IBM Research Report

TeamSpace: A Collaborative Workspace System Supporting Virtual Meetings

Werner Geyer, Heather Richter*, Ludwin Fuchs,
Tom Frauenhofer, Shahrokh Daijavad, Steven Poltrock****
IBM Research Division
Thomas J. Watson Research Center
P.O. Box 704
Yorktown Heights, NY 10598

*Georgia Institute of Technology
801 Atlantic Drive
Atlanta, GA 30332

**Boeing Mathematics & Computing Technology
PO Box 3707
Seattle, WA 98124

Research Division
Almaden - Austin - Beijing - Haifa - T. J. Watson - Tokyo - Zurich

TeamSpace: A Collaborative Workspace System Supporting Virtual Meetings

Werner Geyer*, Heather Richter**, Ludwin Fuchs***,
Tom Frauenhofer*, Shahrokh Daijavad*, and Steven Poltrock***

*IBM Thomas J. Watson Research Center	**Georgia Institute of Technology	***Boeing Mathematics & Computing Technology
30 Saw Mill River Road	801 Atlantic Drive	PO Box 3707
Hawthorne, NY 10532, USA	Atlanta, GA, 30332, USA	Seattle,WA 98124, USA
+1 914 784 7512	+1 404 894 5103	+1 425 865 3270
{werner.geyer, shahrokh, tvf}@us.ibm.com	hrichter@cc.gatech.edu	{ludwin.fuchs, steven.poltrock}@boeing.com

Abstract

TeamSpace is a Web-based collaborative workspace system that supports geographically distributed teams by managing shared work processes and maintaining shared artifacts in a project. TeamSpace supports both synchronous and asynchronous team activities. In this paper, we discuss the distinguishing features we considered while designing TeamSpace. Since meetings are an integral part of teamwork, our current work focuses on supporting virtual meetings as part of a larger collaborative work process. We present our initial prototype of the TeamSpace virtual meeting environment. This Web-based system supports capture, integration, and access of distributed meetings. We present a general-purpose meeting viewer for browsing the captured information. The viewer enables users to efficiently gain knowledge of both current and past team activities. We also describe the architecture and implementation of the system.

Keywords: Team collaboration, virtual meetings, web-based collaborative workspaces, capture and access, collaborative activities, teamwork.

1 Introduction

Teamwork is an integral part of today's work environment as much more can be achieved from the coordinated contributions of people with diverse backgrounds and resources than from those same people working independently. This is especially true for the development of complex systems that require a large work breakdown structure, such as aircraft and other aerospace systems. More and more, large development projects consist of people from different companies at different geographical locations, which makes the coordination of team activities difficult because of reduced team cohesion and limited awareness of team members' activities. Computer support for distributed teams has focused on either improving communication in synchronous distributed meetings or on providing tools to facilitate distributed asynchronous collaboration, but not both.

Boeing and IBM are jointly developing a framework and prototype, called TeamSpace, to support spatially distributed teamwork in a more holistic and integrated manner [11]. TeamSpace is a web-based collaborative workspace system for managing shared work processes and maintaining shared artifacts in a project typically spanning months or years. It covers both synchronous and asynchronous cross-company team activities and provides a seamless transition between different work modes of team

members, such as individual, social and meeting modes. The activities people perform depend on their current work mode. TeamSpace provides a task-oriented workspace that adapts to the current mode. The key to highly efficient teamwork is continuous awareness of each other's activities and timely communication, which is relatively easy to achieve for physically collocated teams. Computer-support for virtually collocated teams can provide awareness functions to remote team members. However, these functions are mostly limited to the desktop, which makes them inefficient in many situations. TeamSpace also attempts to increase team awareness and communication for distributed teams by providing ubiquitous access through the integration of wireless handheld devices.

Meetings are a crucial communication and coordination activity of teams. While computer support for distributed conferences has been investigated, meetings involve much more than the synchronous act of discussion. Meetings relate to all of the various activities of a team, from reporting and scheduling tasks, to raising and debating issues, to reviewing documents. TeamSpace supports distributed meetings as a part of a larger collaborative work process. We are doing this by providing capture, integration and access capabilities for distributed meetings. Captured synchronous information is integrated with other related information in TeamSpace, enabling users to efficiently gain knowledge of both current and past team activities.

