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Review

Knowledge management technologies and applications—literature review from 1995 to 2002

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Abstract

This paper surveys knowledge management (KM) development using a literature review and classification of articles from 1995 to 2002 with keyword index in order to explore how KM technologies and applications have developed in this period. Based on the scope of 234 articles of knowledge management applications, this paper surveys and classifies KM technologies using the seven categories as: KM framework, knowledge-based systems, data mining, information and communication technology, artificial intelligence/expert systems, database technology, and modeling, together with their applications for different research and problem domains. Some discussion is presented, indicating future development for knowledge management technologies and applications as the followings: (1) KM technologies tend to develop towards expert orientation, and KM applications development is a problem-oriented domain. (2) Different social studies methodologies, such as statistical method, are suggested to implement in KM as another kind of technology. (3) Integration of qualitative and quantitative methods, and integration of KM technologies studies may broaden our horizon on this subject. (4) The ability to continually change and obtain new understanding is the power of KM technologies and will be the application of future works.

Keywords: Knowledge management; Knowledge management technologies; Knowledge management applications; Literature survey

1. Introduction

As Francis Bacon said, "Knowledge is power". The power of knowledge is a very important resource for preserving valuable heritage, learning new things, solving problems, creating core competences, and initiating new situations for both individual and organizations now and in the future. How to manage this knowledge has become an important issue in the past few decades, and the knowledge management (KM) community has developed a wide range of technologies and applications for both academic research and practical applications. In addition, KM has attracted much effort to explore its nature, concepts, frameworks, architectures, methodologies, tools, functions, real world implementations in terms of demonstrating KM technologies and their applications.

As a part of KM research, this paper focuses on surveying knowledge management development through a literature review and classification of articles from 1995 to 2002 in order to explore the KM technologies and applications from that period. The reason for choosing this period is that the Internet was opened to general users in 1994 and this new era of information and communication technology plays important roles not only in electronic commerce but also in knowledge management. The literature survey is based on a search for the keyword index 'knowledge management' on the Elsevier SDOS online database, from which 1471 articles were found on December 25, 2002. After topic filtering, there were only 234 articles related to the keyword 'knowledge management applications' and 67 of them were connected to the methodology of keyword 'knowledge management technology'. Based on the scope of 234 articles on knowledge management application, this paper surveys and classifies KM technologies using seven categories: KM framework, knowledge-based systems (KBS), data mining (DM), information and communication technology (ICT), artificial intelligence (AI)/expert systems (ES), database technology (DT), and modeling, together with their applications on different research and problem domains.

The rest of the paper is organized as follows. Sections 2–8 present the survey results of KM technologies and applications based on the above categories, respectively. Section 9 presents some discussion, extending to suggestions for future development of knowledge technologies and applications. Finally, Section 10 contains a brief conclusion.

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2. Knowledge management framework and its applications

Knowledge management does not carry its name accidentally because *management* normally means that 'something' has to be managed (Wiig, Hoog, & Spex, 1997). Since Polanyi's discussion of the distinction between explicit and tacit knowledge (Polanyi, 1966), researchers were developed a set of management definitions, concepts, activities, stages, circulations, and procedures, all directed towards dealing with objects in order to describe the framework of knowledge management as the KM methodology. Different KM working definitions, paradigms, frameworks, concepts, objects, propositions, perspectives, measurements, impacts, have been described for investigating the question of: What is knowledge management? What are its methods and techniques? What is its value? And what are its functions for supporting individual and organizations in managing their knowledge (Drew, 1999; Heijst, Spek, & Kruizinga, 1997; Hendriks & Vriens, 1999; Johannessen, Olsen, & Olaisen, 1999; Liebowitz, 2001; Liebowitz and Wright, 1999; Nonaka, Umemoto, & Senoo, 1996; Rubenstein-Montano et al., 2001; Wiig, 1997; Wiig et al., 1997; Wilkins, Wegen, & Hoog, 1997; Liao, 2002).

