Workspace Awareness in Mobile Virtual Teams

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Abstract

Staying aware of each other in cooperative team work is something we take for granted in the everyday world, even if collaboration is not continuously face-to-face, and team members frequently shift from group to individual activity during work sessions. Maintaining this intuitive fidelity of awareness, e.g. of team members working in the office next door, is on the other hand something that has proven particularly difficult to attain in distributed collaboration systems, where the social interaction protocol is not as established, and the means for becoming aware of the environment are far less common. The work reported in this paper is focussed on workspace awareness, i.e. the "... up-to-the-moment understanding of another person's interaction with a shared workspace" [GuGr 99].

Opposed to the traditional understanding of shared workspaces as being bounded spaces where people can see and manipulate artefacts related to their activities (documents in an office, the whiteboard in a lecture hall or assembly lines in a factory), we consider virtual mobile (team) workspaces as abstract spaces containing objects that constitute the team work.

Keywords: Virtual Spaces, Distributed Cooperative Environments, Multiuser Interaction, VRML, Java.

1 Introduction

The virtualisation of organisational structures is a direct consequence of the availability of new media technologies, global competition, and the advanced mobility of people, devices and services. For team work, improving efficiency, shortening lead times, competence and role based service provision as well as media based remote interactions among co-workers has become crucial. Virtual teams have evolved as a way of working across geographical, time and organisational boundaries. Team members must no longer be co-located, or in the same place, in order to work together. The planning and design of the organisation, the team, and the structuring of business processes is the basis for building a successful virtual team. In addition to these factors, team work must be coordinated through technology, and the team members must interact and keep each other updated.

Virtual spaces based on the metaphor of "shared network places" [FeJo 99] are becoming a well accepted implementation approach for multiuser, multimedia, distributed cooperative work environments to support the work activities and interactions of goal oriented business teams. Similar to real-life physical team rooms, which provide a permanent shared space used by a work group, **TEAMSPACE**, the virtual space presented in this paper, provides a virtual meeting room for (possibly mobile) work teams, i.e. a place to store, retrieve and present multimedia content (documents), to design and construct cooperatively, to brainstorm, to negotiate and make decisions, to run shared applications, to browse enterprise data, or to acquire, formalise and exchange enterprise knowledge. Since physical team rooms rely on the physical proximity of the team members and their easy access to the common work space, this access breaks down when groups are geographically dislocated or moving. For such teams, **TEAMSPACE** provides the electronic equivalent of a physical team room transcending distance, time zones, and organisational boundaries. **TEAMSPACE** is based essentially on open technologies, the virtual reality modelling language (VRML) together with Java. A Java-enabled Web-browser together with a VRML plug-in is thus the only requirement for the execution of **TEAMSPACE** on current consumer hardware.

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2 Mobile Virtual Teams

Team work enabled by electronic collaboration technologies has evolved as a potentially effective way to make working across time, space, organisational and cultural boundaries an easy and practical way to achieve superior result need in today's globalised, lean and agile organisations. In the traditional understanding, computer supported cooperative work (CSCW) environments and tools free work teams from the physical limitations of time and place. Technology is the main trigger for team workplace innovations, i.e. with the emergence and availability of new hardware (e.g. PDAs, Multimedia home platforms, SmartCards), software (e.g. new middleware architectures, new CORBA frameworks, new Enterprise Java Beans, etc.) and communication technologies (e.g. xDSL, Bluetooth, Wireless Application Protocol, etc.), new demands are raised and new fields of application emerge.

The traditional classification of cooperation along the time and location dimensions assumes - according to the distribution characteristics in time and in place of the participating users - that team members cannot both be in different physical places at the same time as perceiving themselves to be in the same virtual place. We therefore extend the traditional space-time matrix with a "virtual place" category, reflecting the possibility of recent synchronous multi-user environments [FeJo 99] to enable users at different physical places to meet in a virtual place. In addition, for our **TEAMSPACE** design, we have identified the following organisational systems to be crucial for the successful support of effective mobile teams:

