Prinz, W. and Gross, T. Ubiquitous Awareness of Cooperative Activities in a Theatre of Work. In Proceedings of Fachtagung Arbeitsplatzcomputer: Pervasive Ubiquitous Computing - APC 2001 (Oct. 10-12, Munich, Germany). Bode, A. and Karl, W., eds. VDE Publisher, Berlin, Germany, 2001. pp. 135-144. (SBN: 0-8007-2636-X).

Ubiquitous Awareness of Cooperative Activities in a Theatre of Work

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Abstract. Awareness of the cooperative activities in a distributed team is essential for successful cooperation between different locations. Different approaches for the provision of this information exist, but most concentrate on the provision of awareness indications at the users desktop. The Theatre of Work collects activity information through a variety of software and hardware-sensors and distributes them through an Internet based event and notification infrastructure. The awareness indications are presented in a multi-user 3D environment. Users and their current actions on shared objects while using groupware applications are represented by avatars and their symbolic actions. Avatars of users who work in a similar context appear spatially close in the 3D environment. The integration of the Theatre of Work into the ambience of a work setting through ambient displays and ambient indicators presents an example for the application of pervasive computing to support distributed cooperative activities. It opens new opportunities for spontaneous encounters and spontaneous contacts in distributed teams.

1 Introduction

In a co-located team, members typically learn from a wide range of cues about the activities of the other members, about the progress in the common task, and about subtle changes in group structures and the organisation of the shared task environment. Most of this group awareness is achieved without specific effort. A distributed (virtual) team – even if its cooperation is based on a state-of-the-art groupware system – today is far from a similar level of awareness and opportunity for spontaneous, informal communication. This reduces the effectiveness of the joint effort, and makes cooperation a less satisfying experience for the team members. The TOWER system[1] aims at bringing the wealth of clues and information that create awareness and cohesion in co-located teams to the world of virtual teams and to present them in a Theatre of Work.

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1 The TOWER system is being developed in the IST-10846 project TOWER, partly funded by the EC.

This information is valid for the mutual orientation in cooperative work processes but also for the social interaction. Organisations are more and more restructured around virtual teams. Thus "they loose opportunities for innovation through the causal sharing of knowledge and learning induced by physical proximity" or as Prusak describes this phenomenon vividly: "If the water cooler was a font of useful knowledge in the traditional firm, what constitutes a virtual one?"

A number of approaches (see section 4 on related work) exist to support awareness information in groupware applications. Common to these approaches is that they concentrate on the provision of awareness information at the users' desktop. Although this is an appropriate approach in many cases, we believe that additional support is possible through the use of ambient awareness displays that are located in the office environment. The TOWER system aims at supporting group awareness and chance encounters through a 3D environment that is at the heart of the Theatre of Work. Users and their current actions on shared objects while using a groupware application are represented by avatars and their symbolic actions. Avatars of users who work in a similar context appear spatially close in the 3D environment. The Avatars perform symbolic actions that illustrate events in an information space, episodes of interaction or non-verbal behaviour.