For example, the concept of 'the knowledge-creating company' is a management paradigm for the emerging 'knowledge society', and information technology can help implement this concept (Nonaka et al., 1996). Some articles have investigated issues concerning the definition and measurement of knowledge assets and intellectual capital (Liebowitz & Wright, 1999; Wilkins et al., 1997). A conceptual framework presents knowledge management as consisting of a repertoire of methods, techniques, and tools with four activities performed sequentially (Wiig et al., 1997). These are also combined with another extension of KM working definitions and its historical development (Wiig, 1997). From the organizational perspective, corporate memories can act as a tool for knowledge management on three types of learning in organizations: individual learning, learning through direct communication, and learning using a knowledge repository (Heijst et al., 1997). Another example is innovation theory based on organizational vision and knowledge management, which facilitates development-integration and application of knowledge (Johannessen et al., 1999). For strategy, Drew explores how managers might build knowledge management into the strategy process of their firms with a knowledge perspective and established strategy tools (Drew, 1999). Furthermore, a systems thinking framework for KM has been developed, providing suggestions for what a general KM framework should include (Rubenstein-Montano et al., 2001). Also, the emergence and future of knowledge management, and its link to artificial intelligence been discussed (Liebowitz, 2001). Knowledge inertia (KI), means stemming from the use of routine problem solving procedures, stagnant knowledge sources, and following past experience or knowledge. It may enable or inhibit an organization's or an individual's ability on problem solving (Liao, 2002). On the other hand, the organizational impact of KM and its limits on knowledge-based systems are discussed in order to address the issue of how knowledge engineering relates to a perspective of knowledge management (Hendriks & Vriens, 1999). These methodologies offer technological frameworks with qualitative research methods and explore their content by broadening the research horizon with different perspectives on KM research issues.

Some applications have been implemented using a KM framework such as: knowledge creation, knowledge assets, knowledge inertia, methods and techniques, KM development and history, organizational learning, organizational innovation, organizational impact, intellectual capital, strategy management, systems thinking, and artificial intelligence/expert systems. The methodology of knowledge management framework and its applications are categorized in Table 1.

3. Knowledge-based systems and its applications

There are common questions and objectives of researchers using knowledge-based systems, including: Will knowledge-based systems (KBS) make an organization more knowledgeable? How knowledge is used and produced within the organization? What must be done so that KBS can earn their place as tools for knowledge management? What technology does KBS support? And How to implement KBS in specific problem domain? (Cauvin,

Table 1
Knowledge management framework and its applications

Knowledge management framework/applications	Authors
Knowledge creation	Nonaka et al. (1996)
Knowledge assets	Wilkins et al. (1997) and Wiig et al. (1997)
Methods and techniques	Wiig et al. (1997)
KM development and history	Wiig, 1997)
Organizational learning	Heijst et al. (1997)
Organizational innovation	Johannessen et al. (1999)
Intellectual capital	Liebowitz and Wright (1999)
Strategy management	Drew (1999) and Hendriks and Vriens (1999)
Organizational impact	Hendriks and Vriens (1999)
Systems thinking	Rubenstein-Montano et al. (2001)
Artificial intelligence/Expert systems	Liebowitz (2001)
Knowledge inertia	Liao (2002)

1996; Fleurat-Lessard, 2002; Kang, Lee, Shin, Yu, & Park, 1998; Kim, Nute, Rauscher, & Lofits, 2000; Knight & Ma, 1997; Liao, 2000, 2001; Lee & Lee, 1999; Martinsons, 1997; McMeekin and Ross, 2002; Stein & Miscikowski, 1999; Tian, Ma, & Liu, 2002; Wielinga, Sandberg, & Schreiber, 1997). The most common definition of KBS is human-centered. This highlights the fact that KBS have their roots in the field of artificial intelligence (AI) and that they are attempts to understand and initiate human knowledge in computer systems (Wiig, 1994). Four main components of KBS are usually distinguished: a knowledge base, an inference engine, a knowledge engineering tool, and a specific user interface (Dhaliwal & Benbasat, 1996). On the other hand, the term KBS includes all those organizational information technology applications that may prove helpful for managing the knowledge assets of an organization, such as Expert systems, rule-based systems, groupware, and database management systems (Laudon & Laudon, 2002).

