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Methods and tools for corporate knowledge management

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This article† is a survey of some methods, techniques and tools aimed at managing corporate knowledge from a corporate memory designer's perspective. In particular, it analyses problems and solutions related to the following steps: detection of needs of corporate memory, construction of the corporate memory, its diffusion (specially using the Internet technologies), use, evaluation and evolution

1. Introduction

1.1. CORPORATE MEMORY: DEFINITIONS

The objectives of knowledge management in an organization are to promote knowledge growth, knowledge communication and knowledge preservation in the organization (Steels, 1993). It entails managing knowledge resources in order to facilitate access and reuse of knowledge (O'Leary, 1998*a*). Knowledge management is a very complex problem and can be tackled from several view points: socio-organizational, financial and economical, technical, human and legal (Barthès, 1996).

There is an increasing industrial interest in the capitalization of knowledge (i.e. both theoretical knowledge and practical know-how) of groups of people in an organization, such groups being possibly dispersed geographically. In Van Heijst, Van der Spek and Kruizinga (1996), "corporate memory" is defined as an "explicit, disembodied, persistent representation of knowledge and information in an organization". For example, it may include knowledge on products, production processes, clients, marketing strategies, financial results, plans and strategical goals, etc. (Nagendra Prasad & Plaza, 1996) define corporate memory as "the collective data and knowledge resources of a company including project experiences, problem-solving expertise, design rationale, etc.": it may include databases, electronic documents, reports, product requirements, design rationale, etc. Its building relies on the "will to preserve, in order to reuse them later or the most rapidly, reasonings, behaviours, knowledge even in their contradictions and with all their

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variety" (Pomian, 1996). Knowledge capitalization is the process which allows to reuse, in a relevant way, the knowledge of a given domain previously stored and modelled, in order to perform new tasks (Simon, 1996). The purpose is to "locate and make visible the enterprise knowledge, be able to keep it, access it and actualize it, know how to diffuse it and better use it, put it in synergy and valorize it" (Gundstein, 1995).

Several kinds of knowledge can be found in a company: *explicit* or *tacit knowledge* (Nonka, 1991). In any operation of knowledge capitalization, it is important to identify crucial knowledge to be capitalized (Grundstein & Barthès, 1996). It has an influence on the kind of corporate memory needed by the enterprise. This corporate memory should help to support the integration of resources and know-how in the enterprise and to cooperate by effective communication and active documentation (Durstewitz, 1994). As often emphasized, a corporate memory should provide "the right knowledge or information to the right person at the right time and at the right level".

As noted in Nonaka (1991) and Van Engers, Mathies, Legel and Dekker (1995), the knowledge chain consists of seven links: listing the existing knowledge, determining the required knowledge, developing new knowledge, allocating new and existing knowledge, applying knowledge, maintaining knowledge and disposing of knowledge. In this paper, we adopt the definition proposed by Van Heijst *et al.* (1996), and we extend it slightly by considering a corporate memory as an "explicit, disembodied, persistent representation of knowledge and information in an organization, in order to facilitate its access and reuse by adequate members of the organization for their tasks". We propose to consider the building of the corporate memory as relying on the following steps [summed up in Figure 1, inspired of (Dieng *et al.*, 1998)]: (1) detection of needs in corporate memory, (2) construction of the corporate memory, (3) diffusion of the corporate memory, (4) use of the corporate memory, (5) evaluation of the corporate memory and (6) maintenance and evolution of the corporate memory.

For each step, we will analyse some methodological or technical proposals offered by researchers. Let us notice that several kinds of publications can be found: survey on knowledge management, analysis of types of knowledge available in a company, reports of industrial experiments, proposal of a general architecture for corporate memory, thorough study of a particular technique such as some knowledge-processing techniques stemming from artificial intelligence and used here for solving a peculiar problem underlying computational corporate memory building. The variety of research topics possibly involved in corporate memory management is illustrated by Figure 1. Clearly, this complex problem has at least organizational aspects to be tackled, and technical aspects to be solved. According to Kühn and Abecker (1997), computer scientists concerned about the use of Information and Communication Technology for knowledge management support tend to ignore the specific requirements and constraints for successful knowledge management in industrial practice while specialists in knowledge management often treat only roughly the aspects of computer support. Therefore, building a corporate memory requires a multidisciplinary approach.

1.2. CORPORATE MEMORY INDUSTRIAL NEEDS

An enterprise is not only a unit of production of goods or services conforming to the expectations of clients, in the best conditions of cost, deadline and quality, but it is also

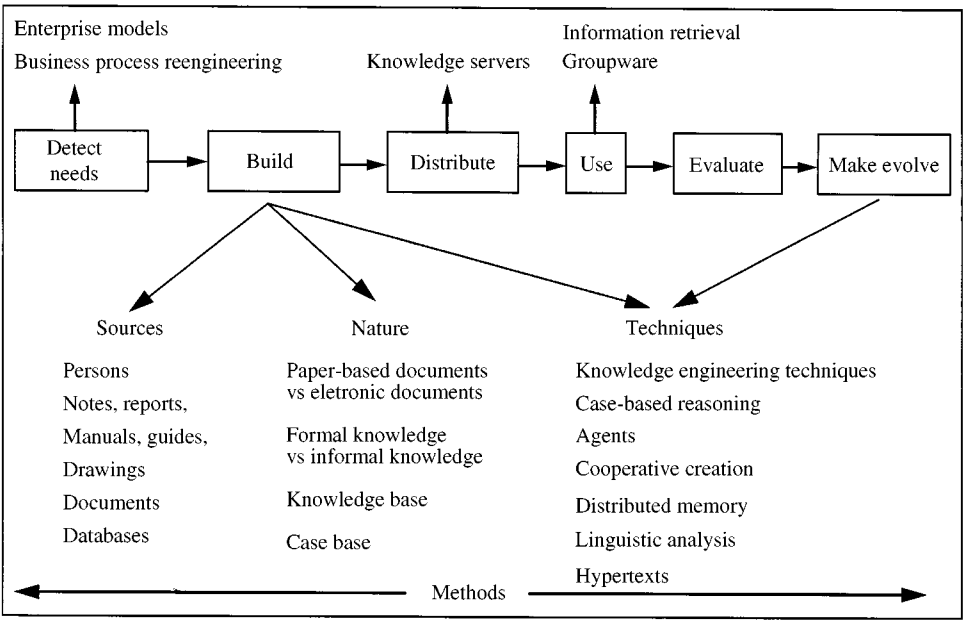

FIGURE 1. Corporate memory management.

a knowledge production unit (Grundstein, 1995). The nature of the needed corporate memory and the efforts needed for building it may depend on the size of the company (c.f. wide-sized groups vs. small- and medium-sized firms). The motivations can be various: (1) to avoid loss of know-how of a specialist after his retirement or mutation, (2) to exploit the experience acquired from past projects, and to keep some lessons from past, in order to avoid reproduction of some mistakes, (3) to exploit the knowledge map of the company for the corporate strategy: a regular inventory of the firm know-how should improve the enterprise ability to react and adapt to change, (4) to improve information circulation and communication in the enterprise, (5) to improve the learning of employees in the enterprise (new as old employees) and (6) to integrate the different know-how of an organization.

1.3. KNOWLEDGE IN THE ENTERPRISE

Several typologies of knowledge in the enterprise were proposed in literature. They can be useful to determine the essential knowledge the company needs to capitalize (Durstewitz, 1994). Grundstein (1995) and Grundstein and Barthès (1996) distinguish on the one hand, *explicit knowledge* corresponding to *the specific know-how* characterizing the ability to design, build, sell and support products and services, and on the other hand, *tacit knowledge* consisting of *individual and collective skills* characterizing the ability to act, adapt and evolve. They distinguish tangible elements (data, procedures, plans, models, algorithms, documents of analysis and synthesis) and intangible elements (abilities, professional knacks, private knowledge, knowledge of company history and of decisional contexts, etc). Therefore, they suggest that in a capitalization operation, the

tangible components can be taken into account through knowledge management (technical data management, document management, configuration management), while the intangible components require know-how formalization (acquisition and representation of know-how and reasoning on such know-how). Know-how, technical facts, product requirements, design rationale, experience or expertise are examples of knowledge types useful for corporate memory (Durstewitz, 1994).

More specifically, in the framework of manufacturing industry, several categories of industrial knowledge useful for design activity are proposed in Bourne (1997) (see Section 3.1).