This paper presents our initial prototype of the TeamSpace collaborative workspace system. In Section Two we discuss the most important features we considered while designing TeamSpace. Our current prototype emphasizes the virtual meeting portion of TeamSpace. Hence, Section Three demonstrates the goals of the virtual meeting support in TeamSpace by describing some desired meeting scenarios. Section Four presents our current TeamSpace prototype, where our focus is on time-based capture and access of virtual meetings. We present a general-purpose access interface to the captured material. The access interface allows browsing and searching the meeting records by using a multi-scale time slider that indicates points of interests ("hot spots") in the meeting. Section Five gives a brief overview of the architecture and implementation of the system. Finally, we conclude with related work and future directions.

2 Design Considerations

Existing team support environments either focus on supporting asynchronous team activities and project management or on synchronous communication support (distributed conferencing). TeamSpace attempts to apply an approach that is more integrated with the way people work.

As part of a long-term program in computer-supported cooperative work, Boeing has conducted observational studies and interviews over several years of teams developing large complex systems [9, 10]. The teams observed spent the majority of their work time performing articulation work [15] to coordinate their work with the contributions of other members of their own team and with other teams.

Interestingly, team members rarely viewed articulation work as their primary work activity but as a necessary but uninteresting facet of large system development, and one that they did not learn in their university engineering classes. These observations indicate that a teamwork technology must fully support team articulation work while being integrated with the remainder of the work environment [14].

2.1 Managing Articulation Information

Articulation work can be roughly divided into formal and informal components. Every team produces and maintains a formal information collection that describes their work and its progress. This collection includes, for instance, a statement of work, a work breakdown structure, schedules, status reports,

specifications, designs, analyses, action items, agendas, test plans, and other documents. An environment for teams should support creation, maintenance, sharing, and access to articulation information (articulation objects).

2.2   Support of Different Work Modes

The informal components of articulation work are a result of ongoing interactions within the team, and they occur as team members shift between three work modes. In the *individual mode,* team members work alone at a computer using specialized tools of their engineering discipline or using general office products to capture information on their work. They usually describe the individual 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. We believe that it is mandatory for a teamwork environment to support these three work modes and to provide a seamless transition from one work mode to the other. This often implies switching between asynchronous and synchronous types of collaboration. Most existing team support tools or systems do not support this workflow. Note that shifting between these modes is frequent and relatively easy for a physically collocated group while it is a challenge for distributed teams.

2.3   Task-oriented Environment

The activities people perform depend on their current work mode: When working alone at their desks, they perform different tasks than when they are attending a meeting. The tools and information they use also depend on the current work mode. When working in social mode, for example, synchronous interactions such as voice conversations gain in importance. Figure 1 summarizes some common articulation tasks performed by teams and the dependence of these tasks on work modes.
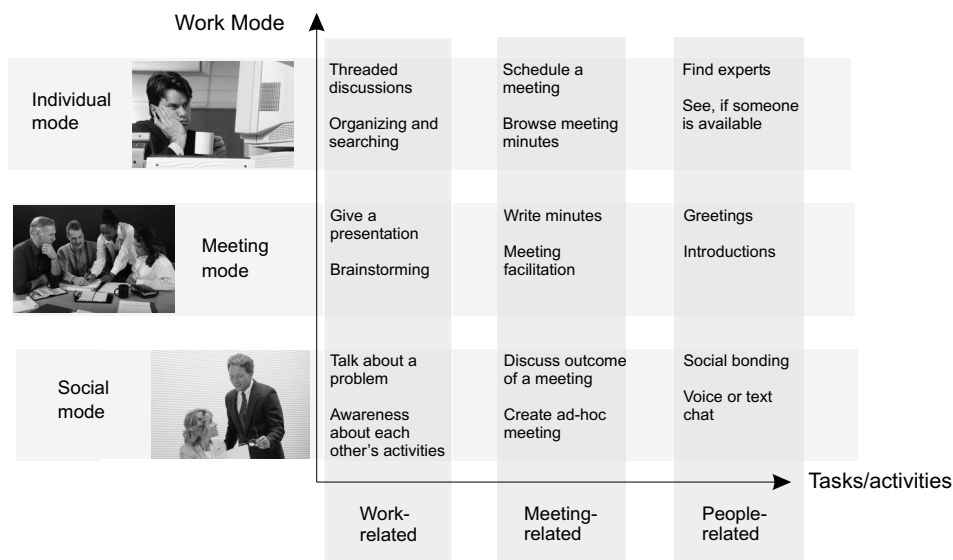

Figure 1: Tasks and work modes

3

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. Consider meeting-related tasks, for example. People work in individual mode to plan meetings, prepare an agenda, or revisit minutes from a past meeting. During a meeting the tasks might include meeting facilitation, engaging in a discussion, or note-taking. An environment for distributed teams should be task-oriented, i.e. the shared workspace should adapt the supported tasks to the current work mode of the team member.

