Stimulating Knowledge Discovery and Sharing

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ABSTRACT

Most of the available knowledge management systems pay little attention to two important aspects: the need of supporting emerging communities of interest together with the official organizational structure; and the need of cluing together knowledge associated with any kind of involved entity including people, communities, and informal knowledge. The MILK system enhances knowledge discovery and sharing by providing services addressing these aspects and supplying innovative interfaces and interaction styles. The goal of MILK is to become a familiar environment integrated in the every-day activities of dynamic modern workers. To meet the users' needs, the solution proposed by MILK roots in ethnographic analysis capturing the common practices within an organization.

Categories and Subject Descriptors

H.5.3 [**Group and Organization Interfaces**]: Computer-supported cooperative work.

General Terms: Management, Design, Human Factors.

Keywords: Knowledge Management, Communities, Profiling, Personalized and Adaptive Systems.

1. INTRODUCTION

The rapid emergence of Knowledge Management as a key issue for improving the effectiveness of work practice [13, 17, 18] should not be surprising. On the one hand, in fact, knowledge has always been recognized as an important component of any sense making practice; on the other hand, the growing complexity of work situations calls for more knowledge to avoid breakdowns.

The ambiguity inherent in the above claim (we already knew that managing knowledge is important versus there is something *new* calling for *new* knowledge management systems) opens large spaces for those who try to re-sell information retrieval and document management systems as knowledge management systems, thus reducing Knowledge Management to yet another buzzword in managerial rhetoric. On the contrary, many scholars in organization sciences have developed both theoretical and empirical insights characterizing in new terms the role of knowledge in organizational practice and its management. Let us recall some of their most important contributions. The characterization of organizational learning has shown as learning within an organization is not only an individual experience but rather a collective experience rooted in its structure and rules [6, 7, 34]. Nonaka and Takeuchi [29] have studied the way organizations create knowledge, transforming existing (tacit and explicit) knowledge into new (tacit and explicit) knowledge within the 'knowledge spiral'. The community of practice concept has brought to our attention the way groups of people sharing their work experiences create and share a distinctive knowledge that is both tacit and explicit [11, 13, 39]. Despite the many and sometimes relevant differences among the above recalled approaches, they share a relevant point: knowledge is not important per se, instead the process of knowing, learning, and creating knowledge is the relevant aspect. This fact candidates them as milestones for CSCW research, since they offer new conceptual categories for deepening our understanding of the intimate nature of cooperation, and challenge us to develop systems supporting cooperation beyond the surface of synchronous and/or asynchronous interaction. The work performed on issues like awareness [2, 30, 32, 33, 35, 36] and organizational memories [1, 37] is already moving in that direction with a high potential for innovation.

An explicit effort towards embedding the development of knowledge management systems within CSCW research has been done by some of the authors of this paper developing ethnographical observations and innovative systems coupling cooperation and knowledge management within a series of EC funded projects. Within the Comic project (1993-1995), a CSCW prototype creating an environment to let participants of cooperative processes share the common context of their interactions has been developed [3]. In Desarte (1996-1997), studies on industrial design practices have brought how new knowledge is created by cooperation among designers [20, 27]. In Klee&Co (1998-2000) deepening the above correlation in analytical terms allowed us to understand how knowledge creation depends on the situation where users act and interact and to introduce the idea of "view with context" as a means to bring forth the context of a cooperative practice, embedding it into a knowledge management system [21, 22].

In all the above projects, the focus was on the communities of practice formed by users. The community of practice is "an informal aggregation of people who share work practices and common experiences" [39]. Communities are social aggregates where knowledge is created. They are characterized by some key elements:

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1. Spontaneous participation. Participation in a community is a personal, self motivating choice.
2. Common goals (shared needs and problems). Relationships between community members are based on common objectives.
3. Social relationships and interactions among people promote the social construction of (tacit) knowledge and the diffusion of explicit knowledge.
4. A common repertoire (place, experiences, and practices) is embodied in a common sense making of the world and a common language.

The MILK project (2002-2004) is a follow up of the findings of the above projects. MILK aims to develop a knowledge management system for communities of professional workers (target users are organizational consultants and software designers and developers). In particular, this paper concentrates on three main features of the interactions with the MILK system via PC.

First, the system, besides offering an environment for accessing knowledge, tries also to bring knowledge where people are doing their work on documents and/or other objects.

Second, the system supports (tacit and explicit) knowledge management both for members of a project team and for their community of practice, composed by all those people in the organization sharing similar professional experiences.

Third, the system helps users to cross-fertilize activities by integrating personal and shared work-spaces and promoting circulation of knowledge among activities and projects.

