Supporting Awareness in Mixed Presence Groupware

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ABSTRACT
Mixed presence groupware (MPG) is software that connects *both* collocated and distributed collaborators together in a shared visual workspace. Our early study of this new genre is that people focus their collaborative energy on collocated partners at the expense of remote partners, which imbalances collaboration. We call this problem *presence disparity,* caused by the imbalance of awareness exuded by virtual embodiments versus actual people. VideoArms is an embodiment technique that mitigates presence disparity by enhancing awareness of remote collaborators in a mixed presence workspace. We describe how VideoArms works, and the design principles behind its construction.

Author Keywords
Mixed presence groupware, awareness, consequential communication, embodiments, gestures.

ACM Classification Keywords
H.5.3.b. Collaborative computing; H.5.3.c. Computer-supported cooperative work.

INTRODUCTION
Prior groupware research has focused on distributed groupware and collocated groupware independently of one another. Yet the proliferation of large digital displays, which naturally support collocated collaboration, make it increasingly important to examine how groupware can support *groups* of distributed collaborators. Consider the following scenario.

You lead a team of designers based in Seattle, and have scheduled a joint brainstorming session with another group in your New York office. This is possible because your company has special meeting rooms in each city location, connected by audio and containing linked electronic whiteboards. This software allows one or more members of either team to simultaneously draw ideas on the wall using styli, where colleagues in either location see those drawings as they are being created in real time.

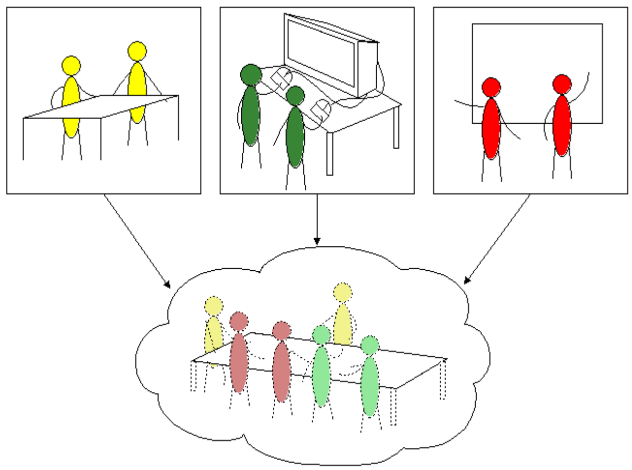

Figure 1. Three teams working in MPG over three connected displays (top), stylized as a virtual table (bottom).

Our research focus is to understand and design the collaborative software described in this scenario, which we call *mixed presence groupware* (MPG). MPG is software that connects *both* collocated and distributed collaborators together in a shared visual workspace. As well, MPG usually represents collaborators as entities within the workspace by some type of *embodiment*—virtual presentations of their bodies. In practice, we have built MPG systems by connecting several distributed displays, each with multiple input devices, thereby connecting both collocated and distributed collaborators. Figure 1 shows a stylized example MPG system where three groups of collocated collaborators (top) work together in a shared virtual space (bottom).

Yet MPG presents a unique problem called *presence disparity*, where collaborators focus their energies on collocated collaborators at the expense of their distributed counterparts [6]. While individuals can maintain a very rich awareness of physically collocated collaborators, presence disparity arises because it is difficult for them to gain an equivalently rich awareness of remote participants via their embodiments. This is because most groupware systems reduce this virtual presentation of the embodiment to telepointers—usually a custom mouse cursor—which