- **Information and Knowledge Management System (Team Memory):** this system represents ways that organisations can respond to the information processing and knowledge gathering needs of teams. Team knowledge is time dynamic (i.e. requires on-the-fly acquisition), extends in action/state-change-perception cycles, demands structuring (indexing, annotation) and must be delivered in user customised multi-media formats.
- **Awareness System (Team Awareness):** this system is dedicated to the perceptualisation of the effects of team activity by communicating work context, agenda and workspace information to the user interfaces of involved team members just-in-time, and granting anytime access to team memory.
- **Interaction Systems (Meeting Support):** cooperation among humans is conducted via direct point-to-point or multi-point interaction, or indirectly via the manipulation of commonly accessible, shared artefacts (e.g. documents). Here, an interaction system is understood as space (e.g. virtual meeting space) for human-human cooperation at the confluence of synchronous and asynchronous interaction.
- **Mobility Systems (Mobile Teams):** mobility systems deploy mechanism to enable any-place access to team memory, the capturing of awareness information from and delivery to any place, as well as ubiquitous workplace presence.
- **Organisational Innovation Systems (Team Workplace Innovation):** these systems integrate aspects of *team design*, i.e. the organisational structure, team composition, team location, and team resources, *team leadership*, i.e. goal, priority, role and responsibility settings, *team integration*, i.e. coordination and effort sharing facilities, *performance review and reward systems*, i.e. systems defining how performance is assessed and how team members are recognised for their efforts, systems for *team training* (employee development, learning environments, formal training, and informal learning opportunities) and *organisational change systems*.

Once having argued for the role of awareness solutions in team support systems, we shall now focus on awareness issues in mobile teams in particular, and present the respective awareness features of **TEAMSPACE** in detail.

3 Team Awareness

To maintain an intuitive fidelity of staying aware of each other collaboration software user interfaces have to be found that support social interaction to a much higher extent than observed today. Most of the user interfaces for multi-user cooperative software suffer from their single user origin, and thus appear inefficient and clumsy as compared to face-to-face cooperations. User helplessness, frustration and denial are the consequences of the awkwardness of many contemporary real-time distributed groupware systems. Supporting awareness of others, therefore, promises the improving of the usability of multi-user remote cooperation systems by maintaining the fluidity and naturalness of team cooperation.

Existing research on real-time distributed groupware has addressed awareness issues in isolated and localised situations and created application or domain specific solutions (like e.g. in WYSIWIS groupware systems [RoGr 96]), but has not yet created general design principles for awareness support systems [GuGr 99]. More principled information on the awareness oriented design of teamware is demanded, allowing for a systematic consideration of concepts for situated applications and purposes. The focus is on the support of team-work rather than task-work, i.e. on the issue of how well a system supports activities involving communication, coordination and collaboration among team members, rather than the execution of domain tasks (e.g. the management of ToDo lists). In supporting team members to stay aware of each other in a team workspace, the respective teamware systems usability improves, and by that team performance and efficiency.

Adopting the terminology of [GuGr 99], we look at workspace awareness as the “... up-to-the-moment understanding of another person’s interaction with a shared workspace”, involving knowledge on who is working in the workspace, where individuals are working, what they are doing or going to do, how and when they are executing their work, and what their motivation is for doing it (why). Figure 1, besides those issues, also highlights the awareness information pipeline and awareness system utility and design factors.

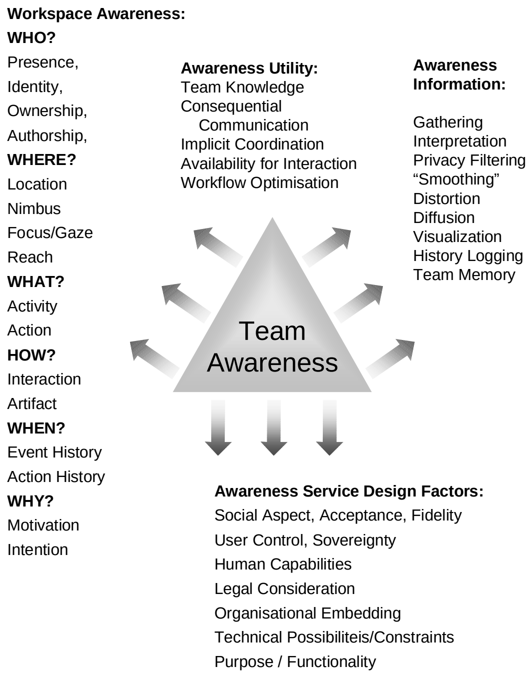


Figure 1: Awareness in workteams

This information is apparently useful in cooperation for the coordinated execution of activities, for finding opportunities for direct interaction or to assist one another, for anticipating others actions, for signalling readiness to physically meet, for notifying the completion of pending and the triggering of new tasks, etc. Opposed to the traditional understanding of shared workspaces as being bounded spaces where people can see and manipulate artefacts related to their activities, we consider virtual (team) workspaces as abstract spaces containing objects that constitute the team work (Figure 2).