The paper is organized as follows: Section 2 presents the work of analysis done within the MILK project, that informs the requirements to be fulfilled by the system; Section 3 summarizes the main characteristics of the whole MILK system; Section 4 describes how the PC environment of the MILK system creates a personal workspace supporting awareness of the project context, knowledge sharing within a community and an effective management of the participation in different projects and/or communities.

2. ANALYSIS OF ORGANIZATIONAL REQUIREMENTS

2.1 Methodology of study

The analysis of communities and their main knowledge management requirements have been conducted through a combination of ethnographic methods and action learning approach, where the focus is on the observation of the working practices and their analysis lead together with involved workers [8]. Our approach is interactive and aims to activate user participation on system design as well as to build a mutual understanding among observers and observed workers. The field analysis mainly focused on: the identification of the main knowledge exchanges among people (i.e., identification of knowledge network among experts in different business sectors) [26, 38] and the study of the social usage of the physical space (i.e., relations among knowledge exchange and people location). Moreover, during the case study, representations of typical working scenarios (i.e., scenario-based design analysis [16]) have been used to support our work.

The idea that knowledge management and learning processes are not managed at formal organizational level but happen spontaneously within daily work activities has been our guidelines. The actors of these processes are people who work in teams and participate in communities. We are persuaded that the design of socio-technical solutions [15] being able to support and empower knowledge management and working performances within an organization [14] are achievable only by studying people practices.

We used different tools and methods according to the different steps of the investigation:

1. *Focused interviews* involving top management people to identify the organizational areas on which to focus the analysis.
2. *Focus groups* with members of the selected organizational areas to identify strategic knowledge areas. The focus group sessions have been supported by the use of the knowledge portfolio analysis tool.
3. Various sessions of *cyclic observations* to distinguish social practices related to working processes. Daily individual and social activities have been observed; an observation grid has been used.
4. *Individual semi-structured interviews* to assess the current knowledge management practices and needs.

2.2 The organizational context

The analyzed communities belong to two different organizations: an Italian consultancy firm and a German software-house, both part of the new economy context and performing knowledge-intensive activities.

The Italian consultancy firm is active, from more than thirty years, in providing professional services to major enterprises and government agencies in the fields of change management, organization, HR, Knowledge Management and Customer Relationship Management. The firm's approach to consultancy is based on working in partnership with the client to build a “tailor made” solution that lasts in time. Therefore, each project requires a specific, in-depth understanding of the clients' organization and needs, aimed at devising specific solutions to maximize effectiveness and quality of working life. The firm employs 50 consultants and 9 staff, located in Milan and Rome, and has had 50% newcomers in the last two years, mainly young and just graduated from University.

The German software house has developed a complete Digital Asset Management (DAM) solution under a single roof: software development, MSP – Managed Service Provider, Hotline and support and consulting services. The company has been founded in 1992 and it is in a growing phase. It employs 60 people, located in 3 offices within two sites: Hannover and Hamburg. In comparison with the consultancy company, the software house has a more heterogeneous population of workers. Due to the nature of its business, there are: technicians that are in charge of developing system functionality; supporting staff people that are responsible for system maintenance and user assistance; and, finally, project managers and sales people both working in direct contact with the clients. The latter are responsible for developing new business while the former are in charge of user requirement analysis and of developing the required solutions.

Even if the two organizations work in very different business areas, they seem to be very similar concerning social practices and knowledge management issues. Both of them are project based. Every employee usually works on different projects, with different customers located in different sites. Knowledge workers continue working by cellular phone, PDA or laptops also while they are transferring from one site to another. Even during business meetings their cellular phones are switched on to get messages and quickly reply to urgent requests, which are very frequent. Thus, all the working activities are characterized by knowledge intensive exchanges in highly mobile contexts.

2.3 Typical working practices, knowledge needs and requirements

The analysis has been realized through the identification of some typical daily working scenarios on the basis of some main issues.

Knowledge network of experts and working practices: in both organizations there are specific networks of people based on the sharing of situated knowledge that is strategic for carrying out their common activities. This knowledge is strictly related to workers' social practices and problems and deals with a specific project or a specific area of business. As a result, there are a lot of different organizational clusters looking like small communities of people with specific languages, technological tools and common informal rules. For instance, technical developers use a web-based, collaborative environment as a forum to discuss common problems; while commercial people share strategic information by telephone calls. Each cluster of workers participates in the organizational processes developing specific working practices, which are usually very effective and innovative for the realization of the business goals.

Social usage of the physical spaces: people use space in different ways according to their working practices and knowledge needs. For instance, the more they move the more they have no personal workstations in the office. Furthermore, during the same day people change workstations according to different ways of working: individual, team working, training on the job, etc.

2.3.1 A typical working day: analysis of knowledge needs related to typical working practices

In the following paragraph a typical working day scenario is described, together with some main barriers to knowledge sharing and learning processes that workers usually experience. The characterization of knowledge needs arises from the analysis of the typical social practices the employees are performing during their working day.