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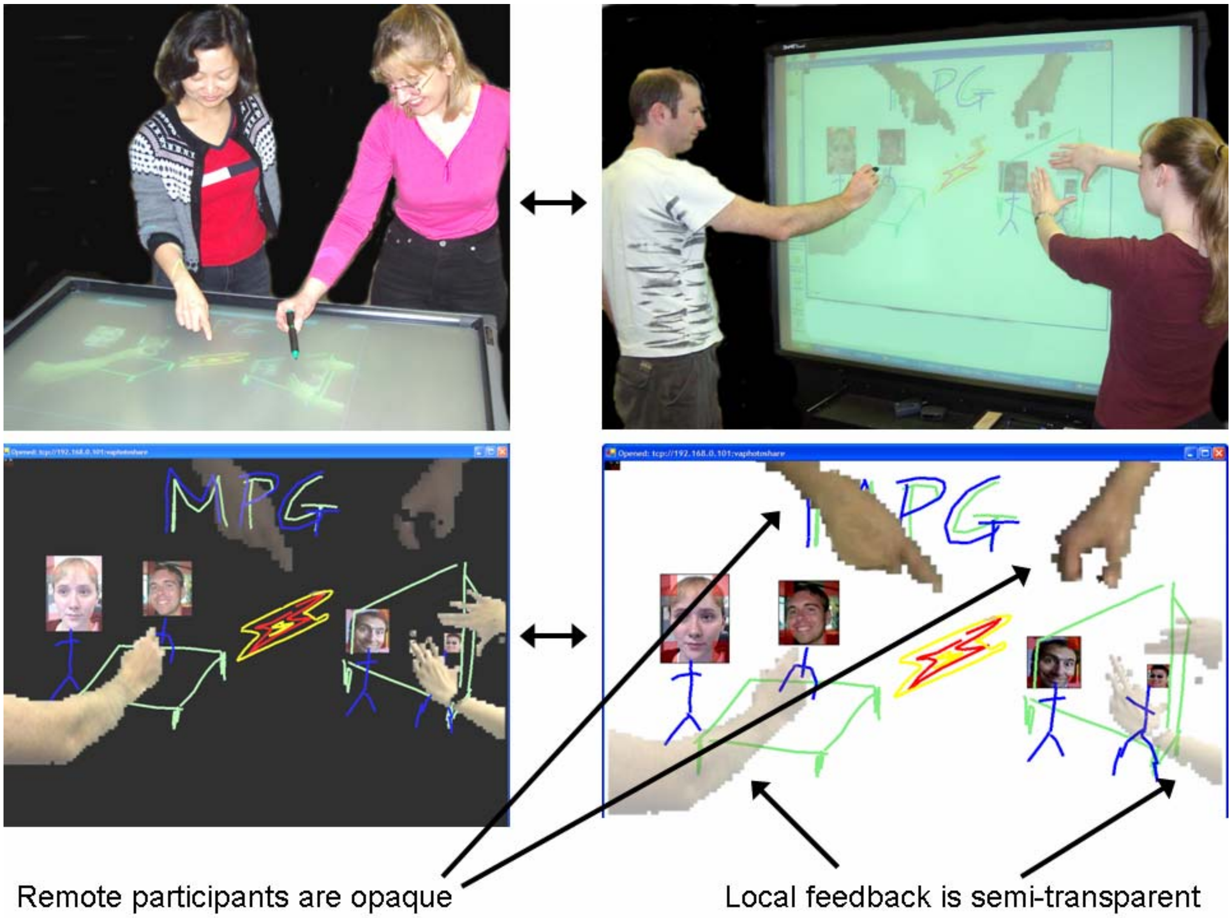

Figure 2. VideoArms in action showing two groups of two people working over two connected MPG displays (top) and a screenshot of what each side sees (bottom). Local and remote VideoArms are in all scenes, but local feedback is more transparent.

clearly cannot compete against the physical body of a collocated collaborator. Thus, presence disparity unbalances the collaborator's subjective experience because even dyadic collaborative dynamics will vary in terms of how one senses presence, engagement and involvement of collocated *vs.* remote partners.

This imbalance between how one is able to maintain an awareness of collocated *vs.* remote collaborators has a negative impact on conversational dynamics. Since MPG collaborators cannot communicate (verbally and non-verbally) as effectively with remote collaborators as they can with those who are collocated, remote collaborators are less likely to be attracted into informal discussions of work objects, and are therefore less likely to perform the task as effectively as collocated counterparts.

In this paper, we discuss the design of VideoArms, an embodiment technique that aims to mitigate the problem of presence disparity in MPG. VideoArms digitally captures people's arms as they work over large work surfaces, and displays them as digital overlays on remote displays. In doing so, VideoArms provides a rich means for collaborators to maintain workspace awareness [2] of remote participants in MPG systems.

