

Facilitating Orientation in Shared Hypermedia Workspaces

Jörg M. Haake

GMD – German National Research Center for Information Technology
Integrated Publication and Information Systems Institute (IPSI)

Dolivostr. 15, D-64293 Darmstadt, Germany

haake@ darmstadt.gmd.de

ABSTRACT

Shared workspaces are an important means for supporting long-term synchronous and asynchronous collaboration. Shared workspaces themselves become difficult to manage due to increasing size and constant change. This is especially true for shared hypermedia workspaces. Thus means for managing the shared hypermedia workspace in terms of keeping an overview of the group's work and coordinating changes become necessary.

In this paper we propose a shared hypermedia workspace model representing not only shared content but also team and process related information. Four complementary tools facilitate orientation and coordination in the shared workspace: a group aware content browser, a group aware overview browser, a shared workspace search tool, and a shared process space browser. Together, these tools should enable groups to stay aware of each other's activities and to control the level of awareness according to their needs.

Keywords

Awareness, Coordination, Shared Hypermedia Workspace, Cooperative Work, Orientation, Collaboration Support

INTRODUCTION

Long-term group work requires some form of shared workspace to facilitate consistent storage of artifacts (e.g. interim and final results of work), joint work, coordination and certain forms of communication between group members. However, shared workspaces themselves become difficult to manage due to increasing size and constant change by many group members. This is especially true in collaborative hypermedia workspaces. On the one hand hypertext concepts such as typed composites and links can express organization of the workspace and reuse of information objects. On the other hand extensive hypertext linking may add to the confusion of the users. Thus means for managing the shared workspace in terms of keeping an overview of the group's work and coordinating changes become necessary. The problem of orientation in shared

hypermedia workspaces has become more important since a growing number of systems supporting shared hypermedia workspaces have become available (examples are BSCW [1], Interlocus [20], and the shared workspace provided by the PoliTeam project [22]).

The situation in collaborative hypermedia workspaces can be characterized by the existence of a common task, by a corresponding hypermedia structure of the workspace (dependant on the domain and collaboration style), by the users and teams (and their respective goals), and by the processes/activities performed by the users.

A common problem is that the dynamic change of the workspace, due to multiple parties interacting with the workspace, makes it difficult to understand the ongoing changes, to coordinate activities with each other, and to recognize conflicts and opportunities for synergy. Thus, each individual group member usually contributes to the group work without knowing all the consequences of their changes on the overall group work and much time is spent on retaining at least a partial overview of the group work. As Mark [17] pointed out, different group member's experiences, practices, and views on the shared workspace create conflict and require extra effort for coordination. For collaborative hypermedia, Mark et al. [16] found that people tend to divide up their labor, thus making awareness even more critical.

Previous work focused either on providing means for coordination or on supporting overviews. Approaches to coordination in shared workspaces include the provision of group awareness, intra- and inter group conventions [17], documentation of previous states (as in versioning systems, or using log files such as in NoteCards [30]), process support (such as shared plans or WFM) or communication support. Means for retaining overviews include fisheye views, flexible Diff-ing [19] or shared task lists. However, previous approaches do not address all the requirements of supporting overviews in shared workspaces.

The objective of this paper is to introduce an approach that solves the above problem by integrating tools for the different aspects. This approach combines (1) a shared awareness approach in the shared workspace with (2) a shared workspace search tool, (3) a group aware overview browser and (4) a shared process space. The resulting system is designed to support groups in planned and ad-hoc

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coordination by easing the tasks of learning about previous changes in the workspace, its current state and ongoing or future activities.

The remainder of the paper is organized as follows: The next section analyzes the problem of providing overviews and facilitating coordination in shared workspaces, followed by a section on related work. Then our approach is presented and the design of the shared workspace as well as the design of the tools are discussed. Finally, implementation issues are briefly discussed. The paper concludes with a summary, comparison to related work, first observations of use, and plans for future work.

PROBLEM ANALYSIS

In this paper, we use the term “shared global workspace” to denote a workspace which consists of an arbitrary hypermedia structure, and which is used by multiple teams or users to facilitate asynchronous and synchronous collaboration. Not all hypermedia objects in such a shared global workspace are in use all the time. Generally, the users may use parts of the shared global workspace as shared local sub workspaces. A shared local workspace can be used for supporting either synchronous collaboration (i.e. a shared workspace offering synchronous sharing of objects and views) or asynchronous collaboration (i.e. only one user works on the objects in the local workspace and other users will access the results only later).

