Knowledge-based systems: a re-evaluation

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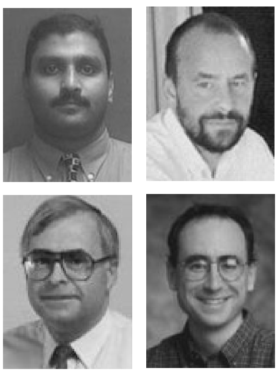

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Abstract

Purpose – *The goal of this paper is to re-evaluate the role of knowledge-based systems (KBS) in knowledge management (KM). While knowledge-based systems and expert systems were widely used in the past, they have now fallen from favor and are largely ignored in the knowledge management literature. This paper aims to argue that several factors have changed and it is now time to re-evaluate the contribution that such systems can make to knowledge management.*

Design/methodology/approach – *The role of KBS in KM is explored through a comprehensive analysis of both the management and the technical literature on knowledge. The literature on KBS and expert systems is reviewed and some of the problems faced by them are highlighted. Some of the probable causes of these problems and some of the solutions that might be used to overcome them are indicated. The paper describes how knowledge systems (KS) could be used as an effective tool for managing knowledge.*

Findings – *The lack of success of KBS technologies for managing knowledge is mainly due to organizational and managerial issues. These problems can be solved through feasibility studies before system development activities. KS technology is now being successfully applied in a variety of newer domains that exploit its capabilities.*

Practical implications – *Some conclusions are drawn concerning integration of knowledge systems with knowledge management, problems of the early implementation of knowledge systems technology, and possible solution to overcome these problems.*

Originality/value – *The main contribution of the article is in re-evaluating the role of knowledge-based systems as a tool for knowledge management.*

Keywords *Knowledge management, Explicit knowledge, Tacit knowledge*

Paper type *General review*

1. Introduction

The need to manage knowledge in organizations has increasingly become the key factor for success in the knowledge economy. Organizations around the globe are developing knowledge management (KM) projects and strategies to harvest knowledge and remain competitive and innovative. Much of the recent KM research effort has concentrated on finding effective ways of managing knowledge through social and managerial approaches. The argument is that because knowledge resides in humans, human centered techniques are necessary for its management.

Notwithstanding this, and with its ever-increasing power, information communication technology (ICT) can also be harnessed, to help with knowledge management. While a great deal of emphasis is now placed on managing tacit knowledge, explicit knowledge is also important to an organization and can be more easily managed by technology. Hildreth and Kimble (2002) argue that successful KM initiatives need to maintain a balance between tacit and explicit knowledge. The authors believe that by re-evaluating the role of knowledge-based systems, a satisfactory balance is achievable.

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The argument will begin with a brief discussion of knowledge and why it needs to be managed; this will also highlight the types of knowledge that are best suited to knowledge-based systems. There is a discussion of both explicit knowledge and tacit knowledge together with the role played by the knowledge conversion process. This will be followed by a concise description of what knowledge-based systems are; it will address some of the issues arising from some of the early failures and outline how these perceived shortcomings could be addressed. The paper will continue with a review of the current trends in the use of knowledge-based systems as practical tools for managing knowledge and the motivations behind their use. It will highlight the wide range of domains within which knowledge-based systems have been implemented, and provide a brief discussion on the role they play in knowledge management. Finally, a list of advantages that knowledge-based systems (KBS) can provide (with key papers cited) will show that they have become a viable tool for managing knowledge.

2. The need for knowledge management

A lifetime's accumulation of facts, events, procedures and so on are stored personal memories that enable us to work in, and make sense of, the world that surrounds us. However, with the ending of the single-job-for-life culture, businesses lose much of that knowledge when an individual leaves the organization. Some have argued (e.g. Hildreth *et al.*, 1999) that this threat of ''lost knowledge'' is the principal driver behind the emergence of KM and a number of authors have argued that KM provides the answer to the ''brain drain'' problem (Gardan and Gardan, 2003; Leung *et al.*, 2003; Lau *et al.*, 2003). In recent years, many large organizations have engaged with KM projects; this has happened in order to improve profits, to be competitively innovative, or simply to survive (Nonaka and Takeuchi, 1995; Prusak, 1997; Wigg, 1997; Davenport and Prusak, 2000).

