Building a Taxonomy for Understanding Knowledge Management

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Abstract: As an interdisciplinary research field emerging recently, Knowledge Management (KM) has been given many different definitions. This paper introduces two studies we carried out to provide a holistic and better understanding of KM. By applying the methodology of domain analysis to investigate leading peer-reviewed journals regarding KM, the first study explores six fundamental issues regarding KM, which are: why is KM necessary; what enables the birth of KM and triggers actions on KM; what does KM deal with; how to implement KM; how to support KM by information technology; and where has KM been applied. By building an ontology structure of research topics within the community of the Graduate School of Knowledge Science at Japan Advanced Institute of Science and Technology (JAIST), the second study examines KM within a more general disciplinary called Knowledge Science, which gives a description of how KM is related to other research topics.

Keywords: knowledge management, domain analysis, ontology

1. Introduction

It is widely agreed that we are entering a knowledge economy and knowledge society, and the ability to manage knowledge has been proved to be the most critical thing for an organization to survive and maintain its competitive advantage (Shariq, 1997; Li & Zhao, 2006; Qi, et al., 2006). Subsequently, triggered or influenced by this, "knowledge management"(KM) was born as a new scientific discipline, followed by the invention of some new words or expressions, such as, chief knowledge officer (CKO), knowledge coordinator, knowledge creator, knowledge facilitator, etc. (Guns, 1997; Ellinger, et al., 1999).

Yet, "knowledge" and "knowledge management" include almost everything, and are difficult to understand, which is also shown in the results of a survey in the next section of this paper. KM seems to be a maze although a large number of publications and new established journals have been booming up in this field. For meta-level research on KM, first, Serenko and Bontis (2005) conducted a meta-review of KM by investigating three leading peer-reviewed journals in this area, namely, "*Journal of intellectual capital*", "*Journal of knowledge management*" and "*knowledge and process management*", in which research productivity and citation analysis were applied to rank researchers, institutions, countries and publications of KM at the world-wide level, for example, leading authors such as "Nonaka, I" and "Davenport, T.H.", and foundational publications such as "The Knowledge Creating Company" and "Working Knowledge" were referenced regularly. Secondly, Sugiyama, Nagata, et al. (2002) in their book introduced and elaborated 64 most important keywords in the discipline of Knowledge Science, such as "knowledge creating company", "SECI model", "Ba", "tacit knowledge", etc. This book is a production by the faculty of a graduate university, and hereby can be considered as a local university-based understanding of KM. Thirdly, Satio (2007) summarized KM field in terms of four basic epistemological perspectives with each leading to different ways to understand knowledge and its management: information, human, computing and strategy.

The above previous studies pursued research productivity and citation analysis on KM literatures, a local understanding of KM, and what KM deals with respectively. Yet a more brief and holistic understanding of KM content at the world-wide level is missing, and the question about how KM relates to other research disciplines is not well answered. Concerning these two points, we carried out two studies on KM. The first study applies the methodology of domain analysis to investigate leading peer-reviewed journals regarding KM which include *Journal of Knowledge Management, Journal of Knowledge-based System,* and 12 special issues on KM from other Journals. In this study, we explore six fundamental issues regarding KM, which are: why is KM necessary; what enables the birth of KM and triggers actions on KM; what does KM deal with; how to implement KM; how to support KM by information technology; and where has KM been applied. The second study examines KM within a more general disciplinary called Knowledge Science, by building ontology structure of research topics within the community of JAIST Knowledge Science School. The result of this study gives a description of how KM is related to other research disciplines.

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The remainder of this paper is organized as follows: Section 2 brings in a survey which indicates how people understand knowledge science and knowledge management differently; Section 3 introduces the methodology of domain analysis and then implements it to describe KM -- the first study; Section 4 introduces the methodology, process, and results of building ontology structure of research topics within the community of JAIST Knowledge Science School -- the second study; Section 5 summarizes this paper and gives concluding remarks.

2. Myths about understanding knowledge science and knowledge management

The catalyst to start this research can be traced back to a corresponding survey we conducted in 2006 at *Graduate School of Knowledge Science, Japan Advanced Institute of Science and Technology.* In 1998, *Graduate School of Knowledge Science* was established as the world's first research and education institute on the theme of knowledge. However, after 8-year research and practices within this research discipline, students and faculties in the school found them still being asked frequently "*what is Knowledge Science*", "*what is knowledge management*", and most of them found it was difficult to answer them. Then, a survey was conducted to obtain a working definition of Knowledge Science (KS)-a KM-related concept. The researchers with positions higher than Post-doctors were invited to take part in the survey, and the distribution of the final 20 respondents is shown in Fig.1. Among these 20, some of the answers are listed below:

- KS is a study of creativity …
- KS is a systematic study of knowledge…
- KS is a study of human science…
- KS is a study of efficient method of knowledge transfer, knowledge utilization and knowledge creation…
- Others