2.4   Awareness and Communication

Informal articulation work benefits from being physically collocated since team members working in the same physical space are continuously aware of the work activities in progress, and they frequently consult with one another about details of the work. 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. Moreover, in earlier days everyone would have readily seen the team's progress as designs evolved on drafting tables and physical models were constructed. Today the designs and models are all digital and greater effort is required to maintain awareness of progress. Awareness cues embedded within the formal articulation work could extend awareness of this progress. 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.

2.5   Ubiquitous Access

Articulation work does not only take place in the office at the desktop or in a computer-equipped meeting room. Thus, a technology to support distributed teams in their articulation work has to be ubiquitous. We strongly believe that using mobile handheld devices in a distributed team environment can leverage efficiency of team members. In particular, being connected everywhere will tremendously increase awareness of team activities, team communication, and thus, team cohesion (see Section 2.4). Using the mobile device as a smartcard will also facilitate switching between different work modes. When entering a meeting room, team members will be automatically logged into the ongoing meeting session. When entering their office, people are automatically logged onto the TeamSpace workspace on their desktop computer. During an ongoing meeting, handheld devices can be used to increase interactivity through messaging, voting, feedback tools, or simply for note-taking or book marking points of interest in the meeting.

Mobile devices can also be used as a means of opportunistic communication, i.e. documents or topics that team members would like to discuss with other members are carried on the handheld and an alarm is triggered when the related people are coming close to the device. For a more detailed description of our efforts in integrating mobile devices into TeamSpace see [4].

2.6   Time-based Information Capture and Access

Teams usually document their work and status by means of formal articulation components (articulation objects) such as work breakdown structure, agendas, action items, or specifications. If stored digitally, these data are usually structured hierarchically by categories. This collection of formal articulation objects is used, for instance, to communicate information between work groups and to orient new project members. However, most of the informal articulation work occurring in the meeting mode or in the social mode is not captured. We believe that a teamwork environment should support collecting all the collaborative activities occurring during the lifetime of a project. This includes the capture of virtual meetings, which are a crucial portion of teamwork. The captured material combined with the formal

articulation information can then be accessed and visualized so that users are provided a more efficient way of gaining knowledge of current and past team activities.

All the gathered information and the captured material have in common the dimension of time. Therefore, in addition to accessing the material hierarchically by categories, a team environment should also provide a time-based structure of the workspace. The notion of time as an access criterion can be very powerful for browsing and finding information. 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 [18]. 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 a formal development process consisting of different phases. If asked for more detail about the work within a phase, people decompose the phase into finer-grained episodes. Teams also adopt idiosyncratic temporal markers, such as before and after Jim joined the project or after a critical design review.

In order to gain a better understanding of how the captured material, especially virtual meetings, is going to be used and accessed, we have identified five different user groups that benefit from the captured information. These groups differ in the tasks they do and in the amount of contextual knowledge they have.

- *Participated*. Participants of collaborative activities, such as virtual meetings, have much knowledge about who, what, and when things occurred. However, their knowledge may not be perfect and they do not remember all of the details. The main task of this group is to review something they or others said, for instance to aid in writing a report or completing an action item. This group is likely to review more recent activities.

- *Not participated*. People who did not attend the meeting, but are active project members, also have much knowledge about the project activities. Their main task is to review or catch up on something others did or said. Even though they were not present, they usually have a good idea of what they are looking for and where to find it. They are also likely to review recent activities.

- *Long-term*. Long-term reviewers have significant knowledge about the project, but little about particular activities and when they occurred because they happened a while ago or over a period of time. Their main goal is to find detailed information, such as why a decision was made, how something was implemented, and who the experts or responsible persons are.

- *New Person*. New project members have little knowledge about the project. They are looking for high-level information and summaries in order to understand the structure of the project and its people. They are also looking for experts and may wish to delve into details as they learn more about the project. Thus, their main goal is to catch up with the current standing of the project.

- *Historical*. Historical reviewers have little knowledge about the project. Their goal is to examine process-related progress and decisions. Thus, their tasks will focus less on project-related details and more on patterns of behavior, decisions and rationale.

These five user groups differ in contextual knowledge and in the time horizon they are looking at. In general, the more contextual knowledge users have and the more short-term their reviewing horizon is, the more they will need flexible, yet detailed browsing and search mechanisms. The less their contextual

knowledge is and the more long-term their reviewing horizon is, the more they will need structural and summarization information.