For example, Alexip is a KBS for the supervision of refining and petrochemical processes (Cauvin, 1996). In addition, KBS can leverage human resource management (HRM) expertise and promote organizational development, as presented by Martinsons (1997). Rule-based reasoning is the basis of KBS, including database updating rules, process control rules, and data deletion rules for logical reference (Knight & Ma, 1997). KBS is also an example of knowledge engineering to offer methods and techniques for KM (Wielinga et al., 1997). A yield management system is one, which uses inductive decision trees, and neural networks algorithm to manage yields over major manufacturing processes (Kang et al., 1998). FAILSAFE is a KBS for supporting product quality with production rule language and team based learning methods (Stein & Miscikowski, 1999). Case-based reasoning is another kind of KBS method for developing conceptual design and military decision support systems (Lee & Lee, 1999; Liao, 2000). AppBuilder, is an application development environment for developing decision support systems in Prolog language (Kim et al., 2000). Knowledge-based architecture integration with Intranet technology also provides a methodology for KBS (Liao, 2001). Expert systems develop the capacity to mimic the reasoning logic of human experts for stored-grain management (Fleurat-Lessard, 2002). HACCP is a KBS for change management in predictive microbiology with hazard analysis and critical control point method (McMeekin & Ross, 2002). A KBS integrating of mathematical models and knowledge rules has also been implemented for RandD project selection (Tian et al., 2002).

Some of these applications which are implemented by knowledge-based systems include the following: knowledge representation, the petroleum industry, human resource management, databases, knowledge engineering, manufacturing, quality management, design, the military, agriculture, risk assessment, microbiology, and project management. The technology of knowledge-based systems and its applications are categorized in Table 2.

Table 2
Knowledge-based systems and its applications

Knowledge-based systems/applications	Authors
Knowledge representation	Cauvin (1996) and Kim et al. (2000)
Petroleum industry	Cauvin (1996)
Human resource management	Martinsons (1997)
Database	Knight and Ma (1997)
Knowledge engineering	Wielinga et al. (1997)
Manufacturing	Kang et al. (1998)
Quality management	Stein and Miscikowski (1999)
Design	Lee and Lee (1999)
Military	Liao (2000, 2001)
Agriculture	Kim et al. (2000) and Fleurat-Lessard (2002)
Risk assessment	McMeekin and Ross (2002)
Microbiology	McMeekin and Ross (2002)
Project management	Tian et al. (2002)

4. Data mining and its applications

Data mining (DM) is an interdisciplinary field that combines artificial intelligence, computer science, machine learning, database management, data visualization, mathematic algorithms, and statistics. Given the enormous size of databases, DM is a technology for knowledge discovery in databases (KDD). This technology provides different methodologies for decision-making, problem solving, analysis, planning, diagnosis, detection, integration, prevention, learning, and innovation (Abidi, 2001; Anand, Bell, & Hughes, 1996; Anand, Patrick, Hughes, & Bell, 1998; Cannataro, Talia, & Trunfio, 2002; Chen & Zhu, 1998; Chiu, 2003; Chua, Chiang, & Lim, 2002; Dhar, 1998; Delesie & Croes, 2000; Feelders, Daniels, & Holsheimer, 2000; Ha, Bae, & Park, 2002; Hui & Jha, 2000; Jiang, Berry, Donato, Ostrouchov, & Grady, 1999; Lavington, Dewhurst, Wilkins, & Freitas, 1999; Lin & McClean, 2001; McSherry, 1997; Nemati, Steiger, Iyer, & Herschel, 2002; Park, Piramuthu, & Shaw, 2001; Sforna, 2000; Shaw, Subramaniam, Tan, & Welge, 2001).

