Infotop – A Shared-context Information Workspace

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Abstract. Knowledge workers collaborate in teams, networks and communities in order to accomplish knowledge processes. They have to be supported with adequate organizational as well as information and communication technological (ICT) infrastructures. From an ICT perspective, requirements have changed when compared to more traditional (office) work due to the considerable higher complexity of data, the focus on communication across the boundaries of corporate ICT infrastructures and the mobility of knowledge workers. This requires the systematic handling of context and substantially extended functionality for collaboration in the knowledge workers' personal workspaces. In this paper, we outline typical knowledge processes and discuss ICT support for the personal management of information, of web content, of collaboration and of knowledge. We propose Infotop, a shared-context information workspace that organizes knowledge resources within six dimensions. We show how Infotop can be used to support typical knowledge processes and discuss some implementation aspects of a prototype workspace.

1 Introduction

During the last decade, knowledge-intensity of products , services as well as organizational processes has substantially increased. Knowledge workers collaborate in teams, networks and communities and have to be supported with an adequate organizational as well as an information and communication technological infrastructure. A knowledge management system (KMS) promises enhanced support for knowledge work through an integrated combination of information and communication technologies (ICT).

So far, KMS in organizations provide technocratic and document-focused basic support for organization-wide information sharing. Even though corporate KMS are already advanced in many organizations, they rarely offer support for the design and management of knowledge workers' personal workspaces as well as advanced functions for knowledge sharing and collaboration. The need for ICT support of knowledge workers is rarely considered when corporate KMS solutions are developed. Consequently, actual KMSs often fail to convince users of their advantages. Goals of this paper are:

- to describe requirements for ICT support of personal information, collaboration and knowledge management with the help of typical knowledge work processes,
- to review how current ICT tools and systems meet these requirements, and
- to propose Infotop, a tool that helps to overcome the shortcomings of current ICT with respect to the identified knowledge work processes.

Infotop is a personal workspace designed to help knowledge workers organize their personal information and knowledge resources and collaborate on the basis of shared context between their workspaces.

In Section 2 we will discuss knowledge work, compare it to traditional work and describe typical knowledge work processes. In Section 3 we will review traditional ICT and recent proposals for tools in the areas of personal information management, web content, collaboration and knowledge management (KM) in support of such processes. In Section 4 we will present Infotop, review its contributions using the knowledge work processes identified in Section 2 and discuss some aspects of implementing such a tool. Finally, we give an outlook to directions of future work.

2 Knowledge work

Knowledge represents the key concept to explain the increasing velocity of the transformation of social life in general and the way businesses and social institutions work in particular [4, 9, 17]. Employees' roles and their relationships to organizations have changed dramatically as knowledge workers have replaced industrial workers as the largest group of the work force. 60% of US organizations think that between 60% and 100% of their employees are knowledge workers [7]. Knowledge workers are well educated, creative and self-motivated people engaged in joint, complex problem-solving processes. Knowledge workers have to be supported with an organizational and ICT infrastructure in which knowledge work can be handled more effectively and efficiently. In the following, we will first contrast more traditional (office) work to knowledge work. We will then elaborate on a set of knowledge work processes for which ICT support is required.

2.1 Traditional work versus knowledge work

Knowledge work can be characterized by a high degree of variety and exceptions and requires a high level of skill and expertise [30]. The increasing specialization means that knowledge workers have to work together in various kinds of groups and teams which differ in their social structure and interactions. Virtual teams, expert networks, best practice groups and communities complement traditional organizational forms such as work groups or project teams and aid collaboration between knowledge workers within and increasingly across organizations. When compared to traditional work, knowledge work can be characterized by stronger communication needs, weakly structured and less foreseeable processes, increased mobility of work spaces and the need for semi-structured data, e.g., hypertext documents, messaging and learning objects, experiences or skill directories.

From an ICT perspective, the main changes in the requirements occur due to the considerably higher complexity of data and the focus on organization-wide and inter-organizational communication and mobility of personally responsible knowledge workers. This requires the systematic handling of context and extended functionality for collaboration in the knowledge workers' personal workspaces (see Section 4). From an organizational perspective, process-orientation has been proposed to help organize knowledge work, especially the recent additions to business process management aimed at weakly structured knowledge-intensive processes which are characteristic for knowledge work, see e.g., [6, 12, 20].