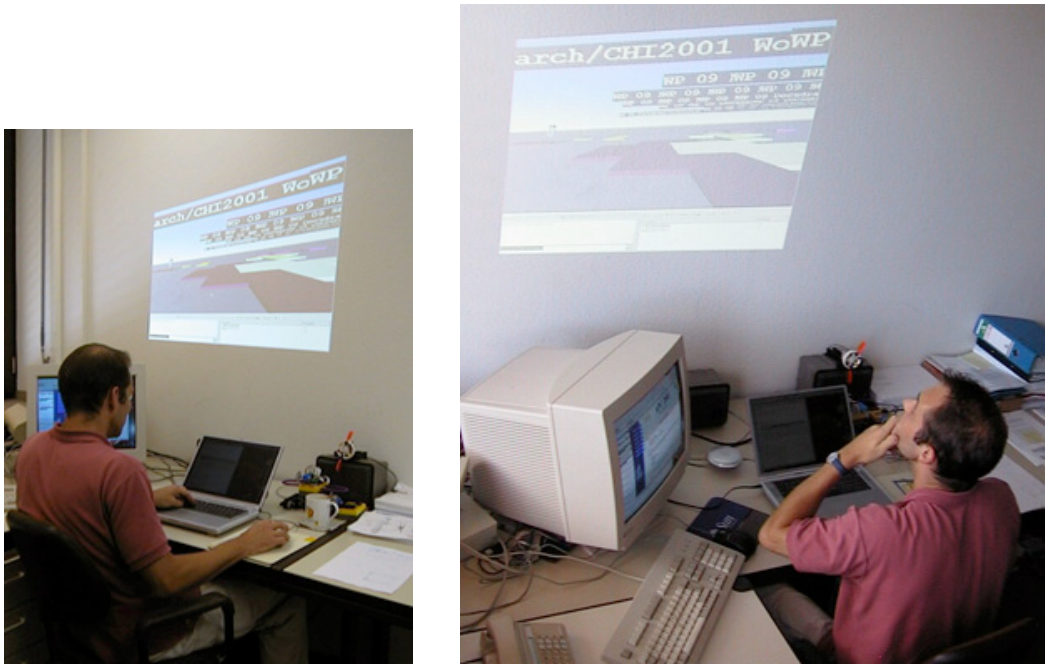

Figure 1. A TOWER world, shown as an ambient display in a user work setting.

We believe that the provision of such a pervasive awareness service is vital for the successful cooperation and knowledge sharing within distributed teams. In the remainder of the paper we will describe the components of the TOWER system and the use of TOWER as a ubiquitous awareness environment. We will, finally, give a short overview of related work.

The provision of awareness information through ambient displays facilitates the integration of virtual and real world settings. It will enable one in the ambience of a real world room, like in the personal office or at home, to perceive awareness information and to be reminded of the performances in the virtual world. Figure 1 shows an example: on the left picture the user works with notebook and PC and captures the activities in the

virtual world peripherally; on the right picture the user saw that there is a lot of movements of avatars in the virtual world and looks up to follow what is going on. Ambient interfaces will help overcome the limitations of current I/O-devices for interacting with the electronic environment and will manifest links between the virtual and the real. Also existing devices like lamps, phones, bells, fans etc. may receive an additional symbolic meaning as indicators of events in the electronic world. Ambient displays should be appealing with respect to artistic and functional criteria. The tangibility as well as the physical characteristics of ambient displays will contribute to making the virtual more comprehensible .

2 The TOWER system

The TOWER system is composed of a number of interworking components. Figure 2 illustrates the overall TOWER architecture. It consists of:

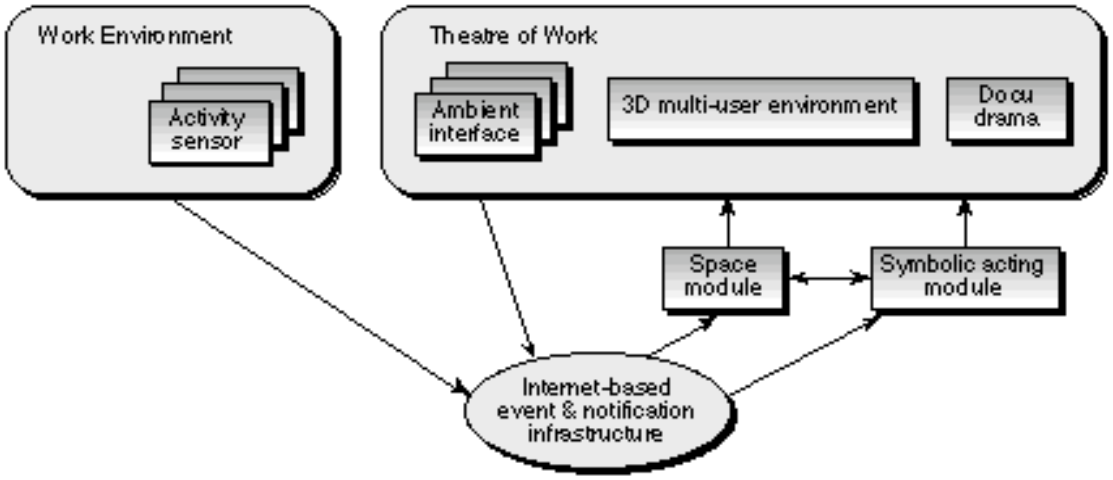

Figure 2. Illustration of the TOWER architecture.

