Knowledge and information management in e-learning environments: the user agent architecture

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Abstract
Knowledge management has recently received considerable attention in the computer information systems community and is continuously gaining interest from industry, enterprises and government. As we move towards building knowledge organizations, knowledge management in combination with information management will play a fundamental role towards the success of transforming individual knowledge into organizational knowledge. In this framework, this paper discusses the key concepts of human-computer interaction in knowledge management, identifies new challenges of knowledge management for Web-based business and proposes a "user agent architecture" for knowledge management in e-learning environments. User agents use artificial neural network technology and can be used in various e-learning or e-training environments, in order to provide them with means of managing information stored, filtering content and enabling better knowledge adoption on behalf of their users.

Introduction

Society is entering into an era where the future essentially will be determined by people's ability to use knowledge wisely. Knowledge is a precious global resource that is the embodiment of human intellectual capital and technology. As people begin to expand their understanding of knowledge as an essential asset, they are realizing that in many ways the future is limited only by imagination and the ability to leverage the human mind. As knowledge increasingly becomes a key strategic resource, the need to develop comprehensive understanding of knowledge processes for the creation, transfer and deployment of this unique asset is becoming critical.

Knowledge management (KM) is today the subject of much literature, discussion, planning and some action (Nonaka, 1991; Wiig, 1993; Wilkins *et al.*, 1997; Davenport and Prusak, 1998; Davenport *et al.*, 1998; Leonard, 1999; Parlby, 2000; Bhatt, 2001). Effectively implementing a sound KM strategy and becoming a knowledge-based company is seen as a mandatory condition of success for organizations as they enter the era of the knowledge economy. Although there is a recognition that knowledge is a key business asset, organizations are still in the early stages of understanding the implications of KM, while a fair percentage of senior managers believe that KM may just be embellished information management and business process reengineering (BPR) efforts; many BPR efforts have been failures, so there is a concern that KM may fall victim to the same perils.

On the other hand, nowadays the academic community is addressing more and more the rise of "online community" that will be instrumental in the realization of advanced learning societies. Internet online environments enable new and interesting designs for the support of traditional learning and for the development of new forms of learning. Ideally, users will be able to access all forms of knowledge in any combination, from any location at any time. This, of course, implies considerable complexity in the software design and a substantial level of intelligence across the systems – from the servers, to the networks, to the user interfaces. Although e-learning environments can be used widely either for educational or for training purposes (Shirley, 2001; Alstete, 2001), the problem which still exists is the efficient management of the content and the effectiveness to the users.

In this framework, this paper presents a "user agent architecture" for knowledge management in e-learning environments. The authors' proposal is based on a clear definition and an unambiguous understanding of what knowledge is and its separation from information (raw data).

Knowledge: a definition approach

The first step of our approach is to define "knowledge" and identify its difference versus information. Since there are several aspects to defining knowledge (Zeleny, 2000), in this paper the e-learning aspect is adopted. Information is considered to be a set of raw data, which may be experiences, skills, actions, historical records or scientific documentation. This set of raw data has no organization and it is in complete ataxia. Moreover, the information dissemination increases this ataxia. The entropy term is defined as a measure for the degree of ataxia for a physical system. It has the opposite value from information. It measures the organization of a physical system. In the

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information theory, the transfer of a message is accompanied by the dissemination of information or by the increment of ataxia. According to this principle, the entropy of a transferred message is always increased and its informational value is always decreased, however great is the volume of this information.

However, in order to utilize this information, the appropriate conditions must be created. So, however great is the volume of the information, it is valueless if it cannot be elaborated. To quantify the "quality" of information (by means of utilization), the term enthalpy is introduced. Enthalpy declares the optimum percentage of the information, which could be utilized under specific conditions. The term utilization here refers to the generation of "knowledge":

> Information enthalpy measures the optimum percentage of information, which can produce knowledge under specific conditions.

Since information enthalpy is a theoretical magnitude, it can only be experimentally measured. For example, it can be the result of the convergence of an experimental function. The enthalpy measure can be used for evaluating a methodology, the specific conditions or even the quality of information itself.

As mentioned above, the utilization of information can only be achieved under the appropriate conditions. However, what does "utilization of information" mean? At this point, the "knowledge" term must be introduced.