3. Defining knowledge management

Although there is a strong and undoubted interest from the commercial world, the term knowledge management still suffers from a high degree of ''terminological ambiguity'' (Hildreth and Kimble, 2002). There is no consensus about what the term really means (Shin *et al.*, 2001; Salisbury, 2003) and researchers are constantly attempting to forge their own definitions. There is no agreed definition now, and there is no prospect of one in the near future. The authors have adopted the following view of knowledge management based on that offered by Sallis and Jones (2002):

> Knowledge management is a systematic method for managing individual, group and organizational knowledge using the appropriate means and technology. At its root it is to do with managing people, what they know, their social interactions in performing tasks, their decision making, the way information flows and the enterprise's work culture.

4. Enabling knowledge management

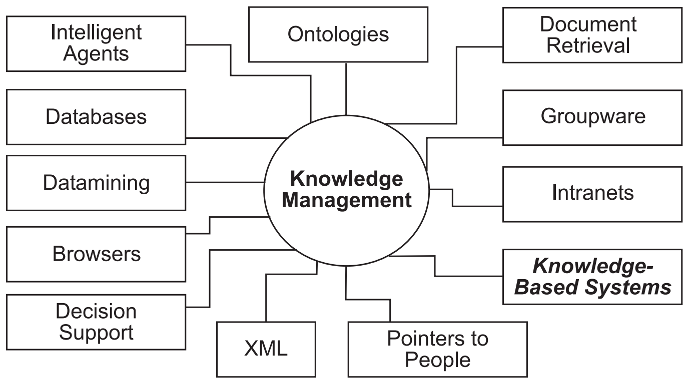
The definition above does not exclude the use of ICT to support knowledge management. This perspective is supported by Tsui *et al.* (2000) in their editorial comments made in a special issue on artificial intelligence in knowledge management. They stated:

> Every knowledge management project should embrace some knowledge engineering (or artificial intelligence or web-based business rule execution) expertise to (attempt to) provide value-added services often needed in knowledge processing.

Devedzic (2001) has listed the technologies from information technology (IT) and artificial intelligence (AI) that are thought to be the major KM enablers, and these are shown in Figure 1.

Ontologies, document retrieval, groupware, intranets, knowledge-based systems, pointers to people, Xtensible Markup Language (XML), decision support, browsers, data mining, databases, intelligent agents are considered to be the major IT/AI components in the KM field. Most software systems developed these days adopt all or some of these technologies and they underpin the services and products of the knowledge economy (Schreiber *et al.*, 1999).

Figure 1 Major IT/AI enablers for knowledge management



5. Knowledge definition

There are many definitions of knowledge from various areas such as cognitive science, management, philosophy, theology and knowledge engineering. However, most of these definitions are very specific in context to the area in which they are used. From the KM perspective, Davenport and Prusak (2000) comment:

> Knowledge is a fluid mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms (Davenport and Prusak, 2000).

While Schreiber *et al.* (1999), from a knowledge engineering (KE) perspective, define knowledge as:

> Knowledge is the whole body of data and information that people bring to bear to practical use in action, in order to carry out tasks and create new information. Knowledge adds two distinct aspects: first a sense of purpose, since knowledge is the ''intellectual machinery'' used to achieve a goal; second, a generative capability, because one of the major functions of knowledge is to produce new information. It is not accidental, therefore that knowledge is proclaimed to be a new ''factor of production'' (Schreiber *et al.*, 1999).

Although both provide a different meaning for knowledge, in principle their focus is that it is an important resource that needs to be managed effectively and efficiently.

5.1 Knowledge classification

Although different authors define knowledge in different ways, a classification of knowledge into two types: tacit and explicit, features in most of the KM literature (e.g. Nonaka and Takeuchi, 1995; Prusak, 1997; Zack, 1999). Explicit knowledge can be defined as things that are clearly stated or defined, while tacit knowledge can be defined as things that are not expressed openly, but implied (Choo, 2000; Bloodgood and Salisbury, 2001; De Carvalho and Ferreira, 2001; Herschel *et al.*, 2001; Zack, 1999). Understanding the differences between these two types of knowledge is important when identifying the type of knowledge-related application/problems that can be solved/addressed using knowledge engineering techniques as they are applied in knowledge-based systems.

