.

Liao, S.-h. (2003), "Knowledge management technologies and applications: literature review from 1995 to 2002", *Expert Systems with Applications*, Vol. 25 No. 2, pp. 155-164.

Lindvall, M., Rus, I. and Sinha, S.S. (2002), "Technology support for knowledge management", *Advances in Learning Software Organizations*, Springer, pp. 94-103.

Lindvall, M., Rus, I. and Suman Sinha, S. (2003), "Software systems support for knowledge management", *Journal of knowledge Management*, Vol. 7 No. 5, pp. 137-150.

Luan, J. and Serban, A.M. (2002), "Technologies, products, and models supporting knowledge management", *New Directions for Institutional Research*, Vol. 2002 No. 113, pp. 85-104.

M. Jasimuddin, S., Connell, C. and H. Klein, J. (2014), "A decision tree conceptualization of choice of knowledge transfer mechanism: the views of software development specialists in a multinational company", *Journal of Knowledge Management*, Vol. 18 No. 1, pp. 194-215.

Maidel, V., Shoval, P., Shapira, B. and Taieb-Maimon, M. (2010), "Ontological content-based filtering for personalised newspapers: a method and its evaluation", *Online Information Review*, Vol. 34 No. 5, pp. 729-756.

Marwick, A.D. (2001), "Knowledge management technology", *IBM Systems Journal*, Vol. 40 No. 4, pp. 814-830.

Merono-Cerdan, A.L., Lopez-Nicolas, C. and Sabater-SÃinchez, R.n. (2007), "Knowledge management strategy diagnosis from KM instruments use", *Journal of Knowledge Management*, Vol. 11 No. 2, pp. 60-72.

Ngai, E.W.T. and Chan, E.W.C. (2005), "Evaluation of knowledge management tools using AHP", *Expert Systems with Applications*, Vol. 29 No. 4, pp. 889-899.

Pan, J.Z., Staab, S., Aßmann, U., Ebert, J. and Zhao, Y. (2012), *Ontology-Driven Software Development*, Springer, Berlin.

Raybould, B. (1991), "An EPSS case study: prime computer", *Handout Given at the Electronic Performance Support Conference, Atlanta, GA*.

Razmerita, L., Kirchner, K. and Sudzina, F. (2009), "Personal knowledge management: the role of Web 2.0 tools for managing knowledge at individual and organisational levels", *Online Information Review*, Vol. 33 No. 6, pp. 1021-1039.

Saito, A., Umemoto, K. and Ikeda, M. (2007), "A strategy-based ontology of knowledge management technologies", *Journal of Knowledge Management*, Vol. 11 No. 1, pp. 97-114.

Shafiei Nikabadi, M. (2014), "A framework for technology-based factors for knowledge management in supply chain of auto industry", *VINE*, Vol. 44 No. 3, pp. 375-393.

Smith, A.D. (2004), "Knowledge management strategies: a multi-case study", *Journal of Knowledge Management*, Vol. 8 No. 3, pp. 6-16.

Staab, S. and Studer, R. (Eds) (2010), *Handbook on Ontologies, International Handbooks on Information Systems*, Springer Science & Business Media.

Tyndale, P. (2002), "A taxonomy of knowledge management software tools: origins and applications", *Evaluation and Program Planning*, Vol. 25 No. 2, pp. 183-190.

Uschold, M. and Gruninger, M. (1996), "Ontologies: principles, methods and applications", *The Knowledge Engineering Review*, Vol. 11 No. 2, pp. 93-136.

Wachter, R.M. (1999), "Technology support for knowledge management", *American Journal of Business*, Vol. 14 No. 2, pp. 13-20.

Wiig, K. (1993), *Knowledge Management Foundations*, Schema Press, Arlington, TX.

Yousuf Al-Aama, A. (2014), "Technology knowledge management (TKM) taxonomy: Using technology to manage knowledge in a Saudi municipality", *VINE: The Journal of Information and Knowledge Management Systems*, Vol. 44 No. 1, pp. 2-21.

Yu, J., Thom, J.A. *et al.* (2007), "Ontology evaluation using wikipedia categories for browsing", *Proceedings of the Sixteenth ACM Conference on Conference on Information and Knowledge Management, ACM.*

About the authors

Parvin Hashemi received MSc in IT Management at the Faculty of Social Sciences and Economics, University of Alzahra, Tehran, Iran. Her research interests include knowledge management, ontology engineering and data mining. Parvin Hashemi is the corresponding author and can be contacted at: prhashemi@gmail.com

Ameneh Khadivar is an Assistant Professor at the Faculty of Social Sciences and Economics, University of Alzahra, Tehran, Iran. Her research interests include expert system, business intelligence, knowledge management, and decision support system.

Mehdi Shamizanjani is an Associate Professor at the Faculty of Management, University of Tehran, Tehran, Iran. His research interests include knowledge management, project management and Digital Transformation. He has published papers in some leading journals such as *Journal of Knowledge Management*.