Organizational Memory: Knowledge Acquisition, Integration, and Retrieval Issues

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Abstract. The demand on Knowledge Management in the management and business sciences has lead to a growing community of IT people who have adopted the idea of building organizational memories or organizational memory information systems (OMIS). However, the range of ideas associated with these terms is enormous, and the community is far from being homogeneous or aligned to a common goal or technological approach. In this paper, we try to contribute to a coherent view on organizational memory. We sketch some important technical requirements, describe some work contributing to these goals and try to envision some beneficial future work.

1 Approaches to Organizational Memory

Enterprise Knowledge Management (KM) has been a constantly evolving term during the last few years in the business and management sciences. Managers have recognized that, due to a number of reasons, effective development and management of an enterprise's organizational knowledge base will be a crucial success factor in the knowledge-intensive markets of the next century. Identification, acquisition, development, dissemination, utilization, and preservation of knowledge in the enterprise have been identified as basic KM activities [14, 29].

A number of recent events and publications addressed the topic of IT support for KM [11, 22, 40]. However, all such comprehensive volumes are characterized by an enormous heterogeneity of goals and techniques which makes it almost impossible to identify a common technical core and philosophy. Even worse, in many articles it is not possible to see why the achievements described should be called "Knowledge Management" although exactly the same research topics were categorized as information systems, expert systems, CBR technology, CSCW systems, workflow engines, data warehouses, data mining, document management, etc., a short time ago. In [21] we proposed to distinguish two basic categories of IT contributions according to their main focus and approach:

1. The *process-centered view* mainly understands KM as a social communication process which can be improved though IT-means by various aspects of *groupware systems*. It is based on the observation that the most important knowledge source in an enterprise are the employees. Furthermore, solving really *wicked problems* [13] is merely a process of achieving social commitment than one of problem solving. Basic techniques for this approach come from Computer-Supported Cooperative Work (CSCW) and from Workflow Management [28, 34].
2. The *product-centered view* focuses on knowledge documents, their creation, storage, and reuse in computer-based *corporate memories*. It is based on the explication, documentation, and formalization of knowledge to have it as a tangible resource. The user's individual knowledge development and usage shall be supported by presenting the right knowledge sources at the appropriate time. Basic techniques come from Document Management, Knowledge-Based Systems, and Information Systems [21, 37].

In the following section, we will try to give an idea where this diversity of technical approaches comes from. This results in the observation that there is no single goal and approach of Organizational Memory, but merely a bundle of motivations and technical aims. We identify some requirements which should nevertheless (in the ideal case) be fulfilled by a system which claims to be an OMIS (section 3). We review a part of the state-of-the-art in the information-system inspired OMIS community pointing out our ideal view, current research approaches, and open questions (sections 4, 5, and 6). This review is mainly based on the approach and results of several research and application projects running at the authors' groups in Karlsruhe and Kaiserslautern, respectively. Both authors' groups have a strong history in the field of expert systems. These, however, exhibit serious deficiencies in industrial practice. Analysing the problems of expert systems has lead to the development of OMIS approaches: instead of *fully* automating *specific* tasks in an enterprise (like diagnosis or configuration) by *completely new* IT approaches (problem-solving methods and formal knowledge-bases), the goals are now more focused on *supporting* the user in performing *arbitrary* processes leveraging and exploiting the knowledge *already contained* in manifold representations in the enterprise. However, to realize such support the given representations are enhanced incrementally for further applications. And here, it turned out that manifold well-known AI techniques (ontologies, inference systems, CBR, etc.) are very well applicable. Finally, we conclude with the proposal to see the integration of product-centered and process-centered view as the abstract goal to be addressed by OMIS research and development (section 7). This paper is an extension of [4].

2 KM Starting Points

In this section we discuss the KM phenomenon from a bird's eye view. In later sections, however, we focus on IT support for KM. In our opinion, the current hype in KM in the business world cannot be explained by a single reason, but is promoted by a number of trends coming together in these days. To mention but a few:

Under the label of *lean management*, the last wave of enterprise reengineering efforts cut off the middle management from many organizational structures. But for decades, just this level of employees had been an important stakeholder of know-how and experience about projects, customers, and products, and used to perform the important task of knowledge gathering, filtering, interpretation, and routing as a preprocessing step preparing the decisions of the upper management.

KM tries to compensate (i) the loss of stable procedural knowledge by explication and formalization using, e.g., organization handbooks or workflow management systems, (ii) the loss of project, customer, or project related experiences and know-how by establishing best practice or lessons learned databases [37], and, (iii) the loss of the middle management information analysis and routing services through new IT solutions like, e.g., intranets, data mining, or data warehouses [25].