5.1.1 Explicit knowledge. Explicit knowledge can be defined as knowledge that can be seen, shared, communicated with others and easy to manage. It can be communicated because it can be expressed (represented) in a formal way using a set of symbols (Choo, 2000). However, most explicit knowledge is in the form of raw data such as documents that contain the work experiences of staff, descriptions of cases or events, interpretations of data, beliefs, guesses, hunches, ideas, opinions, judgment and proposed action (Jones *et al.*, 2000). Choo (2000) noted:

> Explicit knowledge may be object-based or rule-based . . . knowledge is object-based when it is represented using strings of symbols (words, numbers, formulas), or is embodied in physical entities (equipment, models, substances). Explicit knowledge is rule-based when the knowledge is codified in to rules, routines or operating procedures (Choo, 2000).

This means that explicit knowledge is that which can (relatively easily) be codified in computer systems such as knowledge-based systems.

5.1.2 Tacit knowledge. Tacit knowledge on the other hand is embedded in a person's memory and is difficult to extract and share with others (Choo, 2000; Zack, 1999). The knowledge of how to solve the problem is actually a matter of personal interpretation, ability and skill. While the techniques for problem solving can be learnt in the classroom, the solution created by one employee will differ from that of another. For example, Goguen states:

> People may know how to do something without being able to articulate how they do it. In the social sciences, this is called the say-do problem. Some examples are riding bicycles, tying shoelaces, speaking languages, negotiating contracts, reconciling personal differences, evaluating employees and using a word processor (Goguen, 1997).

Consequently, tacit knowledge is difficult (or arguably impossible) to code adequately into a set of rules for a knowledge-based system.

5.1.3 Explicit versus tacit knowledge. Based on the research of others, Bolisani and Scarso (1999) highlight several differences between explicit and tacit knowledge; their findings are summarized in Table I. Explicit knowledge is about knowing something and is regarded as objective knowledge. It is derived from the rationalization of information and thus can be represented in formulae, diagrams, reports and so on. It can be communicated, codified and transferred using appropriate representation techniques and in a shared language such as knowledge representation languages, formal logic and ontologies. Tacit knowledge on the other hand is related to knowing how to do something, which is much more subjective in nature. It is related to ideas, perceptions and experiences. These are difficult to transfer it directly by means of a representation because of a lack of common ground (Clark and Brennan, 1991) and the fact that tacit knowledge is usually only gained through experience and practice.

However, for the purpose of this discussion one of the most important distinctions lies in what Cook and Brown (1999) call ''the epistemology of possession''. Explicit knowledge is abstract and static: it is about, but not in, the world and accordingly it may be owned without being used. Tacit knowledge on the other hand is concrete and dynamic: it is concerned with who we are and what we do; it is not something that can be possessed. Consequently, discussions of ''lost knowledge'' tend to favor explicit knowledge over tacit knowledge.

5.2 Knowledge conversion

As indicated previously, both explicit knowledge and tacit knowledge must be a part of any KM initiative. Fortunately, both tacit and explicit can be managed using techniques and methods developed in the fields of KM and KE. However, in the case of tacit knowledge, it must first be ''converted'' into explicit knowledge.

Table I Explicit and tacit knowledge

Explicit knowledge	*Tacit knowledge*
Knowing about (objective knowledge)	Knowing how (subjective knowledge)
Rationalization of facts; formal methods	Systems of ideas, perceptions, experience
Easy to codify, transfer, reuse	Difficult to transfer

Nonaka and Takeuchi (1995), view ''knowledge conversion'' as the repeated application of the processes of socialization, externalization, combination and internalization shown in Figure 2. Included in this model (shown in italics) are the descriptions of Bolisani and Scarso (1999) for each process of knowledge conversion. The idea of ''knowledge conversion'' however remains contentious. For example, Hildreth and Kimble (2002) have criticized the validity of this process, although others such as Zack (1999) and Schreiber *et al.* (1999) argue that this framework has provided new insights into the management of tacit knowledge.

While there is still some debate as to how widely this process can be applied, and to what extent certain aspects of tacit knowledge might be ''lost'' in the process of conversion, Nonaka and Takeuchi's (1995) knowledge conversion process has proved to be extremely influential. This is particularly so in the field of knowledge engineering and knowledge based systems: because only explicit knowledge can be represented in the knowledge base of a KBS (Choo, 2000), the process of knowledge conversion is absolutely fundamental to all activities employed in the development of such systems (Stein *et al.*, 2003).