2.2 Knowledge work processes

Knowledge workers work together in knowledge-intensive business processes and in especially designed service processes, also called knowledge processes. The latter represent a (portion of a) knowledge life cycle consisting of the activities create (or externalize), value, organize and refine, store, distribute, search, apply as well as feedback/improve knowledge [1, 24, 34]. The life cycle steps can be combined to patterns of typical knowledge processes that are initiated and handled ad-hoc by knowledge workers. A typical knowledge process might handle knowledge externalized in a business process according to the life cycle steps value, organize & refine, store and distribute until it is re-applied in a different business process. Further examples of typical knowledge processes are (a) the acquisition of knowledge from outside the organization or (b) managing communities-of-interest or networks of knowledge workers. The following list provides examples for personal knowledge work processes corresponding to these knowledge processes.

- *Externalization process*
  is used e.g., to create and prepare a paper or a presentation for a conference co-authored by geographically dispersed knowledge workers who share a portion of their knowledge context, i.e., electronic knowledge sources. Examples of knowledge sources are links, documents, web sites, data bases, expert contacts.
- *Submission process*
  comprises the sub-processes submit, value, organize & refine as well as store knowledge. The process is triggered by an individual or a group of knowledge worker(s), evaluated by (members of) a community, e.g., a program committee, reviewed, refined and linked to other knowledge elements by a subject matter specialist. These value-added knowledge elements are occasionally repackaged for specific target groups. Finally, the target audience is granted physical and intellectual access to the submitted knowledge elements.
- *Distribution process*
  handles the creation of interest profiles specific to individual knowledge workers. Subsequently, new knowledge elements as well as links to events, learning offerings, meetings or expert advice are distributed according to these profiles. More generally, this process handles all distribution of knowledge to knowledge workers in geographically dispersed locations.
- *Search process*
  identifies and connects several steps of an individual or joint search for knowledge elements and/or expert advice by a group of connected knowledge workers. Crucial steps in a joint search process include the defini-

tion of search locations, the combination and weighing of personal preferences, and the amalgamation of individual search results.

- *Application process*
  integrates knowledge into the operative work processes and ICT environment of the knowledge worker, e.g., a scientist who uses the shared knowledge workspace to conduct research and to improve teaching.
- *Feedback and improvement process*
  comprises activities concerning the follow-up on feedback that one has gained through the comments on knowledge elements. Scientists' sources of feedback include conferences, newsgroup discussions, email on certain topics, etc.
- *Acquisition process*
  defines and handles the exploitation of external knowledge sources. Access to knowledge sources that have to be paid for is organized centrally and has to be integrated into the information workspace.
- *Community or network management process*
  supports the identification, foundation of and participation in communities-of-interest. For example, a scientist wishes to value, organize and integrate the communities' knowledge resources into her personal knowledge workspace.

3 Technological Support

There are many tools that support knowledge workers. In this section we will present representative approaches in the categories of personal management of information, of web content, of collaboration, and of knowledge.

3.1 Personal Information Management

The desktop is the primary metaphor being used as interface on our computers. Thus, it not only manages personal information stored in files and folders, but it also serves as the main access point to personal information management systems, e.g., calendars, address books. The desktop was introduced when computers were quite different to today's machines, see [15]. While computers, users and the environment have changed, interfaces and the basic handling of data have stayed the same. Countless files are stored on increasingly more capacious storage drives. This has resulted in big hierarchies of folders that make it hard to retrieve information.

Alternatives to the desktop have been proposed to overcome the hierarchical file structure. Some of these alternatives try to completely replace the desktop, while others are placed on top of the desktop. Personal information management systems aim at organizing and visualizing the increasing volume of information that we have to handle. This should help to reduce knowledge workers' information overload leading to more effective decisions and knowledge-related activities [13].

Desktop alternatives. Lifestreams uses a time-ordered stream of documents rather than conventional files and folders [14]. Incoming information is organized, summarized and monitored by stream filters and software agents. Time-Machine Computing is another time-centric approach [28]. Four key features characterize lifelong archival of information history, chronological navigation over archived information, visualizing time in different ways, and inter-application communication of time. Presto is a prototype document management system that provides rich interaction with documents through meaningful, user-level document attributes [8].