Together with the *globalization of businesses*, an enormous market pressure enforces ever shorter product-life-cycles. On the other hand, modern information technology allows world-wide geographically dispersed development teams, virtual enterprises [32], and close cooperation with suppliers, customer companies, and outsourced service providers. All these factors make necessary complex communication and coordination flows, complex both in technical and in conceptual terms. The role of IT is to optimize the information and document through-put, to enable world-wide communication and synchronization. CSCW and groupware tools are often used in such scenarios.

Further, new customer-oriented management and quality principles like *Total Quality Management* (TQM) promote new styles of communication and decision-making in company departments. Following the *concurrent engineering* paradigm, expertise, information, and feedback from customers as well as many, previously separated and timely sequential development steps are thrown together at very early stages in order to have earlier a comprehensive and holistic view on requirements and design. This requires complex communication and collaboration of many people with completely different educational backgrounds and personal goals and perspectives. It requires also a combination of the documents, information flows, and decision processes coming from previously separated groups of people. Here, IT can support cooperative work and store decision processes to enable subsequent decision tracing under changed conditions; it can also support the preparation of well-structured documentation required for quality certification.

All these business phenomena produce a whole bunch of KM related activities comprising (i) better exploitation of already available but unsufficiently used documents, (ii) formalization of business rules in workflows, (iii) better usage of human skills and knowledge through CSCW techniques or enterprise yellow pages and competency databases, (iv) explication of experiences and know-how in best practice databases, and much more. Most of these activities can also be supported by information technoloy, and are in fact already partly supported by conventional computer systems [14]. However, what is still missing, is a comprehensive view on OMIS which characterizes its specific properties.

3 Crucial Points for Realizing OMIS

Since we adopt the IT point of view here, we concentrate our considerations on technical aspects of OM, i.e. the OMIS. Of course, for building and deployment of operational systems in practice, especially the non-technical aspects are of crucial importance. In [41, 21] we elaborate a bit on these issues.

For a thorough system-theoretic analysis of functions and properties of an OMIS, please refer to [35], and to [30] for a recent review of definitions found in the contemporary IT literature. As a working definition, we propose the following:

> An Organizational Memory Information System (OMIS) integrates basic techniques (see section 1) into a computer system which—within the enterprises' business activities—continuously gathers, actualizes, and structures knowledge and information and provides it in different operative tasks in a context-sensitive, purposeful and active manner in order to improve cooperative, knowledge-intensive work processes.

If we have a closer look at the definition and regard some practical aspects which can be extracted from industrial studies [21, 36], we can identify some requirements on each of the three levels of any information or knowledge system (capture, storage, and usage). These conditions help to establish specific requirements for designing and building an OMIS.

All three levels must be able to cope with a huge *variety* of possible knowledge sources and formats, ranging from databases, over text or multimedia documents, to some formal knowledge representation. Especially for the knowledge repository at the core of the OMIS, coping with technical as well as conceptual heterogeneity is a demanding task.

Figure 1 gives an impression what existing enabling technologies can be used for tackling these issues. Now, we will discuss the three levels in some more detail.

4 Knowledge Acquisition and Maintenance

Knowledge acquisition and maintenance are crucial for successful deployment of an OMIS as for any knowledge-based system [21, 14]. In the ideal case, an OMIS would be self-adaptive and self-organizing, gathering within the usual business operations the information and data useful for later reuse without disturbing the normal flow of work of the employees. This would minimize knowledge acquisition costs. This, however, is of course not always possible: manual knowledge

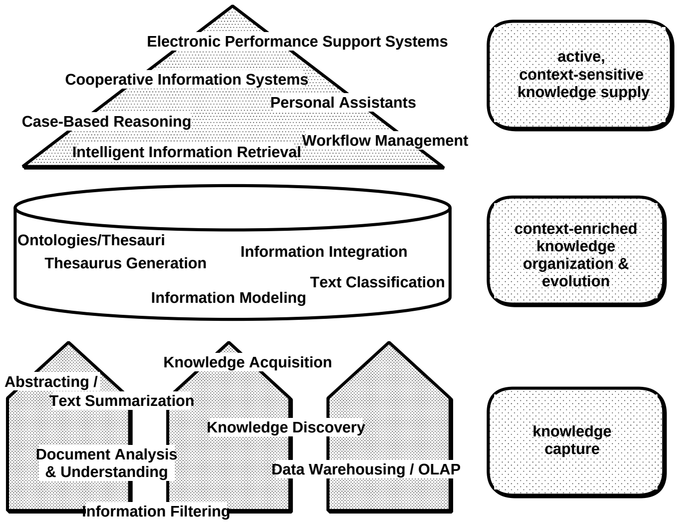

Fig. 1. Some Basic Technologies for Building an OMIS [1]

acquisition performed by a knowledge engineer still remains often necessary, e.g., for establishing ontologies or adding meta data.