6. Knowledge systems and knowledge-based systems

In recent years the term knowledge systems (KS) has replaced the term knowledge-based-system or expert system, which now tend only to be used in the field of AI (Schreiber *et al.*, 1999). The Object Management Group (OMG, 2004) defines a KBS as follows:

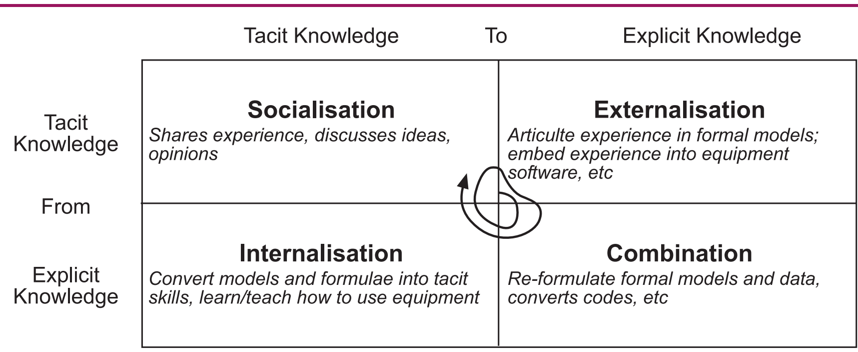
> A knowledge-based system, or KBS, also known as an expert system, is software that has some knowledge or expertise about a specific, narrow domain, and is implemented such that the knowledge base (KB) and the control architecture (i.e. KBE engine) are separate. Knowledge-based systems have capabilities that often include inferential processing (as opposed to algorithmic processing), explaining rationale to users and generating non-unique results (OMG, 2004, p. 22).

No single dividing line differentiates knowledge and information systems, as almost all examples contain elements of both knowledge and information within them. An information system is a set of interrelated components that collects, processes, stores, analyses, and disseminates data and information within an organization (Turban *et al.*, 2001). The main difference between this and a knowledge system is that in a knowledge system it is assumed that the knowledge is represented in an explicit form (Schreiber *et al.*, 1999) in the knowledge base of the system.

6.1 Architecture

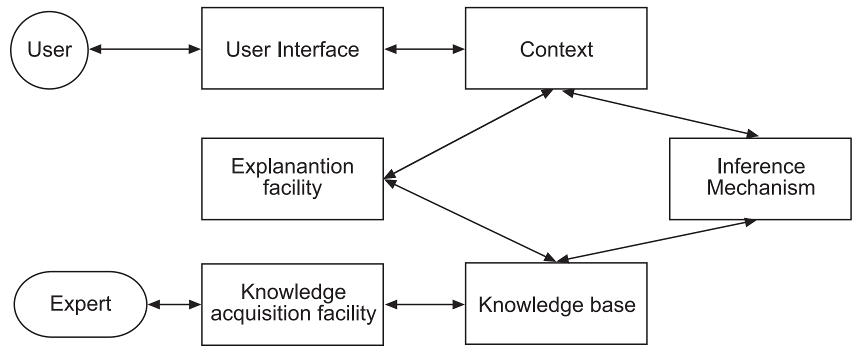
Chau and Albermani (2002) suggest that a KS consists of three basic components: a knowledge base, the context and an inference mechanism (Figure 3). The context

Figure 2 Knowledge conversion model



Source: Adapted from Nonaka and Takeuchi (1995) and Bolisani and Scarso (1999)

Figure 3 Schematic view of a KS



Source: Chau and Albermani (2002)

component contains the current problem scenario. By accessing the knowledge base, the inference mechanism manipulates the context. Other additional components are the user-interface, an explanation facility and a knowledge acquisition system. Users will interact through the interface, which passes the inputs into the system. The reasoning component provides both the reasoning steps and the knowledge used to obtain that reasoning. The knowledge from the domain experts populates the knowledge base through the acquisition system.

The knowledge base is the heart of the system and contains the domain experts' knowledge which is stored using a variety of representation techniques (e.g. semantic networks, frames, logic) (Curtis and Cobham, 2002; Cawsey, 1998); the most widely used technique is the ''if-then'' production rule (Mills and Gomaa, 2000; Liebowitz, 2001). The production rules in the knowledge base are the domain experts' tacit and explicit knowledge.