Work in a shared global workspace can be viewed as a sequence of state transitions over time. Each state describes the current properties of the shared global workspace such as the individual states of nodes and links (e.g. information objects, documents and their relationships) contained in the workspace, and where users are currently working. State transitions are triggered by actions performed by the users of the shared global workspace (such as modifying content of nodes or adding links). In addition, state transitions can also be triggered by time-dependent actions (such as reaching a deadline). In order to orient themselves in such a shared global workspace, which is used over a longer period of time, users need to find out about the past, present and future of the workspace:

1. Comprehending the past (history) of the shared global workspace requires understanding the current state of the global workspace (in terms of structure and content) and understanding the changes and sometimes also why and when and by whom they occurred.
2. To be able to coordinate activities with others one must be able to assess the present, i.e. the current state of the shared global workspace (who is doing what right now).
3. To be able to recognize conflicts and opportunities for synergy requires being able to make informed decisions about the future, i.e. what to do next. This requires knowledge about current tasks to be performed in the group and about relevant parts of the shared global workspace.

Answers to these three groups of issues need to take into account the dynamic nature of cooperative work in a shared global workspace. Tasks and plans might change or even evolve in the course of collaborative work, and opportunities for synergy and conflict usually develop unplanned and in unforeseeable ways.

Also, not all aspects are equally important to users all the time. When making a decision about which task to work on next, users need knowledge about the current state (in terms of who is currently working on which tasks) and about the planned tasks for the future. However, when working on a task, users are more likely to need knowledge about people working on tasks or objects “relevant” to their own work. Thus, they may need a different kind of overview of the shared global workspace than they would need for working on a new task. This general problem can be considered to be a problem of dealing with information overload.

One way of supporting overviews in a shared workspace is to provide “awareness” to its users. Endsley [5] defined awareness as “knowing what is going on”. In general, awareness can take many forms, e.g.: group awareness [4] as a means to communicate presence and activities of collaborators using shared tools, and workspace awareness [8] as up-to-the-moment understanding of another person’s interaction in a shared workspace. In this paper, we use the term awareness to denote the understanding of other people’s interaction in a shared global workspace (thus, including shared local sub workspaces). Thus, awareness is concerned with past, present, and future activities of people on objects in the shared workspace. It includes forms of group awareness provided by shared tools operating on the shared workspace as well as forms of workspace awareness provided by a shared local workspace used by a team solving a task. Thus, the future of the workspace is covered by our definition as well.

Scope/time	past	present	future
One active node	versions	group awareness	related tasks
Multiple active nodes	Versions of active nodes	Group awareness for each active node	Tasks related to active nodes
Sub area of global workspace	Past states of sub area	Structure of and activities in sub area	Tasks related to sub area
Entire global workspace	Past states of entire workspace	Structure of and activities in entire global workspace	Tasks related to entire workspace

Table 1: Examples of awareness information over scope and time

We propose to distinguish between two scopes of awareness in a shared global workspace: local vs. global awareness. Table 1 shows different types of information related to awareness over time and space. Local awareness for a user is tied to the shared local sub workspace (i.e. the current node(s) of the shared global workspace where this

user is currently working). It deals with the content objects, the task and the sub group currently working together. Here, a shared awareness approach is appropriate, which shows local presence and activities by, e.g., user lists, activity markers, telepointers, and WYSIWIS [29] views. On the other end of the awareness spectrum resides global awareness. Here, we are concerned with the overall development of the shared global workspace. Thus, issues like understanding the past of the whole shared global workspace, like getting an overview about its current state, and like understanding what the planned next steps are, are relevant. Approaches to facilitate global awareness include, e.g., radar views and task lists. In table 1, we would call systems showing only awareness information of the first two rows "local awareness systems". Tools also showing awareness information of the latter two rows we would call "global awareness systems". Overall we can say that addressing all three issues of orientation in shared global workspaces seems to require combinations of local and global awareness.

In the next section we analyze previous approaches, which can aid users with respect to the above issues.

RELATED WORK

Coordination in shared global workspaces is a known problem in the CSCW area. Previous approaches include

- provision of group awareness in shared workspaces,
- provision of direct communication channels between collaborators (e.g. notifications, messaging services, informal communication via computer-supported conferences), and
- provision of explicit process support (e.g. workflow management, task-based versioning).