VIDEOARMS: A VIDEO-BASED MPG EMBODIMENT

VideoArms is a video-based embodiment technique for MPG systems that digitally captures collaborators' arms as they work over the workspace using a video camera, and redraws the arms at the remote location. Figure 2 illustrates a sample session of VideoArms. The top images show two connected groups of collaborators. Each group works over a large touch-sensitive surface—the left is a front-projected touch-sensitive horizontal DViT, while the right is a rear-projected vertical SmartBoard. Each surface displays the same custom MPG application that lets people sketch and manipulate images, while displaying video embodiments.

Figure 2 (bottom) also illustrates what users can *see* when using the VideoArms embodiment in this MPG application. First, collocated collaborators can see their own arms as local feedback, rendered semi-transparently, providing feedback of what others can see while minimizing interference. For example, the bottom right image of Figure 2 shows three semi-transparent arms as local feedback for the two collaborators working on the wall display (Figure 2, top-right).

Second, each group sees the solid arms of the remote participants in reasonable 2½-dimensional fidelity (while the images are not truly 3-dimensional, the system captures and reproduces color-based depth-cues). For example, the bottom right image of Figure 2 shows two opaque hands which present the arms of the remote participants working on the table display (Figure 2, top-left) to the two people working on the wall display (Figure 2, top-right).

Third, the remote drawings of arms preserve the physical body positioning relative to the workspace. Both physical and video arms are synchronized to work with the underlying groupware application, where gestures and actions all appear in the correct location[1]. For example, because the people at the table display (Figure 2, top-left) are positioned at the rear of the table, their arms appear on the vertical display as coming from the top (Figure 2, right).

Figure 2 also reveals communicative aspects of the embodiment. In this MPG setting, all participants can simultaneously gesture to the full, expressive extent of arms and hands. The system neither dictates nor implies any sort of turn-taking mechanism, and captures workspace and conversational gestures extremely richly. Furthermore, users are not tethered to any particular place in the workspace: using touch and pens to interact with the groupware application, users are free to physically move around the workspace as they see fit. For example, we can see the use of rich gestures in the top right image of Figure 2 when the woman uses her hands to indicate the intended size of an object. At the same time, the woman on the left of the table (Figure 2, top-left) points to a particular object.

Design Principles

The VideoArms metaphor captures and presents the workspace from a bird's eye view of the workspace. It builds upon the "through the glass" metaphor of previous analog video systems [3,7,8], although unlike them it uses a set of completely digital capture, transmission and display algorithms. Just as in real life, the video arms serve as the primary indicators of a collocated collaborator's presence (Figure 3). To mitigate presence disparity for remote collaborators, VideoArms was designed to support four principles.

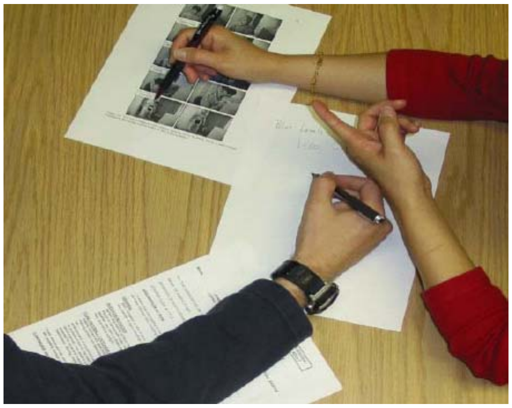

Figure 3. A bird's eye view of a physical workspace.

1. To *provide feedback* of what others can see as *feedthrough*, a person's embodiment should be visible not only to one's distant collaborators, but also to oneself and one's collocated collaborators.
2. To *support consequential communication* for both collocated and distributed participants, people should interact through direct input mechanisms, where the remote embodiment is presented at sufficient fidelity to allow collaborators to easily interpret all current actions as well as the actions leading up to them.
3. To *support bodily gestures*, remote embodiments should capture and display the fine-grained movements and postures of collaborators. Being able to see these gestures means people can disambiguate and interpret speech and actions.
4. To *support bodily actions as they relate to the workspace context*, remote embodiments should be positioned within the workspace to minimize information loss that would otherwise occur.