6.2 Integration of knowledge systems with knowledge management

In the early 1970s and 1980s, expert systems development was ready for the technology that KM would bring (Gill, 1995). Computer scientists from the AI field strongly believed that expert knowledge could be codified and managed through an expert system, and this in turn could replace the human expert. However, this proved to be a costly mistake as human knowledge was much more complex and context dependent than was first thought; in the end, not all of it could be coded into a computer program. Nevertheless, work in this area continued, and by the mid-1990s, expert systems started to be referred to as knowledge-based systems (Speel *et al.*, 2001); the capabilities of these systems were no longer limited to the emulation of expert reasoning, they could also be applied to managing organizational knowledge such as business rules, procedures and guidelines. At around the same time, organizations started to recognize the importance of knowledge as a corporate asset and the knowledge management movement started to gain momentum. However, KM placed more emphasis on managing knowledge as part of a human-related process because it viewed tacit knowledge, which is closely inter-related with human activities, as being the most crucial knowledge for commercial success.

By the end of the 1990s, researchers in AI started to realize that organizational knowledge needed to be managed within a far wider context than the traditional KS application. Tsui *et al.* (2000), felt that KM provided a macro view of managing knowledge, allowing the formulation of strategies such as knowledge capture, sharing and re-use within an organization. Knowledge engineering on the other hand provided the technical focus in areas such as representation, organization, reasoning and searching of knowledge bases. The integration of the AI and KM fields of study has influenced the adoption of techniques such as expert seeking activities and social network analysis used to identify and share knowledge. During this period, knowledge system technology has been adopted in enterprise and internet applications through its new role as an embedded system that provides reasoning capabilities.

6.3 Early implementations of knowledge systems technology

For several years, it was a widely held view that knowledge systems were unsuccessful and that this would always be the case. However, without proper evaluation, this view had no foundation. It seems that the over-optimistic claims, by first generation AI researchers, that expert systems would replace humans in the decision making process (Friedman-Hill, 2003) was flawed.

Today, some of the deficiencies in the technology have been overcome and it is now widely acknowledged (Boury-Brisset and Tourigny, 2000) that knowledge systems can assist (rather than replace) humans in solving problems – humans make the final decision. Stein *et al.* (2003) and Liebowitz (2001) have reported that expert systems are playing an important role in several industry sectors. Indeed, Kingston (2004) believes that knowledge systems are an effective method for managing the knowledge in organizations, as long as they are used in an appropriate area and for an appropriate task.

Gill (1995) has conducted a comprehensive study on assessing knowledge systems and his findings shed some light on the problems that inhibited their growth as a tool for managing knowledge. The successful adoption of knowledge systems is not primarily dependent on either technical or economic reasons. Their lack of success is mainly due to organizational and managerial issues, that is, human related issues: a classic problem in computer science. Gill (1995) described five problems.

The first concerns the coordination of the knowledge system development with that of the organization's business and IT strategies. The system should be able to support the strategic information system needs of the organization and support the overall business processes.

The second relates to the failure to understand the task that the system would best support. Not all tasks can be performed better by the system: there are some tasks that are better performed by humans, especially when the domain task is multidimensional and requires complex judgments. The automation of the task should also justify the cost associated with its long-term maintenance.

The third problem is associated with legal implications. Systems are not accurate in all cases and managers should be aware that such limitations exist, particularly if there is a legal liability associated with the system's decision.

The fourth relates to appreciating user concerns and expectations, as well as managing the whole development team. Knowledge systems focus on expert knowledge in a particular domain. Human experts tend to resist the computerization of their expertise. Most software development faces this problem especially where the human will be re-assigned afterwards.

The final problem is associated with managing the development team members. Knowledge system projects are extremely specialized, requiring the team members to have knowledge of both the problem domain and the development tools. As a result, the team members are highly skilled individuals, and this poses a great problem to the overall project if they should leave the team early in the development or maintenance periods.

6.4 Possible solutions

If overcoming Gill's five problems lead to the successful completion of a knowledge system, what is the key factor that would ensure success? Years of experience by Schreiber *et al.* (1999) and Kingston (2004) lead them to highlight the importance of conducting comprehensive feasibility studies beforehand. Both suggest that there are three separate aspects: the business case feasibility, the technical feasibility and the project feasibility.