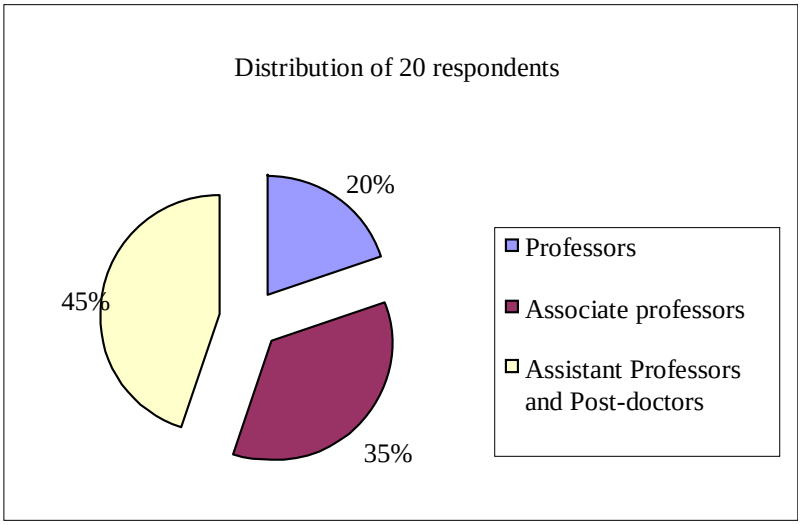

Figure 1: Distribution of respondents

Given these 20 responses, the similarity and dissimilarity among them were measured subjectively and intuitively, which led to a classification of 10 groups shown in Fig. 2, and a key which interprets what each group in Fig. 2 stands for is specified in Table 1. The result told us that, among 20 respondents, 6 of them (A group) argued that KS is about creativity, knowledge creation and knowledge use; 5 of them (B group) argued that KS is about human science and social science; and for the rest, for instance, 1 of them (AC group) argued that KS is combination of A group and C group, that is, KS is about creativity, knowledge creation and knowledge technologies, etc., see below.

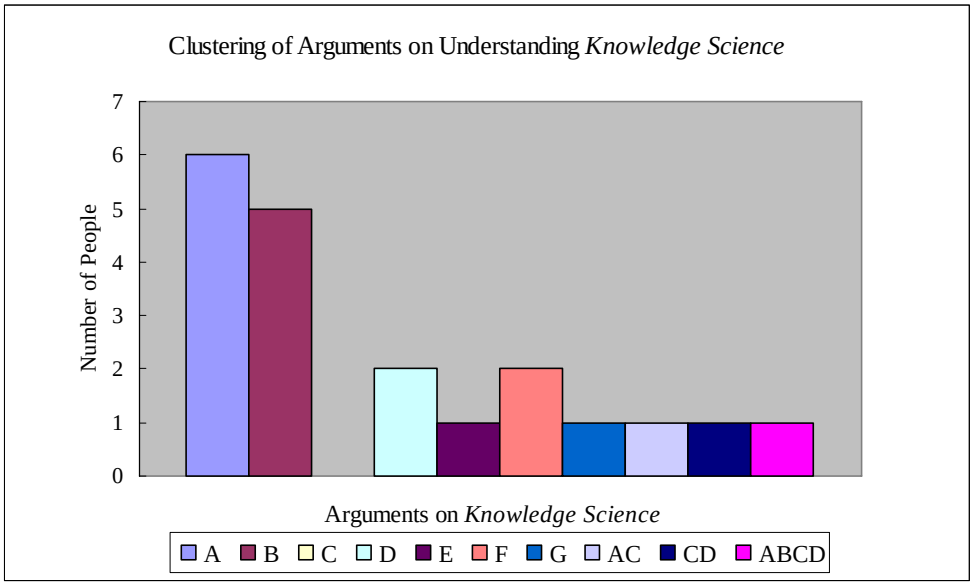

Figure 2: Clustering of arguments on understanding *knowledge science*

Table 1: The key to fig. 2

Group ID	Contents	Number of responses
A	Creativity, knowledge creation, knowledge use	6
B	Human science, Social science	5
C	Knowledge technologies, knowledge systems	0
D	Knowledge process	2
E	Management of Information	1
F	Knowledge itself	2
G	Solve problems produced by knowledge society	1
AC		1
CD		1
ABCD		1
		In total: 20

From this survey it can be concluded that opinions about *knowledge science* are various and not identical, even within a small research group (in our case, *Graduate School of Knowledge Science*). *Knowledge management* and *knowledge science* are much closely connected, and we believe in that KM is suffering the same situation that different people are confused of KM and have many different understandings of KM and this also includes experts, particularly because KM is a new emerging research discipline. Therefore, it is required to research KM and reach a brief holistic understanding of KM to help those who are confused of KM. The approach put forward in the next section is for this purpose.

3. Applying domain analysis to describe KM

3.1 What is domain analysis?

Domain analysis is "the process of identifying, collecting, organizing, and representing the relevant information in a domain, based upon the study of existing systems and their development histories, knowledge captured from domain experts, underlying theory, and emerging technology within a domain"(Kang *et al*., 1990). The idea of domain analysis was originally from software engineering, first

introduced by Neighbors in 1981, then Prieto-Diaz (1987) and Arango et al. (1989) proposed a more cohesive procedural SADT (Structured Analysis and Design Technique) model for performing domain analysis, later on, Bjorner (2006) developed a completely theory of domain engineering in his third of three textbooks on the engineering principles and techniques of software engineering.

It should be pointed out that domain analysis is different from systems analysis; systems analysis is concerned with the objects and operations in a specific system while domain analysis is concerned with objects and actions in a class of similar systems in a particular problem domain (Neighbors, 1981). In the triptych dogma of software engineering interpreted below (Bjorner, 2006), systems analysis can be associated to understanding *requirements*, while domain analysis can be associated to understanding *domain*.

- Before software can be designed, programmed, coded, its requirements must first be reasonably well understood.
- Before requirements can be expressed properly, the domain of the application must first be reasonably well understood.

In the tradition of the methodology of domain analysis, the basic thing is to understand *entities, functions, events, behaviors, plus support technologies* of a domain. A brief introduction and simple example about them are shown in Table 2.

