

# IBM Research Report

## Projector-Camera Systems for Telepresence

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## ABSTRACT

Projector-camera systems provide tools for telepresence that enable novel experiences not possible with currently available schemes for remote interaction including video conferencing systems, virtual reality, and augmented reality systems. Projector-camera systems have the potential not only to allow remote individuals to view each other's environments but also to communicate in new ways by overlaying and embedding information and visualizations on *real* objects and surfaces in the remote environment, without requiring people in the remote environment to “wire” the space or wear special devices. We demonstrate some of this potential with an initial implementation.

## Categories and Subject Descriptors

H.5.1 [Information Systems and Presentation]: Multimedia Information Systems – Artificial, augmented, and virtual realities; H.5.2: User Interfaces; H.5.3: Group and Organization Interfaces; H.4.3 [Information Systems Applications]: Communications Applications – Computer conferencing, teleconferencing, and videoconferencing.

## General Terms

Algorithms, Design, Experimentation, Human Factors.

## Keywords

Collaboration, remote interaction, interfaces, meetings, context modeling, action capture, presentation systems, ubiquitous computing, pervasive systems.

## 1. INTRODUCTION

Research in multimedia and telepresence is working towards the grand challenge of making “interactions with remote people and environments nearly the same as interactions with local people and environments” [10]. There have been many years of research in this area spanning collaborative virtual environments [4], video conferencing systems [11], and augmented reality systems [1]. For the most part, these systems have been centered on special devices – needing a special

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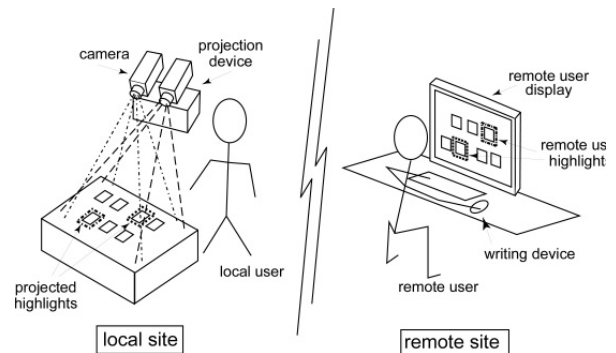
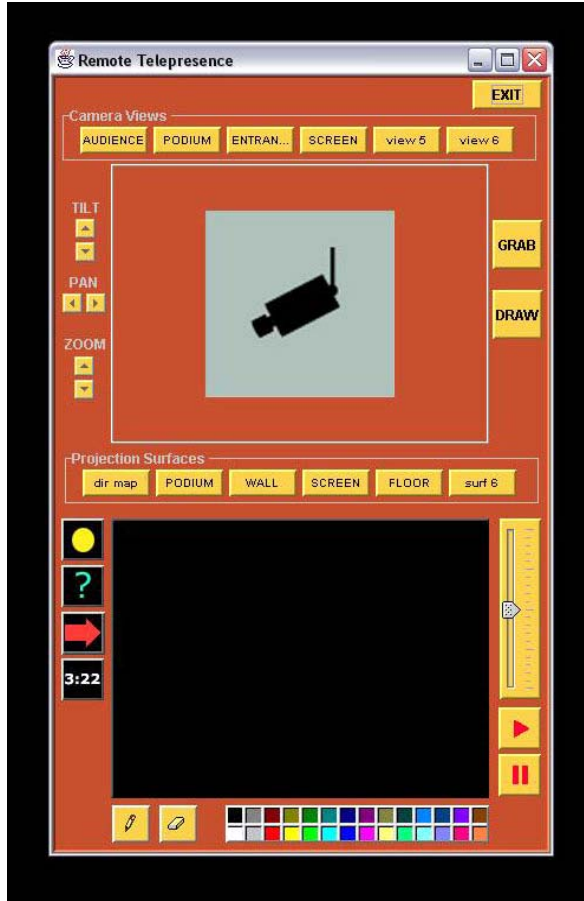


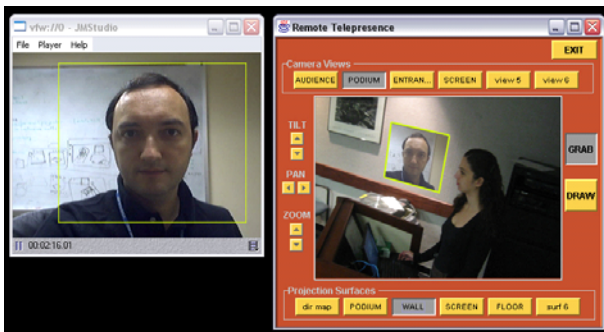
Figure 1. Overview of using a projector-camera system in a telepresence application.