- A number of different activity sensors that capture and recognise user activities in a real and virtual work environment and that submit appropriate events.
- An Internet-based event & notification infrastructure that receives events and forwards these events to interested and authorised users.
- A space module that dynamically creates 3D spaces from virtual information environments, e.g. shared information workspaces such as Lotus Notes and that adopts existing spaces to the actual usage and work behaviour of the users that populate these spaces.
- A symbolic acting module that transforms event notifications about user actions into symbolic actions, i.e. animated gestures of the avatars that represent users and their activities in the environment.
- A 3D multi-user environment that interoperates with the symbolic acting and space module for visualisation and interaction. For this purpose we use a solution provided by Blaxxun[2].

2 http://www.blaxxun.de

- The 3D visualisation is complemented by ambient interfaces integrated into the physical workplace providing activity visualisation methods beyond the standard desktop.
- A DocuDrama component that transforms sequences of event notifications and history information into a narrative or visualisation of the past cooperative activities.

Each component is described in more detail in the following.

2.1 Event and Notification Infrastructure

Primary goal of TOWER is the presentation of activities in a cooperative environment through symbolic acting in the Theatre of Work.

This requires an event and notification infrastructure that is capable of recognising and sensoring user activities on shared objects or in a shared environment [Prinz 1999]. TOWER includes an infrastructure that is fully integrated with the Internet. This infrastructure provides a number of sensors that can be integrated with user applications using Internet protocols such as HTTP, which are available in almost all standard application nowadays.

Agent-like sensors are realised that observe information sources and the population of information by users. Real world sensors like movement and acoustic sensors are integrated to capture the presence of people in different office locations. All sensors submit events that encapsulate activity information to the infrastructure.

Tasks of the infrastructure are to store, aggregate, and forward the activity information to applications that have registered interest in the appropriate information. For the interaction with other applications push and pull methods are realised. Restricted access to activity information is realised through access rights. Reciprocity mechanisms are included to ensure transparency between producers and consumers of information.

Beyond the realisation of these basic functions the infrastructure provides different methods for a context based distribution of activity information, where the context is defined by the spatial, organisational, task-related and personal environment of the cooperating users [Gross & Prinz 2000].

2.2 Space module

The space module dynamically creates 3D spaces from virtual information environments Figure 3 such as BSCW workspaces or the content of other document management systems. These spaces evolve in response to the patterns of space use and behaviour by those who are using them. In this sense the TOWER environment develops a record of its own past history, which will in time act as a powerful asynchronous device, which will help users find their way and find each other. It serves to structure people and information according to classifications based on the conceptual distance between their interests and contents. In this the TOWER environment itself complements the DocuDrama record of past activity, but in a more ambient form, through the groupings and spatial relationships, which evolve in the environment itself.