Table 2: A brief introduction to entities, functions, events, behaviors, and support technologies

Categories	Definition in Software Engineering	A Brief Incomplete Example of "Banking"
Entities	Something fixed, immobile or static, if implemented inside computers, could typically be represented as data.	[demand/deposit, savings, mortgage]bank account; money; clients; bankbook, etc
Events	The occurrence of something that may either trigger an action, or is triggered by an action, or alter the course of a behavior, or a combination of these.	Losing a bankbook, etc
Functions	A mathematical quantity when apply to entities, either test for some property, or observe some subentity or actually change the entity value	[opening, closing, deposit, withdrawal, transfer, statements] operations on accounts, etc
Behaviors	A sequence of actions and events	A specific series of deposit and withdrawal events and actions, etc
Support technologies	Ways and means of implementing certain observed phenomena or concept	ATM machine; bankcard, etc

*Reorganized from material (Bjorner, 2006)

3.2 Design an approach based on domain analysis for describing KM

Treating KM as a conceptual domain, we implement domain analysis on it for getting a better understanding and overview on it. As the original SADT model [Prieto-Diaz, 1987] which is known as a procedural model of describing the process how to implement domain analysis, this paper takes it but additionally considers its some drawbacks to construct a new modified SADT model (see Figure3) in order to adjust to the new application of this study.

Following this new modified model to describe KM, as shown in Fig. 3, the main domain knowledge as input for implementing domain analysis is from scientific literatures, if practicable with financial constraints, question surveys and expert advices are additional inputs; then this study mainly concentrates on answering those five fundamental issues about KM through the iterative process of conducting domain analysis by domain experts and analysts, domain analysts here can be understood as a kind of knowledge coordinators (Nakamori, 2003; Ma, 2006) who is expected to be a person of all trades, he or she must understand systems analysis, the domain of application, the software technology at hand, and be able to communicate with the player among different disciplines; some drawbacks are taken into account and need to be fixed when questions like "Are these five categories sufficient to understand KM?" are probably being asked; a taxonomy of understanding KM is supposed to be produced as the final output of domain analysis.

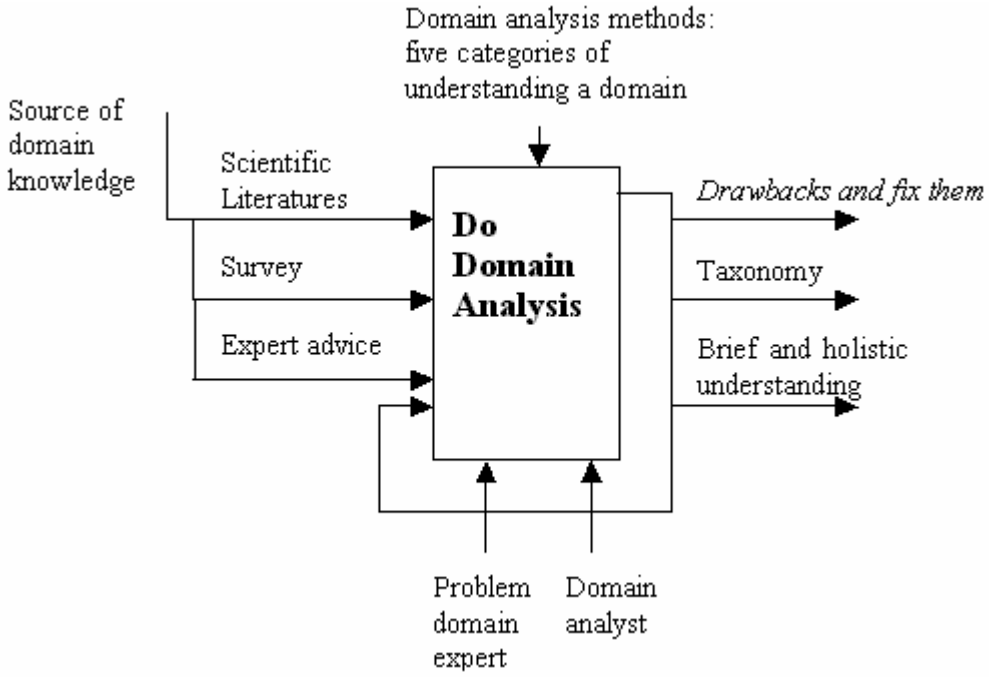

Figure 3: A modified SADT diagram

With this diagram, our approach of implementing domain analysis on KM is composed of the following six phases.

- Phase 1. Selecting leading journals regarding KM
- Phase 2. Extracting keywords from publications in the leading journals
- Phase 3. Analyzing extracted keywords: statistics and visualization
- Phase 4. Assigning keywords to the five categories regarding KM
- Phase 5. Considering the drawbacks and fix them out
- Phase 6. Achieving the taxonomy to understanding KM

3.3 Work on describing KM

3.3.1 Input for domain analysis

Before performing domain analysis, *domain knowledge* is prerequisite. The problem is that how to access and obtain KM domain knowledge, the most direct way might be survey those researchers and practitioners of KM field, but it is a huge project and therefore almost impossible. Then this paper turns to the second strategy that we collect KM domain knowledge from top-ranked scientific literatures by KM experts, these scientific literature covers: (a) *Journal of knowledge management*; (b) *Journal of knowledge-based system*; (c) *12 special issues on KM from various top-ranked Journals*. These sources are chosen based on two main reasons: First, there are other good KM journals, for instance, *Knowledge and process management* is one of noted KM journals, but the keywords information is not specified in those journals; secondly, it is believed that the contents among these sources and other journals largely overlap.

Information from the above scientific literature is rich but disordered, and usually the keywords in a paper specified by the authors can roughly express what this paper contains, so this study simplifies to use these keywords from the raw articles as source of domain knowledge. No doubt, sometimes the information provided by only keywords themselves is not sufficient, and it is highly intuitive to understand what it means by these keywords directly. So it is necessary to refer back often to the articles where these keywords appeared to get what is really meant by them.