Desktop add-ons. PersonalBrain is a tool for managing information by visually organizing resources according to whatever scheme makes sense to the user. [31]. SixDegrees helps in managing the relationship network of personal information. It concentrates on messages, files and people, rather than on a strict file system hierarchy [5]. SemioTagger is a categorization and indexing engine that (semi-)automatically organizes online sources and documents of different data formats into meaningful categories. SemioMap then uses the detailed document profiles to create multi-layered concept maps [11].

3.2 Personal Web Management

In the World-Wide-Web we are drowning in data, but starved of information. Web tools provide the functionality of bringing some order into the multitude of web pages being visited by today's Internet users.

Web Browsers. The favorites or bookmarks mechanism of web browsers is a simple remedy for the administration of many web sites that are visited repeatedly. Spatial memory for document management is used in Data Mountain [29]. It allows users to place documents at arbitrary positions on an inclined plane in a three-dimensional desktop virtual environment.

Enhanced Web Support. TopicShop helps users to evaluate and to organize collections of web sites [2]. It provides support for finding web pages relevant to someone's interests. The Resource Description Framework is part of the Semantic Web Activity. It is intended for representing meta-data about web resources, e.g., title, author, creation date of web pages [33]. This meta-data will allow software like web browsers to provide enhanced features for the organization and retrieval of information on the Internet.

3.3 Personal Collaboration Management

Personal collaboration management includes activities that are needed to communicate, coordinate and cooperate.

Workgroup Computing. A large number of ICT have been proposed to support work groups called workgroup computing, groupware or computer supported cooperative work. Groupware can be classified into communication, coordination and cooperation systems or along the two dimensions space (same/different location) and time (synchronous/asynchronous). Examples of groupware applications are [e.g., 10, 27, 32]: co-authoring systems, electronic discussion groups, electronic meeting systems, group calendars, group (decision) support systems, shared screen systems, teleconferencing systems or workflow management systems. These systems primarily support communication, coordination and decision making in groups as well as the joint handling of objects. A groupware platform combines many of these functions and provides general support for collecting, organizing and sharing information within (distributed) collectives of people. The best known groupware platforms are Lotus Notes and Microsoft Exchange [18, 23].

Information Agents. Information agents help to manage the explosive growth of information that we are experiencing. They perform the role of managing, manipulating or collating information from many distributed sources [25]. Software agents differ from traditional software systems with respect to their autonomy, ability to communicate and cooperate, mobility, reactive and proactive behavior, reasoning, and adaptive behavior [3]. Information agents can be used for many purposes, e.g., to scan email messages, to group and automatically update user-specific messages and information items, to search, integrate, evaluate and visualize information from many sources, to intelligently handle information subscriptions, and to identify and network experts or generally knowledge seekers and providers [19].

3.4 Personal Knowledge Management

There are a number of basic ICT that together form a corporate infrastructure for knowledge management. Examples for such ICT are document, content and workflow management, advanced electronic communication, business intelligence, visualization and e-learning on the basis of an Intranet and/or a groupware platform.

Knowledge Management Systems. More recently, KMS have been proposed as an ICT platform that combines and integrates many, if not all of these ICT, i.e., a number of functions for the contextualized handling of knowledge in organizations [19]. Examples are the KMS platforms Opentext Livelink or Hyperwave Information Server [16, 26]. A knowledge worker accesses the organization's KMS with the help of personalization services using a variety of interfaces, such as a web browser or a personal digital assistant, protected by access and security services. The core knowledge processes — publication, discovery and collaboration — are supported by knowledge services which are key components of the KMS architecture. Knowledge services work on the basis of integration services, e.g., a knowledge repository. These layers are based on infrastructure services, e.g., an Intranet infrastructure with basic functions for messaging, teleconferencing, data, document and web content management. Extract, transformation and loading tools help to integrate the wide variety of electronic data and knowledge sources.

3.5 Résumé

Corporate ICT infrastructures are quite advanced in many organizations, for empirical results see e.g., [19]. However, they rarely offer support for the design and management of the knowledge workers' personal workspaces as well as advanced functions for knowledge sharing and collaboration using these workspaces. Moreover, each of the knowledge processes we discussed in section 2.2 requires a bundle of knowledge services that is also personalized to the requirements of individual knowledge workers. We will focus on the knowledge workers' personal workspaces which are connected with the help of a corporate KMS infrastructure.