computer or special conferencing system at either end or requiring people to sit in front of a special display or wear special devices to interact with remote people. With recent advances, it is increasingly becoming possible to look at controlling and manipulating an entire space rather than one special device in the space. This is leading to “smart” or “active” spaces and “room operating systems” [2] that treat the whole environment with its diverse set of computing, input and output devices, and sensors and actuators, as one collection of resources to be made available to users in a unified manner, much like a conventional operating system treats the resources on a desktop computer. This evolution of computing towards smart spaces is opening up new vistas for telepresence. It is now becoming possible to produce a different kind of immersive experience, remote interaction, and collaboration by augmenting the space as a whole [8]. This whole move towards smart spaces is also significant in the context of experiential computing as envisioned in [5].

In this context, we see a significant role for camera-projector systems [3]. These systems can add a new dimension to telepresence that has hitherto been uncommon. Projection and lighting can be used as an element of telepresence that allows overlaying and embedding information and visualizations on real objects, besides producing informative displays wherever they are needed. The Everywhere Display [9] and its dynamically reconfigurable interactive capabilities [6] is a good example of a projector-camera system that has significantly augmented spaces in this manner. When combined with people tracking and environment modeling, the Everywhere Display can be extended to produce steerable interfaces [7] that appear anywhere in a space and dynamically adapt to user activities in an environment and changes in the environment. While previous work on the camera-



**Figure 2.** Example of control interface for a remote session chair using a projector-camera system to communicate with local conference participants.



**Figure 3.** The session chair projects live video showing his face on to the wall next to the speaker’s podium in the remote environment.

projector systems and steerable interfaces has been primarily focused on local augmentation, we begin to explore its potential in telepresence or remote augmentation here.

Figure 1 shows an overview of our proposal for using camera-projector systems in telepresence. Here, an environment is equipped with steerable camera(s) and steerable projector(s). A user in a remote space can access/view and control both the

projector and the camera through a display and writing device. A user at a remote site can view the local environment through video from the remote camera. The remote user can also control the projector in the local environment to project highlights, video, text, etc. in the local environment. As the projector is steerable, these virtual objects can be moved on to real objects and people in the local environment by the remote user. The remote user’s interface can itself be an interactive steerable display although this is not a requirement. In this paper, we describe an initial demonstration we have put together to further illustrate this vision.

## 2. DEMONSTRATION OVERVIEW

This demonstration uses a steerable projector-camera system – the Everywhere Display – in a local environment and provides a control interface to a user in a remote environment. For illustrative purposes, we demonstrate this system in the context of a conference/workshop taking place in a local environment for which a session chair of the workshop is in a remote location. The chair can view the workshop live from a remote location through on-site cameras and can provide instructions and messages to the local workshop attendees. We assume that the chair also has two-way audio communication to the conference.