Since not all keywords from data sources are essential to KM, the most important keywords ranked by their frequency are selected. As a result, 100 keywords from *Journal of Knowledge Management*, 50 keywords from *Journal of Knowledge-Based system*, and 50 keywords from *special issues on KM* (Table 3), that is, around 200 keywords are taken as domain knowledge, which is then used as input to the following domain analysis. Table 3 provides more details of those scientific literatures and number of extracted keywords from them.

Table 3: Input for domain analysis

Data Resources	Description
Journal of Knowledge Management (Soft perspectives on KM)	From 1997 to 2006, 411 articles, 574 keywords in total. 100 most frequent keywords of all are selected as input to domain analysis
Journal of Knowledge-based System (Hard perspectives on KM)	From 1987 to 2006, 720 articles, 2033 keywords in total. 50 most frequent keywords of all are selected as input to domain analysis
Special issues on Knowledge management (Mixed perspectives on KM)	95 articles, 338 keywords in total from 12 special issues of a variety of Journals, such as *Decisions Sciences, Decision Support Systems, Information Visualizatio*n, etc. 50 most frequent keywords of all are selected as input to domain analysis.

3.3.2 Basic data analysis

Taking Journal of Knowledge Management as an example, basic data analysis investigates frequency of keywords, relations between keywords, and visualization of keyword relations, etc.

Table 4 tells us the most frequent keywords are knowledge management, innovation, intellectual capital, learning organizations, etc. Table 5 relates one keyword with another keyword in terms of their co-occurrence (that is, they appeared together in the keyword list of one or more articles specified by authors). Figure 4 visualizes the relations denoted in Table 6, which provides a more direct and easier way to understand data, and identifies hidden complex pattern behind the data and relationship. From Figure 4 it is easy to see that two isolated groups are formed, and the smaller one includes only two keywords: management and information; while in the bigger group, knowledge management lies in the center and acts as broker/bridge between many other pairs of keywords.

Table 4: The most frequent keywords from *Journal of Knowledge Management*

Keywords	Frequency	Keywords	Frequency
knowledge management	291	organizational learning	15
innovation	38	knowledge processes	14
intellectual capital	28	organizations	14
learning organizations	21	competitive advantage	14
information	18	knowledge creation	12
knowledge workers	18	information systems	11
learning	17	knowledge	11
tacit knowledge	17	networks	11
management	16	knowledge transfer	10
information technology	15	knowledge management systems	9

Table 5: Relations between keywords

Keyword 1	Keyword 2	Number of Co-occurrences
innovation	knowledge management	28
intellectual capital	knowledge management	17
knowledge management	knowledge processes	13
knowledge management	Organizations	13
information	Management	12
competitive advantage	knowledge management	11
knowledge management	learning organizations	11
information technology	knowledge management	11
knowledge management	organizational learning	10
knowledge management	tacit knowledge	10
information systems	knowledge management	9
explicit knowledge	tacit knowledge	8

knowledge management	project management	7
knowledge management	Learning	7
knowledge management	knowledge management systems	7
knowledge management	knowledge transfer	7

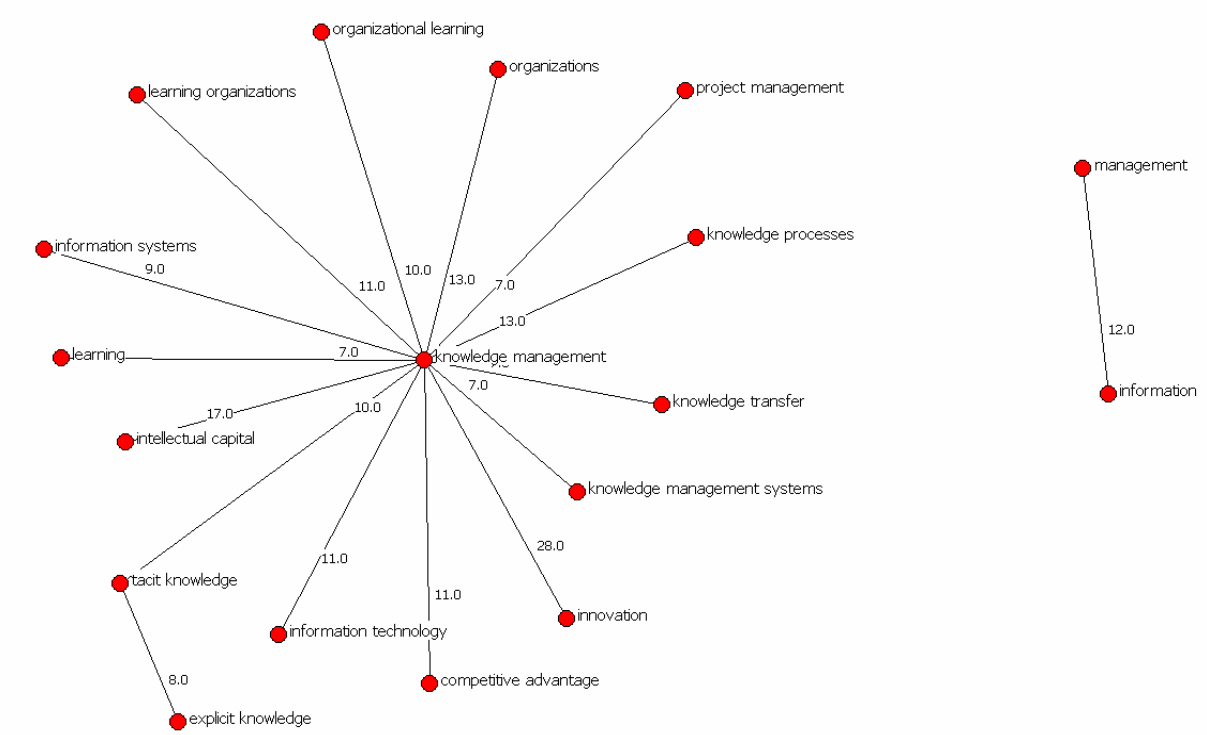

Figure 4: Visualization of keyword relations

(Note: only relations with more than 6 co-occurrences are mapped in this figure)

3.3.3 Match Keywords and five categories

This part mainly dedicates to investigate *entities, events, functions, behaviors, and support technology* of KM domain. To fit these five categories to the context of KM, Table 6 explains them again in contrast to their original meanings in Table 2, where they are slightly different.