Group awareness [4] facilitates the assessment of the present state (who is doing what) in a shared workspace. It is usually a concept that is applied to shared local sub workspaces in order to help synchronously cooperating users to coordinate their activities. It also supports - to some degree - making informed decisions about what to do next (based on knowledge about who is working in which part of the shared local workspace, thus showing some opportunities for synergy or conflict). However, it does not support finding out about the past, and it does not explicitly address current tasks and plans of the group. Most systems in this area provide what we called local awareness. Examples are applications implemented in GroupKit [24] and Suite [3] as well as SEPIA [28], DOLPHIN [27], TeamRooms [23], and ShrEdit [15]. These examples used user lists, activity markers, shared views, and telepointers. Some other systems also provided tools for global awareness. Examples include task lists as in CoAUTHOR [13] or workflow management systems, radar views as in SEPIA, or history logs as in NoteCards [30]. BSCW [1] provides workspace awareness through a user presence and activity monitor since version 3.2. This tool shows the presence of participating users in the workspace. It also

facilitates communication among users. In addition, BSCW provides access control, simple versioning of documents in a workspace, and asynchronous workspace reports. ORBIT [18] organizes a shared workspace using the locales concept (as a means to communicate tailored awareness) and supports global awareness on other locales through a "navigator". The RICH system provided hierarchical view filters as a means for searching hypermedia networks for content and change related predicates [31]. However, RICH does not support search for collaboration related predicates. Another interesting approach is to provide activity awareness between different individual workspaces as in the Interlocus system [20]. Here, notifications and awareness functions provide asynchronous workspace awareness. However, synchronous awareness and assessment of future activities are not supported. Finally, GroupDesk [6] provides presence awareness and activity awareness in a shared workspace. It uses the concepts of work situation and interest context to distribute events in the shared workspace.

Direct communication channels may be used to provide some group awareness (e.g. informing collaborators about ongoing activities via notifications) and may also help to assess the current state and potentials for synergy and conflict. An example is NSTP [2], which provides an infrastructure e.g. to share meta-information about a shared workspace. Here, workspace structure and content are described as places, things, and facades, to enable sharing and navigation in the shared workspace. However, NSTP itself does not offer awareness functions to applications. Using informal communication collaborators may determine which tasks or parts of the document they should work on next. However, assessment of past changes and finding out about parts of the shared global workspace relevant to the task at hand is not supported.

Explicit process support such as WFM type systems (e.g. GroupDesk [6]) and task-based versioning (e.g. CoVER [11]) facilitate informed decisions about the future (based on currently active tasks, or tasks to be activated next). Also, the past can be assessed (in terms of activities finished or active, their states, and the respective versions of the shared global workspace). However, these systems require detailed planning in advance and usually cannot deal very well with frequent changes and emerging structures. In addition, finding out about relevant parts of the shared global workspace, which were not initially modeled as part of the process structure, is not supported. Also, these systems largely focus on asynchronous collaboration (with the exception of versionedSEPIA [10]).

As a result of this analysis we can state that previous approaches do not address all the requirements for orientation in shared global hypermedia workspaces.

APPROACH

In order to overcome the above deficits we propose to provide a shared global hypermedia workspace representing all aspects of group work, which are relevant

to facilitating orientation and coordination (i.e. content of work, tasks, and organizational aspects). On this shared hypermedia workspace four tools are provided, which facilitate orientation in the shared workspace:

- a group aware editor to access the shared local workspace. A shared awareness approach supports assessing the present and coordinating with other users in the same local area of the shared global workspace,
- a group aware overview browser to get an overview about the current state (of the structure of the shared global workspace, and where people are working),
- a group aware search tool helping to find relevant parts of the shared global workspace, and
- a shared process browser helping to assess the past and helping to make informed decisions about the future of the shared global workspace.

In the following sub sections we present first the shared hypermedia workspace and then discuss the four tools.

Design of the shared global hypermedia workspace

In our approach, collaborative hypermedia structures are used to model all aspects of the shared global workspace. The collaborative hypermedia concept extends the hypertext concept with multimedia and collaboration. The hypertext concept distinguishes information components (nodes) that are connected by relationships (links) [21]. Using links, linear as well as nonlinear network structures can be formed. In addition to the basic notion of nodes and links, one can introduce types of nodes and types of links. These types can be used to capture application or domain semantics, e.g., by determining allowed types of nodes as link end points of specific types of links. In addition to simple nodes, many hypertext systems introduced composite nodes (composites) that contain other nodes and links. Thus, they can be used to form aggregated subnets within the hyperdocument which lead to the possibility of layered graphs or networks. A hyperdocument denotes the collection of all nodes and links that constitute the document (i.e., it can be modeled by a top-level composite). Hypermedia extends the hypertext concept by allowing any kind of multimedia information to be the content of nodes. Collaborative hypermedia now adds to the hypermedia concept the possibility of sharing a hypermedia workspace among many people. In a collaborative hypermedia system the hypermedia document can play two roles: 1) to provide a representation of the content and subject matter, and 2) to provide a medium for cooperation and coordination in cooperative work [26].