While the act of capturing virtual meetings and other related team information is not of a collaborative nature per se, capturing and accessing material as part of the workflow can aid collaboration. Team members can participate more fully in discussions when they can rely on the capture system to remember the details should they forget. Additionally, members who did not participate in activities can review the captured material, reducing the amount of articulation that is required from the rest of the team.

3 Virtual Meeting Support in TeamSpace

Since meetings are a crucial part of teamwork, we decided to focus our initial work in the TeamSpace project on developing a prototype that supports virtual meetings. The TeamSpace prototype basically provides capture and access functionality of virtual meetings but also partly supports some of the other design issues presented in Section 2, such as providing a basic set of articulation objects and shifting between different work modes. We also took great care in developing a mostly web-based system since this is crucial for enabling cross-company collaboration, i.e. overcoming the cross-firewall connectivity barrier. Our current research efforts emphasize capture and access in such an environment and we are investigating the usefulness of captured material, e.g. how the user groups described in Section 2.6 can best be supported and what the appropriate visualizations and browsing paradigms are for the captured material.

The following scenarios try to motivate our research, highlighting how captured meeting information can be used, along with the features that we would like the TeamSpace meeting environment to support:

Bill, the team lead, prepares for a weekly status meeting planned the next day. He checks the meeting information in TeamSpace to make sure the rooms are scheduled and adds a few guest participants. Opening last week's meeting, he checks to see if any agenda items weren't discussed and copies them to this week's meeting. He also checks which action item's generated discussion last week, and adds those as well. Finally, he adds a small presentation he has prepared for the meeting.

The following day, team members in Seattle gather in their conference room. Mary, the meeting facilitator arrives a few minutes early to log into TeamSpace and start the meeting. Meanwhile, team members in other locations enter the virtual meeting from their desktop browsers. After team members greet one another and chat for a few minutes, Mary opens the meeting agenda to start. She adds any new items proposed by the team. Pushing the agenda aside, she opens the action item log to get an update on each of the unfinished tasks. As each team member lists their progress, Mary updates the item list, marking off items, changing items, and adding new action items. She also opens the master schedule to determine if any of the unfinished items will delay upcoming milestones.

The next item on the agenda is a presentation by Bill about an interface problem just discovered between their component and another component. Bill opens the presentation and explains the problem. Working at her desktop in St. Louis, Sally circles a region on one of the components and notes some of the manufacturing constraints that influenced its design. Also from his desktop, Jim draws a sketch to explain the reason for these constraints. All of these annotations are automatically saved and attached to the presentation.

The presentation spawns a brainstorming session for solutions. The team sketches their ideas on an electronic whiteboard, with distributed team members drawing at their desktops. The team is split

between two different solutions and needs more data to resolve uncertainties. Mary assigns two subteams the responsibility for investigating these in more depth.

Pat and Jim meet later that day as a subteam investigating one of the proposed solutions. During their meeting, which they also capture, they try and recall a contact Sally mentioned during the earlier meeting. They open up the meeting and browse through it by using a timeline that indicates the spots where Sally was talking. They easily find and replay the portion where Sally was sketching on the components and hear her mention her co-worker Dave. The group looks up Dave's contact information and gives him a call. They explain their problem and ask Dave if he has a few minutes to answer their questions. Dave joins their meeting from his desktop computer and adds his own sketches about the component interface they are discussing. Later, Pat emails Chris, a member of the other subteam, to let him know that their conversation with Dave could be useful for him.

Chris had to leave the weekly status meeting early. Before he meets with the rest of his subteam, he returns to the meeting records to listen to the portions he missed. He skims the meeting with a time slider by jumping from one agenda item to the next. Then he dives into Bill's presentation, using a thumbnail navigation, to replay the portion of the presentation where the group talked about the manufacturing constraints. Later on, during the meeting with his subteam, Chris replays the comments Dave made to Pat and Jim.

One year later, Bill is leading a team that runs into a similar component interface problem. He asks Harry, one of his team members, to look at the problem the old project had, and why they chose their solution. Harry reads the documentation, accesses the meeting records and replays pieces of the various discussions by the subgroups, and prepares a presentation using some of the older material to present his findings.

These scenarios demonstrate how a user might shift between the various tasks and work modes of Figure 1. Users should have support for each the different modes of meeting-related activities, as well as be able to perform work, meeting, and people-related activities while in a meeting. While our current prototype does not provide all of the features highlighted in the scenarios, we do provide most of the meeting preparation, meeting participation, and short-term reviewing capabilities mentioned above.