We perceive our own actions and the consequences of our actions on objects as *feedback*, and we constantly readjust and modify our actions as our perceptions inform us of changes to the environment, or changes about our bodily position [5]. Threading a needle when blindfolded is difficult because without our ability to perceive our own bodies as physical objects in the world, we cannot smoothly interact with it. Thus, the first design principle suggests that a person's embodiment should be visible not only to one's distant collaborators, but also to oneself and one's collocated collaborators.

Our bodies are the key source of information comprising *consequential communication*: awareness information unintentionally generated as a consequence of an individual's activities in the workspace, and how it is perceived and interpreted by an observer [5]. A person's activity in the workspace naturally generates rich and timely information that is often relevant to collaboration. For instance, how a worker is positioned in the workspace and the kinds of tools or artefacts being held or used tells others about that individual's current and immediate future work activities (e.g., the arm poised to write in Figure 3). Therefore, the second design principle addresses the need to support consequential communication by using direct input mechanisms and through high fidelity MPG embodiments.

While consequential communications comprises unintentional body actions, *gestures* are intentional bodily movements and postures used for communicative purpose [1]. Gestures play an important role in facilitating

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[1] VideoArms digitally reproduces a video-captured image of the workspace. In principle, it can therefore support an infinite number of non-overlapping arms. While our goal was to develop a true MPG application with VideoArms, technical limitations imposed by the input devices (the actual SMARTBoards) meant that our final system only supported two simultaneous touches on one display; the other display could only support a single touch.

collaboration by providing participants with a means to express their thoughts and ideas both spatially and kinetically, reinforcing what is being done in the workspace and what is being said (e.g., the pointing arm in Figure 3). For this reason, the third design principle speaks about the necessity for embodiments to capture and display the body gestures of collaborators.

Because consequential communication and gestures occur in the workspace, removing such actions from their context also removes much of their interpretation. For instance, the statement, "Put this object here," is meaningful in the context of Figure 2 and 3, but is unintelligible outside of the context of the workspace. This leads to our fourth design implication, which stresses that embodiments should be placed within the context of the workspace.

From a collaborative standpoint, the VideoArms prototype theoretically provides a rich means for individuals to maintain an awareness of both remote and collocated collaborators. First, local participants know what remote people see because their own embodiments are shown as semi-transparent feedback. Secondly, because the body is used as an input device on the touch sensitive surface, VideoArms supports consequential communication: other collaborators can easily predict, understand and interpret another's actions in the workspace as one reaches towards artefacts and begins actions. Rich gestures (coupled with conversation and artifact manipulation) are also supported well because the remote arms are displayed in rich 2½ dimensional fidelity and a reasonable framerate (~12 fps). Finally, task-related gestures are easily interpreted because they are placed in the context of the workspace. In addition, collocated participants can use and interpret natural body language of as they collaborate.

Implementation

VideoArms uses inexpensive web cameras positioned approximately two meters in front of the display to capture video images of collaborators. The software extracts the arms (and other bare-skinned body parts) of collaborators as they work directly over the displayed groupware application. It then transmits these digital images to the remote workstation, where they are further processed to appear as an overlay atop the digital workspace. To provide local feedback, VideoArms overlays a local person's video on the work surface.

CONCLUSION

The design of VideoArms was motivated by the desire to mitigate presence disparity in MPG systems, a problem which is caused by the differential ability to maintain workspace awareness of remote collaborators compared to collocated collaborators. In this work, we have identified four design factors for MPG embodiments, which are instantiated concretely in VideoArms. Although not reported here, we have just completed a preliminary study that demonstrated that VideoArms supports rich gestures and consequential communication across the link, thereby reducing presence disparity.

VideoArms is not a total solution. For example, eye contact and body positioning, which have been found to be important to collaboration [3], are not supported at all. Yet VideoArms is a reasonable first-step as it provides a richer awareness of the workspace by presenting the parts of the body that appear within it.

VideoArms is a working proof of concept, and as such there is still room to improve its interface as well as the underlying groupware system. These need to be fixed, at which point we will undertake a more thorough empirical evaluation to validate VideoArm's effectiveness as an MPG embodiment. At this point, however, we believe that we have forwarded MPG research into a space where we can begin to understand embodiment design and the tradeoffs between different types of embodiment types within MPG collaboration.

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