For example, EDA is a general framework for data mining based on evidence theory. It provides a method for representing knowledge, which allows prior knowledge from the user or knowledge discovered by another discovery process to be incorporated into the knowledge discovery process (Anand et al., 1996). An algorithm used to improve knowledge discovery efficiency, which includes focusing on a restricted class of exact rules, or limiting the number of conditions in the discovered rules (McSherry, 1997). A DM methodology for cross-sales uses characteristic rule discovery and deviation detection (Anand et al., 1998). A DM in finance uses counterfactuals to generate knowledge from organization information systems, thus promoting human dialog and exploration, which does not occur in routine organizational activity (Dhar, 1998). An approach to deal with query formulation problem is proposed by describing a conceptual model for user-guided knowledge discovery in a database (Chen & Zhu, 1998). For large database management systems, a KDD classification metrics is drawn from paradigms such as Bayesian classifiers, rule-induction, decision tree algorithms, and genetic programming for interfacing knowledge discovery algorithms (Lavington et al., 1999). In addition, another article focuses on the issue of data quality (Feelders et al., 2000). One DM technique, called latent semantic indexing (LSI), is used to construct a correlated distribution matrix (CDM) for mining consumer product data (Jiang et al., 1999). An integration method combines knowledge discovery with operations research to evaluate the performance of cardiovascular surgery, and in another example combines artificial intelligence with fuzzy logic for a power company customer database (Delesie & Croes, 2000; Sforna, 2000).

On the other hand, decision support is the objective for applying DM to extract knowledge from a database for certain management issues, such as customer service support, corporate failure prediction, marketing, and grid services (Abidi, 2001; Cannataro et al., 2002; Ha et al., 2002; Hui & Jha, 2000; Lin & McClean, 2001; Shaw et al., 2001). KREFS, is a knowledge refinement system to refine knowledge by intelligently self-guiding the generation of new training examples (Park et al., 2001). An intelligent middleware system integrates data management and data analysis tools to improve traditional data analysis in order to facilitate linear correlation between attributes and attribute groups (Chua et al., 2002). Also, knowledge warehousing, an important DM technology, is developed as an architecture to integrate the functions of knowledge management, decision support, artificial intelligence and data warehousing (Nemati et al., 2002). A web-based data mining method provides a systematic procedure for analyzing information systems and building mapping rules, supplementing them with a rich layer of links and other tools for navigation, structuring, and annotation (Chiu, 2003).

Some of the applications that are implemented by data mining include the following: general framework, asymptotic complexity, cross-sales, deviation detection, finance, organizational learning, user-guided query construction, interface, consumer behaviors/service, semantic indexing, data quality, health care management, knowledge refinement, prediction of failure, marketing, software integration, knowledge warehouse, grid services, and hypermedia. The technology of data mining and its applications are categorized in Table 3.

Table 3
Data mining and its applications

Data mining/applications	Authors
General framework	Anand et al. (1996)
Asymptotic complexity	McSherry (1997)
Cross-sales	Anand et al. (1998)
Deviation detection	Anand et al. (1998)
Finance	Dhar (1998)
Organizational learning	Dhar (1998)
User-guided query construction	Chen and Zhu (1998)
Interface	Lavington et al. (1999)
Consumer behaviors/service	Jiang et al. (1999), Sforna (2000), Hui and Jha (2000), Shaw et al. (2001) and Ha et al. (2002)
Semantic indexing	Jiang et al. (1999)
Data quality	Feelders et al. (2000)
Health care management	Delesie and Croes (2000) and Abidi (2001)
Knowledge refinement	Park et al. (2001)
Prediction of failure	Lin and McClean (2001)
Marketing	Shaw et al. (2001) and Ha et al. (2002)
Software integration	Chua et al. (2002)
Knowledge warehouse	Nemati et al. (2002)
Grid services	Cannataro et al. (2002)
Hypermedia	Chiu (2003)