Table 6: What Do These Five Categories Mean in KM

Categories	Corresponding issues in context of KM	Short Summary
Entities	What does KM deal with?	Know-what
Events	What enables the birth of KM and triggers actions on entities of KM?	Know-where
Functions	Which actions/operations are performed on entities of KM?	Know-how
Behaviors	Which sequence of actions and events are performed on entities of KM?	Know-how
Support technologies	Which ways and means are used to support KM?	Know-how

So far, 200 most important keywords of KM field were prepared as input for domain analysis. We assume that these input as domain knowledge covers all the above five categories in KM, to proceed domain analysis, we need to match those 200 keywords with five categories carefully and correctly. In order to classify 200 keywords to the five categories, several discussions were hold among the authors and other experts and researchers in KM discipline. Based on those conversations, the category of e*ntities* and f*unctions* is further divided into five detailed sub-categories, namely, general, strategy-oriented, information-oriented, human-oriented, and process-oriented; the category of *events* is further divided into two detailed subcategories, namely, external and internal, and the category of *support technologies* is further divided into

two subcategories, namely, soft and hard. The result of classification of 200 keywords into five categories is reported below:

Table 7: The keywords for the five categories/sub-categories

Categories	Sub-categories	The assigned keywords
Entities	General	organization, knowledge, resources, knowledge-based organization, knowledge base
	Strategy-oriented	Organizational culture/corporate culture, organizational climate, corporate strategy, business strategy, organizational culture, leadership, strategic knowledge
	Information-oriented	Information, explicit knowledge
	Human-oriented	Intellectual capital, intangible assets, intellectual property, human capital, intellectual assets
	Process-oriented	Knowledge process
Events	External	Economic growth, globalization, knowledge economy, knowledge society, knowledge market.
	Internal	Learning organization, culture change, business process reengineering, community of practice, virtual organization
Functions	General	Resource management
	Strategy-oriented	Strategy management, organizational design, management strategy
	Information-oriented	Management of information, information exchange, information networks, information transfer, knowledge mapping, information management, information visualization, knowledge discovery, knowledge capture, knowledge navigation, knowledge retrieval, knowledge extraction, knowledge representation, semantics, case based reasoning, data mining, machine learning.
	Human-oriented	Networks, human resource management, cognition, training, narratives, collaboration, team working, language sense making, communications, motivation, social networks, trust, discussions.
	Process-oriented	Process management
Behaviors	(no sub-category)	Innovation, learning, organizational learning, internet-resourced learning, knowledge creation, knowledge transfer, knowledge sharing, decision making, creativity, performance measurement, benchmarking, modeling, knowledge sharing, problem solving, implementation, best practices, integration, action learning, knowledge engineering
Support technologies	Soft	Knowledge workers, chief knowledge officer
	Hard	Information technology, information systems, KM systems, intranets, computer applications, groupware, expert systems, decision support systems, rule-based systems, human-computer interaction

3.3.4 Fix drawbacks and two more categories

During the process of distributing keywords to the above five categories, there were some keywords that were difficult to assign. What is the reason for those unassigned keywords? A deep analysis showed that the unassigned keywords are not saying something related to those above five categories, but something else. This is considered as drawbacks of traditional domain analysis when it is applied to the new area of describing KM. Therefore, two more categories are added, one is *objectives/targets*, and the other is *applications. Objectives/targets s* answers why to use KM, and *applications* answers where KM has been applied. See Table 8 and 9 below:

Table 8: What do two more categories mean in KM

Two more categories	Corresponding issues in context of KM	Short Summary
Objectives/Targets	Why is KM necessary?	Know-why
Applications	Where has KM been applied?	

Table 9: The keywords for the two more categories

Categories	Sub-categories	The assigned keywords
Objectives / Targets	(no sub-aspect)	Competitive advantage, performance, organizational performance, competences, organizational development

Applications	(no sub-aspect)	Cities, project management, product development, banking, aerospace industry

3.3.5 Taxonomy and understand KM

Based on the above analysis, the taxonomy to understanding KM can be easily obtained, see Figure 5, which help us to roughly conclude KM as following: Resulting from restructuring changes both outside and inside an organization, on the outside, such as, economic growth, globalization, knowledge society, on the inside, such as learning organization, culture change, and community of practice, KM has been established as to improve organizational competitive advantage, organizational competences, etc, it is dedicate to deal with strategy-oriented knowledge (organizational culture, corporate strategy, etc), information-oriented knowledge(information, explicit knowledge, etc), human-oriented knowledge (intellectual capital, intangible assets, etc) and process-oriented knowledge(knowledge process, etc), soft method such as knowledge workers, chief knowledge officers, etc, and hard technology such as information technology, information systems, KM systems, etc, has been developing to support KM, so far, KM has been applied to project management, product development and many other areas.

