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Abstract: This paper describes the development of special visual interfaces to enhance distributed work on multi-threaded, project-oriented tasks.
Since current tendencies in economic restructuring lead to the increased need for small- and medium-sized enterprises to join forces and form virtual enterprises, they also need special tools to support this kind of collaboration. These tools help mediate the increasing complexity of planning and building processes and the decreasing ability to oversee and understand ongoing processes distributed within virtual enterprises.
The aim of the research project described in this paper is to develop tools that support information exchange, communication, and collaboration. These include meta-visualizations of processes and information to offer different levels of insights and transparency regarding the project. These holistic views support recognition of time and process-related aspects and reveal relations among documents and participants. By using the developed tools, users can explore information stored in the underlying document management system in a playful as well as purposeful way (HIR 98). As a result, the access to information can be facilitated and the communication and collaboration among participants improved, ultimately raising the quality of decisions and results.

Keywords: Virtual enterprises, information visualization, process visualization, document management system, planning informatics, collaborative work.

1 Introduction: Enhancement of the Collaboration in Virtual Enterprises

In a building project, the use of information technology (IT) has to start as early as possible during the planning phase and usually ends with the completion of the building. Furthermore, it may also provide data for the facility management that follows. In this process IT is mostly used for data exchange and data storage.
A survey preceding the actual research project showed that the available tools are rarely used to their full potential; many of their features are often ignored because of the increased difficulty of use and a lack of transparency regarding their effects. The survey led to the conclusion that the reduction of IT barriers and the development of new tools to access complex data structures on a visual level are the two aspects the research should focus on. Ultimately, the IT platform has to allow efficient and fast access to data and provide overviews of working processes and the progress of the project.
This research project respects the fact that using powerful document management systems and high-speed data access over global networks is a common and

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powerful way to share project-related information. Therefore we propose not to replace such systems but to offer a framework that can be combined with commonly used systems. Such systems usually structure the data in a hierarchical manner, which can then be accessed by navigating across sections and subsections. A shortcoming of these systems is that they rarely offer useful overviews of the data and working processes. Document management systems fulfill many high expectations, which sometimes makes them appear complicated and cumbersome. A lot of time and energy has to be spent learning and handling these systems. Navigating through the system or searching for documents without knowing the exact title, content or author becomes more and more of an odyssey, the longer the process and the bigger the project.

The reduction of IT barriers can be achieved by providing interfaces that allow easier and more direct access to information and provide different kinds of overviews. Therefore, we see the designing of new visual interfaces as an essential task to support the virtual enterprises. We developed several tools that enable information exchange, communication, and collaboration. They are built around an existing document management system to allow efficient and fast access to documents stored in the system and provide overviews of working processes by means of visual exploration and interaction with large data structures.

In addition to the access and management of information, new levels of transparency should be introduced to help the collaborators understand the process and offer them new ways of accessing important information. The interfaces increase transparency by creating meta-views onto the data. Meta-view denotes a representation that first of all shows the structure of the relations among documents rather than the content. Meta-views are also portals to precisely access the content of the document management system. The introduction of transparency on a meta-level also has a motivating effect, because the individual contribution appears in a larger context.

2 Developments — Four Interrelated Visual Interfaces

The four different visualization tools timeBand, documentDisk, keywordDisk, and userDisk were developed to access the documents stored in the document management system and display relations among them as well as to the collaborators in the project. The interfaces make the recognition of time and process-related aspects possible and they directly interact with each other.

Our prototype system is built on top of the document management system SiteScape [2]. SiteScape already offers many useful functionalities, like information exchange (document and file sharing), on-line discussions and personal agendas. SiteScape stores the document information in a hierarchical system and provides an interface to present threaded documents and discussions. Overall, SiteScape is a program offering the ability to handle and organize all the relevant information occurring during the planning and building process. The interfaces developed in the research project are combined with SiteScape in a web-based interface that allows access to both levels of interaction at one s convenience. Even though the current prototypical interfaces are built on top of SiteScape, the tools are con-

ceived to be transportable and to be used with other systems. To use the developed tools and interfaces with other document management systems requires an adaptation of a limited number of interface functions.
In the following section, the four applets timeBand, documentDisk, keywordDisk, and userDisk are presented and their functional and representational aspects explained. There are many common aspects among these applets, like the different operators to view, order, search, access and filter information, and their interrelatedness. The most important of these aspects is the inter-dependencies - the ability of communication and information sharing between these tools.