5. Information and communication technology and its applications

In today's information economy, rapid access to knowledge is critical to the success of many organizations. An information and communication technology (ICT) infrastructure provides a broad platform for exchanging data, coordinating activities, sharing information, emerging private and public sectors, and supporting globalization commerce, all based on powerful computing and network technology. Information computing offers powerful information processing abilities, and the network provides standards and connectivity for digital integration. Internet is a kind of ICT that combines with some other network technologies and services, such as Intranet, Extranet, virtual private network (VPN), and wireless web, to construct a digital environment to consistently create new knowledge, quickly disseminate it, and embody it in organizations. Some knowledge management software tools of ICT are discussed in terms of their origins and applications (Tyndale, 2002).

As the concept of 'sharing knowledge is power' (Liebowitz, 2001), ICT enables knowledge management activities for collaborative decision support, information sharing, organizational learning, and organizational memory (Caraynnnis, 1999; Chen et al., 2002; Harun, 2002; Hicks, Culley, Allen, & Mullineux, 2002; McCown, 2002; Ramesh & Tiwana, 1999; Robey, Boudreau, & Rose, 2000; Yoo & Kim, 2002). In addition, intelligent software integrates information system across multi-tier enterprises in the US auto industry in order to increase organizational flexibility (Olin, Greis, & Kasarda, 1999), and there is knowledge transfer of different kinds of knowledge in northeast Italy (Bolisani & Scarso, 1999). On the other hand, ontology is the knowledge integration of different representations of the same piece of knowledge at different levels of formalization. The experts who participate in the ontology process are allowed to use their own terminology, facilitating knowledge integrations with cooperative tools (Fernandez-Breis & Martinez-Bejar, 2000).

Some applications are implemented by information and communication technology such as: decision support, new product development, organizational learning, organizational memory, supply chain, knowledge transfer, knowledge integration, ontology, engineering design, knowledge management tools, information sharing, e-learning, simulation, agriculture, and virtual enterprises. The technology of information and communications together with its applications are categorized in Table 4.

6. Expert systems and its applications

Expert systems, an artificial intelligence method for capturing knowledge, are knowledge-intensive computer programs that capture the human expertise in limited domains of knowledge (Laudon & Laudon, 2002). For this, human knowledge must be modeled or presented in a way that a computer can process. Usually, expert systems capture the human knowledge in the form of a set of rules. The set of rules in the expert systems adds to the organizational memory, or stored learning of the organization. An expert system can assist decision making by asking relevant questions and explaining the reasons for adopting certain actions. Expert systems of representing knowledge include knowledge base, rule-based systems, knowledge frames, expert system shell, inference engine, and case-based reasoning (Cunningham and Bonzano, 1999; Doyle, Ang, Martin, & Noe, 1996; Weber, Aha, & Becerra-Fernandez, 2001). Sometimes, expert systems are integrated with other AI methods, such as neural networks, fuzzy logic, genetic algorithms, and intelligent agent, using their functions of automated reasoning and machine learning (AI-Tabtabai, 1998; Hooper, Galvin, Kilmer, & Liebowitz, 1998; Liang & Gao, 1999; Mohan & Arumugam, 1997; Tu & Hsiang, 2000).

On the other hand, object-oriented (OO) programming technology provides an approach to expert systems that combines knowledge and procedures into a single object. Traditional expert systems methods have treated knowledge and procedures as independent components. However, objects belonging to a certain class have the knowledge of that class, and classes of objects in turn can represent knowledge and embed knowledge with OO programming architecture. This leads expert system developments toward to fourth generation language and visual programming methods in order to provide a user-friendly structure and environment (Chau, Chuntian, & Li, 2002; Doyle et al., 1996; Nault & Storey, 1998; Shaalan, Rafea, & Rafea, 1998).

Some of the applications implemented by expert systems including the following: visualization, applets, education, agriculture, knowledge representation, semantic networks, human resource management, project management, ecosystem, knowledge engineering, information retrieval, personalization, lessons learned systems, and water resources. The technology of expert systems and its applications are categorized in Table 5.