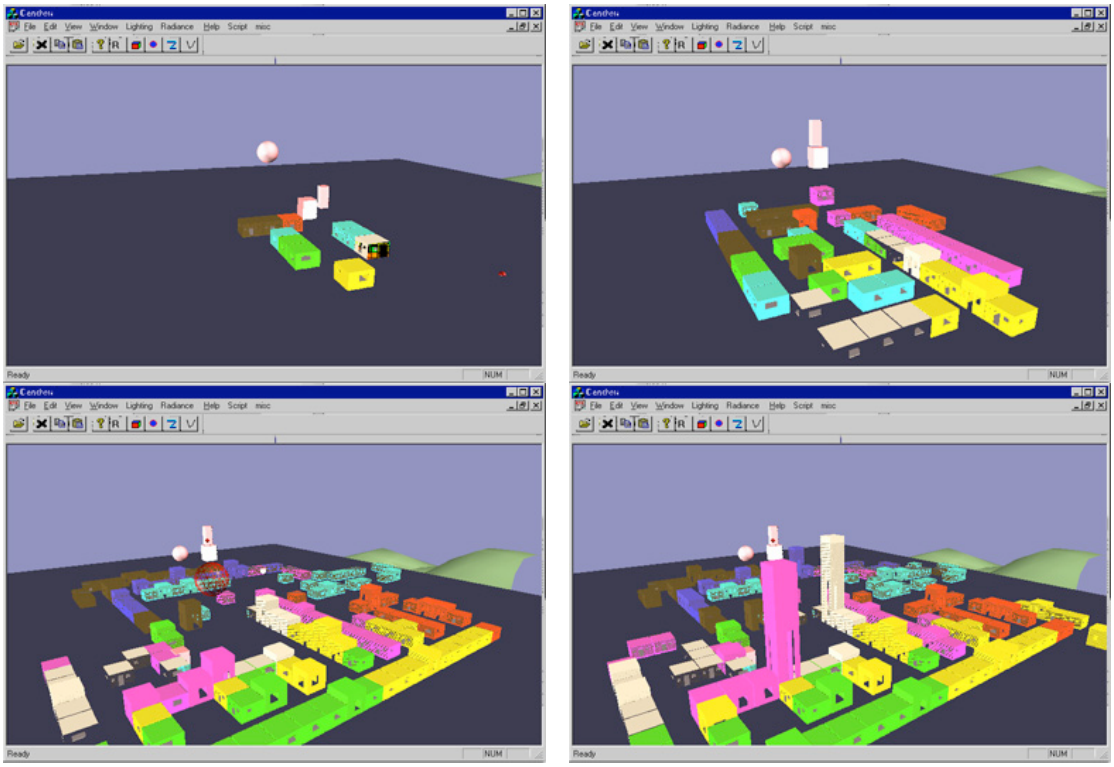

Figure 3. The prototype TOWER world showing growth and rearrangement during the creation process [Gavin *et al*. 2000].

Real built environments are characterised by a complex interaction between movement patterns and static behaviour patterns of those who inhabit them. The spatial structure of the built environment affects movement patterns by creating more and less strategic routes. In turn people take advantage of these patterns of 'passing trade' to locate themselves and facilities . The evolution of a symbiosis between patterns of spatial structure and patterns of behaviour gives rise to the richness of the cultural experience of space at both the urban scale and within building interiors. By encapsulating certain aspects of this kind of emergent process within a space generation rulebase the space module seeks to develop a characteristic spatial culture within TOWER. This is used to investigate how different rulesets can be used to tailor the culture towards that desired by different kinds of organisation. Organisations with well-defined 'proceduralised' tasks and organisational structures may require more controlled and hierarchical spatial forms. Those in which innovation is of greater importance than control require more inter accessible structures with greater degrees of indeterminacy and overlap between categories.

Another criteria for the world creation is the granularity of the mapping of document sets into the 3D information landscape. User workshops yielded different opinions whether a more detailed view or a more abstract overview provides better context for the visualisation of user activities. In our current prototype users can select between different worlds, each created by different selection criteria and generation. In an overview world for example only folders of the shared information space are represented by objects in the 3D landscape, while the detailed world provides a representation for each document. In the overview world activity spots are easier to recognise while in the detailed world clusters of objects with a similar semantic are easier to identified.

The space module can be seen as providing the means by which the setting for symbolic acting will itself carry and constitute meaning. In this sense behaviour patterns within TOWER are 'situated' whether these are determined by the overt behaviour of the users or by the semi-autonomous processes of symbolic acting.

2.3 Symbolic acting

Fostering simple effective communication is vital to collaborative working, the emergence of flexible working and the growing attraction of post-geographical working inevitably introduce distortion into key messages, dissonance between groups and adds additional cognitive effort to even the simplest interaction. Symbolic acting is a concept where the useful information of 'who is doing what' is displayed visually for the benefit of everyone without adding cognitive effort to the users .

The idea of symbolic acting is to automatically detect what the user is up to and use this to control what their avatar does. An avatar acts out the symbolic meaning of the users everyday actions on their behalf. The emphasis in symbolic acting is to show the contextual information telling us about where a user is, who they are and what they are doing right now. By taking away the responsibility for controlling the avatar from the user and automating it we remove the problem of relying on neglect prone manual controls to add life to a world. With symbolic acting the context dependent actions of all users are shown at all times so the world can seem like a more active place as well as more closely reflecting the activities of a user group. We let the system do the walking – and the acting. This is a very powerful and engaging way of solving problems in mediated communication.