Our workspaces use a labeled graph representation, which can be seen as a semantic network. Using a meta-model for shared workspaces, cooperative hypermedia-based workspaces for a wide range of tasks can be defined. The elements of the meta-model are nodes, links, node content pages, and other media objects. Figure 1 shows an example workspace structure. Each node has a content page which may contain media objects (such as text, graphics,

scribbles), nodes and links. Thus, a page is a composite. The name of the node that contains this page is used as the title of the page. The shade under a page indicates that there is a (potentially different) page type for each page. In this meta-model, a workspace is represented as a nested node structure (i.e., a composite node). Its root page type determines the type of a workspace. The substructures (sub workspaces) of a workspace are defined by the page types of the nodes at each level of the nested node structure (see Figure 1). In a structure consisting of nested nodes, an existing page type can be used recursively when the node contents at different levels are of the same type. A 'page' is also an interface metaphor for presenting a workspace.

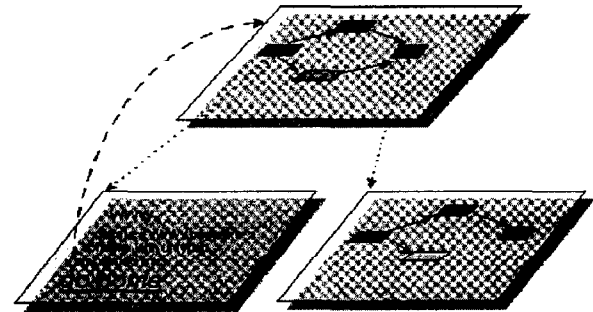


Figure 1: Logical Structure of a Workspace

Links and nodes as well as pages and other multimedia objects can be further classified into *semantic types*. For instance, 'issue' and 'position' are two semantic types of nodes, and 'answers' is a semantic link type connecting instances of the former two. A page type is determined by the set of object types (i.e. node, link, and other media object types) that are allowed in this page type. For example, a page type 'argumentation' is defined by defining the semantic object types allowed in the page type as 'issue', 'position' and 'answers'.

The above hypermedia workspace model is the basis for our shared hypermedia global workspace. Figure 2 shows the three main components of the shared global workspace:

- Content structure,
- Team structure, and
- Process structure.

The content structure models the content of the shared global workspace (i.e. the artifacts and their relationships) using typed hypermedia nodes (atomic and composite nodes) and hypermedia links. Different node and link types are supported, which can be used to express domain semantics as well as constraints. Using an extensible type system ensures that emerging task-oriented structures can be supported. For more details see [12].

The team structure models users and teams working in the shared global workspace using again hypermedia objects and representing relationships between users, teams and artifacts using typed hypermedia links. Examples for such relationships are teams being composed of users, users owning pages, and teams working on pages. This dual use of hypermedia supports simple editing and browsing of organizational as well as content structures in the global

workspace. Note that content and team structures are connected via relationships (such as, a user owns a node). These relationships can be represented as links.

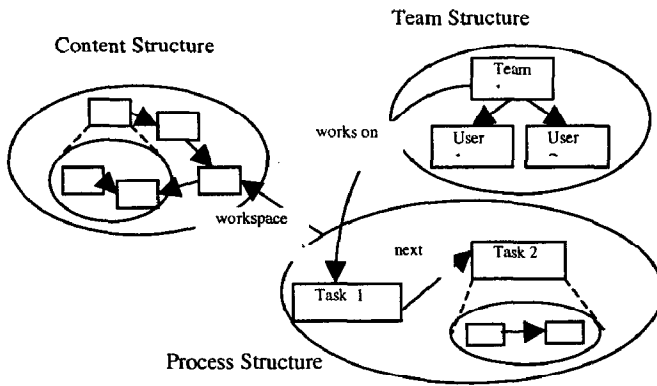


Figure 2: Example components of the shared workspace

The process structure models tasks and activities performed in the shared global workspace. It uses nested hypermedia nodes (of type “task”) and represents dependencies (such as temporal order, control flow and data flow among tasks) between them using hypermedia links. Again, the process structure is connected with the content structure (e.g. a task uses a node as its work area) and the team structure (e.g. a task is performed by a team or a user).

In our approach we assume that the shared global workspace is in principle available to all group members all of the time. This requires means for synchronous access to the shared global hypermedia workspace such as, e.g., implemented in the DOLPHIN [27] and the CHIPS [12] system. However, since group members may join and leave the workspace asynchronous work can also be supported.

Since all three aspects of the shared global workspace (its content, its users, the way it is used) are represented in the shared hypermedia workspace, tools can be provided that exploit the joint data model to facilitate orientation and coordination. In the following four subsections, the design of such tools is discussed in more detail.