4 Infotop

Infotop is a metaphor for a shared-context information workspace. The term infotop covers the dynamic aspect, i.e., the flow of knowledge, in contrast to desktop. In this section, we will present six dimensions for the categorization and visualization of knowledge, shared context of collaborating users, the support of knowledge work processes, and some thoughts about a possible implementation.

4.1 Six Dimensions

The dimensions time (when?), topic (what?), location (where?), person (who?), process (why?) and type (how?) have been identified as being essential for effective categorization, visualization and navigation of collections of contents [21], see Fig. 1. The pile metaphor [22] is used in Fig. 1 to display information about sets of documents. Additionally, the numbers of documents are indicated for each displayed category. In analogy to OLAP (*online*

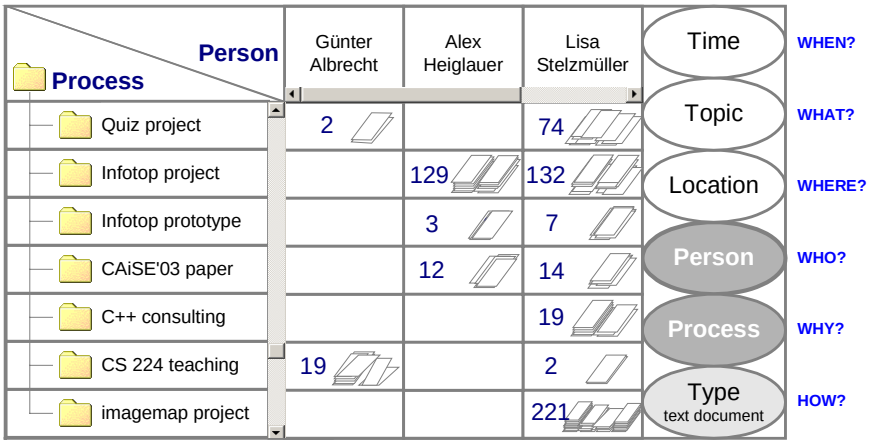

Fig. 1. The two dimensions process and person are selected, the display is limited to text documents.

analytical processing) techniques, these dimensions can be used for slicing, dicing, drilling down, rolling up, and ranging operations on contents of a personal knowledge environment. Several hierarchies of any of these dimensions can be used for display in addition to well-known visualization techniques like icons, thumbnails or lists. Views may be restricted to contents with specific attributes in any of these dimensions, e.g., contents of a specific process or of a specific age. Infotop's one-dimensional views are shown in [21], however, without considering knowledge work processes and shared context.

Facts, i.e. the information on sets of contents represented in each cell, could be e.g., the number of elements as represented in Fig. 1, the amount of data, e.g., the number of pages or Mbytes used, the number of contributions or of questions answered of knowledge providers, an aggregate valuation of elements, e.g., the number of accesses to elements, a measure of the skill levels of knowledge providers in a domain, or, in finer granularity, any other meta-information that is stored along with elements, e.g., the titles of documents, or a comparative measure, e.g., the proximity of competencies between a number of potential knowledge providers in a certain domain.

Time is one of the most crucial attributes of documents, e.g., time of creation, time of last modification, time of last read only access. Typically, only appointments are displayed in calendars, rather than e-mail messages, text documents and other forms of documents, e.g., comments, yellow stickers. It is also useful to display a selection of documents, e.g., we may want to see all documents of a project displayed in the calendar, or all documents of a person, i.e., all e-mail messages from and to that person, all files exchanged with that person, all web documents about that person that we have visited, etc. The meta-data for time and the other dimensions can easily be extracted from context that comes with a content element or the activities that are performed on such an element, e.g., in the case of an e-mail message we can derive sender, receiver (person, location), date (time), subject (topic, process) and type of attached file (type).

4.2 Shared Context

Users have information on their private computers and can also access public resources, typically on the Internet. Additionally, servers on local networks provide extra information that is not accessible to the public, but to a restricted number of users only. We imagine a private, a protected and a public workspace for users. The shared, i.e., protected and public, workspace and the private workspace of an individual can be placed on her computer, see user 3 in Fig. 2. User 3 shares parts of other users' workspaces. The dashed line and the gray boxes indicate her shared-context information workspace, i.e., a virtual workspace that includes her private, protected and public workspace as well as all public and parts of protected workspaces of other users. It is important to note that a user's protected workspace is not open to the public, but rather allows restricted access only to those individuals that she wishes. Thus, access privileges of the protected workspace have to be configurable in a flexible manner. Typically, public workspaces grant permission to read only, whereas protected workspaces may be open to write.