Giovanni's Monday

"It's Monday morning, 8.00 a.m. Giovanni, a project manager in the Human Resources Management area, leaves his house, in Milan, to catch a plane to go to a business meeting at a customer site, in Naples. Before leaving he checks email with his laptop: he downloads and reads new messages, replies to the urgent ones, and takes some notes about actions to do; then he saves the other messages that he will read later on, during the journey. While he is in the taxi for the airport, he makes phone calls to keep informed about business activities related to the projects he's in charge of and to coordinate actions of the project teams. He fixes new appointments, discusses working documents with colleagues and clients, and talks with the secretary to check the preparation of reports, technical equipment and travel tickets for next business meetings of the week. This coordination and integration activities are supported by Giovanni's mobile and personal agenda where he updates commitments and writes down notes about work to do when he will be back in the office. Sometimes he needs to open his laptop to consult documents or his emails inbox where strategic information about clients is stored.

When at the airport, Giovanni meets his CEO, who is coming back from an international conference, in the "vip" lounge. They discuss about different new prospect clients, details about their business activities, next steps to do.

When Giovanni arrives at customer site, he participates in meetings where people are seated around a table, but anyway they are different from traditional meetings since every participant stays connected with the outside world. Giovanni starts to use remote sources to get fresh inputs to be brought in the discussion. He exchanges information and documents with his colleagues and clients in the office through emails and SMS. Thus, the meeting is not limited to people inside the room. Furthermore, while in this meeting, Giovanni has to monitor other processes to satisfy urgent requests (e.g., from customers) in real time."

When in a mobile situation –the analysis has shown– professionals need to access organizational knowledge by using different communication media: phone, laptop, etc. Moreover, as it is shown in the above scenario, mobile users need to access and to work on the same element in different situations through different media: Giovanni uses his laptop as well as his cellular phone exchanging, for example, email messages and SMSs, but the latter are on different support systems and he needs to keep memory of what he has on the phone while using the laptop and vice versa. At the moment, the organization has not a network linking each other and integrating people, information sources and media, so knowledge remains fragmented and difficult to access. From these observations raise the need for a knowledge management system that brings knowledge in a suitable way where people are doing their work.

"After the meeting, Giovanni, who is still working at customer site, has a quick conference call with the project team settled in the office. People involved in the project, working at the company site, move to the meeting room, carrying with them their laptops, to take part to the conference. Conference participants write down notes on paper and/or on white boards and discuss news about the client. Once the meeting is over, Giovanni updates his agenda. People that haven't participated in the meeting are individually informed via e-mail – sometimes detailed, sometimes short messages– or by a phone call. Thus, the project team has the information to continue the work. Documents in progress are exchanged among team members mostly by e-mail. Only some released documents are stored in the company server. Consequently, team members cannot have a clear vision of the status of the project. Therefore, it is likely that some people redo what has already been done or request issues that they will just receive later. Most of Giovanni's communications is for putting order in the knowledge shared by the team."

The analysis underlined two levels of knowledge circulation: inside a project, and within organizational areas.

Knowledge sharing inside project teams is based on personal exchanges of email messages or phone calls, in a flow that is fast

and effective. But these personal conversations do not leave traces in the organizational knowledge system; therefore people participating in different projects cannot access them. The project-based teams include various small clusters of people producing excellence and innovation and having an intense knowledge sharing. However, that knowledge risks to be dispersed every time a new project starts or a new customer is acquired and people are reassigned to projects.

Instead, knowledge circulation within organizational areas is not very effective; it is mostly based on informal, occasional meetings among people. Unfortunately, people do not meet so often to ensure an effective and complete knowledge sharing.

In addition, since professionals use to exchange information and knowledge related to their business activities through emails, the huge number of messages becomes a problem. Finally, people use email messages also to exchange working documents (presentations, offers, final reports, etc.) and organizational knowledge (what the company is doing, who is doing what, where the firm is going, etc.) since the server is not easily accessible from outside the office, so that document versioning becomes difficult to manage. From these observations the need for a system that captures, organize and make available knowledge to team members brings out dramatically.

"Then, Giovanni catches a train to reach the office in Rome. During the journey he reads the emails downloaded before leaving in the morning. He writes down replies that he will send later, when he will be in the office. Here, he connects his laptop, sends stored messages, then he opens his agenda, reads his notes to work on the different business processes and projects he follows during the day.

With regard to the meeting he had in the morning at customer site, he updates his address book with new names and references then, according to the new information acquired during the meeting and to the opinions of colleagues collected by email and by telephone, he makes some modifications to the working documents and sends the new versions to the whole project team by email. Later, looking at his block notes he remembers that there is a new business opportunity he discussed with CEO and he has to write a commercial offer. Even if he doesn't know the new client very well, he is sure that some of his colleagues already worked with it in the past. He browses the company server to find the client's folder, where he finds some general reports about previous projects but no indications about involved people."