4 TeamSpace Prototype System

The prototype we have developed consists of a TeamSpace server that is accessed with a standard Web browser, a number of conferencing clients for conducting and capturing virtual meetings and an access component for the captured material called MeetingViewer.

4.1 Web Interface

The Web interface is the standard entry point into the system. It is used to perform user authentication and to create, edit, share, and delete persistent articulation objects. TeamSpace currently supports the following basic set of objects: Meetings, Action Items, Agenda, Presentation, and User. The Web interface also provides access to ongoing synchronous meetings and to the meeting records of completed and captured meetings. A graphical room map indicating other team members' activities facilitates easy switching from individual, asynchronous types of work to synchronous meetings or social interactions and enhances team awareness. Figure 2 shows the TeamSpace Web interface.

The main control area is tab-organized, allowing users to manage their project activities in work-centered environments (1). Currently we have identified meetings, document management, task management, and

project management. The meeting environment provides access to all meeting-related information: Meetings can be created, edited, scheduled, reviewed, and joined. The document environment allows users to author, share, and manage semi-structured documents, such as text documents. The task environment provides access to the user's action items, and allows tracking and assigning of action items. The people tab contains all the tasks related to user administration. Since our focus is on virtual meetings, we will confine our subsequent discussion to the meeting environment.

Below the main control tabs is a resizable general display area that is divided between a task-view (2) and a document view (3). The task view is used to search and retrieve lists of objects. The document view provides a display and input area for the document content. We currently use this view to enter, edit and display meeting data, agendas, action items, and user information.

On the upper left side we have included an area for the display of meta-information for the selected objects (4). The display also contains tabs that allow the user to switch between general object information, the object history, and a hierarchical folder navigator. The general information tab displays object attributes such as access rights, descriptions, and attachments. The history tab shows a chronological list of events that have occurred for the selected object. The folder navigator provides additional means for structuring the object repository into a hierarchy of folders.
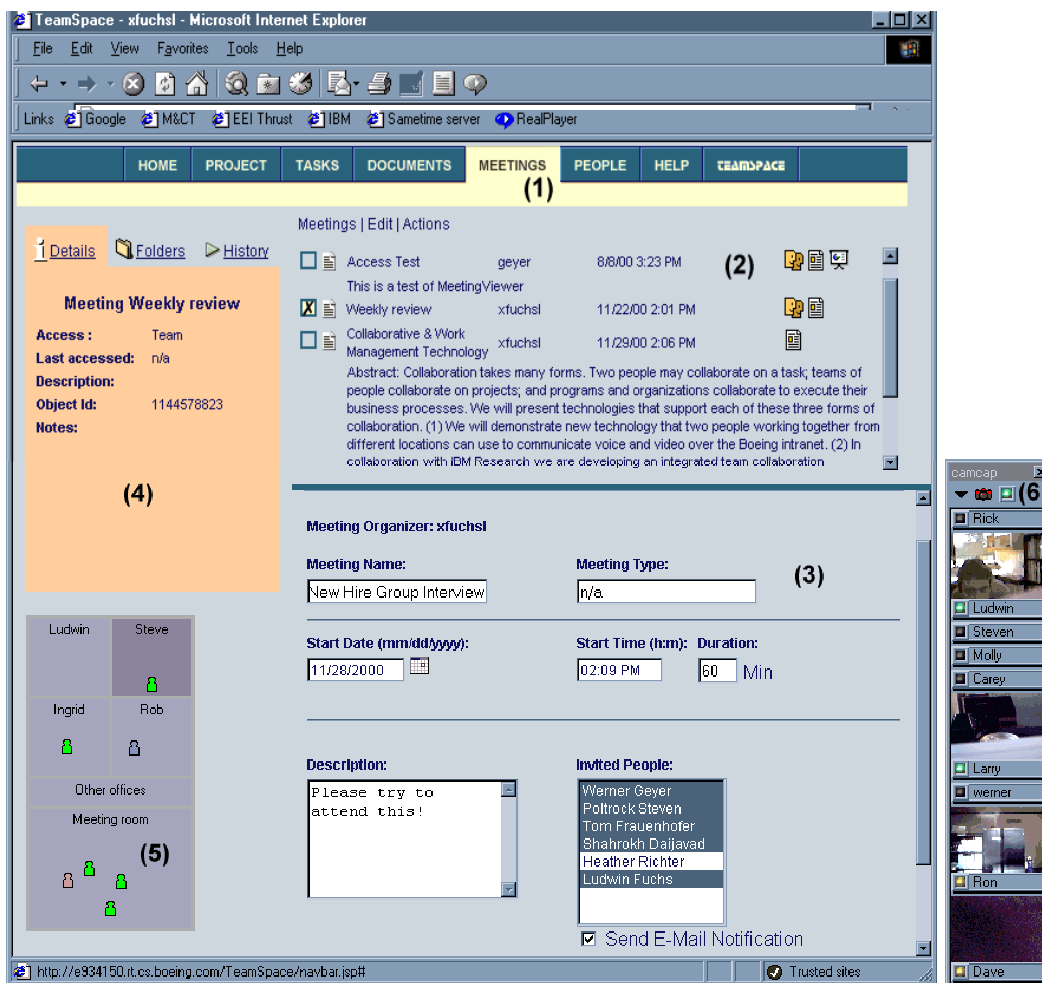