In many scientific articles (Liebowitz, 2002; Wiig, 1997), knowledge is interpreted in terms of potential for action and distinguished from information in terms of its more immediate link with performance. In learning systems, we consider knowledge as a directive graph, with structural cognitive entities as nodes and functional links between each pair of these nodes. The graph may either have inputs and outputs, or form a learning memory. Such graphs refer to neural networks and associative memories (Hopfield net). According to the above, knowledge can be considered as a set of procedures, mechanisms and constraints which elaborate the information for deciding on performing an action. We can conclude to the following definition:

> Knowledge is a set of mechanisms, procedures and constraints, which link information with performance.

In Figure 1, the Gagne model of "learning and recall", based on the theory of "information elaboration", uses some of the principles mentioned above. It represents the procedure of knowledge generation within the human brain. The interaction between environment and human is performed through receptors and effectors (input-output), and the data are saved in the temporary (short-term) memory, while repeating and performing save them in the long-term memory. Then, the response generator performs actions, using data from memory and controlling them by executive control and expectancies. The mechanisms of knowledge acquisition (or learning procedure) can be managed by using the appropriate methods and tools.

Knowledge management and enabling technologies

In this section we review in brief a number of KM-enabling technologies and tools described in the literature and their relationship to the KM applications they enable (Evans and Dansereau, 1991; Neilson, 1997; Bradshaw *et al.*, 1998; Merlyn and Valikangas, 1998; Vail, 1999; Binney, 2001). Several authors stress the fact that what is new about KM is the phenomenal growth of technologies that make it easier to implement KM systems.

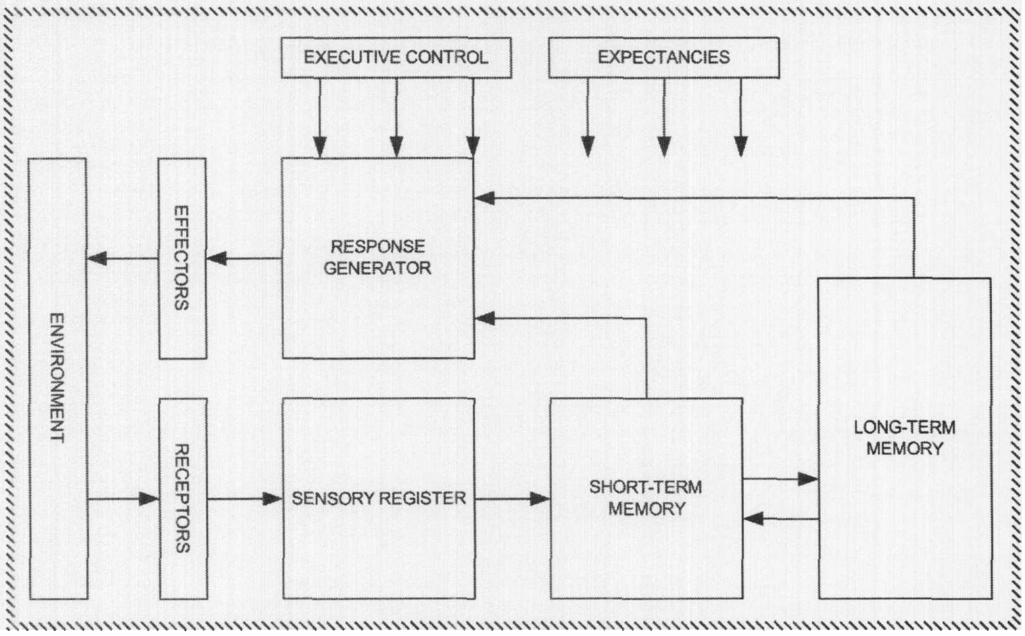
In the review of the literature, a mapping between technologies and specific KM applications emerged. This relationship between a technology and a KM application it supports is presented in Figure 2. As this figure shows, there are a number of technologies which underpin most of today's KM applications and cannot be primarily assigned to only one element of the spectrum. They include Internet/intranet technologies and generic Web elements such as portals.

In our case, we are proposing the use of intelligent agents for the implementation of a model for knowledge management in e-learning or e-training environments. Intelligent agents introduce a new paradigm for instruction that is based on the concept of shared abilities and cooperative learning between humans and computers.