Design of the group aware editor

The primary tool for accessing and working in the shared global workspace is the cooperative editor. Each instance of the cooperative editor tool displays a page contained in the shared workspace (i.e. this page is a local workspace). To aid coordination at the detailed work level, local group awareness is provided in the editor. This is done by four means: Firstly, showing the list of concurrent users of this page (see the user list in Figure 3). Secondly, the editor indicates where in this page these users are currently working (e.g., by showing selections). Thirdly, activity markers (the label “Hans” on the node titled “administration” in Figure 3) are used to display who is working on constituent objects of the page (i.e. on nodes at the next level). This can be regarded as a form of more global awareness. Fourthly, the collaborators can use telepointers.

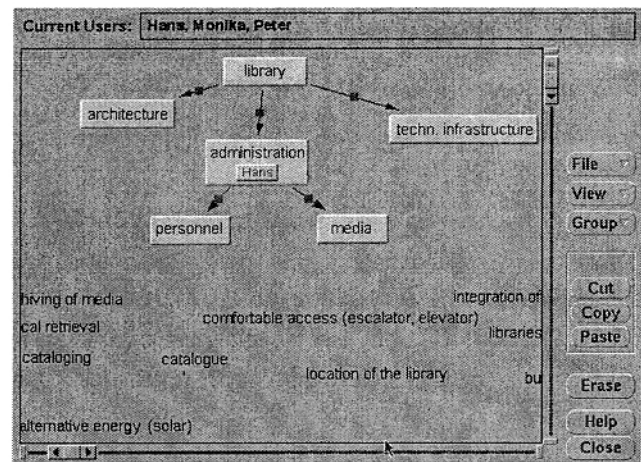


Fig. 3: Cooperative Editor Tool

The editor supports three modes of cooperative work [9]:

- Used in tightly-coupled mode (as a public group editor) strict WYSIWIS [29] is provided in the editor window. Scrolling, navigation and manipulation of content in the current page are strictly synchronized;
- Used in loosely-coupled mode (as an individual but still shared editor) relaxed WYSIWIS is provided. Scrolling and navigational actions are independent from other users' actions in the same page. However, manipulations of the current page are still shared and local group awareness is provided;
- When working alone on a page all changes of this local sub workspace are still made persistent in the shared global workspace. However, since no other user currently accesses the same page at that time, individual work is possible.

Session management in the shared global workspace facilitates proper transitions between these situations. If a user navigates in the editor to a page already in use by others (i.e. that user enters a local workspace of another user or group), the new editor joins the session of the other users. Then it switches from individual to loosely-coupled mode or tightly-coupled mode (depending on the cooperation mode defined in the session).

When navigating the shared global workspace by following links from the current page to other pages of the shared global workspace the editor will first remove the current user from the user list of the last page. Then, it will add the current user to the user list of the destination page and display the destination page. By accessing the respective user objects and properties of the objects in the shared global workspace the cooperative editor ensures proper display of local group awareness in the current page.

Using this approach, group aware editors can provide local group awareness and thus aid coordination in the current local sub workspace. However, no global group awareness is provided (i.e. it is still unclear what is going on in other parts of the shared global workspace), and no indications of past developments, currently active tasks, or future tasks

are given. Of course, users may use several editors in parallel. However, since screen space is scarce the number of parallel editors is limited. So is the global awareness.

Design of the group aware overview browser

Group awareness in the cooperative editor is limited to the currently displayed page and time. Information about work in other parts of the shared global workspace is not available. To fill this gap the Navigation tool is introduced.

The Navigation tool provides an overview about the entire content structure of the shared global workspace. In principle, two options exist for displaying the overall content structure:

- Graphical fisheye views [7] display the overall structure with diminishing detail (dependent on the distance from the center of the display or from the current position). Here, the problem is that large structures require a relatively large amount of space and also a deterministic mechanism for producing automatic layout is needed.
- Indented text views such as those known from the TOC mode in Word processors display the overall structure as a hierarchy. Here, each section of the workspace is represented by a title, and the indentation represents the level in the document structure. This approach requires a hierarchical non-cyclic structure and produces a relatively compact layout.

Since shared global workspaces may grow fast and page titles may be a primary means for understanding global workspace structure and content, we decided to use the indented text view approach (see Figure 4).

Our hypermedia structures can be described as a rooted directed graph consisting of networked pages, which have a title and which contain both atomic content objects and links to other pages. We apply a cycle-breaking traversal algorithm that computes a depth-first order tree structure from the original graph. This tree structure can then be displayed in an indented text view. Each page is listed with its title under its parent node. Each page is expanded only once (i.e. the first time a page is encountered its content is traversed and displayed, too). Every later reference to that page is not further expanded. To facilitate different browsing strategies different filters or display styles can be used: displaying the hierarchy according to depth-first order, or according to alphabetical order of the page titles.