Figure 1: The web-based combination of the newly developed interfaces.

3 TimeBand

Since time is crucial and a widely used reference system in project-oriented tasks, a representation based on a linear representation of time is a necessity as well as a good starting point for the users. The linear representation of time is used in many planning tools, like for example in Microsoft Project. Also, long before the use of computers it was an obvious way to denote time-related occurrences, as we know from the classical music notation system, for example.
The timeBand is a representation of documents along a timeline and provides a good overview of the work in progress, the different tasks, and the interdependencies among them. It allows the user to draw conclusions by visually analyzing the overview of the processes on the project level and the degree of participation of the different partners. Several functions allow the user to access and change relations on this information-level. Along the x-axis documents are displayed according to the time of their creation. Important are the different sorting possibili-

ties along the y-axis, which allow for the ordering of documents according to author, company, time, or type. Users can blend in information about a single document-thread or all existing threads. Furthermore, it is also possible to show or change user-defined relations between documents. This functionality allows one to present and save known references as well as newly created relations and permits the sharing of personal knowledge about connections and relations with participants. Additionally, it is possible to blend in project-relevant information like phases, benchmarks or other data of interest. Other functionalities use different colors to show document-types or document-status related to completed, actual, and future tasks, which might help users gain insights into the progression of the work.

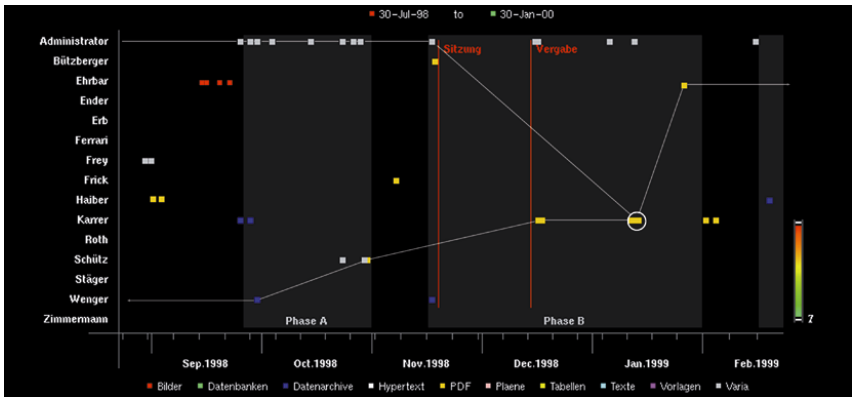

Figure 2: timeBand: The information is displayed along a time axis (x-axis) and allows different sorting possibilities along the y-axis.

Information about the content of a document (i.e. title, author, creation time, and keywords) becomes visible when the user points on a certain document. These keys can be used as filters to search for other related documents, as will be explained later. This is a common functionality provided by each of the interfaces.
The organization relative to time is very helpful when searching for specific documents, because users can often remember when a document was written or was accessed or at least recognize the preceding or successive documents. Restricting the time frame and specifying document-type or keywords can narrow the number of choices down.
The timeBand, as well as all of the following interfaces, creates overviews with different perspectives on the information stored in the document management system and allows for different ways to retrieve specific documents.

4 DocumentDisk

The documentDisk is a mapping of the hierarchical structure used in the document management system onto a planar circular hierarchy. This representation is based on the Disk Tree display developed at Xerox Parc (CC 99). It shows im-

plicit and explicit affinities among information items and reveals relationships that are difficult to discover in traditional representations. For example, proximity or connections between items can reveal complex relationships in a comprehensive way and allow the users to gain visual access to the data structure and detect tendencies or patterns in the process.