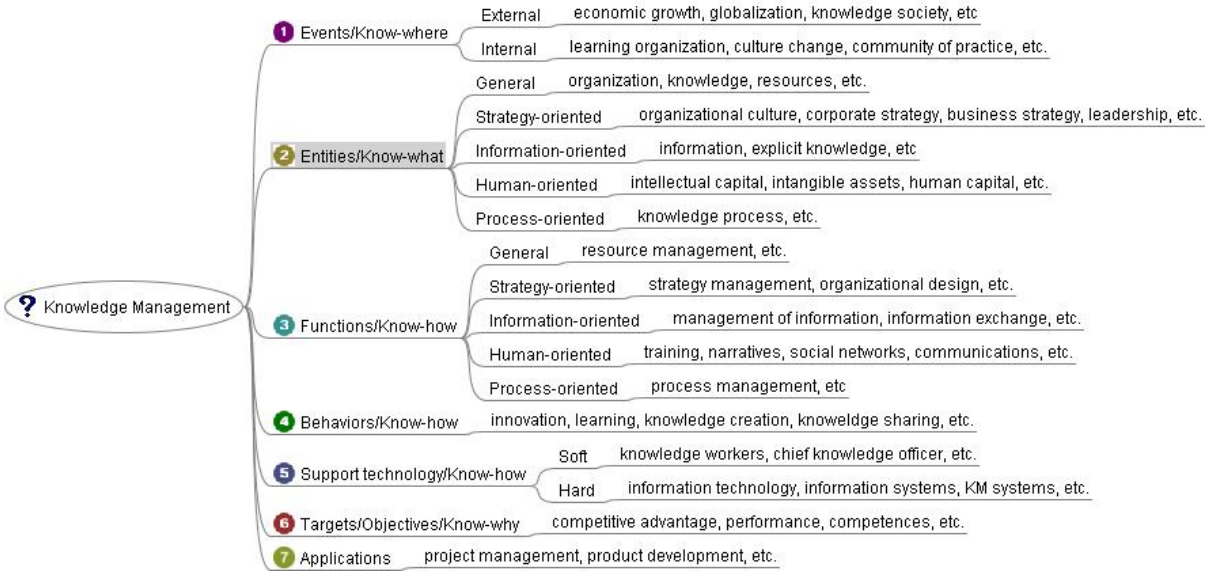

Figure 5: The taxonomy to understanding KM

4. Understanding KM in a more general discipline

The above study focused on KM itself. For a more holistic understanding of KM, it is necessary to examine KM in a wider or more general interdisciplinary to understand its relations with other disciplines or topics. With this purpose, we carried out a study to building ontology structure of research topics within the community of Graduate Knowledge Science School at Japan Advanced Institute of Science and Technology (JAIST KS School).

JAIST KS School specializes in this unique position in the world to have a variety of interdisciplinary or multidisciplinary research. With KM as one of the vast research topics in JAIST KS School, it provides a good chance to see how KM is related to other research topics. This study attempts to map the relationships among past research topics in JAIST KS School, and further construct an ontology structure of research topics for JAIST KS School. This study includes the following process:

- Collecting research topics information from papers/articles in KS school
- Measuring the similarity and mapping the relationships among these research topics
- Clustering the research topics into a certain number of groups
- Building an ontology structure for KS school

Two groups of data are collected; one is master thesis and doctoral dissertation by students in JAIST KS School with the purpose to know what has been done in the community of students, the other is papers/articles by faculty of JAIST KS School with the purpose to know what has been done in the community of KS school faculty. This case study only concentrates on the first group of data.

In the following, we will first introduces I-System methodology and its application in the context of our work in subsection 4.1; then in subsection 4.2 we will introduce an algorithm for building ontology structure, designed the with the help of I-System methodology; subsection 4.3 provides the result of the study.

4.1 I-System methodology

Nakamori (2003) proposed I-System methodology which includes five sub-systems: Intervention, Intelligence, Involvement, Imagination and Integration. I-System methodology stresses that most uncertain complex problem couldn't be solved only from scientific front; social front and cognitive front need to be considered as well. That is, we have to integrate scientific, social and cognitive dimensions in order to arrive at a good solution for an uncertain problem. Figure 6 puts I-System in the context of our work and explains it in more depth.