1.4. TYPOLOGIES OF CORPORATE MEMORIES

The memory of an enterprise includes not only a "technical memory" obtained by capitalization of its employees' know-how but also an "organizational memory" (or "managerial memory") related to the past and present organizational structures of the enterprise (human resources, management, etc.) and "project memories" for capitalizing lessons and experience from given projects (Pomian, 1996).

Tourtier (1995) distinguishes: (1) *profession memory*, composed of the referential, documents, tools, methods used in a given profession, (2) *company memory* related to organization, activities, products, participants (e.g. customers, suppliers, sub-contractors) and (3) *individual memory* characterized by status, competencies, know-how, activities of a given member of the enterprise, (4) *project memory* comprising the project definition, activities, history and results.

Grudstein and Barthès (1996) distinguish *company technical knowledge* (i.e. used everyday inside the company, its business units, departments, subsidiaries by the employees for performing their daily job) from *strategic corporate knowledge* used by the company managers.

In addition to these typologies, we add another distinction between *internal memory* (corresponding to knowledge and information internal to the enterprise) and *external memory* (corresponding to knowledge and information useful for the company but stemming from external world).

1.5. PLAN OF THE PAPER

The paper will successively analyse problems and solutions linked to detection of needs, construction of the corporate memory, its diffusion, use, evaluation and maintenance. Then we will give several examples of dedicated methods and we will summarize the lessons of this study. The purpose of this survey is to prepare a preliminary methodological guide that will enable to choose among methods and tools proposed in literature on knowledge management.

2. Knowledge management

2.1. DETECTION OF NEEDS OF CORPORATE MEMORY

As successful information system development in general, successful corporate memory development must be "underpinned by a clear focus on the situations of use and the

needs of users" (Thomas, 1996), i.e. on the human issues of the development. The history of systems development "shows repeatedly that it is the human issues which "make or break" new methods and tools at work" (Buckingham Shum, 1997). So detecting the "right" users' needs, or the "right" corporate memory needed, is the first task of the corporate memory designers.

2.1.1. Problems

Detecting the "right" needs is not a simple task. Corporate memory designers have to learn as much as possible about who users are,which tasks they have to perform, under what situations, which knowledge types they need to memorize and retrieve (for achieving the tasks), which tools they use, etc. In doing so, corporate memory designers have to face problems about users, tasks, situations, etc. The following are examples of such problems.

- *Users' types*: Who are the "right" users to consider? How to take account of the multiplicity of corporate memory users? Is it worth considering every potential user of the corporate memory?
- *Users' characteristics and behaviours*: Which are the "right" users' characteristics and behaviours to consider? How to "take account of the users' multiple and probably incommensurate perspectives" (Kurland & Barber, 1995)? Can we ignore such "side" users' behaviours as "trusting" (Jones & Marsh, 1997)? Which meaningful knowledge storing and knowledge retrieving activities do users perform to achieve their tasks?
- *Tasks*: Which are the "right" tasks or goals to consider? For example, Simon (1996) identified the following goals of collective memory in the context of dynamic complex situations: (1) innovating; (2) increasing cooperation; (3) managing turn-over; (4) handling exceptions and (5) dealing with critical situations. Also many authors (Davenport, Jarvenpaa & Beers, 1996; Davenport, De Long & Beers, 1997; Conklin, 1992; Buckingham Shum, 1997) refer to the notion of knowledge-intensive tasks or wicked problems as possible candidates for support.
- *Situations*: Which are the "right" situations, or contexts, to consider? For example, dynamic complex situations (e.g. emergency management, traffic control, rescue services, industrial plant control) will imply corporate memory requirements different from less dynamic situations (cf. Wærn, 1996).
- *Knowledge*: Which is the "right" knowledge to consider? Where to get it? What can we do if the source users (those who have the "right" knowledge) have been transferred, or have resigned, dismissed or retired (Guérin & Mahé, 1997)? Concerning the first question for example, managers of the LJC corporation (a French joint factory) claimed that it is important to consider customers' knowledge, because customers "have the entire knowledge of the product in situation" (Guéin & Mahé, 1997). Even though they are not necessarily the system users, customers are important stakeholders and can play the role of knowledge suppliers and knowledge sources.
- *Errors*: Which are the important corporate memory errors to consider? How to handle them? For example, Loftus (1997) reported very interesting studies about false memories showing that "when people who witness an event are later exposed to new and misleading information about it, their recollections often become distorted".

Corporate memory developers have to face not only with such "first-order" problems (i.e problems concerning users directly), but also "second-order" problems (i.e. problems that directly concern designers). How these "second-order" problems are faced with may have great implications on the needs detection task. The following are the examples of such problems.

- *Corporate memory project ambition or cost*: is the project realistic? A major obstacle to the project achievement is that developers often want "too much, too soon" (Knapp, 1997). Stressing the economic facet of assisting complex creative and knowledge-intensive processes, Kühn and Abecker (1997) notice that the fully-automatic support of these processes would be too expensive or impossible
- *Corporate memory design perspective*: is the goal to create a band new corporate memory (design), or improving an existing one (redesign)?
- *Corporate memory underlying representation*: must corporate memory be considered as an object or as a process (cf. Bannon & Kuutti, 1996)?
- *Productivity paradox*: how to cope with the productivity paradox, "whereby the availability of more and more information has actually resulted in reducing the production of the users" (Sorensen *et al*., 1997)?
- *Context paradox*: how to cope with the context paradox, i.e. "the possibility that more context will be needed to interpret whatever contextual information has already been provided" (Buckingham Shum, 1997)?

2.1.2. Solutions

Here are some of the solutions currently adopted to detect corporate memory needs. Whether they are approaches, methods or techniques, they could not appear specific to corporate memory design. There are several reasons for that. We will quote two of them: (1) corporate memories are not entirely new systems; they are adaptations, evolutions or integrations of existing systems; (2) before conceiving memories, the proponents or users of the solutions have taken part in the design of other types of systems (knowledge-based systems, CSCW systems, etc.), and they have transferred the solutions they already know. Most of the solutions can thus be considered as adaptations of existing solutions. It will appear however that these adaptations (or the future adaptations that we can envision today) reveal some aspects more specific to corporate memory design (e.g. how to anticipate the needs of users who still do not exist).

2.1.2.1. Underlying approach: "stakeholder-centred design". The approach to needs detection cannot be disconnected from the approach to the overall development of the corporate memory, or underlying approach. The main underlying approach is the so-called user-centered design (UCD) or human-centered design (HCD) approach. The reason for using a UC[H]D approach is "to ensure that the memory is defined in terms of users' needs" (Durstewitz, 1994). The related UC[H]D methods "cover requirements determination, design and implementation, and are concerned with the social as well as technical issues in new system development […]. The philosophy underpinning this approach is that effective systems are created by a partnership between developers and the users and/or stakeholders in the organization which is to operate the new system" (Eason & Olphert, 1996). The term "*stakeholders*" is worth discussing here. This

term refers to "any individual within the community where the system may be implemented who has an interest or "stake" which may be affected by the system" (Eason & Olphert, 1996); it refers to "anyone who stands to gain from it [the system], and anyone who stands to lose" (Macaulay, 1996). Stakeholders include "potential users but are not restricted to them; other stakeholders may be purchasers, customers, maintainers, etc." (Eason & Olphert, 1996). The current trend among corporate memory developers is to consider stakeholders rather than users (strictly speaking). So corporate memory design/development could be called Stakeholder-Centered Design/Development. As (Eason & Olphert, 1996) claimed: "Systems development should be a partnership in which developers contribute an understanding of the technical opportunities and the methods of design, and the stakeholders contribute their expertise about the domain of application and existing organizational practices and have a right to judge what is in their best interests as the potential owners of the future that is being constructed."