3 Cooperation awareness through ambient displays and indicators

Ubiquitous computing, ambient displays, and sensors have become important issues in the area of user interface and workplace design . The Theatre of Work System provides ways of providing users with awareness information about their physical and electronic environment. One of the big problems in this area is information overload when this information is solely presented at the user desktop. Ambient displays, which are integrated in the environment of the user, promise to provide a good approach to avoid this information overload by providing awareness information in the users periphery.

3.1 Ambient displays

In a TOWER office setting the TOWER world is displayed either through projections in the office environment or by large touch sensitive screens. Figure 4 shows a coffee room scenario in which the TOWER world is displayed at a large touch sensitive Plasma display. The two users have just recognised the presence of remote colleague at a certain location in the TOWER world. This indicates that this colleague is currently working on documents, which are of interest to the users. They touch at the avatars and immediately a video connection is opened to this user which allows them to directly interact with the

remote colleague. This scenario shows the potential of the TOWER world in combination with an ambient display to serve as a contextual chance encounter for distributed teams.

Figure 4. Ambient display and user interaction with a TOWER world in a coffee room setting.

A TOWER environment also consists of various ambient indicators ranging form light, movement, or sound producing entities to artificial objects. For example the water-light is used to indicate web page or web-cam accesses to the visitors of a coffee room (cf. Figure 5).

Figure 5. Example of an ambient indicator.

3.2 AwareBots

The LEGO Robots are used by individual users to display events like the presence of remote colleagues in the office or in a shared virtual discussion room, the availability of a document or a resource, or the value of information gathered by web agents (e.g. traffic jams, weather, stock values). They were built with the LEGO Mindstorms set [Knudsen 1999]. A broad range of AwareBots—LEGO robots capturing and presenting awareness information—is available. Figure 6 shows a simple white wheel with red wings that rotates upon arrival of certain events (it can also be seen on the two pictures of Figure 1). The wing is used in personal offices for indicating activity in shared BSCW workspaces. For

instance, the user might want the wing to rotate for some seconds when a certain threshold of activities in a BSCW workspace is passed. A sensor on the BSCW server generates events whenever a user logs into a BSCW workspace and reads, changes, or adds documents.

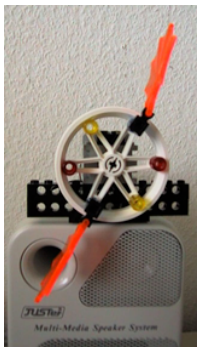

Figure 6. Wheel with wings connected to a motor.

The EyeBot AwareBot provides means for indicating and sensing events (cf. Figure 7). The rotating eyes and dangling nose are used as indicators the flag is used as a binary sensor. The EyeBot is used in the following scenario: The rotating eyes are connected to events produced by read activities. Examples are events produced by remote users who read a document that has been created by the user in a shared workspace. Another application is the indication of accesses to a web-cam that is located in the vicinity of the ambient display. The dangling nose is connected to events produced by communication activities. This can be a chat between project members or emails distributed via a team distribution list. A binary sensor is connected to the flag. If the user places the flag in front of the display such that it almost hides it then the user indicates that he does not want to be disturbed (cf. Figure 7 rightmost picture). This can be indicated to other users and TOWER interprets it such that it does not display or indicate any events. If the flag is turned to the back of the display, the user indicates his availability to others and TOWER will also start to indicate events according to the users preferences.

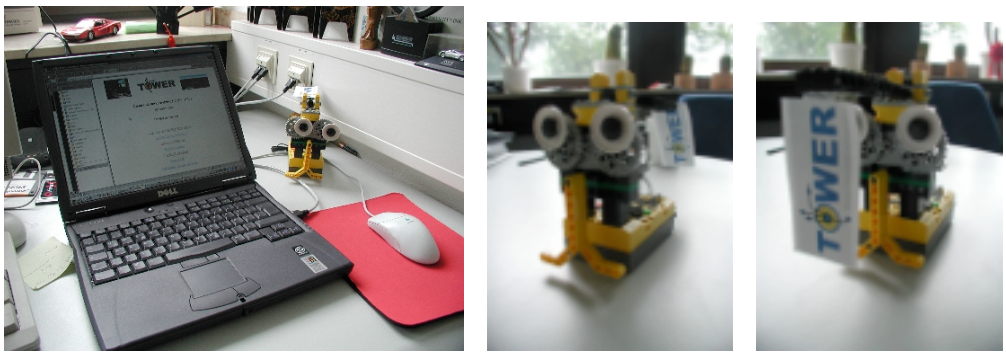

Figure 7. The EyeBot: in work environment; available; busy.