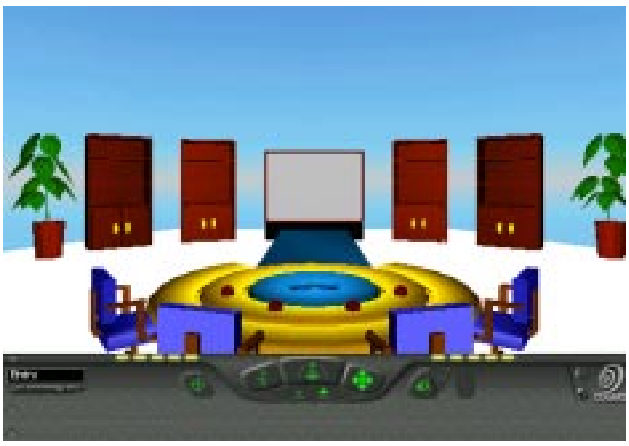


Figure 2: TEAMSPACE – a virtual space for workteams

Unlike real workplaces, not all objects (e.g. documents) need to be visible or co-located with the team member, nor need they do not have a physical representation in the space, nor need they be persistent over time. Activities typically occurring in such spaces are creation (of new objects/artefacts), assembly (combination, aggregation, extraction), manipulation (modification of state like shape, size, colour), organisation (arranging, sorting, reordering), design or exploration (finding certain or new types of artefacts, navigating through e.g. information spaces).

While awareness in face-to-face workspaces is relatively easy to maintain, and the (social and action) protocols of collaboration are intuitive, natural, spontaneous, implicit and unforced, awareness in virtual workspaces is often very difficult to obtain, if not impossible at all. The obvious reasons for this are, that:

- the restrictive communication spectrum of input and output devices allow only for the delivery of a fraction of the perceptual information that is available in face-to-face workspaces. It is essential to preserve (identify, gather and deliver) the media richness of face-to-face interactions for virtual workspaces.
- much of the awareness information in a physical work space (and not represented in virtual spaces) comes from the direct manipulation of shared real world objects (e.g. grasping a folder from the shared book shelf leaves an empty slot in the shelf, while pressing "delete" in a file folder does not), or just changing position in the space (e.g. taking a seat at the conference table). Extending the computational workspace now understood as the influence sphere of the desktop computer display and keyboard, to physical workspaces like the office environment, departments, buildings, cities, regional areas to a global dimension, will improve awareness for virtual team workplaces.
- although a considerable amount of awareness information is available from the physical workspace (like time and frequency of keyboard interaction (team member is busy), the current occupation of a telephone line (team member is not ready for interaction), the GSM terminal is presently located on the highway (team member will be back in office in about 2 hours), etc.), traditional groupware fails to exploit this information to serve virtual teams. We aim to make explicit provision of workspace information readily at hand, and systematically investigate options of gathering awareness information from physical workspaces.

The main challenge for the development of **TEAMSPACE** hence was the provision of team memory and team awareness enabled meeting support systems, in the software instance of media spaces providing virtual teams with **real life meeting fidelity**, a **large scale availability** and **universal access**. Particularly access and availability is forcing a radically new approach opposing e.g. multi-user collaborative virtual environments as coming from virtual reality research [WaBa 97] (like e.g. Massive [GrBe 95], DIVE [Hags 97], COVEN [COVE] or CAVERN [CAVE], which by nature of the highly specialised hardware and software components involved prohibit user access on a broad scale. To this end, the employment of standard and open internet technology appears mandatory, hence we committed to the realisation of **IP based Media (Meeting) Spaces** –or in other words– **Internet Collaboratories**.

Quite a few research projects have attempted inter-connecting (e.g. special interest) teams out of geographical dispersion needs: The Spectro-Microscopy Collaboratory [SMC] is an ad-hoc solution providing remote access to analytical tools at Lawrence Berkeley Laboratory's ALS to spatial visualisations of chemical structure information; DOE2000 is a new initiative to fundamentally change the way scientists work together and how they address the major challenges of scientific computation. To accomplish this change, DOE2000 explores new computational tools and libraries that advance the concept of "national collaboratories"; In the Materials Microcharacterisation Collaboratory [MMC], Centers of Excellence join into a single on-line interactive virtual laboratory - scientists, educators, and students have access to a shared environment also offering control of remote instruments and electronic notebooks; Collaborative Computing Framework [CCF] is a suite of software systems, communications protocols, and tools that enable collaborative, computer-based cooperative work in a virtual work environment on multiple computer systems connected over the Internet; The InterMed Collaboratory Project [IMC] aims to transform the health care information system to a collaborative environment and to develop a robust framework for collaboration over the internet; Finally, dedicated to teams, TeamWave [TeWa] is a set of cooperative tools like e.g. a shared whiteboard and chat options to enable some of the synchronous as well as asynchronous communication demands.