Figure 2: Screen shot of TeamSpace's Web interface

8

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-centered status indications that are prevailing in standard instant-messaging tools (e.g. Sametime Connect [6] or ICQ [5]). With the TeamSpace Communicator, users can create IP-based audio- and video channels to the team members in the same room. 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).

4.2   Capture Clients

From the TeamSpace web interface, a user can join an ongoing meeting. Upon joining, several client applications are automatically launched and connected to a conferencing server that is part of the TeamSpace server. We are currently using the following synchronous clients:

- A slide annotation tool for sharing and annotating PowerPoint presentations.

- A low-bandwidth video tool, called TeamSpace Communicator (see Section 4.1), providing real-time awareness of the current activities and work modes of other team members.

- An agenda tool for viewing, creating and checking off agenda items.

- An action item tool for viewing, creating and checking off action items.

Each of these tools uses the conferencing server to broadcast data and to synchronize its application state. All synchronous activities during the meeting are time-stamped and recorded. The meeting records are automatically stored on the server's file system. The slide, agenda, and action item tools can be used with an electronic whiteboard or pen tablet so that ink or drawing annotations can also be captured. Thus, the capture clients are appropriate to use either in a meeting room or at a desktop machine.

Note that we are currently not transmitting audio over the network. The main reason is the poor quality leading to bad detection rates when transcribing the audio. Instead, we are currently using a mixed recording of the conference call. After dialing into the conference, a dedicated audio client, which is also connected to the conferencing server, automatically digitizes the audio and stores it on the TeamSpace server at the appropriate location.

4.3   MeetingViewer

After a meeting is completed, the meeting records are automatically available on the server for retrieval. In this prototype we have focused on retrieving meeting details to support time-based access for both participant and non-participant users (see Section 2.6). Users can select completed meetings in TeamSpace and launch a MeetingViewer to view and playback these meetings. We are using this general-purpose access interface to investigate visualizations and browsing mechanisms for captured meetings.

Figure 3: Screen shot of MeetingViewer

The MeetingViewer, shown in Figure 3, integrates all of the meeting information based on time. The viewer uses a two-scale timeline for navigating a set of selected meetings, providing random access playback. The timeline is painted with interesting events as both a visual summary of the meeting, and as an aid for navigation. Interesting events may be people speaking, people joining and leaving, agenda items being discussed, action items created, slides visited, or keyword locations. Users can control which of these events they view and can use the events to find relevant portions within a meeting to playback. This timeline visualization is based on the Multi-scale Timeline Slider [12]. Playback of a meeting not only involves playing the audio and video, but also involves playback of all of the recorded events of a meeting such as slide visits or agenda item discussion.

The remainder of the meeting information is displayed on a series of tabbed panes for each of the articulation objects related to the meeting, including descriptions and summaries of the meeting, agenda, presentations, action items, and video images. These panes are a very general approach for displaying a large amount of related information. However, to enable customized views, each pane can be opened in a separate window, moved and resized. In this way, users can view any subset of the information they wish at once. Additionally, as we add more articulation objects to TeamSpace, we can easily add more meeting-related objects to this interface, such as documents that were reviewed or referenced during the meeting. We anticipate that as we learn more about the types of information users need for various tasks, we can design task-oriented views that are simpler and more integrated. Additionally, we are now

investigating visualizations to navigate through very large sets of meetings to support long term and new reviewers.