2.1.2.2. Approaches to requirements analysis. Approaches to needs detection can be appropriately described in terms of requirements analysis because (1) getting at users' needs is the aim of requirements analysis (Thomas, 1996), and (2) research on corporate memory and knowledge management often refers to requirements analysis (e.g. Kühn & Abecker, 1997). "The earlier designers of systems understand the needs and problems of their users, and […] the better they understand them the more able they will be to develop systems which meet users' needs", according to (Macaulay, 1996), that describes four types of approaches to CSCW requirements analysis [cf. a great amount of CSCW work is done in the context of corporate memory (Wærn, 1996)]:

1. *Traditional approaches.* Traditional approaches are approaches such as the structured analysis approach, or the object-oriented approach (cf. OO analysis). In such approaches, users have a passive role; they are considered as the sources of information and the reviewers of models developed, and the systems analyst is considered as responsible for eliciting requirements from users.
2. *Participation.* In the participation approach, "users are expected to contribute", by assisting in analysing their problems at work, complete job satisfaction questionnaires, etc. Participation is used "in situations in which initiators of projects do not have all the information needed to design the change, and where users have considerable power to resist."
3. *Design team.* The formation of a design team is often recommended "to smoother the transition from requirements to design". In the design team, the roles of the technical experts and the customers are clearly identified. Technical experts "contribute their skills to the creation of a system", and customers "are concerned with the world they will have to inhabit after the change caused by the system".
4. *Group sessions.* In the group sessions approach, people "jointly design systems in facilitated group sessions". Macaulay's (1996) cooperative requirements capture is a stakeholder centred approach consisting of the following steps: (1) identify the problem; (2) formulate the team; (3) group sessions1: explore the user environment; (4) validate with users; (5) group session 2: identify the scope of the proposed system and (6) validate with stakeholders. Each group session has a number of steps; for example, session 1 includes: (a) the business case, (b) workgroups, (c) users, (d) tasks, (e) objects,

(f) interactions and (g) consolidation. Each step includes an introduction, brainstorming, prioritization and generation of agreed descriptions using checklists and proformas which deal with user-related issues.

It is important to notice that requirements analysis is strongly related to evaluation: if for requirements analysis the aim is "to get at users' needs", for evaluation the aim is "to tune the system to make sure that it really does meet those needs" (Thomas, 1996).

2.1.2.3. Methods: classics

(i) *Literature review*. Analysing the literature on corporate memory is one of the classical methods used to detect corporate memory needs. For example, from the Macintosh's (1997) work on knowledge asset management, Kühn and Abecker (1997) elicited the following "major impediments to more productivity in knowledge-based work process": (a) highly paid workers spend much of their time looking for needed information; (b) essential know-how is available only in the heads of a few employees; (c) valuable information is buried in piles of documents and data; (d) costly errors are repeated due to disregard of previous experiences and (e) delays and sub-optimal product quality result from insufficient flow of information. These impediments can be considered as introducers to requirements.

(ii) *Interviews/discussions*. Performing interviews or discussions is another classical method used for identifying corporate memory needs. For example, Kühn and Abecker (1997) had interviews with prospective users and discussions with information technology personnel and managers to get requirements. They suggest crucial requirements for the success of a corporate memory information system project in an industrial practice: (a) collection and systematic organization of information from various sources; (b) integration into existing work environment; (c) minimization of up-front knowledge engineering; (d) active presentation of relevant information; and (e) exploiting user feedback for maintenance and evolution.

(iii) *Observations/experiments*. Observing real corporate memory practices or conducting experiments about them, are a third classical method used to detect corporate memory needs. For example, observing the Design Rationale activity of a real industrial project conducted in a design office of Aerospatiale, the French aerospace company, Karsenty (1996) showed that designers having to reuse a past solution elaborated by others, often asked themselves: "Why did they do so and not else?" If they had no answer to this question, experienced designers often considered the alternative solution they spontaneously found as better than the past one (even if it later revealed itself worse). Less experienced designers often selected the past solution. These results suggest requirements such as: a corporate memory for Aerospatiale designers should contain justification or argumentation knowledge; this knowledge must be "past-solution oriented" for experienced designers, and "present-solution oriented" for less experienced designers.

2.1.2.4. Dedicated methods and approaches: some trends

(i) *Lead user methodology*. The "lead user methodology" (Urban & von Hippel, 1988) prescribes to perform needs detection with "lead users". Lead users are "users whose present strong needs will become general in a marketplace for months or years in the

future". The anticipatory character of the "lead user methodology" appears particularly interesting for designing corporate memories. We know indeed that users of memories are not only current members of the company, but also its future members, i.e. people who will enter the company 5, 10, 50 years or more, later. It is thus essential to anticipate as far as possible who would be future users, and which could be their needs, or at least to foresee possible difficulties of use of current memories to at least propose ways of overcoming such difficulties. We can consider that other anticipatory methods will appear in the future, which will allow the construction of memories really usable in the long term.

(ii) *Advisibility analysis.* The CORPUS project (Grundstein & Barthès, 1996) offers a process-centered and problem-oriented approach called advisibility analysis of knowledge capitalization. The purpose is to help determine the nature and field of crucial knowledge that needs to be capitalized, the company members who have this knowledge, in which form, the members who use this knowledge, when and how, and the risks in case no capitalization operation is performed. The main steps of this approach are: (1) determine sensitive processes essential for the company functioning; (2) distinguish determining problems that make critical activities fragile (i.e. activities contributing to sensitive processes); and (3) determine crucial knowledge necessary to solve determining problems.

(iii) *Enterprise models.* Some research focuses on enterprise analysis and modelling (Fox, 1993) [http://www.aiai.ed.ac.uk/ ~ enterprise/enterprise/] and can be useful during a corporate memory construction. For example, the evolution of the enterprise through time, its experience acquired from past projects are elements interesting to take into account. An enterprise ontology, defining concepts relevant for description of an enterprise, is proposed in Uschold *et al.* (1998). Such an ontology can be used as support for exchange of information and knowledge in the enterprise (Fraser, 1994). Organizational structure, processes, strategies, resources, goals, constraints and environment of the enterprise can thus be modelled. Intra-enterprise modelling and inter-enterprise modelling can be distinguished. Beauchène, Mahe and Rieu (1996) model an enterprise organization, using a model stemming from quality management and focussing on "customer–supplier" relationships between the enterprise members. The interest of exploiting an enterprise model is to determine the weak points of the enterprise, that could possibly be improved by a knowledge capitalization operation.

A distinction is often made between process- and product-oriented models of the enterprise. A process-oriented view on the organization can be inspired by research on workflow management: for example, Maurer and Dellen (1998) offers a process modelling language for representing knowledge upon work processes (e.g. "process, product and resources models, project plans and schedules, products developed within projects, project traces, background knowledge such as guidelines, business rules, studies").

The MNEMOS EUREKA project (see http://www.delab.sintef.no/MNEMOS/dir.html) aimed "to develop a new generation of information systems to increase the competitivity of the enterprise through a better circulation of the corporate knowledge, a more efficient management and support to the human creativity processes". This project proposed an enterprise model based on eight dimensions: document,

programme, budget, contacts, organization, material, calendar, results (Feray *et al.*, 1998). The memory of a research laboratory was built using this enterprise model.

(iv) *Cognitive models.* Theoretical models of workers' cognitive functioning and of knowledge used in work situations may be useful for needs detection purposes. Bollon (1997) showed the interest of these models and especially the methodological precautions they induce during field observations conducted to capitalize knowledge (see also Poitou, 1997). The MKSM method (Ermine, Chaillot, Bigeon, Charreton & Malavieille, 1996; see Section 3.3) is an example of a direct application of linguistic and psychological theories to corporate memory design. By recommending to shift the perspective on organizational memory from a passive view (memory as a store) to an active view (memory as a process), Bannon and Kuutti (1996) encouraged the exploitation of classical models of human active memory (individual and collective) for the design of memory systems. The interest of these models is to make explicit the mnemonic processes and functions that people use when performing a task, and to more clearly specify an assistance of these processes (in addition to the more classical implementation of the products of these processes). Not elaborated for system design purposes, the models of active memory however need to be adapted to better meet design purposes. One adaptation strategy is to confront them with the actual practices of the corporate members (Giboin, 1998). As a by-product, this confrontation may orient towards alternative models of memory.

(v) *Anthropotechnology.* Anthropotechnology (Wisner, 1997) refers to the transfer of organizational systems and technologies in countries having different cultures. This methodology can be designed within the same country or the same organization, in which different-culture sub-groups can be identified. From the anthropology viewpoint, culture-related requirements need to be identified for a successful transfer. Anthropotechnology is currently oriented mainly towards what can be called "synchronic transfers", i.e. transfers from place to place in the same periods. It would evolve towards another kind of transfers that deeply concerns corporate memory design, namely "diachronic transfers", i.e. transfers in different times (e.g. 5, 20, 50 years later).

2.1.3. Conclusion

The phase of needs detection may help to determine the type of corporate memory needed (e.g. project memory, profession memory, organizational memory, individual memory), the potential users of the corporate memory, and the possible modes of exploitation useful and adapted to their work environment. Let us note that the analysis of the needs does not stop with the needs detection phase. It can continue in the later phases, and particularly at the time of evaluation. New needs can appear then or existing needs can be specified.