In both organizations people spend a lot of time searching general information and strategic knowledge related to a specific client (e.g., previous projects, contact people, roles, plans, strategy, etc.). Several documents and/or reports are present in organization's repositories; however, they include only part of the necessary knowledge. Moreover, documents are not linked to daily activities and context of work, so they are difficult to retrieve when people need them. In the consultancy company, the current support for document sharing consists of a mere file system on two servers (one for each site) in which documents are organized hierarchically by client or by project. Project teams are responsible for organizing and managing their own files. Nevertheless, there are not well-established procedures or shared practices for this handling. Thus, accessing documents is extremely difficult except for people belonging to the project team creating them.

Regarding the software company, currently different systems are in use to support working activities: a document management system as a central repository; a "grass-root" Intranet; various task related systems; a bug-tracking system; internal newsgroups, and MS Exchange Server. All these systems are not integrated and, therefore, also in this case knowledge is highly fragmented and difficult to access when and where needed. These observations confirm the need of a knowledge management system integrating and making available knowledge of any kind when and where it is needed.

"Giovanni prints some documents and goes to the printer where he meets Paola, project manager of the CRM area, they start a conversation about ongoing work. When Paola looks at the documents printed by Giovanni, she tells him that also Carlo of the CRM area has worked with that client the year before. Paola tells Giovanni that Carlo is in the office in Milan so he can immediately call him and collect useful information. In particular, Carlo informed him that in the company server there are some interesting documents about that client and at the end of the conversation sends their coordinates to Giovanni via email."

These informal discussions represent a key cross-fertilization way for knowledge sharing. Another occasion for cross-fertilization occurs when people join new projects; in this case knowledge flow is particularly slow. However, because of the fast growing business that makes people traveling a lot, the chances for casual encounters and conversations is strongly reduced. Therefore, the conditions for knowledge exchange are missing. Moreover, knowledge shared within informal meetings cannot be recorded in any of the repositories of the company, and therefore remains private.

"Now Giovanni writes down a draft of his commercial offer, sends it to his strict co-workers asking for feedback. However, other people, who can give him useful feedback or can exploit the draft for their work, cannot consult it."

In conclusion, from the ethnographic analysis of the working practices, it appears that the observed organizations need something more than a server, an address book and an Intranet. They need a system able to integrate knowledge (and knowledge sources) with working contexts according to the various existing communities of practices, to the business areas and to the whole organization, considering not only documents of any type but also people, roles, teams, etc.

From the analysis of the users' practices, some main knowledge needs arise that have to be taken into account in the design of the MILK system:

- Distributed knowledge, located in different places (within the organization –areas and/or departments– and outside – marketing knowledge bases, customer sites, etc.) should be integrated.
- Innovation through cross-fertilization and communication (in terms of time and complexity) should be supported also among people located in different places.
- Tacit knowledge of organization members should be accessible together with explicit one.
- Documents (and document versions) should be presented to users where and when they may need them.

3. OVERVIEW OF THE MILK SYSTEM

In this paper we mainly focus on those services of the MILK system devoted to support and stimulate knowledge discovery and sharing via the PC interface. However – to better position the work in the context of the project – we provide a short overview of the whole system. The MILK system has been designed to be a tailorable solution, which can be adapted to different kinds of organizations. In particular, each installation can be different with regard to available interaction interfaces, archiving systems, internal work organization, and finally technology such as server types and so on. To reach this goal, a multi-tier architecture has been adopted to structure the system in independent and cooperating modules. The clear advantage is the possibility of adding, replacing, updating and tailoring components without really changing the system. The result is an open architecture that can be easily adapted and evolve over time and situations.

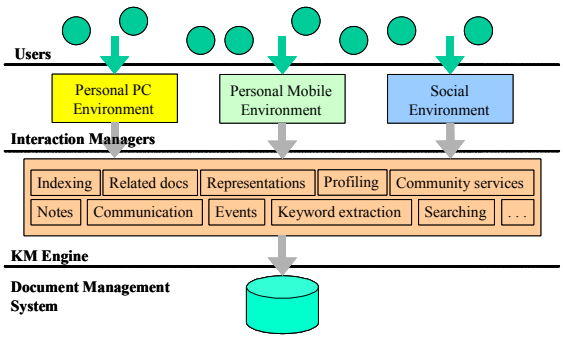

Fig. 1. The MILK architecture

The MILK system architecture, as illustrated in Fig. 1, is composed of three basic kinds of modules: interaction managers that are devoted to the presentation and the interaction; knowledge managers whose tasks are defining, maintaining, indexing and searching element profiles; and finally archiving systems – e.g., personal data management systems, and document management systems.