Knowledge management and e-learning systems

Contemporary e-learning (and e-training) systems hold a great volume of information. The problem that pops up is how the user can take advantage of this information and acquire knowledge.

Figure 1
Gagne model of "learning and recall"



The solution, which is presented in the following section, is based on the computer managed instruction (CMI) architecture. CMI systems aim at the complete impression of the learning environment by modeling the properties and the procedures of the learning entities. These entities (or learning objects) are used or involved in the procedure of the knowledge acquisition. Educational material and courses, multimedia files, educational software and tools may form learning objects. In general, computer based training (CBT) systems, interactive learning environments, computer aided instruction (CAI) systems, distance learning systems and e-learning systems use learning objects to support their educational process.

At the end of the 1980s, the European Union launched several programmes to finance and support educational technologies. For many years, the DELTA programme promoted the development of educational technology. The DELTA programme was included in the information society technologies programme, in a special priority axis (education and training) with the following directives:

- the school of tomorrow;
- the learning citizen; and
- trials and best practice addressing advanced solutions for on-the-job training in SMEs.

There are also a number of initiatives, projects and technical options in the area of knowledge management in e-learning environments, which are being developed in the USA and EU:

- IMS initiative projects, which refer to smart systems in industrial production and are coordinated by the DG XII and XIII of EU (IST and growth programmes), Learning Technology Standardization Committee of CEN, W3C, several special interest groups for standardization of educational technologies.
- SCHEMAS (IST programme) project is a new project, which provides the developers of metadata models with a research forum. Part of this project is the Metadata Watch, which will organize the analytical list of projects, programmes, software tools and instructions, which refer to the sector of knowledge management and metadata.
- Dublin Core is a small basic set of metadata elements, which are designated to facilitate information search and restore.
- Resource description framework (RDF) is a framework/model, which ensures the interaction of applications, exchanging information through Internet.
- In the European Schoolnet, the European Schools Treasury Browser is being developed. It aims at the development of a network infrastructure for the educational materials repositories of the European schools and the functional management of their metadata.
- Digital libraries and on-line organization and dissemination methods of educational

Figure 2
Knowledge management and enabling technologies

	Transactional	Analytical	Asset Management	Process	Developmental	Innovation & Creation
Knowledge Management Applications	• Cased-Based Reasoning • Help Desk Applications • Customer Service Applic. • Order Entry Applications • Service Agent Support Applic.	• Data Warehousing • Data Mining • Business Intelligence • MIS • DSS • Customer Relationship Management • Competitive Intelligence	• Intellectual Property • Document Management • Knowledge Valuation • Knowledge Repositories • Content Management	• TQM • Benchmarking • Best practices • Quality Management • BPR • Process Improvement • Process Automation • Lessons Learnt • Methodology • SEI/CMM, ISO9XXX	• Skills Development • Staff Competencies • Learning • Teaching • Training	• Communities • Collaboration • Discussion Forums • Networking • Virtual teams • R&D
Enabling Technologies	• Expert Systems • Cognitive Technologies • Semantic Networks • Rule-based Expert Systems • Probability Networks • Decision Trees • GIS	• Intelligent Agents • Web Crawlers • DBMS • Neural Computing • Push Technologies • Data Analysis & Reporting Tools	• Document Management Tools • Search Engines • Knowledge Maps • Library Systems	• Workflow Management • Process Modeling Tools	• CBT • Online Training	• Groupware • E-mail • Chat Rooms • Video Conferencing • Search Engines • Voice Mail • Bulletin Boards • Push Technologies • Simulation Technologies

Source: Binney (2001)

material. Although there are several technological systems for organizing the material of libraries, it is necessary to develop the appropriate infrastructure for the on-line material that is constantly produced.
- Desire projects (DESIRE toolkit), CD-DOT, META-LIB project (State and University Library of Lower Saxony).