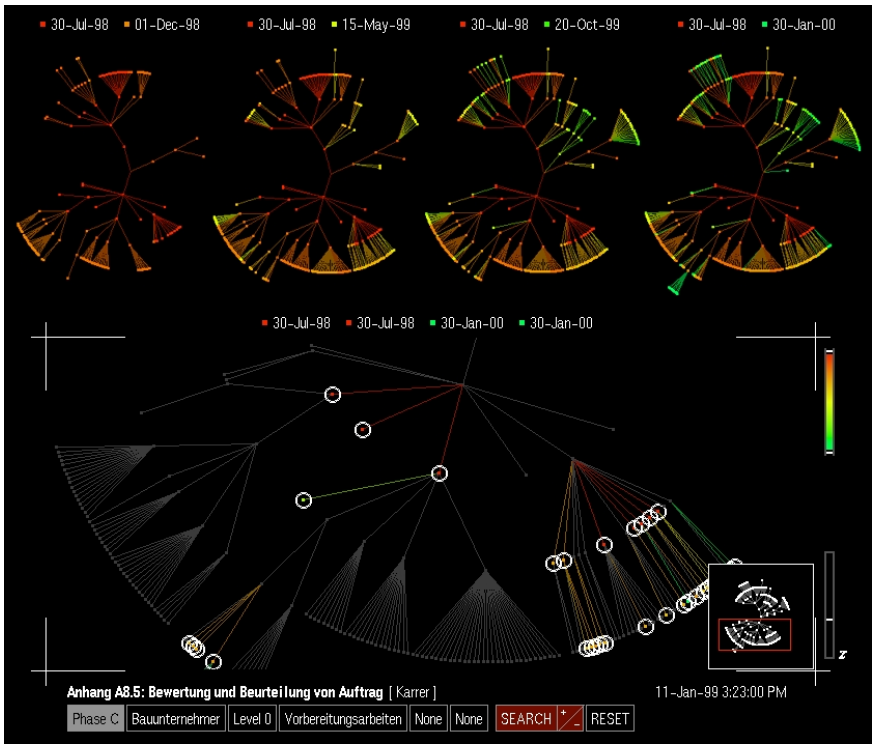

Figure 3: documentDisk, a representation that reflects the structuring of the underlying document management system enhanced with different operators for the representation, the filtering and the meta-data.

Different interaction possibilities to read, access and filter the information were added to this meta-level representation. The framework for the different operators had to be carefully planned to result in a comprehensive tool. Based on the findings in (CR 98) and the Visualization taxonomy by Chuah and Roth (CR 96), a set of operators was developed. Each of them belongs to either representation (zoom, color mapping), filtering (keyword, time, type) or meta-data (connections). These operators facilitate the intuitive use of the interface and encourage playing, experimenting, and exploring. They support the information search as well as analytical examinations of the process.

The user s ability to interpret and read the meta-information yields after a short time of use. To focus on specific aspects, zoom and filter functions help to visu-

ally differentiate them. Zooming allows for the enlarging of a part of the overall information space, refines the level of detail, enables the retrieval of a specific document, and gives access to its content. Filtering functions are provided to limit the number of represented documents, thereby reducing the amount of meta-information to browse, as for example when time filters restrict the time frame that is viewed. Another filter is provided to select documents according to a project-relevant keyword structure. By mapping further textual or numeric information onto the visualized structure or by coding the size or shape of items, additional levels of information can be introduced. For example, by using different colors or shapes, we can indicate the creation date, type or working status of a document. Items can be dyed according to their creation-date, file type or working status, so that documents in progress appear in colors that differ from those of completed or future documents. A further filtering option allows for the tracing of documents of a single author and the visualization of his or her contributions and influences regarding the whole project or a specific phase.
The documentDisk uses a less familiar layout than, for example, the timeBand. It proved to be an appropriate representation of the information space for two reasons: 1) The usual planning and construction processes create an increasing number of branches as the project proceeds, a characteristic the circular layout can more easily accommodate than traditional top-down representations of hierarchies. 2) An advantage of the circular layout lies in the fact that it gives every branch a distinct direction, thereby enhancing the mnemonic qualities of the representation.

5 KeywordDisk

The keywordDisk allows users to look at the information space on a content-related level, again using a planar, circular representation. The representation is based on an established keyword hierarchy from the building industry, a topological hierarchy that is applied to order the documents. The representation clearly positions items with equal and similar content at the same or neighboring tree branches and can indicate relations on the content level. The center of the visualization corresponds to the highest level and each node symbolizes and introduces a new keyword. According to the number of keywords connecting the center with a particular document, the content of a document is determined. By using a hierarchical keyword-structure, the same keyword can occur within the same representation at different places.
The same operators in the documentDisk regarding representation, filtering, and meta-data are available in this interface. The major difference is the visual context and consequently, the possible readings of the representation. Regarding the process analysis, this representation allows the user to easily focus on specific aspects of the project, for example the branch that deals with the construction and within this, the branch regarding the foundations of the building. The menu item show document allows for a switching between representations focused on the documents, also dying them according to document-type, creation time or status, and a representation which primarily shows the keywords.