Interaction Managers

Users access the system by various interaction managers that provides them with presentation and navigation facilities. The aim of interaction managers is to provide users with various contextualized interfaces and interaction mechanisms fitting different working situations. Moreover, they are requested to provide multimodal interactions according to different user terminals. Three main scenarios, arisen from users' analysis, have been addressed:

- Personal office environment – users work alone in front of a PC;
- Personal mobile environment – users change their position in space. They are connected through mobile communication terminals, such as cellular phones and PDA;
- Social environment – users work in social situations, such as meetings, and group work sessions. Tools like wall screens and interactive screens support the interaction among users.

To collect and organize knowledge to be displayed, interaction managers rely on the services delivered by the Knowledge Management (KM) Engine.

KM Engine

The services included in the KM Engine have collectively the task of capturing and maintaining the knowledge associated with pieces of information and with users' activity. Its architecture is service-based to decompose the engine into service components that can be freely aggregated to deliver tailored instances of the MILK system. Service-based architecture addresses issues like independent development and deployment. Services may be at different logical level, which means that only some services are directly visible to users while others just supply utilities to them. More details about those services devoted to support the organization, maintenance and especially stimulating the discovering and sharing of knowledge will be presented in the next Section; here it is worth saying that the core component is the Metadata Management System (MMS) that is in charge of capturing and organizing knowledge on profiles that include metadata describing various aspects of involved objects.

Archiving Systems

MILK has been designed to be independent from specific archiving systems; in other words, it can be coupled with any existing database or document management system. The actual prototype is build on top of BSCW (Basic Support for Cooperative Work [9]). The BSCW shared workspace component is concerned with the integration of collaboration services, including features for uploading documents, version management, group administration and more. For instance, the various KM components exploit the BSCW programming interface to retrieve standard document information such as the person uploading a document, the upload time, and so on. With respect to personal data, BSCW provides ELDAP-compliant accessing facility.

4. COMMUNITIES, CONTEXTS AND PROFILING IN MILK

The analysis of work practices discussed in Section 2 has brought out the need of capturing and integrating various kind of knowledge associated with organizational issues (meeting minutes, work plans) and ongoing work (working documents, finalized reports,...). This knowledge includes information about people and their activities. Knowledge organization in MILK is centered on a profiling mechanism that allows for associating common knowledge descriptions with objects of different nature. The objective is to be able to integrate knowledge associated with objects – *elements* in the MILK terminology – like documents, people, communities and projects comprehensively. The key factor is the ability of comparing and contrasting elements of any type to compute various kinds of relationships. The task of the MMS component is to address the issues of computing and maintaining profiles and relationships.

Profiles are based on three main metadata categories. Over *generic metadata* – such as name and references for people, author and creation date for documents, etc. – *content metadata* are associated with elements to capture the knowledge. An ontology is used to support the process of identifying terms to be used as metadata values. Elements are then indexed by content metadata to support navigation and information retrieval. Finally, *qualifying metadata* describe the relevance of an element over time and usage. User actions on elements like rating, recommending, accessing, etc. together with the age and context of use of an element contribute to qualify each element for

providing users with the most accurate response from the system. Without entering into much detail of the adopted algorithms and rules, for example, frequency of usage affects the *relevance* metadata of documents and, similarly, the documents accessed by users affects their interests and expertise. Therefore, assuming that a conversation between user A and B has occurred and that the subject was section S of document D, the profile associated with document D will be updated, as well as the profile of users A and B. Readers can refer to [10] for more details.

We would like to stress that, in many existing systems, some elements –like people– are considered external to the knowledge management system. Moreover, MILK profiles, even if including the same kind of information, might be handled and used differently depending on the specific element type. For example, rating a person and rating a document is quite different due to the social implication of rating a person. Therefore, the rate attribute of a person element is not currently considered.

The rest of the Section explains how MILK exploits the profiling mechanism to supply innovative features. First, the process of handling communities of interest to support cross-fertilization of knowledge among project teams is examined. Then, a peculiar interaction metaphor – the View With Context – to effectively support exchange and sharing of knowledge is discussed. Finally, the issue of providing effective benefits to users from a private workspace – the Limbo – integrated in the system is presented.

4.1 FROM PROJECT TEAMS TO COMMUNITIES OF INTEREST

As already stated in Section 2, the organization of the work in both companies is based upon project teams, which are established on the basis of different client orders. While within a particular project exchanging and sharing knowledge results fast and effective, cross-fertilization among projects is slow and inadequate. In this way, of course, the awareness and consequently the potential for re-use of work previously done, of the achieved outcomes, and of the problems that have been already dealt within the organizations are occasional and have a limited extent. It is straightforward claiming that the lack of inter-projects exchange of knowledge is particularly severe due to the high mobility of employees: they mostly work on client sites and, moreover, both organizations are distributed in various sites. In particular, the members of different projects—still more than people belonging to the same project team— have rare occasions to meet, socialize and informally discuss on topics of their interests.