2.2. CONSTRUCTION OF THE CORPORATE MEMORY

As emphasized during KAW'96 track on "Corporate Memory and Enterprise Modelling", a corporate memory is of course different from a knowledge-based system. The techniques adopted to build a corporate memory depend on the available sources: human specialists, existing paper-based or electronic documents such as reports or

technical documentation, emails, existing databases, case libraries, dictionaries, CAD drawings, etc. They also depend on the nature of the needed corporate memory according to the intended users: the corporate memory, considered as a product, may consist of paper-based documents making explicit the enterprise adequate members' knowledge, that had never been yet elicited and modelled (Dieng *et al*., 1998). It may also be a computational memory materialized through an intelligent documentary system, a database, a knowledge base, a case-based system, a web-based system or a multiagent system. We note that even though paper-based or electronic documents can themselves represent a corporate memory they are often considered as a first step in the implementation of the corporate memory (Simon, 1996). These are different ways to materialize a corporate memory (considered as a product). This product is obtained owing to a complex process of communication, argumentation, negotiation in the enterprise. Therefore, both the product- and the process-oriented views need to be taken into account.

In the next sections, we describe different approaches for the construction of a corporate memory.

2.2.1. Non-computational corporate memory

A *non-computational memory* is made of paper-based documents on knowledge that had never been elicited previously. The construction of such a memory may be guided by two different aims: (1) to elaborate synthesis documents on knowledge that is not explicit in reports or technical documentation, and is more related to the know-how of the experts of the enterprise, and (2) to improve enterprise production through expert propositions on their tasks in a design process.

In the first aim, the memory is composed of knowledge described in existing documents and interviews of experts or elaborated from observations of experts' activities. The KADE-TECH Company proposes a method called CYGMA (Bourne, 1997) to produce different documents that contain memory about a profession (see Section 3.1). Simon (1996) considers that this kind of memory provides "a global view of the knowledge of the firm", and "allows experts from different sites to describe their knowledge in the same format in order to be able, afterwards, to compare them more easily". However in Simon (1996), this elaboration of synthesis documents is a first step in the construction of the computational corporate memory that it helps to implement: it enables homogeneization of know-how in different sites of an enterprise distributed geographically.

In the second aim, the firm RENAULT proposes MEREX approach (Corbel, 1997). This approach, guided by the quality approach, is based on positive and negative experience return on previous projects. The memory is constituted by forms, where an expert can describe a solution or a decision in a task of design process. These forms are validated by a system check-list and stored in a form management system. They are used in the product-specification phase, before the artefact design. The captured knowledge can then be found later on, by a keyword-based access to the forms, facilitated through the form management system.

Remark. Notice that often such paper-based documents are later stored in an electronic form, but we make a difference between simple electronic documents and an actual documentary system.

2.2.2. Document-based corporate memory

A document-based corporate memory relies on the principle that all existing documents of the firm can constitute the corporate memory. However, those documents are not well-indexed or they constitute a personal bibliography for each expert of the firm. So the construction of such a corporate memory begins by indexing all reports, synthesis documents or references used by the different experts. It requires an interface to manage documents (addition of documents, retrieval of documents, etc.). Poitou (1995) considers that: "a good documentation system is very likely the least expensive and the most feasible solution to knowledge management" and prefers a computer assistant to documentation (i.e. to writing or reading) rather than knowledge representation: according to him, a document is already a representation of knowledge. So the main need is assistance in preparing, storing, retrieving and processing documents. The notion of corporate knowledge collective management system (Poitou, 1997) answers well to this need: e.g. SG2C proposed by Poitou and DIADEME proposed by Electricité France (Ballay & Poitou, 1996).

In his principle for knowledge management, Ballay (1997) distinguishes several integration levels of documents that may be exploited in a corporate memory: (1) expertise check-lists (e.g. reference bibles in a given profession), (2) visual documents such as photos, scanned plans, iconographic documents, (3) usual office documents (such as technical reports, norms, archive documents digitalized by the Optical Character Recognition), (4) (multimedia) hyperdocuments (e.g. guides, dossiers of technological intellligence, on-line documentation, user manuals, digital books, business dossiers, etc.).

2.2.3. Knowledge-based corporate memory

Knowledge engineering is naturally useful for building a corporate memory based on elicitation and explicit modeling of knowledge from experts or even for a formal representation of knowledge underlying a document. Therefore, several researchers who have been working on expert systems for years evolved towards corporate memory building where they could exploit their past experiences. However, the goal of a corporate memory building is different from the goal of an expert system: instead of aiming at an automatic solution for a task (with automatic reasoning capabilities), a corporate memory rather needs to be an assistant to the user, supplying him/her with relevant corporate information but leaving him/her the responsibility of a contextual interpretation and evaluation of this information (Kühn & Abecker, 1997). Kühn and Abecker (1997) notices that "in contrast to expert systems, the goal of a corporate memory is not the support of a particular task, but the better exploitation of the essential corporate resource: knowledge" and cites some knowledge-based corporate memories (e.g. KONUS system aimed at support to crankshaft design). The SACHEM project offers an example of a huge, industrial, operational knowledge-based corporate memory in iron and steel industry. SACHEM is a computer-assisted blast-furnace control system. Built using KADS method, after knowledge elicitation from dozens of experts, it comprises 20 knowledge bases, corresponding to rubrics such as melting quality, global permeability, thermical analysis and includes 25000 objects.

O'Leary (1998*b*) describes several kinds of knowledge bases useful in consulting firms: engagement knowledge bases, proposal knowledge bases, new knowledge bases, best practices knowledge bases and expert knowledge bases. Such knowledge bases may

consist of document bases without a formal representation. They may also be implemented through databases.

Knowledge engineering methods such as COMMET (Jonckers, Gedolf & Devroede, 1992; McIntyre, 1992) and CommonKADS (Breuker & Van de Velde, 1994; Schreiber *et al*., 1998) can be useful in the construction of a corporate memory, because they allow to analyse and represent an activity at the knowledge level. Steels (1993) notices that the organization of a production is more and more horizontal, i.e. the production is organized through activities gathering experts stemming from different departments. So the corporate memory of such an enterprise can be based on activity description through three perspectives: task, method and information and can thus be realized using KREST (Jonckers *et al*., 1992). In the same way, even though CommonKADS was not primarily dedicated to corporate memory building, some models offered by CommonKADS (organization, task, agent, communication and expertise models) give an interesting basis for knowledge-based corporate memory (Kingston, 1994; VanderSpek, 1994; Corby & Dieng, 1997). Table 1 summarizes the CommonKADS models that seem the most useful for the different types of corporate memory.

In the same way, ontologies can be exploited for building a knowledge-based corporate memory. Ontologies are very useful in a profession memory or in a technical memory, for representing a terminology and a conceptualization shared by a given profession in an organization. As noticed by O'Leary (1998*b*). "ontologies provide some structure for development of knowledge bases as well as a basis for generating views of knowledge bases". Therefore, some companies build their own ontologies in order to construct a knowledge-based corporate memory relying on them: for example, the consulting firms cited in O'Leary (1998*b*). In Bernardi, Hinkelmann, Kuhn and Sintek (1998), several kinds of ontologies are suggested for offering an "intelligent support by context-sensitive knowledge supply": information ontology (for describing the information metamodel, i.e. the structure, access and format properties of the information sources), domain ontology (for modelling contents of the information sources) and enterprise ontology (for describing information context in terms of the organizational structure and the process models). Research on methods or tools for building new ontologies, for reusing existing ones, for comparing ontologies or for visualizing them can be exploited (Farquhar, Fikes & Rice, 1996; Tennison & Shadboldt, 1998; Visser, 1997; Dieng & Hug, 1998).

TABLE 1
CommonKADS models and types of corporate memories

Type of corporate memory	Relevant CommonKADS models
Profession memory	Expertise model (in particular, ontologies and domain models)
Company memory	Organization, task, agent models
Individual memory	Agent, expertise models
Project memory	Task, agent, communication models
Technical memory	Task, agent, expertise models
Managerial memory	Organization, task models

2.2.4. Case-based corporate memory

The expoitation of another artificial intelligence technique, case-based reasoning, can also be very useful (Simon & Grandbastien, 1995; Simon, 1996). Indeed each firm has a collection of past experiences (successes or failures) that can be represented explicitly in a same representation formalism allowing to compare them. The use of a case base for representing the corporate memory is dedicated for the following aims: (1) avoid the scattering of the expertise by concentrating knowledge of all experts in dedicated cases and (2) allow a continuous evolution of the corporate memory owing to the progressive addition of new cases.