Private workspaces contain information that is stored locally on our computers. Public workspaces include information that is published via the Internet. Protected workspaces lie somewhere in between. They contain information that is not accessible for everyone, but for whoever the owner grants explicit access, e.g., digital libraries. For a shared-context information workspace, we imagine to have private, protected and public workspaces institutionalized on all workplaces. Additionally, any informa-

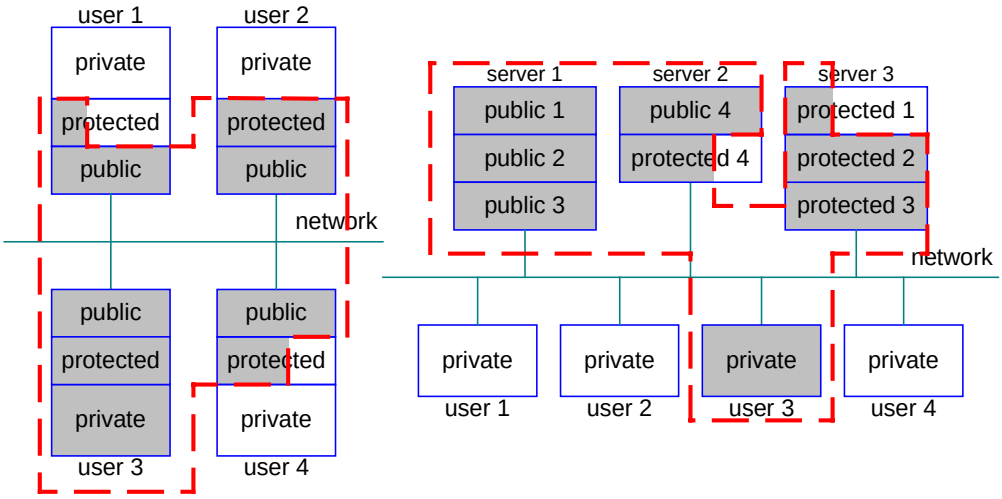

Fig. 2. Four users have their private, protected and public workspace on their individual machines (left side), or distributed on server machines (right side).

tion in these workspaces has to have meta-information attached, according to the six dimensions mentioned above, such that powerful query mechanisms can be supported. Assignment to topics is crucial for workspaces. This allows us to have several virtual workspaces for different topics of interest, i.e., several dashed lines in Fig. 2. Virtual workspaces can overlap, because workspaces and sets of documents can be assigned to more than one topic.

In Section 4.1 we have used multiple dimensions to organize and visualize information of an individual, isolated workspace. In this section we have depicted a shared-context information workspace where users share parts of their workspaces. Organizing and visualizing this shared-context information workspace for each individual remains a challenging task. We argue that the multi-dimensional workspace can be used with minor modifications in a shared context. The six dimensions are helpful, no matter whether the information is private or shared. What remains unclear is how to support workspace management and how to distinguish between different workspaces. It may be sufficient to have meta-information assigned to workspaces, e.g., to have a protected workspace restricted to a certain topic. This allows access to this workspace via that specific topic. Moreover, a workspace might be defined using any combination of restricted dimensions and grant access according to these restrictions. The six dimensions have been introduced to get rid of the rigid file hierarchy. The shared context should conceal network structures and stress the logical boundaries among knowledge elements. However, explicit consideration of workspaces and thus a seventh dimension may be necessary to visualize social networks and promote the sharing of context.

4.3 Knowledge Work Processes

In Section 2.2 we have outlined several knowledge work processes that are important for collaborating knowledge workers. Subsequently, we will outline how these processes can be supported by Infotop, see Fig. 3. A user externalizes, distributes, submits, acquires, searches, applies information in her shared-context information workspace. The solid ellipse in Fig. 3 depicts the user's individual workspace, while the dotted ellipse depicts the user's shared-context information workspace.