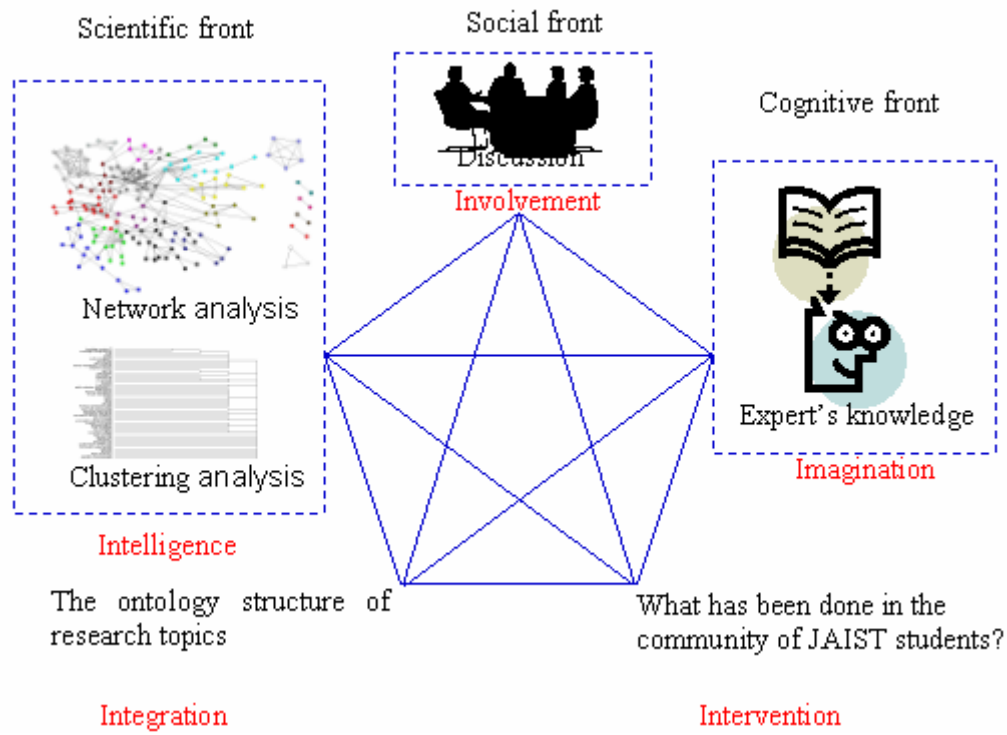

Figure 6: I-System methodology

In our work, I-System is used to assist thinking and working on how to build ontology structure of research topics.

- Subsystem of Intervention: "Intervention" is the first subsystem in which the faced problem has to be shaped or clarified clearly. To us, the problem needed to be solved is "what has been done in the community of JAIST students". Once has a problem, this subsystem request the following three subsystems to concentrate on it from scientific front, cognitive front and social front respectively.
- Subsystem of Intelligence: "Intelligence" is bottom-up approach to analyze research topics. In our work, two important techniques, namely, network analysis and clustering analysis are applied.
- Subsystem of Imagination: "Imagination" is experience-based or top-down approach to analyze research topics. .
- Subsystem of Involvement: "Involvement" is from social front, we believe that both scientific method and cognitive method do have their advantages and disadvantages, and a conflict between them often happens. And this subsystem attempts to build a bridge between scientific and cognitive front.
- Subsystem of Integration: "Integration" is final subsystem. The tasks of this subsystem is to integrate results from the above four subsystems, and submit the final report.

4.2 Algorithm for ontology construction

Here we explain how to build the ontology structure based on the I-system methodology that we mentioned above. Our procedure that combines stages of expert-supervised and automatic construction is articulated below:

Step 1: Start by selecting an ontological category that needs to be divided. This category can be determined either by expert or automatic construction.

Step 2: In the expert-supervised stage, the experts specifies several examples objects for the ontological category given in step1.

Step 3: In the automatic construction stage, all objects that are similar to those example objects are clustered to the same ontological category automatically.

Step 4: The resulting division in step3 may again be submitted for the approval of the experts, if the experts disapprove, go back to step 2.

Step 5: Steps 1-4 forms one iteration. The entire procedure is repeated for as long as there are no more categories that need to be divided, or until another stopping condition.

Step 6: The final version of ontology is achieved and submitted to experts for evaluation of looking for incompleteness, inconsistence, and redundancy. Future maintenance and refinement are allowed.

In automatic construction stage, two important techniques, network analysis and clustering method, are specifically used. Network analysis allows measuring the degree centrality of a research topic which is defined as the number of other research topics directly connected to it (Hanneman, 2005; Wasserman, 1999). Because degree centrality can speak the power of a research topic in the network, that is, the higher degree centrality is, the more powerful a research topic has. By this reason, we also found that research topics with higher degree centrality are always top-level concepts, like *knowledge management, knowledge creation, system*, and vise versa, see Table 10. So network analysis assists assigning research topics into different layers of ontological category.

Table 10: Top keywords ranked by degree centrality

Keyword	Degree Centrality
knowledge creation	17
knowledge management	16
system	16
leadership	15
simulation	13
innovation	11
data mining	10
community	10
groupware	9

Our clustering method is based on network similarity which can be understood as the same pattern of connectivity in the network (Hanneman, et al. 2005; Wasserman et al. 1999). That is, two research topics are similar if they are connected to the same other research topics. As an example, two research topics, *brainstorming* and *brain writing*, both of them are connected to research topics *divergent thinking* and *groupware*, they are considered having high similarity and thus they are clustered together into the same ontological category even they don't have a direct connection between them. Therefore, to measure similarity of two research topics, **first**, co-occurrence matrix is calculated and obtained from data, each value in the matrix represents the frequency of a pair of research topics, that is, the total number of the two research topics appearing together in all papers; **secondly**, classical similarity measuring algorithm, in our work, Euclidean distances-based algorithm is performed on co-occurrence matrix which is then converted to similarity matrix. See Formula 1 and Formula 2, in Formula 1, $R(k_i, k_j)$ is computed from co-occurrence matrix by considering a fact that the values in co-occurrence matrix are dependent on the frequencies of their two connected research topics and thus are not comparable with each other; in Formula 2, $S(k_i, k_j)$ is computed again from $R(k_i, k_j)$; **finally**, classical cluster analytical method is performed on similarity matrix to group those research topics that are most similar first, then similarity matrix is then re-calculated, and the next most similar pair are then joined, this process continues until all research topics are joined together and hierarchical dendrogram including all research topics is produced, Our work uses single-link, or nearest

neighbor method (Manning et al., 1999), in which in each step the two clusters whose two closest members have the smallest distance, or the two clusters with the smallest minimum pairwise distance are merged.

$$\begin{aligned}&\#\,\text{relation between keyword i and keyword j}, R(k_i, k_j)\\ &= \frac{\#\,\text{joint frequency of keyword i and keyword j}}{(\#\,\text{frequency of keyword i}) \times (\#\,\text{frequency of keyword j})}\\ &= \frac{frequency(k_i, k_j)}{frequency(k_i) \times frequency(k_j)}\end{aligned} \quad (1)$$

$$\begin{aligned}&\#\,\text{similarity between keyword i and keyword j}, S(k_i, k_j)\\ &= \frac{1}{\text{Euclidean distance between keyword i and keyword j}}\\ &= \frac{1}{\sqrt{\sum_{s=1}^{n}\left[R(k_i, k_s) - R(k_j, k_s)\right]^2}} (s \neq i, s \neq j)\end{aligned} \quad (2)$$

4.3 Results and discussions

Research topics are considered as building blocks and are collected from master theses and doctoral dissertations of JAIST KS School, In total, 415 papers are collected and the top 200 research topics are selected depending on their frequency in the total number of papers. Then these 200 research topics are used as resources to build domain ontology of knowledge science.