The RoboDeNiro AwareBot uses two motors and one sensor. When the event occurs the RoboDeNiro indicates it by starting or stopping a motor. For instance, a user could wait for a colleague to log in. When the colleague logs in, an event is generated and sent to the ENI server. The ENI server then sends this event via the ENI client to the RoboDeNiro AwareBot, which lifts its hat. Similarly, an upload of a document into a BSCW workspace

can make RoboDeNiro rotate its body. The arm of the robot is equipped with a touch sensor and is used for logging into the system. When the user touches the arm an event is generated and sent to the ENI server: the user gets logged in and the other users get the information that this user is now available. Figure 8 shows RoboDeNiro in action.

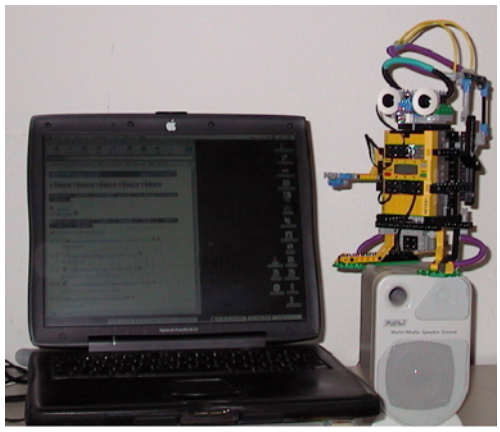

Figure 8. The RoboDeNiro AwareBot in action.

3.3 AudioSpace

In addition to the ambient interfaces and AwareBots we described so far, we are also developing an AudioSpace that allows the user to hear events. The AudioSpace allows users to specify contexts they are interested in and to map SoundScapes to these contexts. So, although that sound is played in the background and the users only capture it peripherally it is intuitively clear from which context a sound origins. For instance, a user can specify contexts for the projects she is working on. Contexts consist of persons, artefacts, tools, locations, and so forth that are involved in a particular project. For instance, for project X the user selects the SoundScape beach, for project Y the user selects the SoundScape DownTown. Now, anytime an event occurs that relates to project X the user can hear sounds from the beach (e.g., seagulls, waves, wind).

If the user wants to receive more precise audio notification, she can decide to have a more fine grained specification. So, the user selects single values of attributes (e.g., person P as a member of project X; document D as an artefact belonging to project X) and assigns specific sound to them (e.g., a wind howl for person P; a cry of a dove for document D). Now, anytime an event occurs in which person P is involved, the user can hear the sound of waves; any time document D is involved the user can hear a cry of a dove). Additionally, for either of the two types of events the user hears a basic sound (e.g., a wave sound). So, the user knows from which context the sound origin. For events with a short duration (e.g., a simply Web access) only a short sound is played. For ongoing events (e.g., the period of a login of person P) the interested user can choose if a sound should be played only at the beginning of the event, or for the whole duration of the event. This last option can be easily changed with a simple on/off-switch. As, there are considerable advantages and trade-offs for both options, this seems to be important. The advantage of a short notification is that the user is not permanently disturbed. The advantage of the on-going notification is that the user does not miss the audio notification,

in case she is not in her office when the event starts (e.g., in the printer room, out for lunch).

4 Related Work

The comprehensive approach of the Theatre of Work is unique in the area of awareness research. Thus we concentrate the discussion of related work on the different system components.

A protocol for presence awareness for web users is presented in . The proposed architecture includes also an awareness server and client. However, both the architecture and the protocol are intended for the provision of presence awareness on web pages. The authors do not consider the provision of a generic awareness infrastructure.

"Buddy Lists" application such as ICQ or AOL messenger are widespread presence information tools. Since recently an IETF working group is developing an instant messaging and presence activity proposal , which results in PIP, a "Presence Information Protocol" . These proposals are focussing on presence awareness only; other forms of awareness are not investigated. The scope of TOWER goes beyond presence awareness, but we observe the standardisation initiatives and plan to incorporate the PIP protocol in future versions of the TOWER event and notification infrastructure.