In many best-practice projects in consulting companies [27] as well as in the area of "Experience Factories" for learning software organizations [8, 9], the role of a Knowledge- or Experience Manager has been proposed who acts as kind of a knowledge clearinghouse and is responsible for preparing knowledge for reuse, bringing it into a useful form and adding appropriate meta data to ease later reuse.

Though this makes sense for rather complex and worthful pieces of enterprise knowledge (like best practices are), it is quite an expensive strategy, especially in large and diverse organizations. Furthermore, it is not appropriate for many less complex, less important, and less ambitious knowledge acquisition and maintenance tasks. It is also not appropriate being confronted with huge amounts of data and information to be scanned and analyzed for useful knowledge.

In such cases, acquisition tools and automated approaches would be helpful. Consequently, the knowledge capture level in Figure 1 shows several input streams which feed the OMIS with knowledge extracted from texts and from databases. As a first approximation, we propose to have specialized analysis tools and knowledge discovery agents constantly searching the enterprise internal and external web and knowledge sources in order to feed interesting input into the OMIS; see [25] for some examples implemented at Price Waterhouse. Another part are user-friendly system interfaces which collect user feedback, comments, and memos in a context-sensitive and inobtrusive manner.

Although there have been interesting results in document analysis and understanding (DAU) since more than one decade (see, e.g., [17]), the application scenarios for methods like document structure analysis, information extraction, and automated summarization are still quite limited. The Price Waterhouse systems show that already simple text analysis technology can produce useful results. The DAU community should tackle more such comprehensive application scenarios. First steps toward analysis of Web pages have already been done (see, e.g., [12]), topics like Web OCR are still in their infancy and currently known as "Wrapper generation" (cf. [39]). We propose usage scenarios where DAU facilities are deeply integrated with the overall business information infrastructure: in the DFKI VirtualOffice project [10], knowlegde about open workflows is used for improving DAU results by generating some expectations which guide the analysis process.

5 Knowledge Integration

The core of an OMIS is a repository system which must—technically seen—grow out of the integration of several legacy systems (which usually cannot be replaced) enriched by some new information and meta data that allows retrieval of useful knowledge and documents in a given application situation. This repository is characterized by heterogeneity wrt. several dimensions:

Concerning *meaning and content* of knowledge, categories such as product and process related knowledge, reasons for decisions, individual competencies and skills, etc., can be found in an enterprise. Contemporary systems usually manage just one kind of such knowledge. However, the power of KM comes exactly from the playing-together and synergetic view on multiple kinds of knowledge in their usage and creation context. Concerning *representation*, text and hypertext documents, e-mails, graphics etc. are often already there and are much more comfortable and expressive for the human user than any formal knowledge representation. On the other hand, only formalized notions allow for sophisticated inferences and precise retrieval. So we have to aim at a meaningful combination of formal and informal knowledge items.

A good example for the beneficial synergy between several kinds of knowledge are *Issue-based Information Systems*. The QuestMap tool [33] allows to embed design artifacts (like graphics, minutes of meetings, or requirements texts) into a graphical notation of the discussion and decision process of the design group which led to these artifacts. So, one can retrieve all pros and cons encountered in a discussion, or can trace all decisions influenced by some preconditions in the case that the preconditions change.

Also in the design area, we tested how additional, complementary views for business process modeling (BPM) could be used for analyzing and controlling document and knowledge creation, utilization, and flow in a design project [23, 16]. To us, extending BPM toward representing knowledge, documents, and expertise seems to be a promising approach. Moreover, it must be possible that several kinds of knowledge and documents interact, thus generalizing the quite specific IBIS idea.

Concerning technical integration of multimedia information types, the KARAT system [3, 36] developed at DFKI provides a simple, yet robust and useful solution. Assuming that all information items to be managed are available in the intranet and can be displayed by a WWW browser, we simply generated an HTML page for each information unit containing a link to the original source, some textual descriptions and additional textual information for each information unit (annotations), plus an arbitrary set of classification links. These links either establish predefined relationships (e.g., part-of, or causal relationships) between information units or associate an information unit with classes chosen from freely definable organization models which allow for a flexible multi-criteria classification of information. The tool can also generate suggestions for associating information units to model categories on the basis of IR text categorization models. However, since all freely defined organization models are internally handled just as flat lists of categories the semantics of which is not known to the system, KARAT is not able to draw sophisticated inferences over organization models for finding information units.