5 Architecture and Implementation

The TeamSpace virtual meeting prototype system is a Web-based client-server multi-user system that additionally uses a conferencing server and several synchronous clients to capture virtual meetings. Figure 4 depicts a rough overview of the system architecture.
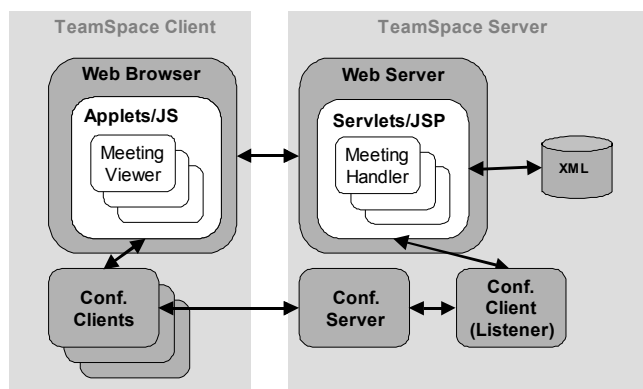

Figure 4: Architecture of the virtual meeting prototype

The TeamSpace server consists of a Java-enabled Web server with servlets and Java Server Pages (JSP) to handle data storage, retrieval, manipulation and presentation. We use a conferencing server to establish synchronous conferencing sessions and to broadcast the information between the conferencing clients. A dedicated conferencing client (Listener) on the server side records and time-stamps all the synchronous activities (events) during the meeting. TeamSpace data and meeting records are kept persistent by storing them on the local file system as XML files. Note that storing the data as XML files is a comfortable approach for a demonstrator, but not a viable alternative for a system in use since file system storage does not scale for a large amount of users. On the client side, we are using standard Web browsers (supporting Javascript and Applets) to access the meeting environment and synchronous conferencing clients to conduct and capture virtual meetings. All the conferencing clients described in 4.2 have been developed in Java. In order to make this system usable across companies' firewalls, the TeamSpace server is required to reside outside a firewall. Clients either connect via HTTP or TCP if outbound TCP traffic is tolerated.

6 Related Work

As a team collaboration environment, TeamSpace has many predecessors. TeamSpace builds on prior research integrating synchronous and asynchronous collaboration capabilities, as in TeamRooms [13] and CVW [16]. Like TeamSpace, both TeamRooms and CVW used room metaphors to provide persistent places where people could communicate and interact with one another. TeamRooms included multi-user synchronous applications developed in Tcl/Tk, and CVW was based on the lambda MOO environment. The concept of places or locales for workgroup collaboration was integrated with the web in wOrlds [3] and its descendent Orbit [7]. Unlike TeamSpace, wOrlds has not focused on synchronous meetings or their capture and playback.

In this phase of development of TeamSpace we focused on capture and access of team meetings. Capture and access systems have been a concentration of the multimedia community and the ubiquitous computing community for the past decade. Research has explored automated capture in both education and meeting domains. One particular success, Classroom 2000 [1], focused on providing students automated access to lecturer's notes and audio and video recordings and has been used to record over 1000 lectures at several universities. The system's success is due to addressing the real needs of students: to be able to easily review slides and notes, augmented with audio and video. In contrast to TeamSpace, Classroom 2000 only captures the local classroom experience and does not support remote collaboration. Many meeting capture systems, such as [2, 8], have also focused on augmenting presentations and hand-written notes with audio and video streams. Unlike TeamSpace, these systems do not integrate capture and access into the larger context of a collaborative work process, i.e. they focus on the capture of the synchronous experience only.

The emphasis in the multimedia domain has been on innovative ways to access, segment, and review media streams. Both CueVideo [17] and Informedia [19] provide search and retrieval within a single media stream or across a library of streams. Similarly, TeamSpace must search a library of meetings, then the contents of a single meeting. This is particularly important for supporting the long-term reviewers, new project members, and historical reviewers described in Section 2.6.

7   Conclusion

TeamSpace is targeted at enabling geographically distributed, cross-company teams to match the high performances achieved by collocated teams. Members of a high performance team are continuously aware of team activities, and they move fluidly and easily between individual, social, and meeting work modes. Providing all the collaboration capabilities needed by such teams is an ambitious long-term goal. In TeamSpace we have defined an architecture and conceptual framework for these capabilities, and then focused on one aspect of work, team meetings.

Our Web-based prototype TeamSpace supports meetings as events in the team's work context. It supports the primary artifacts used in meetings, including agendas, action items, and presentations. TeamSpace supports planning and scheduling future meetings, conducting and capturing a meeting in progress, and finally searching and reviewing prior meetings. The design of the system architecture enables cross-company collaboration.

Because meetings are key events for many teams, they define temporal markers in a team's work history. We are beginning studies of the use of TeamSpace by project teams, and we plan to develop searchable meeting libraries organized both chronologically and topically.