However, we have to consider that project teams reflect the organizational structure of the companies; people are associated with projects by managers. Sometimes composition of project teams may not take into account people experience, expertise and interests but has to deal with contingent aspects (e.g., people workload, budget issues). On the other hand, it is worth noticing that, one of the more natural exchanges of knowledge is around topics and people interests instead of organizational structures. Therefore, to facilitate knowledge sharing among different project teams, MILK supports communities of interest other than organizational projects. Communities and projects are two complementary and transversal views on knowledge. They allow shaping knowledge stressing the focus, depending on the specific need, either on the organization of the work or on interesting topics.

Projects and their members are defined by the organization. In particular, the MILK system —to correctly handle access rights— needs the list of memberships of projects. People usually participate in various projects with different roles, responsibilities and participation degrees (which can be specified by the organization or, in some cases, partially deduced by the system). Within the shared workspace of a project, members make use of the system according to their role and to pre-defined rules defined by the organization or by the specific project if any. On the contrary, communities reflect the interests and/or expertise of people that are free to join one or more communities for: receiving help on specific fields; recommending or publishing any piece of information; informally discussing on themes; rating or inserting comments on elements; and so on. People can even create new communities and call interested colleagues to participate in them. People can play different roles within a community, such as owner, participant or expert. The membership role can be manually inserted or partially deduced by the system from member behavior. As in project workspaces, community workspace contains (other than people) any kind of knowledge ranging from formal documents to informal annotations. However, publication of materials within communities should not follow organizational rules as for projects. MILK does not enforce a particular policy. If it is the case, the owner of a community may act as a moderator, being free to set up access rights according to a tailored policy.

A project may be related to various communities depending on the addressed topics; and, vice versa, a community has correlations with all those projects working on the specific interest of that community. To systematize the management of these content-based correlations MILK communities are organized around the definition of ontologies. An ontology is exploited by the MMS component to define concepts to be stored into element profiles along with the other metadata information describing memberships and associations with communities.

Ontologies have become a popular topic in various research fields and in particular within the knowledge management area (see for instance [24]). They have been developed to provide an explicit conceptualization describing the semantics of data. Among the different definitions of ontology, we adopt the Gruber's one [25]: "An ontology is a formal, explicit specification of a conceptualization". A 'conceptualization' refers to an abstract model of some phenomenon in the world, which identifies the relevant concepts of that phenomenon. 'Explicit' means that the type of concepts used and the constraints on their use are explicitly defined. 'Formal' refers to the fact that the ontology should be machine-readable. Therefore, ontology is an abstract model of a particular field of knowledge; it describes concepts, attributes of concepts, and the relationships between concepts providing an agreed and shared vocabulary of terms and relations, as a consensual knowledge accepted by a large group of people. In MILK, the Ontology Manager Module is in charge of maintaining a (multi)-domain ontology and supplying services to navigate, insert and delete terms, unify synonyms and multi-language entries, categorize elements by keywords, compute similarities, support categorization of new keywords within a domain, compute statistics on term usage, etc. MILK ontology is defined as a set of *terms*, with corresponding definitions, organized in a tree structure. The root defines a general category that is refined going down along the branches. The leaves define keywords; the

same term may appear in different positions to reflect that it may be used in different contexts.

When creating a new community, people are forced to position it within a specific node of the ontology tree. Any node of the ontology tree is, potentially, associated with a community of interest since it represents a key topic for the organization. Actually, ontology is not a static definition of concepts, instead it has to be perceived as a live entity that change and evolve following the evolution of communities of interest as well as of various organizational domains of work. We believe that communities, sub-communities and relationships among them are quite naturally modeled upon the ontology tree.

With respect to projects, organizations are free to associate a specific project with one or more ontology entries to state relationships with communities. Note that these associations can dynamically change during project lifetime.

Of course, the use of ontology also faces the issue of better correlating the content associated with MILK elements (and consequently with communities and projects). For example, users may associate documents with terms selected from ontology entries. Other features of the Ontology Manager Module deal with managing multiple languages; for more details on the Ontology Manager Module see [10].

Associating projects with communities stimulate cross-fertilization and knowledge sharing. Anyway, it is worth to underline that any technical solution alone, even the MILK services, is not sufficient to ensure the active participation of people into communities. A complete analysis of other relevant aspects to be taken into account is out of the scope of this paper (for some hints on it see [5]).

