TeamSpace: An Environment for Team Articulation Work and Virtual Meetings

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Abstract: *We present TeamSpace, a collaborative workspace system to support the articulation work of high performance development teams. TeamSpace distinguishes between individual, social, and meeting work modes, and facilitates transitions between modes. The system provides a shared workspace that supports understanding and reporting the team's past progress and activities. Awareness of current team activities is supported by a place-based representation of team members' work modes and by a multimedia awareness and communication tool facilitating intentional and serendipitous interactions.*

1. Coordinating Teamwork

Teamwork is a vital and ubiquitous element of the workplace. The importance of teamwork is especially evident in the development of complex systems such as aircraft and other aerospace systems. Each member of a development team is selected for the specialized knowledge and skills they contribute, and the team's success depends on coordination of their unique contributions [11].

High performance teams coordinate their work through awareness of each other's activities, coupled with timely communication and information sharing. Time critical work may demand continuous awareness of all team activities. In professional basketball, for example, players continuously monitor the position of the ball and all other players. Development work progresses at a much slower pace, accommodating intervals of solitary work and far less attention to each other's activities. Development teams generally achieve adequate awareness easily when they are collocated at adjacent desks, cubicles, or offices. If this arrangement fails, teams may all move to a war room where they maintain heightened awareness while tackling hard problems and getting their development work back on track [2].

These comfortable work modes require physically collocating all team members, which is often impractical or expensive. Large development projects generally include people from different companies, different countries, and even different continents. Teamwork can no longer be neatly compartmentalized into a single place or time, and both the geographic distances and time zone differences complicate coordination. In response, teams devote more resources to coordinating their work, substituting structure for mutual awareness.

We are investigating how technology can enable teams to work together more effectively across time and distance. Our objective is to support team coordination, not their specific development tasks. Our hypothesis is that teams can work together effectively with less effort if they are aware of their colleagues' activities and progress and can easily communicate with one another.

This paper describes a framework and prototype called TeamSpace developed to support geographically distributed teamwork. The next section describes key aspects of teamwork that TeamSpace is intended to support. Then we present the technology framework and a prototype based on this framework. We conclude by comparing this framework with other approaches.

2. Requirements for Team Environments

As part of a long-term research project, we have conducted observational studies and interviews over several years of teams developing large complex systems [11]. The teams spent the majority of their work time performing articulation work (see [12]) to coordinate their work with the contributions of other team members.

Their articulation work has formal and informal aspects. Every team produces and maintains a formal information collection that describes their work and its progress. It includes a statement of work, a work breakdown structure, schedules, status reports, specifications, designs, analyses, action items, test plans, and other documents. Teams attempt to decompose their work into pieces that can be performed by a single person working as independently as possible, and these documents capture, to the extent possible, the information needed to understand the team's work and status now and in the future. A newcomer is orientated to the team's work by studying this collection. The team lead extracts and reports status based on its contents.

An environment for teams should support creation, maintenance, and access to this articulation information. Furthermore, it should be structured to support the uses made of this information.

The informal components of articulation work are an outgrowth of ongoing interactions within the team, and they occur as team members shift between three work modes. In the *individual mode* they work alone at a computer using specialized tools of their engineering discipline or using general office products to capture information about their work. Teams often describe this mode as the "real work." At regularly scheduled times all team members gather in a meeting room for work performed in a *meeting mode*. The primary activity in these meetings is to review their progress with respect to their schedule, identify any problems in meeting the schedule, and devise solutions to these problems. They also may hear presentations from other teams performing related work. Both the individual and meeting modes are often interrupted for work performed in a *social mode*, in which two or more people talk informally.

The activities people perform depend on their current work mode: When we work alone at our desks we perform different tasks than when we are attending a meeting. The tools and information we use also depend to some extent on the current work mode. When working in social mode, for example, synchronous interactions such as voice conversations gain in importance.

Figure 1: Tasks and work modes.

Figure 1 summarizes some common articulation tasks performed by teams and the dependence of these tasks on work modes. We categorized the tasks as work related, meeting related, or people related. Although these three task categories appear to have a one-to-one relationship with the three modes, Figure 1 shows that people perform some work from each category in other modes.