Since the meaning of words and keywords is context-dependent, three methods for the content-based retrieval of stored documents through navigation or queries are provided. The first method is to navigate along the branches of the visual representation, while the second refers to the formulation of queries composed of special sets of keywords. The third possibility is the full text search provided by SiteScape. This permits one to filter documents relating to individual keywords as well as to search for keywords in a precisely defined context. For example, the term development can be used in several senses: Property development or in-house development. One or the other can be accessed by navigating the hierarchical structure. To retrieve documents relating to both, a query has to be formulated. To target a specific document the full text search may be the most effective one. This example shows that even though the system does not contain any functionality for semantic interpretations, it supports strategies to quickly and precisely access information regarding the content of the documents. The ease of use is supported by the visual interface that helps to differentiate, understand and apply the appropriate method.
This visualization not only facilitates searching for documents or their topics, it also gives a clear overview of actual tasks, areas of interest and documents requiring more attention.

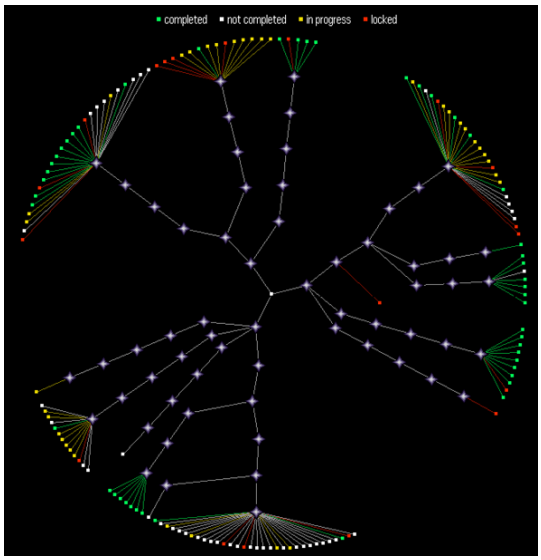

Figure 4: keywordDisk creates a diskTree according to a given keyword structure and attaches the documents to it.

6 UserDisk

The userDisk representation displays an organization diagram revealing the structure of the participating firms, employees, and responsibilities on a particular project and provides information on how to contact the members.

This representation is useful for getting an overview of the teams and participants involved in a project and to reorganize teams for different phases. Normally a person does not work on a single task; depending on his or her specialization or to what extent the company is involved, he or she can be involved in several aspects of the ongoing project. Due to this level of complexity, it is helpful to know which team a person is part of.

7 Important Common Features

All of the interfaces can be displayed simultaneously, and they are able to communicate and share information with each other in real time. This makes it possible to browse through data using different possibilities for visualization and interaction at the same time. Furthermore, it enables the comparison of single items in different representational structures. Changing the selection of documents in the keywordDisk will also affect the other representations, as they all show the same result in different kind of representations. For example by highlighting all documents of a person, it becomes possible to reveal his or her expertise on particular topics (keywordDisk), the processes and projects he or she is involved in (documentDisk and timeBand), and his or her position within the virtual organization (userDisk).

The combination of applied filters can be stored. By storing the filter and not the result, the system can always display the actual result including items that were added after the filter was generated. The saving and the possibility of sharing filters avoid the repetition of processes and support collaboration.

An important addition to the display on the screen is the possibility to generate high-resolution postscript files for printing. Printouts of the circular representations can be used like mindmaps (BB 94) as a basis for process planning and brainstorming. The printouts also provide a convenient means for exporting information from the limited display space of the screen into another means to be used in parallel with the online information.

8 VirtualOffice — An Interface to Support Communication

For a virtual enterprise, communication support is as important as a sophisticated data management system. While the interfaces to the document system support the project-related work, the virtualOffice introduces a means to enhance the appreciation of the team members for the virtual team by providing the necessary representation and information in the form of a virtual office space.