Case-based reasoning allows to reason from experiences and cases already encountered, in order to solve new problems: e.g. for maintenance of a complex equipment, the collective memory of past incidents can be useful for taking a decision in case of a new breakdown. The retrieval of a similar past case can be used to suggest a solution to a new problem to be solved (this solution can be reused or adapted if needs be). Improving representation of the cases, organization and indexing of the case base is important for enhancing efficiency of case retrieval.

Simon and Grandbastien (1995) and Simon (1996, 1997) describe an example in metallurgy, where the aim was to capitalize knowledge and know-how about descriptions of production of produced steels and metallurgical defects encountered during these productions. The purpose of the corporate memory was to exploit past successes and failures in order to minimize error risks in design of new steels. The method consisted of: (1) creating synthesis documents common to all sites and respecting a homogeneous format, (2) proposing models to implement a corporate memory based on such synthesis documents and (3) providing capitalization processes allowing to use the corporate memory for defects detection purpose. The corporate memory consisted of the set of metallurgical defects represented by a collection of cases. A case described the general information on a defect (defect name, general context of appearance, physical description of the defect) and the information useful for detection of the defect (incriminated metallurgical parameters, parameter influence on the defect, description of how the parameters combine to produce the defect). The system performed case-based reasoning on this base of defects: for a new steel production process , it retrieved the defects (i.e. the cases) most liable to appear in this context. This retrieval of past cases relied on an indexing method and on a similarity measure. The indexing method consisted of comparing the general context of a defect with the new steel production process. Once the defects having a context close to the steel production process context are obtained, a similarity measure enabled to evaluate their similarity with the new steel production process and the risk of occurrence of such defects. This example shows the interest of case-based reasoning for a corporate memory when it can be described through a set of cases.

2.2.5. Construction of a distributed corporate memory

A distributed corporate memory is interesting for supporting collaboration and knowledge-sharing between several groups of people in an organization or in several collaborating organizations, such groups being possibly dispersed geographically. A distributed memory is essential for virtual enterprises made of distributed organizations and teams of people who meet and work together on-line. Generally, for such virtual

enterprises, this distributed memory naturally relies on the exploitation of the Internet and of the Web (O'Leary, 1997). For example, the GNOSIS project on intelligent manufacturing (Gaines, Nossie, Lapsley & Shaw, 1996) involves several enterprises distributed through several continents. Coordination of this project and management of distributed knowledge among the participants is performed through the Web. The tools developed in the GNOSIS project are used for keeping a memory of the project.

As another approach, Ribière and Matta (1998) propose a guide for building a project memory with multiple viewpoints, in the framework of the virtual enterprise constituted by several designers possibly stemming from different companies and cooperating for a concurrent engineering project.

A distributed corporate memory can be made of distributed, heterogeneous knowledge bases or of distributed, heterogeneous case bases or of a multiagent system. For example, in the MEMOLAB project, the corporate memory of a research laboratory is implemented through a multiagent system (with agents such as a bibliographic agent, a notebook agent, a "tips and tricks" agent and a proxy agent) (Vandenberghe & de Azevedo, 1995). The implementation of a distributed memory can also rely on both distributed case libraries and artificial agents responsible for information retrieval among such libraries (Nagendra Prasad & Plaza, 1996). Bradshaw *et al.* (1997) describe how agent technology can help knowledge management by "(1) managing dynamic loosely-coupled information sources, (2) providing a unifying framework for distributed heterogeneous components and (3) coordinating interaction at the knowledge level".

The construction of a distributed corporate memory may often involve several experts. A protocol for collective knowledge elicitation is proposed in Dieng *et al.* (1998). Among others, it relies on collective case studies performed by the experts,with a combination of the disciplines the experts stem from. Problems of consistency of the obtained corporate memory elements, of cohabitation of several viewpoints must be solved: a protocol for cooperative creation of a consensual corporate memory is thus offered in Euzenat (1996). In the particular case of a distributed corporate memory relying on the reuse of ontologies, research on the collaborative creation of ontologies via ontology servers such as Ontolingua (Farquhar, Fikes & Rice, 1996), APECKS (Tennison & Shadboldt, 1998) or WebOnto (Domingue, 1998) can be exploited.

If we consider the process-oriented view of corporate memory, groupware tools may enhance collaborative work. O'Leary (1998*a*) gives examples of consulting firms the knowledge management system of which relies on Lotus Notes databases.

2.2.6. Building of a project memory

Buckingham Shum (1997*b*) emphasizes the importance of negotiation and argumentation in the employees' works flow: he stresses that the knowledge invested in any complex project is the product of much argument, compromise and reconciling of different perspectives. According to him, the corporate memory (in particular, a project memory) must be able to do the following:

- "Represent and reconcile multiple stakeholders' perspectives.
- Re-negotiate project priorities in response to changed circumstances.
- Communicate the rationale for decisions to others.
- Recover insights and solutions from past scenarios, to avoid "reinventing the wheel" ".

The issue-based information system (IBIS) argumentative method (Rittel, 1972), the hypertext prototype graphical IBIS (gIBIS) (Conklin & Begeman, 1988), the Decision representation language (Lee & Lai, 1991), the questions-options-criteria (QOC) approach (MacLean, Young, Bellotti & Moran, 1991) enable to visualize argumentations during discussions of a group. As emphasized by Buckingham Shum (1997*b*), this visualization of (past and present) discussions of a group supports the process of discussion and negotiation between multidisciplinary stakeholders: it provides a common space in which arguments can be evaluated. Capturing the product of such negotiations, it enables to build the group memory or the project memory. The interest is to capture knowledge collaboratively, *in situ*, during a meeting or asynchronous debate, in the immediate context of one's work (Buckingham Shum, 1997*b*).

2.2.7. Combination of several techniques

In some cases, both informal knowledge (such as documents) and formal knowledge (such as knowledge explicitly represented in a knowledge base) are needed. Therefore, research on the management of links between document and knowledge base can be exploited (Euzenat, 1996): Martin (1996) and Martin and Alpay (1996) describe CGKAT, a tool enabling the user to build a knowledge base represented through conceptual graphs, and linked to structured documents (corresponding to interviews of experts or to technical documentation); the user exploits the hyperlinks between documents and conceptual graph base, for browsing both documents and knowledge base; she/he may request the knowledge base and obtain answers either in the form of conceptual graphs or in the form of document elements (texts or images). Such an association of documents and conceptual graphs is also offered, with a navigation over the Web in Martin and Eklund (1988). In the same way, research on the semi-automatic extraction of knowledge (for example, terminological knowledge, etc.) from documents owing to natural-language analysis can be useful (Trigano, 1994; Zarri, 1996; Hahn & Reimer, 1998). Nakata *et al.* (1998) support collaborative concept extraction and management, owing to a concept index. The user can extract concepts by highlighting words and phrases in a document. Such extracted concepts are then indexed, cross-referenced in related documents and exploited for navigation in the document space. The concept index can be edited by a group of users collaboratively: it enables the construction of a "community knowledge". This approach is interesting for enhancing collaborative work (in the process-oriented view of knowledge management). Reimer (1988) studies knowledge integration problems for building a corporate memory: integration of distinct knowledge bases and integration of several representations of the same knowledge with different degrees of formalization (formal representation, semi-structured text, etc.). Kühn and Abecker (1997) and Abecker *et al.* (1998) propose an interesting corporate memory architecture where the corporate memory can be composed of different sorts of memories: documents, databases, knowledge bases, etc.

2.2.8. Conclusions

If modelling expertise of members of the enterprise is needed, a knowledge-based memory can be thought out. If the company has experiences that can be collected as past cases from which inspiration can be derived for solving new problems, a case-based memory seems useful. If the cohabitation of multiple viewpoints needs to be preserved,

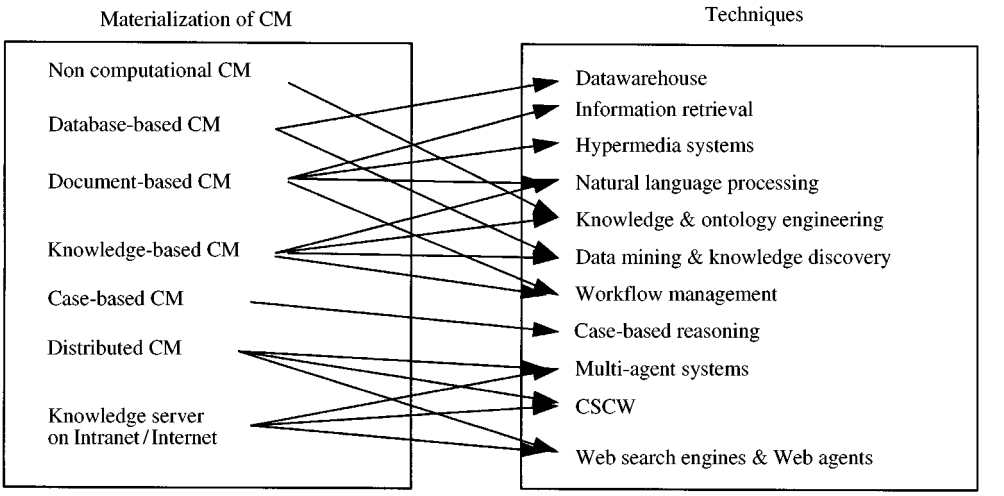

FIGURE 2. Links between materialization of corporate memory and techniques possibly used.

a multiagent system may be interesting. If the company has numerous databases from which the corporate memory must be built, data mining may be relevant. For building a project memory, CSCW tools offering possibilities of design rationale can be exploited.