4.2 The View with Context Interaction

Users are usually enabled by systems to *search* for getting information; instead, the MILK approach is to help users *discovering* information while they are using the system. Discovery is supported by automatically selecting, grouping, organizing, and finally presenting any kind of information that are related to what the user is doing and to the content of his/her actions. To achieve the goal, the MILK system presents any piece of information surrounded by contextual information to continuously support awareness [2, 30, 32, 33, 35, 36] and to stimulate knowledge discovering. This interaction mechanism is named *View With Context* (VWC) to specify that any element is displayed immersed in its related information (i.e., documents, annotations, e-mail messages but even people, communities, and projects).

This approach is exemplified by the prototype interface in Fig. 2 displaying a document – more precisely, its profile –surrounded by elements' profiles that are related to that document. According to a multimodal approach to interaction, the VWC interaction has been selected as main presentation style for office environments that are based on PCs. It is also viable for social environments based on large screens. Instead, it is not suitable for mobile environments that usually exploit tiny screens.

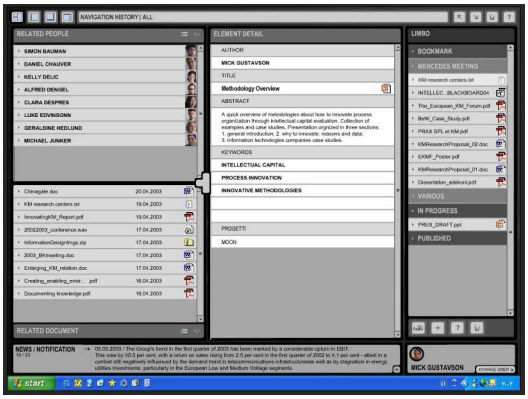

Fig. 2. A "view with context" screenshot.

The view with context metaphor addresses the issue of providing users with a common perception of any piece of knowledge associated with elements of different nature. That is, the VWC bonds together different kind of elements to support common view and access. To reach this goal, the profiling mechanism of MILK has been exploited. In fact, associating common descriptions with elements allows MILK to include any kind of element in the same knowledge process.

The VWC enhances the processes of knowledge diffusion and cross-fertilization by knowledge discovery. So, for example, given the profile of a project, it is possible to collect information about any other project that has similarities with the current one, be aware of people that are interested in the same subject, or identify documents that talk about the same argument.

Common profiling of elements enables MILK to supply users with personalized services based on their profiles and context of use. Personal profiles include rights (e.g., security info, access rights and group memberships) and expertise (e.g., roles and interests). According to profile information, available knowledge is filtered and selected to meet the user needs. Moreover, the context of use defines what and how has to be presented. For example, browsing knowledge and editing document situations may require different system behavior. Editing a document means that the user may need to access various sources to make up the document. Browsing means that the user may need related information in read-only mode. Another example of contextualization is given by the use of the system during a meeting: documents should be proposed in suitable formats for projection, e.g., a slide presentation or similar.

To address this issue, documents are not considered just files. In MILK, a document could be a collection of various files, each of them being a different representation of the same conceptual content –e.g., the full-text and slide presentation for a paper. This allows the system to supply to people the most appropriate representation depending on the activities they are performing and on the specific situation. Moreover, a single representation can have different file formats (e.g., HTML, pdf, ppt for a presentation). Finally, since MILK supports versioning to keep track of document evolutions, versions of any representation may be also available. The system supplies users with preferred file formats and newest versions.

The use of profiles to implement the indexing and retrieval features has the additional advantage of being more accurate when dealing with textual documents. In facts, the common technique of full-text indexing to support full-text searching has the severe

drawback of being too little selective: even secondary terms are considered with the result of including unrelated documents. MILK indexing and retrieval facilities are more accurate since profiles include only keywords that really describe the content of documents. Moreover, profiles include information, like relevance, popularity and so on, to qualify elements for ranking.

4.3 The Limbo workspace

One of the main problems of any system supporting, at least, the sharing of explicit knowledge is how to convince users to use the system. In fact, very often, users are skeptical on the effective rewards of making their knowledge available to others. Of course, people know that they may obtain benefits sharing their knowledge with other people. However, the *do-ut-des* is a weak, vague, too distant and too uncertain rewarding mechanism for being a powerful and effective stimulation for people to disseminate their own achievements. Often, organizations rely on employee sense of responsibility and sometime introduce various form of coercion (e.g., rules, procedures as well as mandatory internal reports) to force people to both make explicit their implicit knowledge and, at least, to externalize any already explicit knowledge. Moreover, it is well known that there is a possibly heavy overload for publishing any information within a knowledge management system (e.g., consider uploading a new document with profile in a corporate Intranet).

The Limbo workspace tackles the problem of motivating people by introducing more direct rewarding mechanisms and by making publishing of explicit knowledge as simple – less tedious and time consuming – as possible.

The Limbo workspace provides users with a private workspace that is integrated in the system and therefore can take advantage of system features. The Limbo allows for collecting and organizing documents and bookmarks. Documents are typically those that are not ready to be published, or documents that users won't to share yet. Bookmarks allow users to create their own organization of the knowledge. Elements in the Limbo can be freely clustered to shape the information.