Just this goal was tackled by the Karlsruhe Ontobroker project [15]. Here, (informal) text in web pages is annotated wrt. a domain ontology using new HTML (or, XML, resp.) attributes such that a formal representation can be automatically extracted. Now, the formal representation can be processed with the help of the ontology and additional domain background knowledge for query answering and retrieval across the borders of single HTML pages. So there is a formal-informal combination which enables powerful inferences, but is still easy to maintain. The knowledge (ontology) and inference part of the Ontobroker system is based on Frame-Logic [20].

In the DFKI KnowMore project [1] the idea of an independent, knowledge-rich information modeling level is elaborated. It encapsulates access to the several knowledge sources and holds all relevant meta data (see Figure 2). Similar to the Ontobroker approach, the information modeling level is based on a formal knowledge representation thus providing the inferences services missing in KARAT.

The whole area of information modeling and meta modeling for precise-content retrieval is an active and demanding field since it is the playground for knowledge retrieval and exploitation agents (section 6). Interesting subproblems are efficient inference mechanisms scalable for large OMIS knowledge bases, as well as the appropriate processing of uncertainty naturally occurring in Information Retrieval. [38] pointed out semantical problems when melting together deep formal models of background knowledge and parts of the application ontology with rough, pragmatic classification systems usually employed for describing content of legacy document bases and libraries.

6 Knowledge Retrieval

From the point of view of knowledge utilization, we see two important features which should distinguish an OMIS from conventional information and knowledge

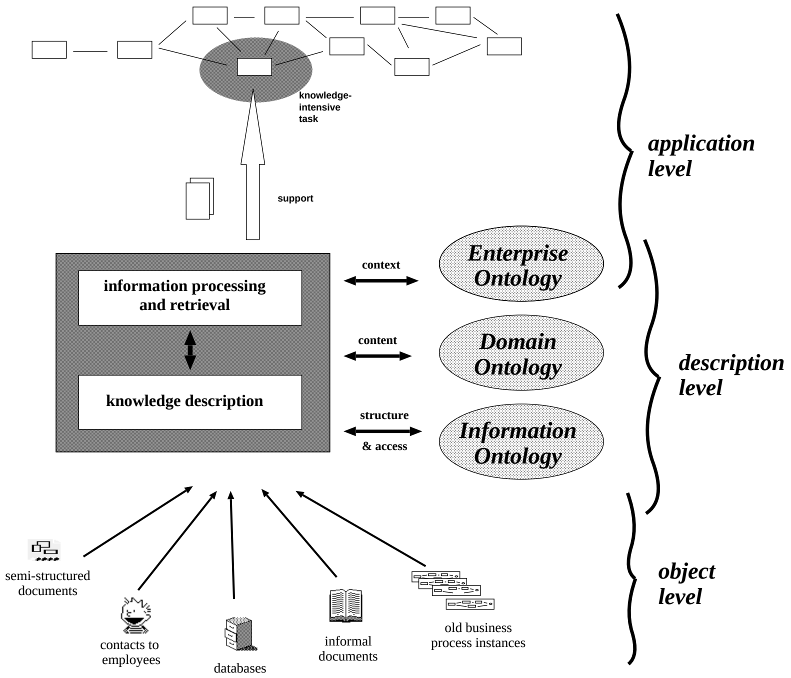

Fig. 2. OMIS Levels in The KnowMore Project [1]

systems: (i) the *active, context dependent* supply of knowledge and information useful for the user in a given situation, and (ii) the *application independence* of the OMIS knowledge base which should be useful for manifold task specific assistant systems. To this end, task specific OMIS exploitation and retrieval services can act as intelligent assistants to the user that

- accompany the execution of tasks, and
- present relevant information which helps the employees to do their work better and more effectively.

Consequently, such an intelligent assistant must have some notion of the work process it supports and must be able to perform a precise-content retrieval from the OMIS archive. A first step in this direction are user, group, or task specific knowledge push mechanisms constantly filtering and actively delivering interesting OMIS contents to their subscribers.