Figure 2 shows the possible techniques available according to the kind of materialization of the corporate memory.

Figure 3 shows an example of heterogeneous corporate memory. It also illustrates the variety of research topics, relevant for knowledge management.

2.3. DIFFUSION AND USE OF THE CORPORATE MEMORY

2.3.1. Possible modes of diffusion

Adequate elements of the corporate memory must be distributed to the adequate members of the enterprise: this distribution may be passive or active, as either the user can search by himself needed information where it is available, or knowledge distribution can be systematically decided and taken in charge by an adequate person or group of the enterprise. When the company workers are too busy to look for relevant corporate information, a passive distribution is insufficient: Kühn and Abecker (1997) recommend an active distribution (e.g. a regular recall of the existence of relevant information). Van Heijst *et al.* (1996) distinguish several cases according to the kind of collection and of diffusion of the corporate memory.

- *Knowledge attic*: both collection and diffusion are passive. It corresponds to the case of a corporate memory used as an archive which can be consulted when needed.
- *Knowledge sponge*: the collection is active but the diffusion is passive.
- *Knowledge publisher*: the collection is passive but the distribution is active, as the corporate memory elements are forwarded to people for whom they will be relevant.

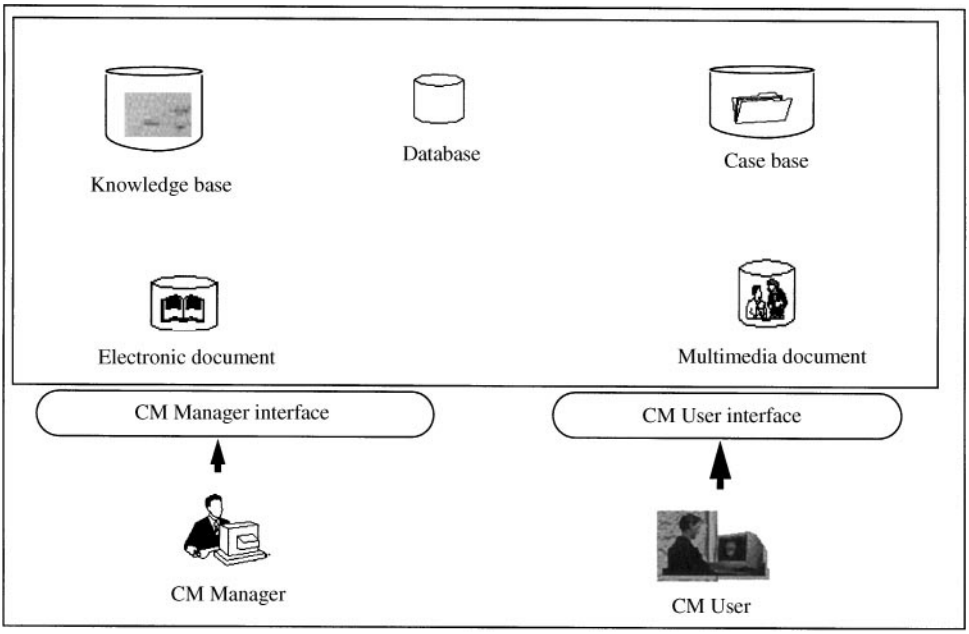

FIGURE 3. Example of heterogeneous corporate memory.

- *Knowledge pump*: both collection and diffusion are active. For example, in ICARE project (Bologna & Gameiro Pais, 1997), in each department of the company, a "knowledge watcher" is responsible for planning the knowledge element collection from his/her department and for inciting the members of this department to consult the corporate memory.

Mahé and Rieu (1998) emphasize the interest of a pull approach: in the framework of project memory, such a pull approach aims (1) at bringing people together, so that they directly exchange knowledge or (2) at orienting them to relevant archives of past projects. This pull approach requires to focus on the context of knowledge rather than on the knowledge itself: it thus avoids a knowledge formalization stage.

2.3.2. Diffusion via Intranet/Internet

Individuals and organizations can take advantage of the remarkable possibilities of access to data, to information and to knowledge provided by Internet. Knowledge diffusion can, for example, exploit the possible access to Internet or to an Intranet inside the enterprise.

Diffusion can rely on a knowledge server on the Web or on publication on the Web (Euzenat, 1996; Corby & Dieng, 1997). Martin and Eklund (1998) enable navigation over the Web through documents indexed by a base of conceptual graphs. Different kinds of elements can be accessed through Internet/Intranet: documents (classic digital documents, HTML documents, XML documents, etc.), databases, ontologies, knowledge bases, case bases, articles of digital journals, etc. Therefore, several kinds of knowledge

servers can be thought out: document servers, ontology servers, knowledge base servers, database servers, journal servers or digital libraries. The main problems to be solved are (1) retrieval of elements of the corporate memory to answer a request and (2) adaptation of the answer to the user. Research on user profiling can thus be useful for this purpose (Sorensen, O'Riordan & O'Riordan, 1997). XML, the new standard for distributing documents on the Web (Bray, Paoli & Sperberg-McQueen, 1998), has interesting advantages for knowledge management, as emphasized in Rabarijoana, Dieng and Corby (1999).

Exploiting our previous distinction between internal memory and external memory, let us recall that a corporate memory may not be restricted to the sole enterprise: an internal corporate memory can rely on an internal competence map inside the company, while an external corporate memory rather includes information and knowledge stemming from the external world but useful for the enterprise work. Therefore, the retrieval and integration of information explicitly put on the Web by other companies working in the same area may be interesting for an external corporate memory. The Intranet of the enterprise can be exploited for construction and diffusion of an internal corporate memory, while an external memory can rely on (1) either an Extranet connecting the company and some privileged partners such as customers, suppliers, subcontractors, etc., or on (2) Internet and the Web in the case of "technological intelligence" purposes. Revelli (1998) analyses the different kinds of "intelligence" interesting for a company: technological intelligence in order to follow an existing or an emerging technology, competitive intelligence and marketing in order to know about activities, products or services of the enterprise competitors or of other actors of the enterprise market (distributors, suppliers, customers, etc.).

Remark. Sometimes managers of some enterprises are reticent w.r.t. Internet and the Web, due to potential problems such as confidentiality, security, reliability of accessed information and risk of information excess that may disturb the employees in their work. However, security problems are studied actively by researchers, as they are a significant condition for success of Internet-based applications such as electronic commerce.

2.3.2.1. Example of diffusion via Internet/Intranet Let us detail an example of exploitation of Internet/Intranet. In our team, we have developed a component, called WebCokace, that enables to distribute expertise on the Internet (Corby & Dieng, 1997). The expertise is modelled in the CommonKADS framework (Breuker & Van de Velde, 1994) with the CML formalism (Schreiber *et al*., 1994). WebCokace relies on the hypothesis that CommonKADS may be useful for building knowledge-based corporate memories.

WebCokace takes advantage of the Web technology to interface an expertise model development environment with an HTTP server. The expertise model environment functions in a server mode and is connected to an HTTP server (that acts here as a client of the knowledge server) by means of a CGI interface. Modelled knowledge is then available on the Net.

In order to facilitate user interaction with the system, we have developed a search engine, a query language and an interpreter for this language. Users can emit queries to the knowledge server and get CommonKADS objects in response to the queries. CommonKADS objects are prettyprinted with HTML hypertext links to related objects in such a way that hypertext navigation is possible in expertise models. For example,

a concept references its super-types, a task and its sub-tasks. The system generates interactive graphic views on the expertise. It is possible to visualize concept and task hierarchies, domain models, etc. Clicking on a node of a hierarchy leads to the corresponding object definition. So the end-user may rely on the graphics instead of CML text.