Table 4
Information and communication technology and its applications

Information and communication technology/applications	Authors
Decision support	Hicks et al. (2002) and Ramesh and Tiwana (1999)
New product development	Ramesh and Tiwana (1999)
Organizational learning	Ramesh and Tiwana (1999), Caraynnnis (1999) and Robey et al. (2000)
Organizational memory	Ramesh and Tiwana (1999) and Robey et al. (2000)
Supply chain	Olin et al. (1999)
Knowledge transfer	Bolisani and Scarso (1999)
Knowledge integration	Fernandez-Breis and Martinez-Bejar (2000)
Ontology	Fernandez-Breis and Martinez-Bejar (2000)
Engineering design	Hicks et al. (2002)
Knowledge management tools	Tyndale (2002)
Information sharing	Chen et al. (2002) and Yoo and Kim (2002)
Law enforcement	Chen et al. (2002)
E-learning	Harun (2002)
Simulation	McCown (2002)
Agriculture	McCown (2002)
Virtual enterprise	Yoo and Kim (2002)

7. Database technology and its applications

A database is a collection of data organized to efficiently serve many applications by centralizing the data and minimizing redundant data (McFadden, Hoffer, & Prescott, 2000). A database management system (DBMS) is the software that permits an organization to centralize data, manage them efficiently, and provide access to the stored data by application programs (Laudon & Laudon, 2002). However, some large databases make knowledge discovery computationally expensive because some domains or background knowledge, hidden in the database may guide and restrict the search for important knowledge. Therefore, modern database technologies need to process

Table 5
Expert systems and its applications

Expert systems/applications	Authors
Visualization	Mohan and Arumugam (1997) and Chau et al. (2002)
Applets	Doyle et al. (1996)
Education	Doyle et al. (1996)
Agriculture	Mohan and Arumugam (1997) and Shaalan et al. (1998)
Knowledge representation	Nault and Storey (1998)
Semantic networks	Nault and Storey (1998)
Human resource management	Hooper et al. (1998)
Project management	AI-Tabtabai (1998)
Ecosystem	Liang and Gao (1999)
Knowledge engineering	Cunningham and Bonzano (1999)
Information retrieval	Tu and Hsiang (2000)
Personalization	Tu and Hsiang (2000)
Lessons learned systems	Weber et al. (2001)
Water resources	Chau et al. (2002)

Table 6
Database technology and its applications

Database technology/applications	Authors
Hierarchical modeling	Zhong and Ohsuga (1996a)
Knowledge refinement	Zhong and Ohsuga (1996a)
Machine learning	Zhong and Ohsuga (1996a)
Error analysis	Zhong and Ohsuga (1996b)
Knowledge representation	Zhong and Ohsuga (1996b) and Owrang and Grupe (1996)
Knowledge discovery	Zhong and Ohsuga (1996a,b) and Owrang and Grupe (1996)
Ontology	Sugumaran and Storey (2002)
Database design	Koschel and Lockemann (1998), Huang et al. (2000), Sugumaran and Storey (2002)
Knowledge reuse	Allsopp et al. (2002)
Knowledge repository	Allsopp et al. (2002)
Geosciences	Sokolov and Wulff (1999)
Web applications	Sokolov and Wulff (1999), Huang et al. (2000), Wilkins and Barrett (2000), and Shafer and Agrawal (2000)

large volumes, multiple hierarchies, and different data formats to discover in-depth knowledge from large databases. For example, multi-dimensional data analysis, on-line analytical processing, data warehouses, web and hypermedia databases (Huang, Shi, & Mark, 2000; Koschel & Lockemann, 1998; Shafer & Agrawal, 2000; Sokolov & Wulff, 1999; Wilkins & Barrett, 2000).