With these 200 research topics and the procedure discussed in the above section, it is able to construct the ontology structure of research topics for JAIST KS School. A part result is given below:

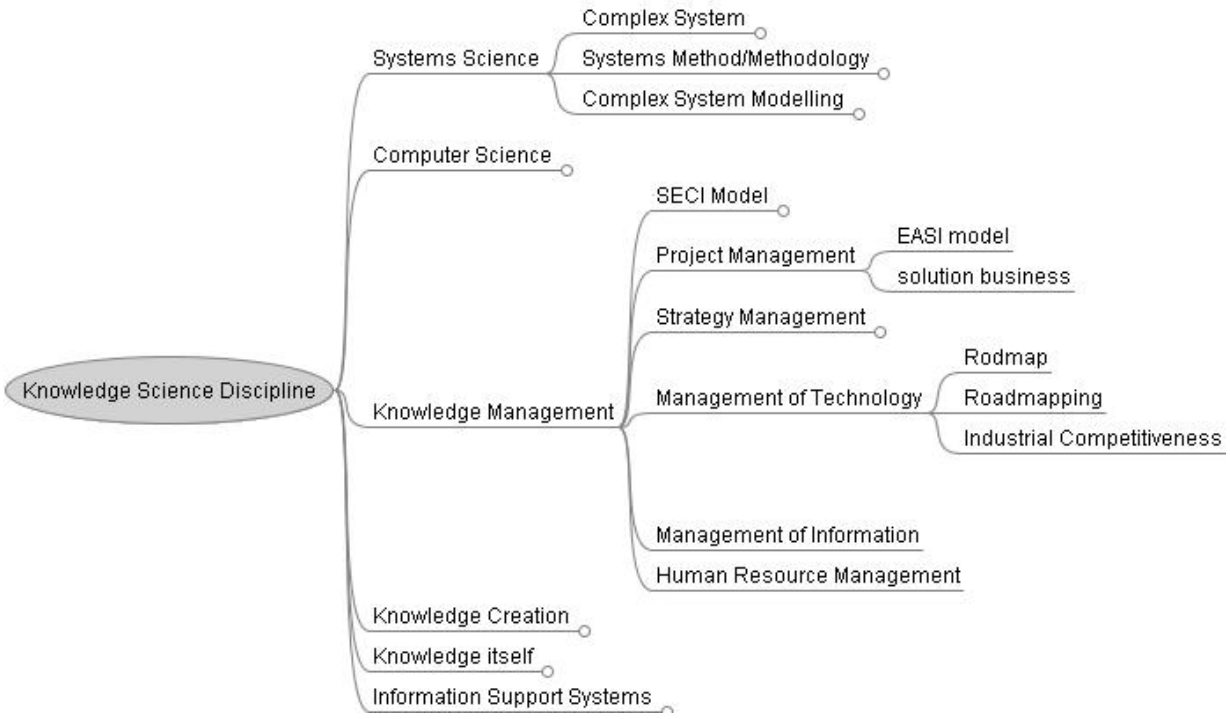

Figure 7: Ontology structure for research topics at JAIST KS school

The result of this study (Fig. 7) showed that within the boundary of knowledge science discipline, “knowledge management” is closely connected to essential concepts like “system science”, “computer science”, “knowledge creation”, “knowledge itself”, “and “information support systems”. The constituent elements of each category and each sub-category can also be seen, for example, the research topics under category of

"knowledge management" include "SECI model", "management of information", "human resource management", etc.

5. Concluding remarks

As a new emerging research field, "Knowledge management" has received a lot of focus, and its importance has been emphasized in both industry and academia. Nevertheless, literature analysis and our survey indicated the presence of much confusion of understanding it, different people means different things when they use this term.

A better and holistic understanding of "knowledge management" promises to help people share and transfer knowledge within this domain, and thus speed up development of this research area. For this reason, two significant things need to be figured out, one is an intensive clarification rather than giving a simple definition of "knowledge management", the other is to see how this new research area is related to other current existing research topics. In our work, two studies have been carried out to achieve to these purposes. The first study investigates leading peer-reviewed journals regarding KM by applying domain analysis methodology to provide a taxonomy for understanding six essential issues about KM, that is, why to use KM, what enables and triggers KM, what to deal with in KM, how to implement KM, how to support KM by technologies, and where has KM been applied. The second study examined KM in a more general research discipline by constructing an ontology structure of research topics for JAIST KS School.

We have organized some seminars to introduce and explain our methods and results to researchers and practitioners of KM fields, they agreed that our research really help in providing a big picture of what KM is, and reduce the people's confusion about this new area. However, we still believe in that further future evaluation and refinement of this research is of necessity. Particularly we are now constructing an ontology-based semantic search engine that incorporate the results from this research, the users can use semantic search engine in parallel with our constructed ontology to access KM relevant documents. This system allows users to send comments about both search engine and ontology as well, which then can be used as very important information for future improvement of this research.

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