The system also manages references between expertise models and electronic documents by means of HTML hypertext links and URL. A CommonKADS model can be annotated with references to source documents (e.g. technical documentation, articles, etc.), and conversely, a document can be annotated with references to expertise models. The links are activated once loaded in a Web browser and it is then possible to navigate between models and documents in a hypertext way.

Using WebCokace, we have developed (1) a generic library for conflict solving in concurrent engineering and (2) an oncology server. We have also implemented parts of the CommonKADS modelling generic library.

WebCokace is implemented on the Centaur programming environment generator, developed in the Croap project at the INRIA. Owing to the underlying generic technology (i.e. Centaur), WebCokace can be used as a *program server* for any programming language that is implemented in Centaur. Within Centaur, programs are internally manipulated as abstract syntax trees (AST). AST support abstract computations on programs that enable to answer to queries. A program server can be useful in companies having libraries of programs to be included in their corporate memory.

2.3.3. Information retrieval

The corporate memory is supported to be used by adequate members of the enterprise: in all cases (documentary system, knowledge base, case-based system, Web-based system, etc.), we must notice the importance of information search, if possible adapted to the users' needs, their activities and their work environment. The problems to be tackled are the following. How can the user express his/her requests? How to improve hypertext navigation by the user? How to retrieve elements of the corporate memory in answer to a request? Is full-text search sufficient? How to index the documents to retrieve? What additional meta-information (such as enterprise models, knowledge models, user models) could help to filter the information to be retrieved? Are inference capabilities needed in this purpose?

Research on ontology servers such as Ontolingua (Farquhar *et al.*, 1996), APECKS (Tennison & Shadboldt, 1998) or WebOnto (Domingue, 1998) could also be exploited, since a part of the corporate memory can rely on an ontology. A corporate memory infrastructure relying on techniques of information search on the Internet is proposed in Huynh, Popkin and Stecker (1994).

2.3.4. Information search agents on the Web

Many tools are available for information search on the Web: Altavista, Excite, Hotbot, Infoseek, Lycos … Generally, a Web search engine consists of the following

- *A robot* which visits million documents regularly in order to store their contents.
- *An indexing system* allowing to analyse information so that users can find it by using suitable keywords.

In addition to such traditional search engines, more ambitious tools were developed: meta-engines and intelligent agents. In Revelli (1998) O' Leary (1998) and Samier and Sandoval (1998), several intelligent agents for information search on the Web are described and compared. Several types of agents for the Web can be distinguished, according to their functions:

- *Search meta-tools*, functioning by meta-index and launching in parallel search on several search engines to compile their results.
- "*Intelligent agents*" *for the web*: such software can be parameterized by the type of request, the number of consulted search engines, the depth of the links, the form of the results, the number of backed up pages, the backup of links, the automatic generation of bookmarks, etc. Their operation relied on the following stages: (1) parameter setting of the request, (2) choice of the search engines, (3) launching of search, (4) automatic recording of the results, (5) elimination of the identical pages, and (6) generalization of a summary of the results, updating of possible search to detect the new pages.
- *Complex intelligent agents*, that, in addition to the previous functions, carry out information filtering, learning and intelligent management of the results. The advantage is that they obtain more relevant answers, the disadvantage is their cost in resources.

Samier and Sandoval (1988) compare several Web search tools according to several criteria (search, indexing, filtering presentation, distribution and decision-making support). In Revelli (1998), several intelligent agents for information retrieval on the Web are compared: let us cite among others Autonomy, Umap Web, Webseeker, etc. O' Leary (1998*a*) also cites some search engines and intelligent gents enabling searching of information on Intranet and Internet: WebWatcher, Letizia. Such tools may be useful in the framework of information retrieval in a Web-based corporate memory (either an internal corporate memory or an external corporate memory). Moreover, guiding the searching on the Web by thesaurus (Leloup, 1998) or by ontologies (Fensel, Decker, Erdmann & Studer, 1998) or by expertise models (Corby & Dieng, 1997) should have promising applications in corporate knowledge management. Personal information agents can help to adapt search for information on the Web to the user profile (Moore, 1997).

2.4. EVALUATION AND EVOLUTION OF THE CORPORATE MEMORY

2.4.1. Evaluation of the corporate memory

As noted in Ermine (1996), operational projects of corporate memory are necessarily time-consuming and expensive. Therefore, an evaluation of such projects is important, from several viewpoints: economico-financial, socio-organizational and technical.

From an *economico-financial viewpoint*, one aim of the corporate memory is to improve the enterprise competitiveness. As noticed in Durstewitz (1994), it can be measured by a gain between the success of the enterprise products or services, and its production (and maintenance) costs. There must be an evaluation of the gain obtained owing to the introduction of a corporate memory, generally aimed at enhancing productivity. Return on investment is important for justifying the interest of building a corporate memory, from the viewpoint of the managers. However, methods or tools are needed

to assess the actual improvement on account of the introduction of the corporate memory: it may be an improvement in safety—cf. avoidance of past errors—, in quality and in performance.

From a *socio-organizational viewpoint*, the corporate memory can aim at improving employees' work organization (owing to information circulation improvement, etc.) and employees' satisfaction in their work. But the criteria for such an evaluation are often qualitative and hardly quantitative: they can rely on classical criteria used for evaluating user-centred tools such as easiness of use, easiness of information retrieval, adequacy of retrieved information, confidence in such information, usability for the user's activity, etc. As noticed in Kühn and Abecker (1997), users', feedback should be exploited for detecting possible deficiencies of the corporate memory and suggest improvements of the corporate memory.

From a *technical viewpoint*, the transfer of know-how inside the enterprise seems to be an evident benefit. But an effective transfer depends on an effective use of the corporate memory and on its adaptation to such a knowledge transfer.

There may be some bias in the use of the corporate memory. The introduction of a corporate memory can imply changes in individual and collective work in the enterprise. Some reorganizations prescribed by the managers may not be accepted by the employees. For example, an official procedure for storing lessons or experiences linked to a given project may be prescribed by the company managers but not respected for reasons such as lack of time, lack of motivation, etc. Moreover, a corporate memory may be used otherwise than planned. We found very few publications analysing reactions of corporate memory users: for example, in Ballay and Poitou (1996), a survey of satisfaction of DIADEME users is presented. It relied on a questionnaire on their use of automatic bibliography and hypertext links, their experience and satisfaction of the databases, their experience and satisfaction with the full-text document retrieval TOPIC included in DIADEME and their satisfaction with the workstation. The lesson of this survey was that even though DIADEME was aimed at being a collective knowledge management system, its users rather exploited the system as a set of different specific tools. In Kühn and Abecker (1997), three case studies are analysed: KONUS for crankshaft design, RITA for quality assurance for vehicle components and PS-Advisor for bid preparation for oil production system. The authors noticed that all three systems failed to go beyond prototype state and be integrated in company's daily operational work. The reasons of such failures were: "costs of customer-tailored solutions with unpredictable return of investment, insufficient experiences with corporate memory applications and poor integration into the conventional Information Technology landscape". As a lesson learnt from these case studies, they suggested crucial requirements for a corporate memory (see Section 2.1.2.3), they proposed a general corporate memory architecture and a kind of methodological guide for development of a corporate memory, insisting on requirement analysis, human factors, cost-benefit analysis, knowledge evolution and technical realization.

A study of business-oriented tools offering metrics for assessing enterprise performacne, in order to determine how useful such metrics can be for knowledge management, could be interesting.

As a conclusion, we must distinguish evaluation by users (with criteria based on users' satisfaction) and strategic evaluation by managers (with criteria based on return on

investment). At present, there are too few effective operational corporate memories, and companies need to stand back for evaluating them precisely.

2.4.2. Maintenance and evolution of the corporate memory

For maintenance and evolution of the corporate memory, it is necessary to take into account the results of the evaluation of what already exist. Problems linked to addition of new knowledge, removal or modification of obsolete knowledge, coherence problems underlying a cooperative extension of the corporate memory, must be tackled. Some of such problems were already relevant during the construction of the corporate memory. Likewise, both organizational problems and technical problems underly the possible evolution of the corporate memory. In the construction as in the evolution of the corporate memory, some problems may stem from conflicts between persons, reticence, lack of motivation, lack of time, etc.