During the business case feasibility study, there are important factors that should motivate the development of a knowledge system: do the organization's operations require expertise, is there a problem acquiring that expertise (availability, time restriction) and are there

> “With the ending of the single-job-for-life culture, businesses lose much of that knowledge when an individual leaves the organization.”

additional benefits such as the production of a learning tool for new recruits? Thus, conducting a business feasibility study should address Gill’s (1995) first and third problems.

The technical feasibility study focuses on classification, monitoring, diagnosis, assessment, design, configuration and control. Other considerations include what form the knowledge should take and how appropriate that form is for symbolic reasoning about concepts, objects or states and will there be a need for ‘‘condition-action’’ statements such as procedures, regulations or heuristics. It is vital to choose the most appropriate technologies for the task and the appropriate knowledge type. The technical feasibility study should solve Gill’s (1995) second problem.

The project feasibility study involves measuring the commitment of management to the overall project and determining whether it is willing to make the necessary organizational changes to accommodate the knowledge system. Are users willing to use the system and will they be able to perform the necessary functions with the aid of the intended system? The design team needs to be familiar with all stages of the development process, be comfortable with the chosen programming tool and be able to perform systems maintenance. The domain experts must also be willing to cooperate at all stages of the systems development process. The project feasibility would solve Gill’s (1995) fourth and fifth problem.

Finally, a comprehensive methodology for developing a knowledge system that incorporates both aspects of knowledge management and knowledge engineering, and addresses the feasibility issues discussed above is required. The CommonKADS methodology (Schreiber *et al.*, 1999) fills this gap. CommonKADS has become the *de facto* standard for developing knowledge systems; it is used extensively in European research projects. It supports structured knowledge engineering techniques, provides tools for corporate knowledge management and includes methods to perform detailed analysis of knowledge intensive tasks and processes. A suite of models supports the modeling of the organization, the tasks that are performed, the agents that are responsible for carrying out the tasks, the knowledge itself, the means by which that knowledge is communicated, and the design of the knowledge system (Vollebregt *et al.*, 1999; Schreiber *et al.*, 1999).

7. Some current issues in knowledge systems for managing knowledge

Systems developed in the late 1980s and early 1990s concentrated only on the ‘‘classic’’ domains of planning, diagnosis, recommendation, tutoring, and prediction (Davis *et al.*, 2004). More recently, and with the growth in the relatively new field of knowledge management (Lin *et al.*, 2003), there has been a greater recognition of the importance of intellectual capital in the knowledge economy. Furthermore, while traditionally knowledge systems were stand-alone, today they are becoming a part of an enterprise’s information system. While once they were a research laboratory technology, now they are commercial applications (Liebowitz, 2001; Gill, 1995) and a tool accepted by industry (Venkatraman and Venkatraman, 2000). They provide solutions that cannot be obtained by conventional methods (Metaxiotis, 2004).

More and more domains have begun to exploit the capabilities of modern knowledge systems technologies. Examples are: software architecture design assistant (Bachmann *et al.*, 2003), a tool for inferring semantic concepts from visual models (Mills and Gomaa, 2000), hospital management (Moreno *et al.*, 2001), clinical management (Torralba-Rodriguez *et al.*, 2003), managing bank loan risk (Yang *et al.*, 2001), and currency exchange advising (Nedovic and Devedzic, 2003). Other examples include: legal regulations (Metaxiotis, 2004), knowledge-based engineering for managing knowledge related to product design (Gardan and Gardan, 2003), learning context management for e-learning applications (Lin *et al.*, 2003), and the production of metals and related compounds (Stein *et al.*, 2003).

Although many of the problems that plagued earlier knowledge based systems and expert systems have been resolved, and newer knowledge systems are gaining wider acceptance, some concerns remain. Will research level laboratory systems successfully mature and be able to handle business-sized operations? How can we represent the knowledge that is already embedded in such systems? Will these systems be able to successfully integrate with existing enterprise systems? Will inference engines improve sufficiently to enable people to obtain precise decision support?