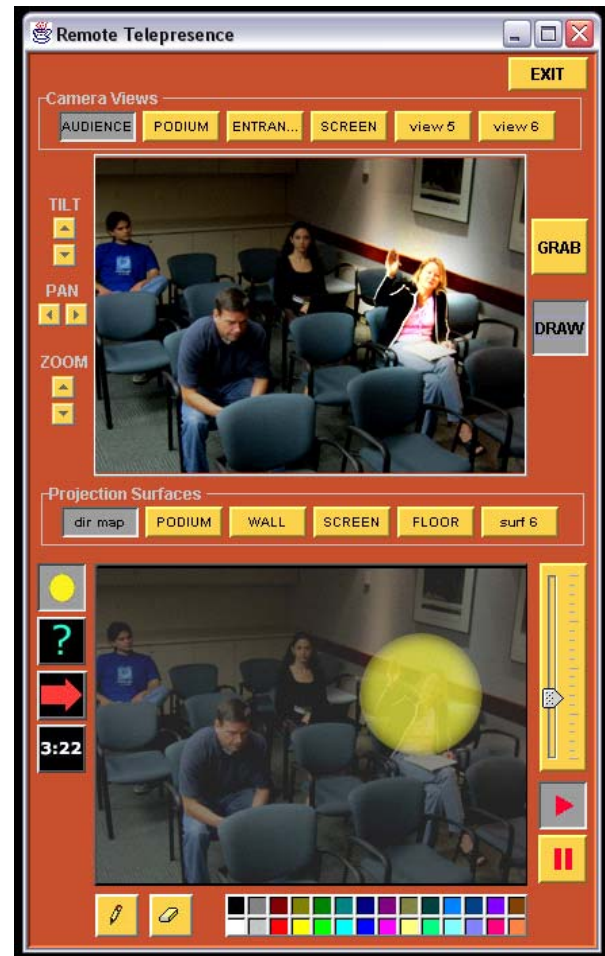
Figure 2 shows a screenshot of the control interface available to the session chair. The upper window in this figure shows the interface to camera views. This window displays video from (one of) the remote camera(s) and enables the chair to manipulate the remote camera(s) through the pan, tilt, and zoom controls and also define camera views. In the example in Figure 2, pre-defined views include audience, podium, entrance, screen etc. The lower window in Figure 2 shows the interface for the chair to control the remote Everywhere Display projector. As discussed in [6], this projector has the notion of a “projection surface”. Calibration of a projection surface ensures that projections can appear on these surfaces without keystone distortion as discussed in [9]. Different projection surfaces can be defined and calibrated for the environment in which the ED-projector is situated. The mid window in Figure 2 (labeled “Projection Surfaces”) shows how these pre-defined projection surfaces are made available to the remote user, the session chair in this case. Several available projection surfaces are shown in Figure 2 such as podium, wall, screen, floor etc. In addition to pre-calibrated surfaces, there is also a “direct mapping” option which automatically associates the current camera view to an overlapping projection, as will be discussed shortly.

There are two basic ways determine what is going to be projected on the selected projection surface: grab and draw, corresponding to the two buttons on the upper right of Figure 2. The “grab” button on the upper right in Figure 2 allows the chair to grab any portion of his computer desktop and project it on the remote environment. Any computer application on the grab area is then projected onto the selected surface of the local environment. For example, the chair may choose to project his own image (as shown in Figure 3), a webpage running on a browser, etc.

Pressing the “draw” button on the upper right of the control interface shown in Figure 2 enables an embedded drawing application that allows the chair to easily “paint” the projected surface. Any drawing appearing on the lower window is immediately and efficiently transferred to the remote projector. The blank area in the lower window of Figure 2 is therefore a



**Figure 4.** The remote session chair indicates to the speaker how much time is left for her talk.



**Figure 5.** The remote session chair throws a spotlight on an audience member to give her the chance to speak.

drawing canvas. Moreover, the real effect on the local environment can now be monitored through the live video in the upper window.

The icons on the left of the lower window show predefined drawing icons such as a highlight (which the session chair can use to highlight an object in the remote environment), a question mark (which the session chair can use to indicate it is time for questions), an arrow mark (to provide directions or point to objects in the remote environment), and a stop-watch icon (that can be used to show a speaker how much time is left for their talk). Besides these icons, the chair has a regular paint/drawing interface to draw on the canvas. The icons on the lower right allow the session chair to resize any element of the drawing canvas, and to switch between “live drawing” (the “play” button) where any modification on the canvas is immediately projected on the conference environment; and “hidden drawing” (the “pause” button), where the chair can draw, size, and compose all elements before displaying them.

The following three figures and descriptions provide some examples of how this interface is used by the session chair for telepresence in the remote conference session.

In Figure 3, the remote session chair has selected the podium as the camera view, the wall as the projection surface, and used the grab option to provide the participants a video stream of his face. To do so, he simply runs his standard application to a local camera that displays his image on the computer desktop. By selecting the grab option, the chair can place the camera application exactly on the area where the desktop is being grabbed (shown by a yellow rectangle in Figure 3). As seen in the camera view on the right, the live video showing the chair’s face is projected on the wall next to the podium in the conference room. Of course, the quality of the video depends on the speed of the connection between the local and the remote environments.

In Figure 4, the session chair has selected the same camera view and projection surface. In this case, however, he has used the “draw” option to transmit the drawing in the lower window, where he is showing the time left for the speaker. As seen in the live camera view, this information is projected on the wall next to the speaker in the conference.