The proposed architectural model

The architectural model proposed is a coordinated cooperation of user agents, content management, learning objects metadata and e-learning models. The goal of this model can be divided to the following axes:
- *Categorization of the information according to the user's needs.* The information will have different hierarchy and will be sorted according to the user's personal needs. This will be achieved with metadata tags, which will categorize the content with the support of the user agents.
- *Users' progress monitoring and support.* The user agents will be the entrance point of the users in the e-learning environment. The user agents will monitor the input and output data of the environment. So, they will be able to record the users' steps, interests, needs and also the feedbacks of the environment. After a period of training, the user agents will be able to propose, filter, search and present the appropriate information to the user.
- *Rapid, reliable and accurate content restore and presentation.*
- *Compatibility with pedagogical and e-learning models.*

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The architecture of the proposed model is presented in Figure 3.

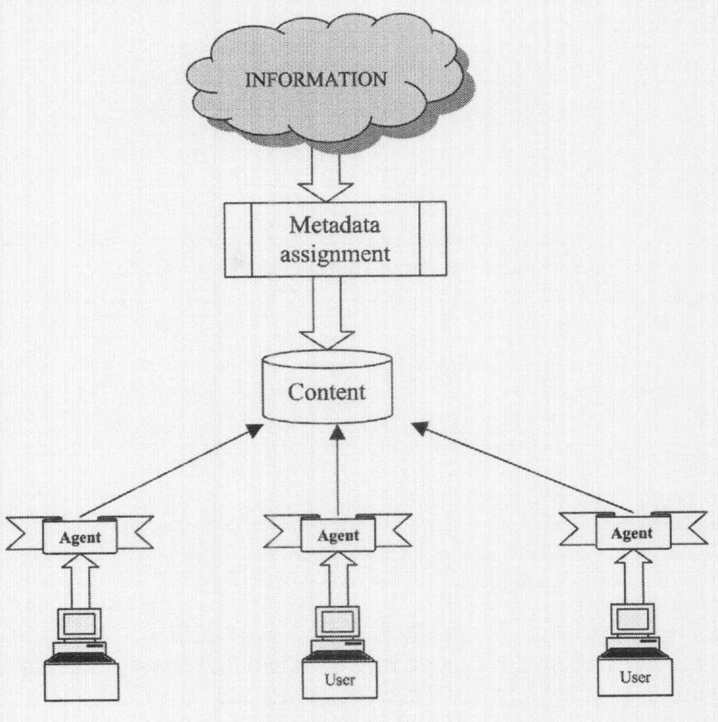
Before the information is saved in the content database, the metadata assignment procedure takes place. This procedure does not identify the data directly, but assigns several property metadata tags. These tags are used by the user agents to categorize the data. Then, the data are saved in the content database along with their metadata tags.

The user agents are the users' representatives: they forward their selections, record their steps, filter information and collect the environment's feedbacks. This is achieved through the elaboration of the metadata tags: the users' agents are trained, for an initial period of time, to identify the correct data by searching through its metadata tags.

After the training period, the users' agents have a complete view of their users' needs, selections, interests etc. Then, they are able to work on-line, even if the user is off-line: they can perform searches, filter the results and present them to the user when he/she connects back to the system.

According to the above, the users' agents are a part of Gagne's "learning and recall" model. They simulate the learning and facilitate the recall process. The technology used for the implementation of the users' agents is based on artificial neural networks and associative memories, as already mentioned.

Figure 3
Architecture of the proposed model



Conclusions

Nowadays, the Internet has proved to be a powerful adjunct to traditional computer learning environments due to its capacities for a nearly limitless supply of information. In parallel, applied artificial intelligence, via agent technologies, provides a means to realize the objectives of Internet personalization and customization (Maule, 1997). The fields of AI and agents are well established and quite comprehensive. A detailed discussion of these areas is well beyond the scope or intent of this paper. Rather, the objective herein is to present agent technology as the enabler through which knowledge management can be effectively introduced into e-learning environments. The architectural modeling of the users' agents combined with metadata tags can, indeed, produce an open, extensible, flexible and reliable solution. Compatible with most e-learning and e-training systems, it can be used for educational purposes, training personnel, smart search engines etc. The advantages of the users' agents are:

- they impersonate their users' needs and interests in the environment;
- they "learn" to act, filter and search;
- they are compatible with most environments; and
- they take full advantage of the metadata features.

It is our belief that the usefulness of KM-tools in e-learning and e-training will gain more recognition if they are properly integrated with other AI techniques, especially expert systems. The authors are now conducting further research in this direction.

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