7.1 The maturation of knowledge systems

Because it is a maturing technology, the Object Management Group, which governs object-oriented software standards, has started a standardization process for knowledge-based engineering services (OMG, 2004) and production rule representation (OMG, 2003). There are a number of commercial knowledge systems, for example, Design-a-Trial (DaT) by InferMed Ltd assists in designing and planning clinical trials (Nammuni *et al.*, 2004) and EULE, developed in-house by Swiss Life (a leading provider of life insurance) processes insurance contracts (Reimer *et al.*, 2000). EASE, developed at the University of Edinburgh for the Health and Safety Executive of the UK is used for assessing workplace exposure to potentially hazardous new substances (Kingston, 1997), and TURBOLID was developed in Spain for on-line plant-wide supervision of the continuous processes to be found in a sugar-beet factory (Gonzalez *et al.*, 2001).

7.2 The representation of knowledge in knowledge systems

The development of semantic web technology enables the information on the current web to have precise meaning and machine-interpretable form, that would allows computers and people processing the same data to have a common understanding of what the terms means (Berners-Lee and Miller, 2002). Semantic web is used in KBS development through ontologies that enable the construction of KBSs through reusable components across domains and tasks (Gomez-Perez and Benjamins, 1999). Ontologies are used to represent domain knowledge in knowledge-based programs. This is achieved using formal declarative representations of the domain knowledge; that is sets of objects and their describable relationships (Gruber, 1993). Researchers in the area of knowledge modeling have started to realize the importance of ontology in developing domain models since the underlying principle of modeling is to achieve agreed representations in a unified manner for the domains in which they are investigating. Through the use of semantic web languages such as DAML + OIL, SHOE and RDF, ontologies can be described and these descriptions are used to create the knowledge base of the KBS (Noy *et al.*, 2001). This allows the KBS developer to focus on domain knowledge representation instead of markup tags and correct syntax to build KBS faster (Noy *et al.*, 2001).

7.3 Integrating knowledge systems with other enterprise systems

Modern enterprise systems bring together various systems built on different platforms and enable them to communicate with each other. Similarly, knowledge systems will be more attractive if they can be integrated with existing conventional systems (Gill, 1995; Davis *et al.*, 2004). Knowledge systems have been integrated with computer aided design (CAD)

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> “No single dividing line differentiates knowledge and information systems, as almost all examples contain elements of both knowledge and information within them.”

systems to manage engineering product design knowledge, e.g. Gardan and Gardan (2003) and the MOKA project (Stokes, 2001). Other examples of integration can be seen in the field of power system monitoring using SCADA where the knowledge system is successfully used to perform intelligent SCADA alarm interpretation (Hossack *et al.*, 2001). Some KS capabilities have been integrated into geographical information systems (GIS) to provide intelligent advice (Cooper and Jarvis, 2004). They have also been incorporated in popular mail clients such as Microsoft Outlook, Eudora, Netscape Messenger and OS X Mail, so that messages can be sorted according to address, name, subject heading and so on (Friedman-Hill, 2003). E-commerce systems have adopted knowledge systems in order to provide recommendations (Chun and Hong, 2001; Friedman-Hill, 2003).

7.4 Developments in inference engines

As suggested earlier, most knowledge systems adopt production rules to drive their inference engines. These are written in a declarative rather than procedural programming style (Friedman-Hill, 2003) such as RETE (Kang and Cheng, 2004). Earlier inference engines (such as CLIPS, VP-Expert, XeprtRule and KnowledgePro) used shell-based production rule systems. Today, the Java Expert System Shell (JESS) (Friedman-Hill, 2003), based on CLIPS, has been developed enabling enterprise software to have some built-in reasoning capabilities. Other types of KBS technology that are widely used are: fuzzy-based logic (Lau *et al.*, 2003; Ammar *et al.*, 2004), genetic algorithms (Lau *et al.*, 2003), case-based reasoning (Lau *et al.*, 2003), neural networks (Liebowitz, 2001), and others such as ontologies.