We believe, informal articulation work benefits from awareness of the activities of other team members in a physically collocated work environment. One team leader noted the value in being able to see his team members from his desk. If he wanted to speak to someone, he could see at a glance whether they were absent or occupied. An environment for geographically distributed teams should provide awareness of the activities of other team members, facilitate communication with available team members, and provide awareness about the status of formal articulation information.

3. A Framework for Team Coordination

We developed a framework and prototype called TeamSpace intended to support the articulation work of distributed system development teams. The major components of TeamSpace are summarized here and described in detail in the subsequent sections.

Task structured workspace: TeamSpace offers a number of persistent "articulation objects" to support informal and formal components of articulation work. The articulation objects are accessible in a task-oriented environment organized according to work-related, people-related, and meeting-related activity categories. Task awareness is supported by the concept of episodes that represent the structure of team activities over time.

Place-based adaptation to work modes: TeamSpace uses persistent places [7] to organize information and capture the user's mode of work. The place approach allows easy transitioning between work modes. When a user shifts to a different work mode, TeamSpace adapts the presentation of tasks to support the articulation work performed within that mode.

Synchronous and asynchronous communication and awareness: The TeamSpace communicator is a low-bandwidth multimedia tool that provides real-time awareness about the current activities and work modes of other team members. The communicator also includes synchronous collaboration features, instant messaging, and IP-based voice and video conferencing.

Figure 2 presents an overview of the user interface of the TeamSpace prototype. The lower left side (5) contains a graphical representation of user activities displayed on a two-dimensional room map. The room map shows the current status of users (active, busy, inactive, connected, disconnected) and gives an indication of which mode users are working in. Thus, it provides a very basic awareness function.

In addition, the rooms automatically establish a chat communication channel and are integrated with the TeamSpace communicator (6). Whenever a user enters a room he can see live images of other users who are in the same room in the TeamSpace Communicator. The images are captured at a very low frame rate (approximately one frame per minute) to restrict the demands on bandwidth. But they are sufficient to convey more vivid and spontaneous awareness about other's activities and go well beyond

the purely technology-cantered status indications that are prevailing in standard instant-messaging tools. With TeamSpace Communicator, users can create IP-based audio- and video channels to the team members in the same room.

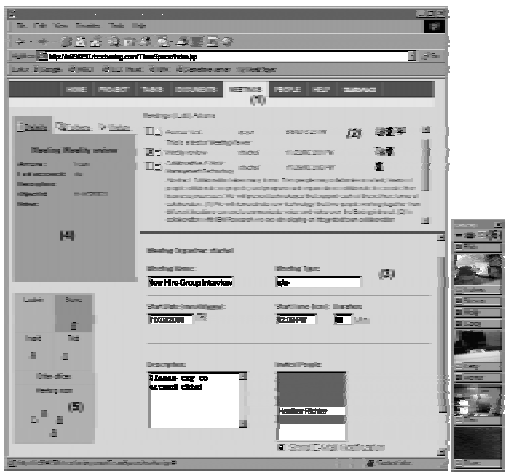

Figure 2: The TeamSpace web interface

Overall, the tight integration of these synchronous awareness and communication features with the asynchronous parts of the TeamSpace user interface provides an attempt to facilitate shifting between the different work modes (individual, social and meeting) Users can change their work mode by moving from place to place. Alone in their own virtual office they may work in an individual mode. By joining someone in their office and by joining a group in a meeting room, users can shift to social and meeting modes. To support these mode changes, TeamSpace associates places with information spaces, each of which is represented by a set of distinct task environments (1-4). The task environments adapt to the type of place, the presence of users in the place, and the activities in progress. The following sections describe the framework components in more detail.

3.1. Task Structured Workspaces

TeamSpace supports a range of individual and collaborative work activities. (1) It serves as an information store offering team members easy access to shared information. (2) It acts as a task management environment, enabling teams to coordinate processes and track the progress of work. (3) It is a communication environment offering easy access to a variety of communication channels and provides team awareness. (4) It provides a virtual meeting environment where teams can give presentations, and hold discussions, and brainstorm solutions.