On the other hand, hierarchical model learning approach for refining/managing concept clusters discovered from databases is been proposed. Its approach can be cooperatively used with other sub-systems of Decomposition Based Induction for knowledge refinement (Zhong and Ohsuga, 1996a,b). One example is domain knowledge used to guide to test the validity of the discovered knowledge (Owrang & Grupe, 1996). Recently, database and architecture design are other methodologies for implementing ontology creation heuristics and intelligent agents into database conceptual modeling and knowledge repository domains (Allsopp, Harrison, & Sheppard, 2002; Sugumaran & Storey, 2002).

Some of the applications implemented by database technology including the following: hierarchical modeling, knowledge refinement, machine learning, error analysis, knowledge representation, knowledge discovery, ontology, database design, knowledge reuse, knowledge repository, geosciences, and web applications. These database technologies and their applications are categorized in Table 6.

8. Modeling and its applications

Quantitative methods for exploring the issues of knowledge discovery, knowledge classification, knowledge acquisition, learning, pattern recognition, artificial intelligence algorithms, and decision support are the modeling technology of knowledge management. Some methodologies are presented as examples of fuzzy logic, including: process modeling, cognitive modeling, pattern language, system dynamic, decision trees, knowledge value modeling, genetic algorithms/programming, intangible assets modeling, and mathematical modeling (Dekker & Hoog, 2000; Hinton, 2002; Kitts, Edvinsson, & Beding, 2001; Maddouri, Elloumi, & Jaoua, 1998; Muller & Wiederhold, 2002; Wirtz, 2001; Wong, 2001).

Modeling technology becomes an interdisciplinary methodology of KM in order to build formal relationships with logical model design in different knowledge/problem domains. For example, the value of knowledge, intellectual capital, and intangible assets, are difficult to measure on profit-loss sheets and accounting systems of most businesses. Exploring problems that would remain hidden in ordinary profit and loss balance sheets could yield valuable information that could then be used to construct strategic decisions as to expenditure or income in different organizational areas, new investments, and business assets measurement. Furthermore, modeling technology can provide quantitative methods to analyze subjective data to represent or acquire human knowledge with inductive logic programming or algorithms so that artificial intelligence, cognitive science and other research fields could have broader platforms to implement technologies for KM development.

Some applications are implemented by modeling, such as: knowledge discovery, knowledge classification, learning, business value, pattern languages, knowledge acquisition, cognitive modeling, value of knowledge, process re-engineering, intellectual capital, intangible assets, and knowledge transforming. The technology of modeling and its applications are categorized in Table 7.

Table 7
Modeling and its applications

Modeling/applications	Authors
Knowledge discovery	Maddouri et al. (1998) and Wong (2001)
Knowledge classification	Maddouri et al. (1998)
Learning	Maddouri et al. (1998) and Muller and Wiederhold (2002)
Business value	Hinton (2002)
Pattern languages	Hinton (2002)
Knowledge acquisition	Muller and Wiederhold (2002)
Cognitive modeling	Muller and Wiederhold (2002)
Value of knowledge	Dekker and Hoog (2000)
Process re-engineering	Dekker and Hoog (2000)
Intellectual capital	Kitts et al. (2001)
Intangible assets	Kitts et al. (2001)
Knowledge transforming	Wirtz (2001)

9. Discussions and suggestions

9.1. Discussions

Knowledge management technologies and applications are broad category of research issues on KM. Some specific methodologies and methods are presented as examples in terms of exploring the suggestions and solutions to specific KM problem domains. Therefore, technologies and applications of KM are attracting much attention and efforts, both academic and practical. From this literature review, we can see that KM technologies and applications developments are diversified due to their authors' backgrounds, expertise, and problem domains. This is why a few authors can appear in the literature of different technologies and applications.

On the other hand, some technologies have common concepts, and types of methodology. For example, database technology and data mining, or knowledge-based systems versus artificial intelligence/expert systems. However, a few authors work in different technologies and applications. This indicates that the trend of development on technology is also diversified due to author's research interests and abilities in the methodology and problem domain. This may directs development of KM technologies toward expertise orientation.