In addition to the structural information, the Navigation tool also displays global group awareness information: after each page title, the Navigation tool shows the list of the names of the current users. In figure 4, listing “(GROUP)” after the “Top Page” indicates that a tightly-coupled editor to the whole group displays the top page of the global workspace. The pages entitled “Microfilm” and “Videos and cassettes” are currently displayed in individual mode for user “Christian”. Page “ftp-archives” is open in loosely-coupled mode and shared by users “Norbert” and “Joerg”. Optionally, the “GROUP” label can

be expanded into a list of group member’s names. Thus, the identity of users and the cooperative mode the users are working in are encoded in the display. Optionally, the tasks which the users of pages are currently executing can be displayed (see sub section on process support). The Navigation Tool supports different kinds of views: The button ‘History’ causes the browser to display the navigation history of the user. The buttons ‘All Pages (Alphabetical)’ and ‘All Pages (Hierarchical)’ cause the browser to display the entire structure but listed according to alphabetical order of page titles or to hierarchical structure, respectively. Finally, the button ‘Pages Referencing this Page’ causes the browser to display only those pages that contain the selected page.

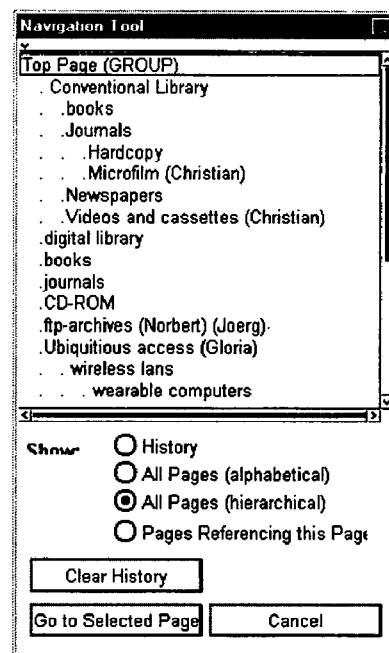


Fig 4: Navigation tool

Using the Navigation tool users can get an overview of the entire structure of a shared global workspace (assuming page titles are a meaningful description of page content). They also get information about who works in which page at this time. Filters allow restrictions on what global group awareness information is needed and to what part (e.g. sub structure) the visualization should be constrained. Furthermore, by folding and unfolding sub structures on demand, and by initially only presenting unfolded sub structures up to the nodes where people actually work, the size of the displayed structures can be lowered. Thus, information overload [14] can be limited. However, in this tool detailed local group awareness can not be provided, nor can the user get an overview about the process structure or about past developments of the shared workspace. Furthermore, it is not possible to easily identify those parts of the shared global workspace that are relevant to a task at hand (beyond those sub parts already included in a page associated as a local workspace to this task).

Design of the shared workspace search tool

Finding relevant pages in the shared global workspace can be done in several ways:

1. *Browsing the shared global workspace:* using the cooperative editor users can browse the content of the shared global workspace. Using the Navigation tool users can browse the current state of the global workspace structure and the state of current cooperation. However, if the structure is huge, this does not seem to be a feasible choice.
2. *Observing changes in the shared global workspace:* Similar to a search, the system might observe the users' actions and instantly build up an index of concepts. Now, when a user is working in a local workspace the system can find and display links to pages matching the user's current activity in the shared global workspace. The user can then decide whether to look at the proposed pages. If there are still collaborators working on the target pages (and the system might display this awareness information easily), the system might also help to establish mutual communication and collaboration.
3. *Searching the shared global workspace:* it is useful to be able to search for relevant parts of the shared global workspace thereby also dealing with large structures.

Fig. 5: Shared workspace search tool

In our work, we first focused on the search approach. Criteria for relevance might include:

- *content-related criteria:* e.g., page title or page content matching a query, structural queries
- *team-related criteria:* e.g., pages worked on by members of team X or by a specific user
- *cooperation state related criteria:* e.g., pages being used in a specific cooperation mode or by groups of a certain size
- *task-related criteria:* e.g., tasks currently active, active tasks worked on by specific teams or users, pages being used as the local workspace of a specific task
- *change-related criteria:* e.g. pages that were changed at all, changed during a specific time interval, changed by specific teams or users

Since all the required information is present in the shared global workspace representation we implemented a shared workspace search tool (see Figure 5) that allows specification of above predicates. Here, all predicates are combined using logical AND. The resulting query is then performed on the shared global workspace and the matching objects are displayed in the Navigation tool window. From there, the user can further browse the shared global workspace. Optionally, the query result can be stored as content of a new page.

Using the search tool users can directly find parts of the shared global workspace matching their query. In addition to the usual content-related predicates, cooperation-related predicates are now also possible. The combination with the Navigation tool for displaying search results supports exploration of search results via the standard user interface. However, still no information about past developments and future tasks is available.