8   References

1. Abowd, G., Atkeson, C., Brotherton, J., Enqvist, P., and LeMon, J. "Investigating the capture, integration, and access problem of ubiquitous computing in an educational setting," in *Proc. CHI 98*, 1998.

2. Chiu, P., Kapuskar, A., Reitmeier, S., and Wilcox, L. "Notelook: Taking Notes in Meetings with Digital Video and Ink," in *Proceedings of ACM Multimedia '99*, 1999.

3. Fitzpatrick, G., Tolone, W., Kaplan, S., "Work, locales and distributed social wOrlds", in: *Proceedings of the 1995 European Conference on Computer-Supported Cooperative Work (ECSCW'95),* Stockholm, Sweden, Kluwer Academic Press, 1-16.

4. Frauenhofer, T., Geyer, W., "From Sametime Connect to TeamSpace: Evolution of a Pervasive Collaboration Environment", in: *Proc. PACT 2000*, 1st Pact 2000 Workshop on Ubiquitous Computing, Philadelphia, PA, USA, October 15-19, 2000.

5. ICQ Homepage, "ICQ.com", URL: http://www.icq.com/, November 2000.

6. Lotus Sametime Homepage, "Real-Time Collaboration That's Fit for Business", , URL: http://www.lotus.com/Sametime, November 2000.

7. Mansfield, T., Kaplan, S., Fitzpatrick, G., Phelps, T, Fitzpatrick, M., Taylor, R., "Evolving Orbit: A Progress Report on Building Locales", in: *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Wor*k, Hayne, S. C. and Prinz, W. (eds.), 1997, Phoenix, AZ, ACM Press, 241-250.

8. Moran, T.P., Palen, L., Harrison, S., Chiu, P., Kimber, D., Minneman, S., vanMelle, W., and Zelweger, P. "'I'll Get That Off the Audio:' A Case Study of Salvaging Multimedia Meeting Records," in *Proc CHI '97*, Atlanta, GA, 1997.

9. Poltrock, S., Engelbeck, G., "Requirements for a Virtual Collocation Environment", in: *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Wor*k, Hayne, S. C. and Prinz, W. (eds.), 1997, Phoenix, AZ, ACM Press, 61-70.

10. Poltrock, S., Engelbeck, G., "Requirements for a Virtual Collocation Environment", in: *Information and Software Technology* 41, 6, 1999, 331-340.

11. Poltrock, S., Fuchs, L. Harkness, R, Daijavad, S. Frauenhofer, T.V., Geyer, W., *Conceptual Model of a Virtual Meeting Support Environment*. Internal IBM/Boeing Document, April 5, 2000.

12. Richter, H., Brotherton, J., Abowd, G. D., Truong, K., *A Multi-Scale Timeline Slider for Stream Visualization and Control*. GVU Center, Georgia Institute of Technology, Technical Report GIT-GVU-99-30, June 1999.

13. Roseman, M, Greenberg, S. "TeamRooms: Network Places for Collaboration", in: *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work (CSCW′ 96*), Ackerman, M. S. (ed.), 1996, Boston, MA, ACM Press, 325-333.

14. Schmidt, K., "The Organization of Cooperative Work: Beyond the 'Leviathan' Conception of the Organization of Cooperative Work", in: *Proceedings of the 1994 ACM Conference on Computer Supported Cooperative Work (CSCW′ 94*), Furuta, R. and Neuwirth, C. (eds.), 1994, Chapel Hill, NC, ACM Press, 101-112.

15. Schmidt, K. and Bannon, L., "Taking CSCW Seriously: Supporting Articulation Work", in: *Computer Supported Cooperative Work (CSCW)* 1, 1-2, 1992, 7-40.

16. Spellman, P. J., Mosier, J. N., Deus, L. M., Carlson, J. A., "Collaborative Virtual Workspace", in: *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Wor*k, Hayne, S. C. and Prinz, W. (eds.), 1997, Phoenix, AZ, ACM Press, 197-203.

17. Srinivasan, S., Ponceleon, D., Amir, A., Petkovic, D., "'What is in that video anyway?': In Search of Better Browsing", in: *Proceedings of the IEEE International Conference on Multimedia Computing and Systems Volume I,* 1999, Florence, Italy.

18. Tulving, E., "On the uniqueness of episodic memory", in: *Cognitive neuroscience of memor*y, Nilsson, L.-G. and Markowitsch, H. J. (eds.), 1999, Hogrefe & Huber Publishers, Göttingen, Germany.

19. Wactler, H. D., "Informedia – Search and Summarization in the Video Medium", in: *Proceedings of Imagina 2000 Conference,* Monaco, 2000.