Furthermore, some applications have a high degree of overlap in different technologies. For example, knowledge discovery, knowledge sharing, knowledge representation, knowledge engineering, knowledge refinement, and knowledge acquisition, are all topics of different technologies, which implement KM in a common problem domain. This indicates that those applications are the major trend of KM development and many technologies are focused on these problems. This may direct development of KM applications toward problem domain orientation.

In this paper, most of the articles discussed were from computer science and social sciences journals on the Elsevier SDOS online database. A few articles were from journals of agricultural and biological sciences, clinical medicine, environment sciences and technology, and mathematics. We do not conclude that KM technologies and applications are not developed in other science fields. However, we would like to see more KM technologies and applications of different research fields published to readers in order to broaden our horizon of academic and practice works on KM.

9.2. Limitations

Firstly, a literature review for the broad category of KM technologies and applications is a difficulty task due to the extensive background knowledge needed for studying, classifying, and comparing these articles. Although limited in background knowledge, this paper makes a brief literature review on KM from 1995 to 2002 in order to explore how KM technologies and applications have developed in this period. Indeed, the categorization of technologies and their applications is based on the keyword index on this research. Therefore, the first limit of this article is the author's limited knowledge in presenting an overall picture of this subject.

Secondly, some other academic journals listed in the science citation index (S.C.I) and the social science citation index (S.S.C.I), as well as other practical reports are not included in this survey. These would have provided more complete information to explore the development of KM technologies and applications.

Thirdly, non-English publications are not considered in this survey to determine the effects of different cultures on the development of KM technologies and applications. We believe that KM technologies and applications in addition to those discussed in this article have been publishing and developed in other areas.

9.3. Suggestions

(1) *Other social science methodologies*. In this article, the definition of KM technology is not complete because other methodologies, such as statistical method, were not included in the survey. However, qualitative questionnaires and statistical methods are another research technology to solve problems in social studies. Some KM issues, for example, the success of knowledge sharing in organizations, are not only technological but also related to behavior factors (Calantone, Cavusgil, & Zhao, 2002; Hertzum, 2002; Kidwell, Mossholder, & Bennett, 1997; Lang, Dickinson, & Buchal, 2002; Walsham, 2002). For example, expert interviews, critical success factors method (CSFs), and questionnaires are used to implement statistical methods for exploring specific human problem. Therefore, other social sciences methodologies may include KM technology category in future works.

(2) *Integration of qualitative and quantitative method*. The qualitative and quantitative methods are different in both methodology and problem domain. Some articles present their variables, modeling, and system design without expert advice or considering human behavior from real world situations. These belong to laboratory research and it is difficult to implement KM technology into individual and organizations. On the other hand, some articles have presented their brilliant KM concepts without a scientific or systematic approach, which leads KM methodology to remain at the stage of discussion. Therefore, integration of qualitative and quantitative methods may be an important direction for future work on KM technologies and applications.

(3) *Integration of technologies*. KM is an interdisciplinary research issue. Thus, future KM developments need integration with different technologies, and this integration of technologies and cross-interdisciplinary research may offer more methodologies to investigate KM problems.

(4) *Change, is a source of development*. The change due to social and technical reasons may either enable or inhibit KM technologies and application development. This means that inertia, stemming from the use of routine problem solving procedures, stagnant knowledge sources, and following past experience or knowledge may impede changes in terms of learning and innovation for individuals and organizations. Therefore, to continue creating, sharing, learning, and storing knowledge may also become the source of KM development.

10. Conclusions

This paper is based on a literature review on Knowledge Management technologies and applications from 1995 to 2002 using a keyword index search. We conclude that KM technologies tend to develop towards expert orientation, and KM applications development is a problem-oriented domain. Different social studies methodologies, such as statistical method, are suggested to implement in KM as another kind of technology. Integration of qualitative and quantitative methods, and integration of KM technologies studies may broaden our horizon on this subject. Finally, the ability to continually change and obtain new understanding is the power of KM technologies and will be the application of future works.

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