Design of the shared process space

The final component of the shared global workspace is the process structure. As has been shown in the CHIPS project [12], hypermedia structures can be used to represent process structures in terms of nested task nodes and process links. Task nodes contain descriptions of the work to be done (including further task nodes to specify sub tasks) as well as references to the shared local workspace (containing nodes and links) to be worked on. They can also be used to specify actors, roles and access permissions. To support enactment of process structures computations are attached to task nodes and process links. By enactment we mean computer-supported execution of tasks (e.g. where the computer supports the flow of control and data between tasks). For details on the process modeling see [12]. Our cooperative process space browser exploits these features. Essentially, this tool is a cooperative editor, which displays (a part of) the process structure contained in a shared global workspace. The cooperative process space browser can be used in two modes: First, when using it in non-enacted mode the user can browse the process structure, modify it (if permitted), and activate tasks ready for enactment. Second, when used in enacted mode, an interpreter determines the tasks already running or ready for enactment. The user can then choose which task to join or to activate. The browser can then be used to open the shared local sub workspace of the selected task.

Using the process space browser users can browse the task structure and get an overview about the overall state of work (e.g. which tasks have been finished, which are ongoing, and which are still to be done) as well as about currently active and future tasks. Thus, informed decisions about which tasks to open or join become possible. Furthermore, the process space itself provides global group awareness information (who works on which sub task is shown using activity markers; further global awareness can be obtained via the Navigation tool). When finishing a task

its state is frozen (i.e. all objects in this task are protected against further change). By opening finished tasks historical development of the shared global workspace may be understood. However, at the moment no information about the detailed historical development is captured. Here, versioning support could be integrated. Based on our experiences with versioning support in shared workspaces (such as in the versioned SEPIA system [10] and in VERSE [11]) this seems worthwhile to pursue.

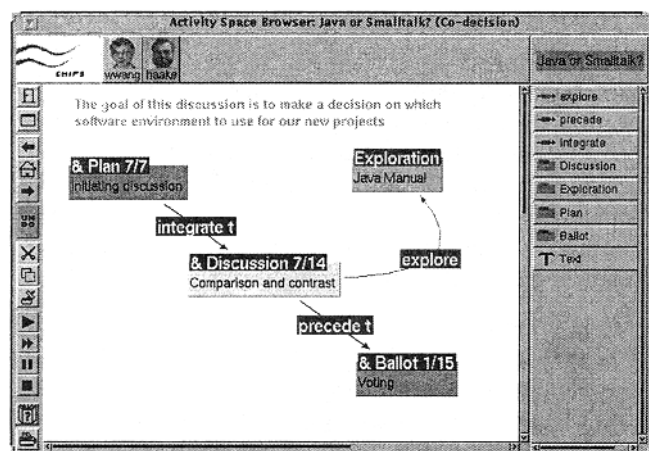


Figure 6: Cooperative process space browser

IMPLEMENTATION

Our prototype system is based on the COAST toolkit [25] and uses a replicated architecture (see figure 7). The shared workspace is stored in a database accessed via a multi-user backend storage server. It is represented as global objects, which are replicated at all sites (i.e. each tool or suite of tools at a client's host works on a local replica of the shared workspace). Mediators provide session management services, maintain consistency of replicas and ensure persistency of global object changes for specific pages.

In figure 7, two users work on the same shared global workspace in two sessions. User 1 works alone using cooperative tool 1 on the page provided by mediator 1. Both users work together on another page in session 2 served by mediator 2 using tools 2 and 3.

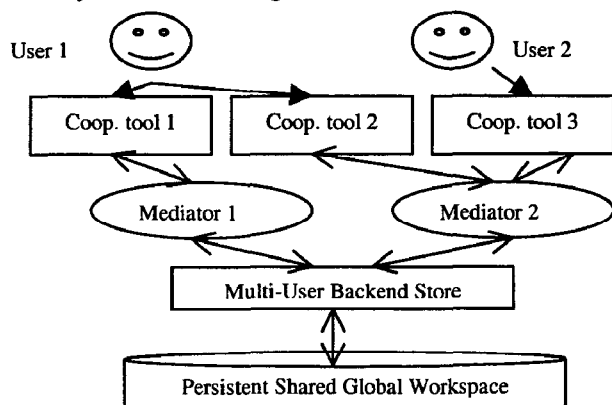


Fig. 7: Architecture of the shared global workspace

So far, cooperative editors, cooperative process browsers and the Navigation tool have been implemented and are in use in our group and at selected test sites outside our

group. The implementation of the search tool is finished but deployment has so far been constrained to the group. Our experiences with the current prototype are reported in the next section.