TeamSpace provides a set of *articulation objects* that are accessed in accordance with different task environments. Currently, the system supports persistent articulation objects for general-purpose documents, projects, workspaces, meetings, as well as task management. Meeting objects support planning, scheduling, and conducting of virtual meetings using a multi-user slide presentation tool. Meetings can be captured and the system offers browsing facilities to enable team members to access meeting minutes, presentations, and action items that were assigned during the meeting. The meeting features of TeamSpace are described in more detail in [6].

The TeamSpace user interface is structured into different *task environments* for information sharing, planning and scheduling, task management, meeting management, and both people- and organization-related tasks. Each task environment applies a user interface approach that has proven useful for effectively managing the corresponding activity. For example, the information-sharing environment provides a container-oriented view whereas the planning environment uses a shared calendar and project plans as the primary metaphor.

Product development teams work under constant pressure to meet their deadlines. It is crucial that teams meet regularly to establish shared awareness about performance with respect to the schedule and to detect potential conflicts before they actually happen. We are planning to help teams understand and explain their work by presenting an *episodic view* that mimics the ways in which team members talk about their work. This approach is motivated by cognitive psychology research in episodic memory, our memory of life experiences. In contrast to the information in semantic memory (which might be compared with a dictionary), episodic memory allows us to reconstruct sequences of events that have occurred in the past [15]. Our goal was to allow users to view and understand the sequences of events that comprise their shared work.

When asked to describe a project's work during a given time frame, team members structure their responses in terms of well-known scripts or templates such as the formal development process consisting of requirements definition, preliminary design, design, production, integration and testing, and certification. If asked for more detail about the work within a phase, people decompose the phase into finer grained episodes. Teams may also adopt idiosyncratic temporal markers, such as before and after Jim joined the project or after a critical design review.

The TeamSpace UI will offer an episodic browser that presents the project activities as a timeline divided into phases and sub-phases as outlined in Figure 3. The browser allows horizontal (along the time axis) and vertical (between phases and sub-phases) navigation. On each level the timeline is marked by episodes describing activities that were taking place. The phase views are annotated with small vertical bars indicating episodes. In the lowest level, three meeting episodes and a deliverable-

authoring episode are shown as icons that can be viewed by double-clicking.

Technically, episodes are sets of semantically related events that are generated in response to user interactions. All episodes involve collaborative activities that are associated based on the task-structure imposed by the workspace. For example, a presentation by a user in a virtual meeting is automatically associated with the meeting episode instantiated when the meeting was scheduled. Similarly, creating meeting minutes or assigning action items in an ongoing virtual meeting results in new activity entries in the corresponding meeting episode.

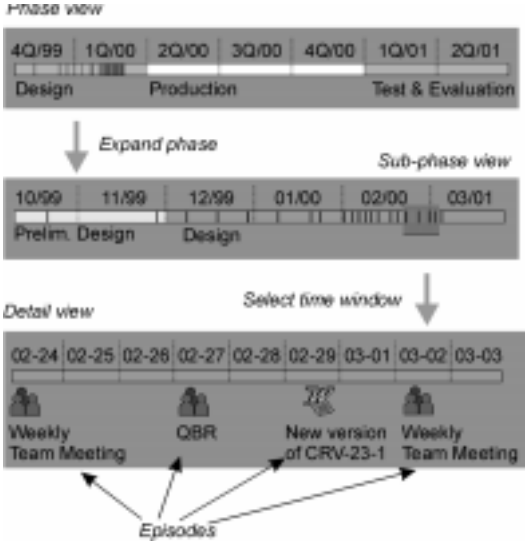

Figure 3: The TeamSpace web interface

We believe, episodic awareness is a significant enhancement to change notifications, the mechanism for providing asynchronous awareness applied in most collaborative tools (see e.g. [5]).

3.2. Adaptation to work modes

Much of the work of a collocated team is done while team members visit each other at their work places and when the whole team gathers for meetings. Collocation provides awareness of team activities with little cognitive cost. Effective team collaboration relies on our ability to easily see and act upon another's activities and availability, and to quickly switch back and forth between different work modes (i.e., individual, social, or team work). The cognitive cost of communication and awareness increases rapidly as physical distance increases (see e.g. [9]).

TeamSpace attempts to restore the awareness and ease of communication available to collocated teams through the use of a place-based user interface [7]. Places provide an intuitive means for team awareness. Anyone can see at a glance whether team members have congregated in a meeting room, are gathering in a team room, are working alone in their individual rooms.