8. Advantages of knowledge systems

Having shown that the problem that lead to the perceived failure of knowledge-based systems and expert systems have been overcome, and that many of the outstanding issues associated with knowledge systems can be resolved, we will now turn our attention to the advantages that such systems might bring. A review of the literature on knowledge systems highlight the following advantages:

- *Time saving*. The amount of time spent on doing the work manually is reduced (Kingston, 2004; Metaxiotis, 2004; Horn *et al.*, 2002; Wei *et al.*, 2001; Stein *et al.*, 2001; Reimer *et al.*, 2000; Gill, 1995).
- *Quality improvement*. The quality of decisions made increases because there are fewer errors than if the decision were performed manually (Kingston, 2004; Metaxiotis, 2004; Stein *et al.*, 2003; Horn *et al.*, 2002; Stein *et al.*, 2001; Bryant, 2001; Reimer *et al.*, 2000; Gill, 1995).
- *Practical knowledge made applicable*. Systems can assist experts in decision making even if they have that knowledge to hand; this improves the accuracy and timeliness of the decision made (Kingston, 2004; Metaxiotis, 2004; Nedovic and Devedzic, 2003; Horn *et al.*, 2002; Venkatraman and Venkatraman, 2000).
- *Infallible and complete*. Unless there are implementation errors, knowledge systems will always produce the desired result, as they will not leave out any rule (consideration) in the reasoning process (Metaxiotis, 2004; Stein *et al.*, 2003; Reimer *et al.*, 2000).
- *Replication*. Human experts are a scarce resource. They are physically bound to their geographical location and can only be available at one place at a time. Knowledge

systems can be replicated and in effect be transferred to other locations to perform a task (Kingston, 2004; Metaxiotis, 2004; Nedovic and Devedzic, 2003; Spronck and Schilstra, 2001).

- *All day, every day*. Human experts have fixed working hours or are only available for a limited time throughout a day. They will also experience fatigue because of working long hours, which might have a deleterious effect (Stein *et al.*, 2003; Spronck and Schilstra, 2001).
- *Consistency*. Results produced by a knowledge system are consistent throughout its operational lifespan. Two copies of the same knowledge system will provide the same answer to the same problem; human experts do not achieve this level of consistency (Nedovic and Devedzic, 2003; Spronck and Schilstra, 2001; Bryant, 2001; Gill, 1995).
- *Reporting facilities*. Knowledge systems can have built-in reporting facilities that provide a written record of the rationale for a decision. In contrast, human experts need additional time and effort to write a report and it is a tedious task (Spronck and Schilstra, 2001).
- *Updating knowledge*. Knowledge can be updated easily by editing the rule-base; human experts take time to re-train (Horn *et al.*, 2002; Spronck and Schilstra, 2001).
- *Learning tool*. Knowledge systems can be used to disseminate expert knowledge in a structured manner (Kingston, 2004; Nedovic and Devedzic, 2003; Stein *et al.*, 2003; Gill, 1995).
- *Cost savings*. Operational and other overhead costs result from implementations (Kingston, 2004; Nedovic and Devedzic, 2003; Stein *et al.*, 2001; Venkatraman and Venkatraman, 2000).
- *Productivity*. As manual processes are automated and the results of the decision-making process become error-free, so enterprise productivity improves (Nedovic and Devedzic, 2003; Venkatraman and Venkatraman, 2000).

9. Conclusion

The use and management of knowledge in enterprises has become a commercial necessity; organizations now need to manage their corporate intellectual assets effectively in order to gain and maintain competitive advantage. Since most knowledge resides in human memories, managing it is seen as a human-oriented process rather than one that is technology-based. Nevertheless, technology (including the Internet and groupware systems) can serve as an enabler for knowledge management.

One of the prominent tools in managing knowledge is the KBS. In this paper it has been argued that the traditional KBS, which has its roots in the field of AI, has been replaced by a new technology which has come to be known as knowledge systems in order to differentiate it from the older knowledge-based systems. Knowledge systems can be deployed as the technological means for capturing and managing both explicit and tacit knowledge as part of an organization's knowledge management initiative. In the early days of knowledge-based systems there was some doubt cast over their effectiveness due mainly to an over-optimistic view of the technology's potential and a misjudgment of how it would work in practice. Together with the failure to recognize the importance of conducting feasibility studies and

“The successful adoption of knowledge systems is not primarily dependent on either technical or economic reasons.”

managing the human-related issues in the system development process, it has led to the view that these systems could never work.

However, the current generation of systems has evolved from being stand-alone expert system machines, to being part of a larger group of enterprise-wide systems; these now incorporate such features as expert location and social network analysis. With the new features and the growing demand for stable and scalable technology in managing knowledge, knowledge (based) systems has become one of the most important applications for knowledge management.

The authors strongly believe that the time has come to re-evaluate the role that knowledge (based) systems can play and urge both academics and practitioners alike to realize that they can be usefully employed in knowledge management.

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