The techniques used to maintain and make evolve the corporate memory also depend on the kind of corporate memory: according to the case, addition, removal or modification will concern elements of a knowledge base or cases in a case base or (elements of) documents in a document base or agents in a multiagent system. The corporate memory evolution also depends on whether the collection (resp. diffusion) of corporate memory elements is passive or active (Van Heijst *et al*., 1996). Evolution of the corporate memory depends on both the corporate memory builders/maintainers and the corporate memory users.

According to Kühn and Abecker (1997), knowledge evolution should be "a continuous activity performed by a corporate memory administrator in close cooperation with the users who can make improvement/update suggestions tightly integrated into their work process". This solution corresponds to an active collection and diffusion, as for instance in the ICARE project (Bologna and Gameiro Pais, 1997). In some cases, a given service or a given person of the enterprise is responsible for the maintenance/evolution of the corporate memory. In other cases, any employee may make evolve the corporate memory, while respecting some constraints. Filling and updating the corporate memory continuously is crucial for keeping the memory alive.

3. Examples of dedicated methods

This section will give few examples of methods dedicated to the building of a corporate memory. The purpose of this description is to show the principles guiding some corporate memory-dedicated methods (in comparison to knowledge engineering methods such as COMMET or CommonKADS).

3.1. METHOD CYGMA (KADE-TECH)

CYGMA (CYcle de vie et Gestion des Métiers et des Applications) is a method allowing the construction of a profession memory in a manufacturing industry (Bourne, 1997). It defines six categories of industrial knowledge for design activity.

- *Singular knowledge*: positive and negative, relevant or out of bound experiences.
- *Terminological knowledge*: alphabetical list of terms used in the profession domain.

- *Structural knowledge*: It contains the ontological knowledge, and a factual knowledge base comprising the initial data of the design problem to be solved and the initial goals describing the design problem solution to be found.
- *Behavioural knowledge*: dynamic elements of profession knowledge.
- *Strategic knowledge*: knowledge allowing an optimized use of structural and behavioural knowledge.
- *Operating knowledge*: knowledge describing the problem-solving process as a chaining of operating activities based on structural, behavioural and strategic knowledge.

The results of the method application consists of four different documents.: *profession glossary* gathering singular and terminological knowledge, *semantic catalogue* describing structural knowledge, *rule notebook* comprising behavioural knowledge, *operating manual* made of strategic and operating knowledge. These documents can then be exploited by the enterprise as a way of communication with sub-contractors. The method has already been applied to different professions in different firms: blacksmith profession for Rolls-Royce, turner profession for Eurocopter automatician profession for Fiat and steel manufacturer profession for Aérospatiale.

3.2. METHOD REX (CEA)

REX method (Malvache & Prieur, 1993) relies on the following steps: (1) needs analysis and identification of sources of experience, (2) construction of *elementary pieces of experience* from documents, databases or interviews, (3) building up a computer representation of the knowledge domain and (4) installation of a software package on user's workstation: this package includes a multimedia interface and a *retrieval engine* that produces information files on the basis of questions in natural language.

3.3. METHOD MKSM (CEA)

Method for knowledge system management (MKSM) (Ermine, 1996; Ermine *et al*., 1996) aims at reducing complexity of knowledge system management, using different models at different grain levels. It is a systemic-based decision-support method. It relies on the hypothesis that the knowledge assets of an organization can be considered as a *complex system*. Modelling such a complex system relies on several viewpoints: syntax, semantic and pragmatic, each viewpoint being itself modelled through three viewpoints: structure, function and evolution. The three components of a knowledge system are *information* (requiring data processing), *signification* (requiring task modelling) and *context* (requiring activity modelling). The method offers five modelling phases: knowledge system modelling, domain modelling, activity modelling, concept modelling, task modelling.

3.4. COMPARISON OF THE METHODS

CYGMA is dedicated to profession memory, in the framework of a design task, while REX and MKSM do not focus on a kind of corporate memory and do not restrict to a kind of task. REX relies on the building of pieces of experience, stemming from several kinds of sources (human, documents, databases); such pieces can be retrieved to answer a natural language request.

MKSM takes inspiration of complex system theory for offering a theoretical analysis of an organization knowledge, considered as a complex system. The modelling phases proposed by MKSM are close to CommonKADS notions. All three methods were applied to several industrial applications. Criteria for comparing them more precisely could be: the complexity level of the method application, the kind of corporate memory it enables to build, the kind of task it restricts to, the number and features of effective applications built with them and evaluation of such applications by their end-users.

4. Conclusions

We presented a survey guided by the steps of a corporate memory lifecycle (needs detection, construction, diffusion, use, evaluation and evolution) different from other existing surveys (Macintosh, 1994; Kühn & Abecker, 1997; O'Leary, 1998*a*). It offers an analysis of research on different kinds of materialization of corporate memory: non-computational corporate memory, document-based corporate memory, knowledge-based corporate memory, case-based corporate memory and distributed corporate memory.†

Our main conclusion is that in all the described research, an important aspect is that *an organization can be analysed at several levels, according to several viewpoints.* Most methods focused on some viewpoints and relied on an implicit or explicit model of the enterprise, or at least of the enterprise knowledge. The analysis of the enterprise needs for a corporate memory can help determine the kind of needed corporate memory. According to the case, it may imply to build an individual memory (cf. an expert retires or is muted, so it is interesting to make explicit, model and store this expert's know-how in a knowledge base or to store his/her experiences in a case base), a project memory (cf. elements of a given project could be necessary for later projects), a managerial memory needed by the company managers for strategic decisions, etc.

As a conclusion, our survey confirms the multiple research fields relevant for building a corporate memory—which definitively requires a multidisciplinary approach. The choice between the different construction techniques can be based on several questions that an enterprise should answer before building a corporate memory.

1. *Needs detection*
   - Who are the potential users of the corporate memory and what are the users' profiles?
   - What is the intended use of the corporate memory after its construction: is it …
     — A way of communication between distant groups?
     — A way of communication between an enterprise and privileged partners?
     — A way to enhance learning of new enterprise members?
   - When will the corporate memory be used: in short-term, in mid-term, or in long-term?
2. *Construction*
   - What are the knowledge sources available in the firm: paper-based, semi-structured or structured documents, human specialists, databases?

†*Remark*: In spite of its rather wide spectrum, our survey is not exhaustive: for example, it does not detail research on databases relevant for knowledge management (cf. datawarehouse, data mining, etc.).

- Can the quality, volume, availability of the knowledge sources be assessed?
- What is the knowledge map of the enterprise departments involved in the knowledge management operation?
- What kind of knowledge must contribute to the construction of the corporate memory:
  - — Knowledge already described in documents such as reports or synthesis document on a project?
  - — Elements of experience and professional knowledge not already described in documents?
- Is it necessary to model knowledge of some enterprise members or is a document management system sufficient?
- What is the preferred materialization, according to the computer environment of both future users and developers and according to the financial, human and technical means available for the corporate memory construction and maintenance?

3. *Diffusion*
   - What is the preferred scenario of interaction between the future users and the corporate memory?
   - What interface will be the most adapted to the users' activity environment?
   - What will be the privileged diffusion means (Internet, Intranet, etc.), according to the computer environment of both future users and developers?
4. *Evaluation*
   - What will be the evaluation criteria?
   - When, how and by whom will such an evaluation be carried out?
5. *Evolution*
   - How will be evaluation results be taken into account?
   - When, how and by whom will the corporate memory be maintained, verified and incremented?
   - How will obsolete or inconsistent knowledge be detected and removed (or contextualized)?
   - Will the evolution of the corporate memory be centralized by a department or will it be distributed among several members of the organization?

5. Perspectives

What is the future of research on knowledge management? Even though there are tools marketed by industrial companies, many problems remain to be solved and a lot of research still needs to be carried out. Let us cite relevant research topics.

1. *Detection of needs*: enterprise models.
2. *Construction of corporate memory*: collaborative building of ontologies or of knowledge bases, semi-automatic building of ontologies or of knowledge bases from documents, consistency in case of construction from multiple knowledge sources or by multiple users, data mining and text mining, CSCW, design rationale, case-based reasoning, building of heterogeneous corporate memories (including structured, semi-structured and non-structured data), architectures for corporate memory, knowledge representation standards in enterprises.

3. *Diffusion and use of corporate memory*: ontology-guided search for information, exploitation of XML, intelligent agents for information search, intelligent personal assistants, learning on user.
4. *Evaluation of corporate memory*: corporate memory—dedicated metrics, methods and tools for evaluating performance of a corporate memory.
5. *Evolution of corporate memory*: knowledge base revision, case base revision.

This survey emphasized the need for a multidisciplinary research and the convergence of such research areas will probably grow in the next years.

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