4 Implementation

TEAMSPACE is conceptually developed as shared network places to support distributed cooperative work activities and virtual teams. The TEAMSPACE is an arrangement of one ore more virtual rooms (VIRTUALROOM), which can be used for different work tasks by different team members at different times and for varying purpose. Each of these rooms can have different characteristics tuned on the special needs of the work done therein (Figure 3).

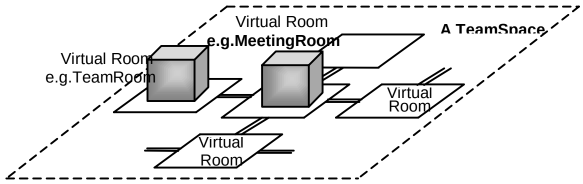


Figure 3: A TEAMSPACE and Virtual Rooms

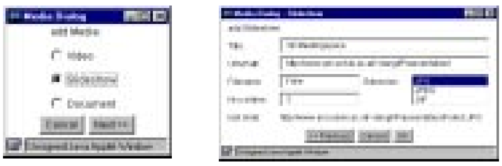
TEAMSPACE is is based essentially on open technologies, Java together with the virtual reality modelling language VRML. In its software architecture, TEAMSPACE follows a centralized server approach. (A detailed presentation of the software architecture of TEAMSPACE is presented in the companion technical report [Fers 00].) First, the VRML world and its current state must reside (or be stored) somewhere on the Internet when no users are currently in the world. This is most conveniently achieved through the use of a dedicated server. When the server is running, the current state of the world resides in the memory of the server. When new participants join, the server simply has to send descriptions of all active objects (VRML files) and their current state to the new participant. New “rooms” can be added to TEAMSPACE dynamically on demand. Like in other client/server architectures, scaling to a large number of users is limited, since the server soon becomes the communication bottleneck due to the overwhelming amount of messages which must be forwarded [Bla] [AWS]. In typical cases, the number of simultaneous users in client/server DVEs has a practical limit in the range of tens of users, with loss in performance increasing as the number of users grows [Bro 98] – those observations also hold for TEAMSPACE.

5 TEAMSPACE Showcase

As a demonstration showcase we have constructed a virtual meeting space for workgroups, MEETINGROOM – which is just one instance of a “room” on top of the TEAMSPACE software architecture, following an office metaphor for environment visualization (Figure 2). When a user connects to the TEAMSPACE server invoking the log in procedure (ID and password), it is up to him to decide where to get seated in the MEETINGROOM. The log in procedure as handled by the client applet requests user profile data like a UserCard or an image for the users preferred avatar representation. All user information is provided in a location independent way by entering respective Web URLs. The user data (and/or URLs) are transferred to the server, and (in our example) the MEETINGROOM is reloaded to display the virtual room with the contained objects for the participating users. A birds view of the MEETINGROOM is given in Figure 4 (the side-table lists the functionality of objects in this room).

Figure 4: Birds view to MeetingRoom

Every connected user is assigned a seat and cupboard, like outlined in Figure 4, bottom. Given now a user wants to deposit some media content into his cupboard (red arrows indicate the seat to cupboard mapping) to make it available also to other users joining a virtual meeting (let the type of media be a slide based presentation) then upon clicking his cupboard he first chooses "Slideshow" in the Media Dialog box:



The „Next“ button induces a dialog where related data, like title of the presentation, URL path, filename, number of slides and the file extension are to be entered. A variety of other content types could be added to the cupboard, like e.g. video or (text-) documents. Media objects integrated into the scene dynamically (upon user request) are being displayed consistently adhering the real life metaphor: Figure 5 shows the representation of the deposited media items in the cupboard, i.e. a tape like object for a video media object, and a slide drawer for the slide show.