CONCLUSIONS

In this paper we analyzed the problem of facilitating orientation and coordination in shared workspaces. Our approach combines (1) a shared awareness approach in the shared workspace with (2) a group aware overview browser and (3) a shared workspace search tool and (4) a shared process space. A prototype system has been implemented and is used.

Scope/time	past	present	future
One active node	Process browser showing results of finished tasks	group awareness in editors	Process browser showing related tasks
Multiple active nodes	Process browser showing results of finished tasks	Group awareness in each editor of active nodes	Process browser showing tasks related to active nodes
Sub area of global workspace	Process browser showing results of finished tasks belonging to sub area; search tool	overview browser on sub area shows structure and activities; search tool	Process browser showing tasks belonging to sub area; search tool
Entire global workspace	Process browser showing results of finished tasks belonging to entire workspace; search tool	Overview browser shows structure of and activities in entire global workspace; search tool	Process browser shows tasks related to entire workspace; search tool

Table 2: Provision of awareness information over scope and time by proposed tools

As shown in table 2 the tools provided by our approach provide local and global group awareness for all situations. By selecting and configuring the right tools users can get an overview of past, present, and future of the shared hypermedia workspace.

Early observations

Using earlier versions of SEPIA [9, 10, 28], DOLPHIN [27] and CHIPS [12] revealed several problems with shared global workspaces. In SEPIA, radar view-like overviews and shared awareness in the editors were sufficient to support awareness of ongoing work in global workspaces of limited size. To support long-term collaboration versioning capabilities and extended awareness features were added in the versioned SEPIA system [10]. However, even in that system overviews had to be navigated step by step, and search functions were missing. Also, task support had to be operated manually (i.e. no enactment feature). Although versioned SEPIA and the versioned DOLPHIN prototype made change tracking and merging of parallel work easier, our observations indicated problems when unplanned dependencies arose, and the amount of work required to feel oriented enough were considered high. The new search tool addresses this problem. Switching between process view and content view seems to work fine in CHIPS.

Our approach combines automatic provision of group awareness (e.g. by the cooperative browsers, by the Navigation tool) with awareness information demanded by the users (e.g. by opening the search tool, the Navigation tool, and the task browser). This way, users are still in control and can select the required awareness information (avoiding overload with awareness information).

Using hypermedia to structure the shared workspace facilitates the construction of a common workspace as well as the maintenance of private or sub workspaces. In the current system, these private workspaces have to be manually constructed. However, linking supports the reuse of material as well as integration of individual results into the larger workspace. Orientation in the hypermedia structure does not require perfect knowledge of the workspace structure (at least, not more knowledge is required than when using a shared file system as a persistent group workspace). Rather, users can browse and explore an evolving workspace as well as search for interesting places and situations, or identify and access relevant tasks.

Overall, the proposed combination of tools seems to facilitate orientation and coordination at least in small groups. Using hypermedia for both representing and presenting workspaces simplified the user interface problem, since we could reuse cooperative editors for displaying and manipulating shared workspaces.

Comparison to related work

Previous approaches addressed only some of the issues which arise when dealing with overviews and coordination in shared workspaces. Group awareness approaches are usually limited to local awareness and to the current situation. Compared to Interlocus our approach also supports synchronous awareness and cooperative work. Similar to the awareness views in Interlocus our search tool can be used to find out about interesting changes in the past. However, our search tool also supports access to other information (e.g., tasks, which are missing in Interlocus). Current support in BSCW is likewise limited: no task structure is supported, and global awareness is limited to individual workspaces and participating users (who also run the activity monitor). Furthermore, using BSCW in its basic form delivers only asynchronous workspace awareness. The focus of GroupDesk is on awareness of past and present situations, while individual overviews (which could be constructed using our search tool) are not supported.

Process support provides information about the past and planned activities. However, they cannot deal very well with opportunities for synergy since they require the predefinition of process structure and they do not therefore help to identify new relevant parts of the workspace. The search tool and the provision of group awareness in the cooperative process browser address this problem. We believe that automatic observations of the shared global workspace and appropriately notifying users about

matching work could further help to solve this problem. Communication approaches neglect the past and also the problem of finding relevant parts of the workspace. The approach proposed in this paper addresses all three aspects by combining different approaches in a new way. Its value originates not only from the provision of the individual tools but also from the way they are integrated via the shared global workspace data model and the use of a common user interface.

Future work

Although we tested our approach in our own proprietary system we believe that the principles can be applied to any shared global workspace that provides synchronous access and hypermedia structures. We are planning a Web-based version of our tools to allow easier distribution and tests with larger user communities. We are especially interested in usage aspects of the proposed approach, in particular in the cognitive effects on users. Other lines of research concern the integration of versioning support into the shared global workspace and the development and testing of automatic observers that help users to find relevant work and collaborators in the shared global workspace.

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