More related to TOWER event and notification infrastructure are the Internet notification service Elvin and Khronika . Elvin is a publish-subscribe notification service where consumers use content-based addressing to select notifications of interest. The developers consider the application domain for Elvin in area of network management, legacy application integration and as an infrastructure for computer-supported cooperative work. Khronika is an event browsing and notification system that addresses the problems of information overload and information distribution. Key elements are events, daemons, and notifications. Initial motivation for Khronika was the information overload caused by the massive distribution of undirected event-information, e.g. through email list. The system provides a central service for the management of such events. Users can express their interest in events by constraints that are observed by daemons. Instead of being swamped with email announcement users can select the information they want to be aware of.

Initial experiments with the symbolic acting approach can be found in [McGrath 1998]. The idea to create and populate 3D environments based on information spaces is explored in [Benford *et al.* 1997].

Video based media spaces [Lee *et al.* 1997; Mantei *et al.* 1991] are an alternative approach to provide peripheral awareness through ambient displays for distributed teams. The difference is that video based systems do not allow the creation of artificial rooms as we do with the space module. From a video image it also difficult to guess what type of operations a user is currently performing on shared material. By the visualisation of a users action through symbolic animations of the users avatar this kind information is much easier to present. For the perception of real rooms video is a very useful approach. However, the advantage of symbolic representations based on acoustic sensors and motion sensors is the provision of a higher grade of inaccuracy, thus protecting more privacy. Observers can see a level of activity, but they can't see who is actually acting. Video

images can be blurred to reduce the accuracy of the original, but we believe that a sharp 3D visualisation is more attractive than a blurred video image.

Our research on ambient displays has been influenced by the work at the MIT Media Lab . Similar approaches can be found in . However these approaches concentrate only on ambient artefacts, but do not take the combination of these artefacts with a virtual world into consideration.

As far as the AudioSpace is concerned some approaches with some similarity can be found. For instance, the Environmental Audio Reminder (EAR) system provides unobtrusive audio cues that are played in offices and around the building. They inform users about ongoing events and remind users about upcoming events. EAR uses the Khronika event infrastructure. Compared to TOWER, EAR only provides simple and short 'cartoon-like stereotypes of naturally-occurring sounds' . The audio aura system aims at providing serendipitous information to mobile users via background auditory cues . Whereas in TOWER we want to provide users with serendipitous information and information that is important for the user and the cooperation, the AudioAura system plays information that provides some additional benefit to the user, but is not needed .

The TOWER infrastructure provides a generic and open platform for the submission, transformation, and notification of events that are relevant for the promotion of task-oriented and social awareness in a cooperative setting. The integration of virtual and real-world sensors and indicators as well as the transformation of discrete events into a contextual presentation in the form of a Theatre of Work are unique characteristics of the TOWER environment.

5 Conclusion

With TOWER, new workplaces will be opened which enable people to benefit from currently available pervasive ubiquitous computing technology for the development of new working situations for distributed teams. With TOWER the limitations of working condition of non-collocated groups or teams can be overcome. Distributed teams or groups will be the working conditions of the future. Such teams connect expertise from various source and countries. We believe that current groupware systems provide only the necessary but not the sufficient functionality to support communication and cooperation between distributed teams in an adequate manner compared to co-located teams. With the Theatre of Work we provide a pervasive environment that is complementary to existing groupware systems and that augments these systems to achieve an environment that increase the awareness and cohesion in distributed teams.

Temporal and spatial distances currently limit the operability and effectively of virtual teams and erode the cohesion among team members. Teamwork depends deeply on the opportunity of its members to have immediate occasions for social contact. Social contacts are relevant for both the smooth progress of cooperative work as well as for the motivation and well being of the individuals. Currently distributed teamwork suffers from the lack of occasions for face-to-face social contacts.

The usage of TOWER increases the likeliness of synergy effects to occur in virtual teams, and may contribute to improved team cohesion. The perception of co-presence in a pervasive environment may affect the quality of the work with respect to the quality of the outcome. It will improve the working atmosphere by the reduction of planning,

synchronisation, and coordination efforts. It will avoid or at least reduce the feeling of isolation of teleworkers and will contribute to orientation in both the social and the task related environment.

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