Since the members of the different teams by default work in different locations and may also be traveling while working on a project, the virtualOffice was created to provide a common space. It shows the members that are currently online and it helps users to contact on- and offline members through different means of communication. Currently, this includes email, an online message system, an instant messenger system, phone, mobile phone, and SMS (short messages via mobile phones). The phone numbers and further contact information gets automatically updated to the current location of the individual member.

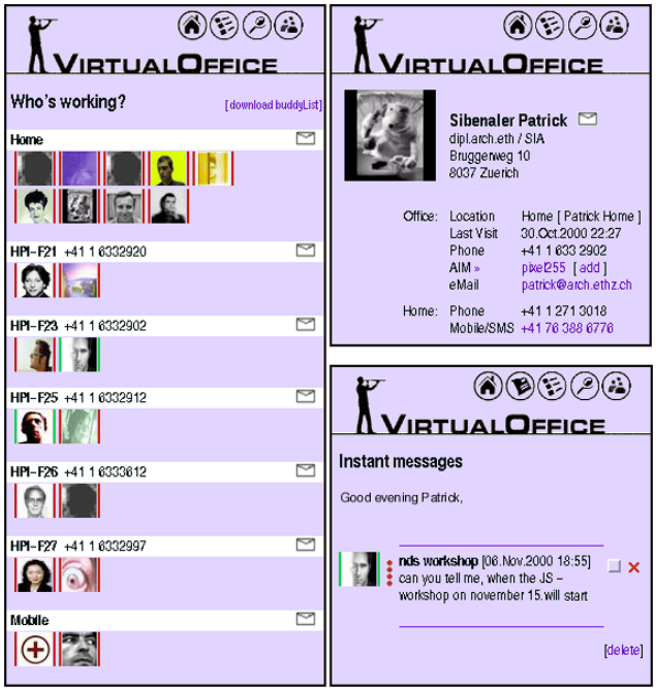

Figure 5: The virtualOffice supports different means of communication.

9 Conclusions

The original task to enhance the use of IT for virtual enterprises and to reduce IT barriers was carried out by improving commonly used document management systems with additional interfaces and data representations and by adding the virtual office. The evaluation happened in regular benchmark sessions, where six experts gave their feedback to the presentations.

The overviews and their functionality were well accepted. The experts confirmed that they enhance the understanding of the working process among different teams. In addition to the single interfaces, the parallel use of different representations, including high-resolution printouts, was appreciated. The seamless connection to the document management system and its direct accessibility offer numerous possibilities to efficiently retrieve relevant information. However, the chosen strategy does not achieve the goal of reducing IT barriers, which include: the lack of time to get familiar with new IT tools, the lack of self-confidence regarding the ability to learn to use new tools, and sometimes a lack of interest, because the currently used tools seem to work well enough. Since our interfaces require being part of a virtual team, only people who are willing to work extensively with IT will actually get to use them. Consequently the two goals set at the outset could not be achieved within the context of one project.

A few prototypical visualizations were implemented that used three or more dimensions. But these representations have to cope with the 'occlusion problem' in

readability and showed performance problems with larger amounts of data. Other developments based on dynamic hyperbolic views (LR 95) were interesting, but considering all aspects, they showed no overall advantage over the more static views generated with diskTrees. On the technical level, the major difficulty involves access to the document management system and averting security violations. In the case of SiteScape, where information is stored in a linear database, the relevant information had to be exported into a relational database.
The virtualOffice, which on the one hand offers the feeling of a being part of a team, on the other hand also creates the feeling of being observed. We tested the virtualOffice for several months at our institute allowing the researchers to work wherever and whenever they choose. While some people were always visible in the virtualOffice, others did not get into the habit or deliberately avoided logging in to the virtualOffice. Those that need or like to communicate frequently with others tended to be good users of the virtualOffice.
Next goals are the further tightening of the connections between the interfaces and enhancing the consistency of use. In the virtualOffice, the possibility to distinguish different groups of peoples will be implemented. Then we will focus on interfaces that better support the decision making process and the integration of planning and workflow tools. The research will stay focussed on interfaces and representations that wrap around available tools to show meta-information.

10 Thanks

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