Element:		Description:	interaktiv:
1.	Avatar	Users are displayed in the MEETINGROOM via multi-functional avatars. Upon a mouse click the UserCard of the user is displayed.	yes (Avatar)
2.	Table	The table is the central element of this room, and holds interaction contol mechanisms (indicator).	no
3.	Chair	At the start of a session every user is assigned a seat which he keeps until he leaves (logout) the MEETINGROOM.	no
4.	Indicator	Placed in front of every user is a round button indicating the access right to scen objects, e.g. the monitor to present a slide show.	yes (Indicator)
5.	Cupboard	Every user has his own cupboard where he can deposit his documents or media material.	yes (Container)
6.	Monitor	The monitor is used to show the media content to every user, e.g. video streams, slide shows.	no
7.	Decoration	These elements are for decoration.	no
8.	Computer	The computer is used to log in and out of the MEETINGROOM.	yes (Entryway)
9.	Control panel	The VRML browser control panel.	
10	Phone	This item is used to allow the user to change his/her transfer properties	yes (Property)

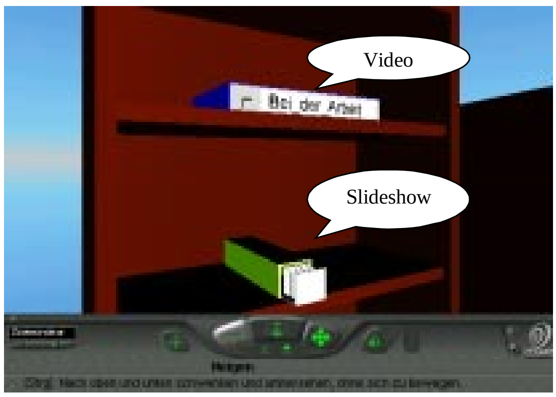


Figure 5: Video/Slideshow objects deposited in board

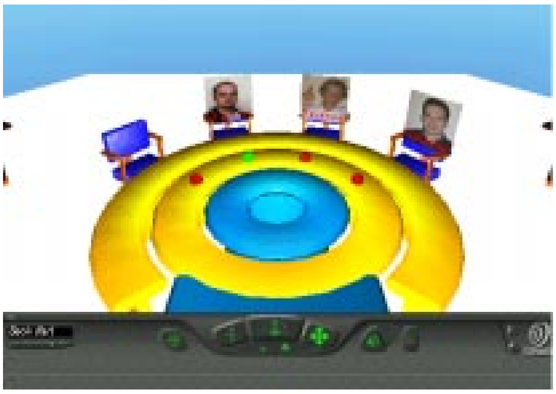


Figure 6: members aware of each others presence

Connecting users upon their "arrival" can already "see" their cooperation partners (their avatar representations) in the MEETINGROOM, and clicking on each others avatar allows them to inspect their UserCards (Figure 6). It is important to stress here, that both the physical position of an avatar in the scene as well as its orientation is glued to the actual browser (viewer) position and orientation of the respective client representing that user. In this way, it is possible for meeting participants to watch both movements (navigation) of other participants in real time. Both the awareness concepts of focus (spatial area of environment perception) as well as nimbus (presentation to surrounding environment) are realized with this kind or user abstractions.

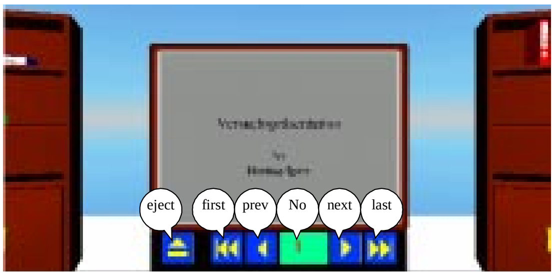


Figure 7: Presentation screen controls

Being in the shared space, the meeting partners can now start collaborating, i.e. exchanging and investigating their documents. To present a slideshow loaded onto the presentation screen for example, a user can use the control buttons to scroll through and jump within the sequence of slides in an intuitive way (Figure 7). Other traditional office oriented documents like text documents or spreadsheets can as well be deposited into the cupboard by simply providing their URL for reference over the WWW, and be opened upon download with local software (wordprocessors, spreadsheetprocessors, etc).

6 Conclusions

Multiuser distributed cooperation environments are one of the fastest growing industrial fields of application of the Internet [WAS 97], particularly its most popular service, the WWW. It is becoming an indispensable vehicle for the interconnection of humans in the interactive execution of their cooperative work agenda. This paper has exemplified the organisation of mobile virtual teams interacting "on the move" and across geographical boundaries, and has developed a workspace awareness solution for a distributed cooperation environment, exclusively based on standard Internet technologies. The commitment to open standards was the consequence after systematically pointing out the misconception of proprietary, platform and application dependent cooperation software. Hence, an integrated software architecture for a distributed cooperative work environment has been developed – the TEAMSPACE – and key features of such an environment have been implemented as a proof of concept. As a showcase, a virtual team room, the MEETINGROOM, has been used to demonstrate selected awareness features.

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