Of course, activeness and task independence are somewhat conflicting goals. Really "intelligent" approaches to active support require so much domain and task knowledge that they can hardly be built in an application-independent manner. [21] describe an early OMIS prototype, the KONUS system for conservation of crankshaft design rules. KONUS already actively suggests design decisions or generates a warning if the user violates stored rules. However, these services are paid for by a completely task and domain specific architecture. Moreover, they are based on a fairly expensive knowledge acquisition and modeling process.

In [31], the EULE/2 prototype is presented which supports employees at Swiss Life Corporation on the basis of a declarative, knowledge-rich formalization of business processes, business rules, and relevant laws and regulations. These formal models are employed for controlling open workflows, for automated data gathering for open cases, and for semi-automatic consistency-checks for user decisions with relevant business rules and laws. In the case of violations, the system can actively warn the user and offer the relevant pieces of rules and legal texts. Though it is a specific business solution for Swiss Life Corporation, we see an important contribution made by the EULE/2 system: it introduces some notion of business process model for controlling the KM process.

The DFKI KnowMore project [1] goes a step further and proposes conventional business process models (BPMs) as a first step to KM solutions. The process of building and analyzing BPMs is used as a vehicle to organize enterprise KM in the same stream of work. Knowledge-intensive tasks are identified as integral parts of "tame" business processes. Standard BPMs are extended by variables which carry decisions from previous business activities thus defining kind of context and input for subsequent knowledge-intensive tasks. Workflow enactment controls the overall business process and thus gives us a chance to activate specific task assistants as a hook on the conventional workflow engine. If some knowledge item is created within such a business process, the actual workflow context already defines its creation context which might be assessed for its later reuse in other business processes.

Cased Based Reasoning (CBR) can provide robust and effective techniques for retrieval. Meta data is added to knowledge resources. Queries are processed employing an appropriate measure which estimates the similarity between query situation and stored experiences. An experience factory like approach along these ideas is described in [6]. The advantage is the possibility of incremental formalization: at first, cases can be described very roughly; more sophisticated meta data can be added if required by the application. Similar to the approaches in section 5, sophisticated retrieval is based on an ontology for formulation of resource meta data.

The above mentioned workflow-embedded activation model for knowledge retrieval agents is still in its very first stage. It has to be clarified how far already existing *knowledge broker* approaches can be used and tailored inside an enterprise [7, 18, 42]. Agent-based approaches for exploiting the OMIS content seem definitely appropriate in order to tackle the manifold integration problems in a scalable manner. Such approaches are typically based on wrapper/mediator architectures as proposed by Wiederhold and others in the database area [39]. Moreover, up to now, we have only investigated quite structured business processes with knowledge-intensive tasks embedded as black boxes. It is an open question whether there can also some aspects of knowledge-intensive tasks be modeled to ease knowledge supply.

7 Conclusions

In this paper, we sketched some necessary conditions for an OMIS to be a real evolution from conventional information systems. We see active knowledge supply, heterogeneity of knowledge sources with a predominance of informal representations, and task-independence of the architecture as the main challenges in this area. We also reviewed some contemporary work and proposed possible future developments. In our projects, we will primarily address the above challenges in the areas of (i) intelligent assistants exploiting the OMIS repository, (ii) knowledge-centered enterprise modeling for identifying knowledge needs, defining knowledge context, controlling support processes and controlling information flow, (iii) knowledge-intensive, contextually enriched information modeling at the core of the repository system, and (iv) learning and self-adaptive knowledge discovery agents for capturing knowledge and filling the archive. Innovative approaches often grow out from the integration of known technolgies at the borders of different technologies and dimensions. Consider, e.g., the DFKI VirtualOffice project at the intersection of workflow and document analysis, or the AIFB Ontobroker at the interface between formal and informal representations. Coming back to the introductory chapters, we consider it an excellent point made by Borghoff & Pareschi [11]: most approaches to KM concentrate either on storage and retrieval of documents (this is what we call the product view on KM), or on collaboration support for people (the process view). Next generation systems will come from the integration of both views via some *knowledge flow* mechanism on the basis of some *knowledge cartography.* This view is consistent with Nonaka & Takeuchi's [24] analysis of kinds of enterprise knowledge and knowledge transformation processes; it is also reflected by O'Leary's recent analysis who argued that KM essentially amounts to *making connections* [26]: connecting people and people, connecting knowledge and people, and so on. Although such considerations are still quite abstract, we hopefully gave some concrete hints for possible technical contributions in the future. One other still open point arises when building an enterprise-wide OMIS from several previously independent archives. Since it is not realistic to expect an enterprise-wide, consistent organization schema and terminology, the questions of ontology mapping and ontology merging for organizing the overall system seem crucial to us.

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