In Figure 5, the chair has selected the camera view that shows the audience in the conference. In the lower window, he has chosen the highlight as the drawing option and moved this highlight onto the face of one of the audience members who has raised her hand

to ask a question. Using the direct mapping option instead of a pre-defined surface, he uses the highlight (without any keystone correction) to “point” to the audience member to give her a chance to speak. As seen in the live video in the upper window the audience member in the conference room is now highlighted with a projected spotlight. By using processes like this, the chair can effectively point to people and objects in the conference environment in a very intuitive manner.

### 3. APPLICATIONS

We see a number of other applications for such remote controlled projector-camera systems. In workspace collaboration, such systems allow people in remote offices to work with each other using the whiteboards, table etc. in each other’s offices for collaboration. In a retail application, a remote expert can interact with a customer in the store who needs help and explain the features of a product by pointing to and drawing/writing on the product. Similarly, a remote expert on store design or advertising and signage can guide local store personnel in many stores equipped with such systems. Such systems can also help people with accessibility needs in assisted living homes. Here, remote nurses and healthcare professionals can view and help people with instructions and advice at the location where the person in need happens to be such as the bed or the floor. These systems also provide new capabilities for education and distance learning as illustrated by the example in this paper. Finally, new forms of entertainment and shared interactive games between remote people are enabled by such systems.

### 4. CONCLUSIONS AND FUTURE WORK

In this paper, we presented a simple demonstration to indicate the power of projector-camera systems in telepresence applications. The applications detailed in this work focus on providing mechanisms for a remote participant in a meeting to act on the local environment through projected imagery.

Future work will address several issues. One important problem is providing better means for remote people to calibrate new projection surfaces in a local environment. This can also be important simply as a way for a remote expert to set up such a system in an environment even in applications that are not focused on telepresence. Another interesting issue is exploring new forms of interaction when users at both ends have projector-camera systems as the primary means for interaction.

### 5. ACKNOWLEDGEMENTS

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### 6. REFERENCES

[1] R. Azuma. A Survey of Augmented Reality, In Presence: Teleoperators and Virtual Environments , Vol. 6, No. 4, August 1997, pp. 355 -385.

[2] Renato Cerqueira, Christopher K. Hess, Manuel Román, Roy H. Campbell. Gaia: A Development Infrastructure for Active Spaces. In Workshop on Application Models and Programming Tools for Ubiquitous Computing (held in conjunction with the UBICOMP 2001), September 2001, Atlanta, Georgia.

[3] T.J. Cham, C. Pinhanez, J. M. Rehg, R.S. Sukthakar. IEEE International Workshop on Projector-Camera Systems, Nice, France, October 2003.

[4] Churchill, E.F. and Snowdon, D. Collaborative Virtual Environment: An Introductory Review of Issues and Systems. *Virtual Reality*, 3, 1998, 3—15.

[5] R. Jain *Experiential Computing*. Communications of the ACM. Volume 46, Number 7, pp. 48-54, July 2003.

[6] Kjeldsen, F.C., Levas, A. & Pinhanez, C.S. (2003), Dynamically Reconfigurable Vision-based User Interfaces, in *ICVS'03: Proceedings of the Third International Conference on Computer Vision Systems*.

[7] Pingali, G.S., Pinhanez, C.S., Levas, A., Kjeldsen, F.C., Podlaseck, M.E., Chen, H. & Sukaviriya, N., (2003), Steerable Interfaces for Pervasive Computing Spaces, in *PerCom'03: Proceedings of the IEEE International Conference on Pervasive Computing and Communications*.

[8] G. Pingali and N. Sukaviriya. Augmented Collaborative Spaces. ACM Workshop on Experiential Telepresence. December 2003.

[9] Pinhanez, C. The Everywhere Displays Projector: A Device to Create Ubiquitous Graphical Interfaces. In Proc. of Ubicomp'01. 2001. Atlanta, Georgia.

[10] Lawrence Rowe and Ramesh Jain. ACM SIGMM Retreat Report on Future Directions in Multimedia Research. [http://www.acm.org/sigmm/main/events/sigmm\\_retreat/sigmm-retreat03-final.pdf](http://www.acm.org/sigmm/main/events/sigmm_retreat/sigmm-retreat03-final.pdf). March 4, 2004

[11] Y. Rui, L. He, A. Gupta, and Q. Liu, "Building an Intelligent Camera Management System," Proceedings of ACM Multimedia Conference (MM'01), 2001.

[12] V. Vinge. When Cyberspace leaks into the real world. Proceedings of the 4th International Conference on Collaborative Virtual Environments, Bonn, 2002.