Although places are associated with information repositories, they do not predetermine the information that is accessible. In TeamSpace their primary benefit lies in the social interaction and awareness they facilitate. We are particularly interested in finding out if places are appropriate to support shifting between different work modes by linking rooms to specific team activities and providing a suitable adaptation at the user interface depending on the kind of place a user has entered. Currently, we use simple heuristics such as the type of room, the number of other users in the room, and the ongoing communication activities to determine the work mode.

As users move from room to room, TeamSpace adjusts the current task environment. For example, the meeting-related tasks that are accessible via the user interface depend on whether the user works alone in an individual place or is in a meeting room with other people. In an individual room the user is likely to plan a meeting or retrieve information about past and future meetings. In a meeting room, the user requires access to those sub-tasks that constitute participating in or running a meeting.

4. Discussion

TeamSpace integrates inherently synchronous technologies such as audio, video, and data conferencing with real-time awareness and asynchronous technologies to support articulation work. Our goal was not to merely bundle these tools under a new common roof, but to combine them in order to achieve a benefit for the team. E.g. we have combined commercial tools for planning, scheduling, and conferencing to create an articulation object for virtual meetings. The functionality of these objects embraces the whole life cycle of virtual meetings using synchronous and asynchronous technologies that enable teams to revisit the decisions they made and track the assignment of tasks and responsibilities.

TeamSpace, like a number of other collaborative workspace systems such as CVE [14] and Orbit [10], has drawn upon familiar aspects of the notion of places in order to balance out social factors such as privacy, availability, and conventions. However, TeamSpace combines a domain-specific task model with places to track high-level modes of work that are common across the work domain: work-related, meeting-related, and people-related. By intelligently embedding support for these tasks in the place-based environment, TeamSpace offers a powerful approach for managing teamwork across dislocated teams.

A number of collaborative technologies are completely targeted at the social aspects of shared spaces, basically applying a philosophy that treats the environments as purely interaction oriented. For example, media space technologies [3] facilitate unanticipated encounters among users. TeamSpace

also aims at facilitating planned and serendipitous encounters but places interaction in a broader context by making use of knowledge of the common task and shared information.

On the opposite side of the spectrum there are environments that apply a purely document oriented philosophy on the support of collaborative work. Among those are systems such as BSCW [1] and POLIAwaC [13] and most of the commercial team environments that are more and more offered as services on the Internet. These tools provide a container-hierarchy where the team can add and change a repository of documents. The shared container approach has proven very successful for teams with restricted size that do not employ formal processes for coordination.

TeamSpace tries to combine the advantages of both of these worlds using a palette of distinct task environments, each of which addresses different aspects of collaboration. The task environments in turn are adapting to the user's mode of work and ongoing interactions and vice versa the user's interaction capabilities are influenced by her current task. In addition, TeamSpace places much emphasis on tracking progress and creating a shared understanding about the team. The system addresses this by providing specific articulation objects for tracking and planning as well as a novel model for supporting awareness.

The role of awareness for team performance has been pointed out in a number of field studies (see e.g. [8]). TeamSpace provides synchronous and asynchronous awareness mechanisms. The synchronous awareness features use two levels of detail about ongoing activities. First, a place-based global overview offers team-wide visibility about current activities. Second, the TeamSpace communicator offers a detailed view of the physical work environment along with instant messaging and high-bandwidth communication channels for selected users and those users whose actions are closely related.

We are currently working to extend the awareness support by persistently capturing and notifying about changes that occur in the environment using the episodic approach outlined before. Our goal is to summarize sets of events that occur over time involving related articulation objects into more coherent episodes in order to gain leverage from the human ability to remember information episodically [15] and to support their need to report episodic information. These ideas are influenced by similar approaches for information management, particularly the Lifestreams system [4]. Lifestreams facilitates temporal browsing as a method of document retrieval. In contrast to Lifestreams the TeamSpace episodic browser is broader in scope. Instead of documents it will give access to event information for all kinds of articulation objects. Hence the focus is primarily on change awareness but the strategy also offers the potential of being a powerful all-purpose information retrieval mechanism.

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