The Limbo workspace is a mean to integrate common user practices with the use of the MILK knowledge management system to enhance usability – users can smoothly pass from the Limbo private environment to the shared one. Therefore, the Limbo is an effort to reduce the actual dichotomy between private, individual work and social group cooperation. In particular, this gap emerges when dealing with documents (in the MILK meaning of documents). As a matter of fact, communities and projects are shared elements by nature, while documents need to be made public and shared explicitly. Therefore, communities and projects are created and managed directly in the MILK shared workspace, while documents are typically produced in the local computer of a user and then published. Publishing process provides for uploading the document file, building up its profile, and computing the relationships with the other elements already present in the system. Serious drawbacks of such a process are that users are forced to use two completely independent environments and, as already noted above, there are no direct rewards for a time consuming activity.

As already discussed in previous sections, a key feature of MILK is to provide context information of elements that are part of the system. Documents included in the Limbo workspace are considered included in the system even if they are still private to the user. Therefore, the system can supply the user with contextual information – build up a VWC – for those documents. This feature is specially rewarding when documents are not completed yet. Assume the user writes a report. It is likely that, during writing, the author may need to refer to other material that is already available within the system – read a similar report that has been developed in another project, read a project document, get an image from a presentation, contact an expert in the subject to verify an issue, and so forth. Today, the report writer has only the chance of searching the databases or navigating the shared document repositories to look for and collect information. The VWC provides for the right information at the right time.

To illustrate the Limbo features, let us consider a typical scenario. Assume that Maria needs to write a report. The report profile is created in the Limbo using the MILK functionalities. Of course, the report is created empty, but the profiling information associated with it allows the system to compute the relationships with other elements. Therefore the VWC related to the new document can be created and presented to the user. Maria navigates the context of the newly created document, watching at the profiles of people or moving from one element to another through their VWC. She is lucky, she identifies a document that is strictly related to the one she is writing –she may use some pictures and description from it. Moreover, she becomes aware that Marco, a colleague working at another organization site, is an expert on an aspect that she does not know very well. Unfortunately, the system says that he is not available at the moment – she will contact him later to ask for some help. To keep track of the discovered information, Maria creates a new cluster in Limbo to collect the report she is writing and the bookmarks to Marco and the related document. In the future she will be able to retrieve them very easily.

Another issue that Maria is requested to face is the decision of making the new report available to others even if it is not yet ready. The MILK solution of this problem is to consider the documents that are stored in Limbo as private, while the profile associated with Limbo documents can be shared. The first decision was taken since letting another user to read a document while it is under writing may make little sense. Anyway users can take advantage of the versioning feature of MILK to publish uncompleted, but readable, papers. Instead, the possibility of sharing profiles is important to enhance the system quality of service. One of the main goals of MILK is to promote awareness about the life of the organization; hence, announcing that Maria is writing a report on a certain subject as part of certain project may be important to other users. Assume that also Carlo is about to write a similar report –e.g., the state of the art in a certain field. If he can get the information that Maria is already writing a similar document, then he may contact her to see if they can write a joint document, instead of duplicating the effort.

5. CONCLUSIONS AND FUTURE WORK

In this paper, we described the main features of the MILK knowledge management system. Such features are a proposal to solve the problems that have been brought out by the analysis of users' requirements. The View with Context, the community support and the Limbo workspace are the novel design concepts that meet users' needs and practices. Their implementation has required a well-balanced combination of sophisticated interfaces, information retrieval techniques and intelligent agents. What remains to be analyzed is the effectiveness of the interactions at

the micro-level with respect to the practice and behavior of users. It is almost impossible to make secure forecasts with respect to this point, since the interactions we have designed are radically new (they are not recreating in a virtual environment the interactions people performed in the physical world) and only user experience can tell us if they are able to induce in users the invention of new practices.

A second important point, that has to be investigated in the experimentation that will be carried on in the MILK project, is the integration among the different interactions supported by different media into a knowledge management system. Again, the issue cannot be faced at the theoretical level of making a simulation of the system, since new interactions create new scenarios of usage. It has to be underlined that the design of a knowledge management system that is accessible through different media in different work situations requires the co-design of interaction modes for each of them, since there is a mutual influence. When users shift among different media – private PC, cellular phone, and social interactive screen – designers must pay attention to the boundaries between one interaction mode and the other ones, putting on them adequate resources for supporting integration and switching [12, 19].

The MILK team has already developed an observation and evaluation method to test the first prototype and to offer guidelines for improvements and/or changes. The evaluation is based on the analysis of effectiveness and efficiency for users and on the analysis of the system impact on the corporate financial and intellectual capitals [23, 28].

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