- *Externalization process*
  Externalization of information is done with regular applications, e.g., a word-processing software, or (co-) authoring tools. This process results in documents that typically are at first stored in the private workspace. It is important to have meta-information attached to these documents. This is not sufficiently supported by today's applications. Infotop provides rich contextualization of documents using the six dimensions.
- *Submission process*
  In the simplest case, submission means publication of a new knowledge element and its distribution towards a topic-oriented network, i.e., in a protected or public workspace. Versioning of information and the support of workflows is required for the submission process.
- *Distribution process*
  The distribution process involves moving or copying information from one's private to one's protected or public workspace. It is useful to have this process combined with some sort of notification, especially in the protected workspace.

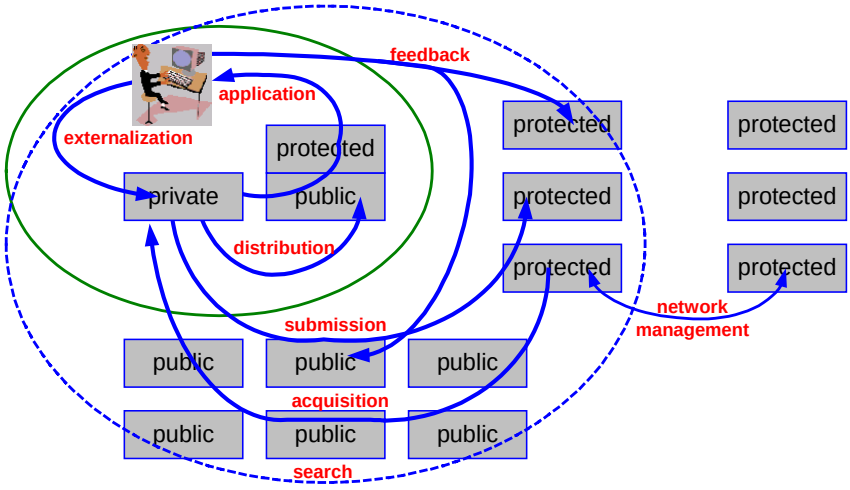

Fig. 3. Knowledge work processes.

– *Search process*
Searching is done primarily based on meta-information in one's workspace consisting of one's private, accessible protected and public workspaces. Protected and public workspaces have to be prioritized according to topics, e.g., workspaces of research groups have to be considered only when the search process is aimed towards the research topics of these groups. Findings in protected workspaces are typically more relevant than findings in public workspaces.
– *Application process*
The application process involves any usage of information that has been retrieved from an arbitrary source, i.e., from protected and/or public workspaces.
– *Feedback and improvement process*
Responses or reflections to information in an arbitrary workspace can improve the quality of information. Feedback includes communication to information holders, i.e., workspace owners, citations, etc.
– *Acquisition process*
The acquisition of information includes the extension of the search domain to include new workspaces, the location of information in any of the accessible workspaces and copying this information or a link to it into one's individual workspace.
– *Community or network management process*
Communities share their interest in certain topics. It is necessary to have topic directories in public work spaces, where users can register and obtain permission to participate in protected workspaces that are assigned to these topics. The consideration of new topics results in new dashed lines, see. Fig. 2. The acquisition of information is supported by the extension of one's workspace by including additional protected workspaces.

Fig. 3 depicts these knowledge work processes involving the entire shared-context information workspace of a user.

4.4 Implementation

We imagine an implementation of a shared-context information workspace based on a combination of web service, data base and configuration management technology. Web service technology can be used to seamlessly integrate other users' shared workspaces into one's own workspace in a platform-independent way. A data base is required in order to manage the meta-information created by Infotop. Configuration management and version control is needed to avoid versioning conflicts and to allow coordinated and cooperative work in the shared context. Also, Infotop has to exchange meta-information with other applications, e.g., messaging, office management and a search engine. The presentation of the workspace has to be modeled according to the six dimensions identified in Section 4.1. We are currently implementing a prototype using web services for the creation of protected workspaces.

5 Conclusion

We have discussed the differences between traditional work and knowledge work and have outlined typical knowledge processes in which knowledge workers collaborate. ICT support has been found insufficient for the personal management of information, of web content, of collaboration and of knowledge. We have proposed Infotop and discussed six dimensions in a shared-context information workspace. This workspace can be used to support typical knowledge work processes.

KMS are typically restricted to one organization's boundaries. A significant portion of knowledge processes crosses these boundaries and thus can only be supported on the level of a personal knowledge workspace. We imagine Infotop as the main access point both for personal knowledge management and for ad-hoc collaboration in a shared context.

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