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Of Vampire Mirrors and Privacy Lamps: Privacy Management in Multi-User Augmented Environments

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ABSTRACT

We consider the problem of privacy in a 3D multi-user collaborative environment. We assume that information objects are represented by visual icons, and can either be public or private, and that users need effective methods for viewing and manipulating that state. We suggest two methods, which we call *vampire mirrors* and *privacy lamps*, that are unobtrusive, simple, and natural.

KEYWORDS: Augmented Reality, Virtual Reality, Privacy, Collaborative Work

Introduction

Privacy is an important issue in the design of any multi-user system. We present two methods for visually representing and manipulating the privacy state of objects in multi-user 3D environments. These methods are being developed for a proposed networked collaborative immersive environment [3] incorporating camera imagery and synthesized graphics [5]. Each user will sit in a physical *telecubicle* whose two walls and desk are stereo projection displays. A set of up to four remote telecubicles will be assembled electronically into one large virtual room (see Figs. 1 and 2). A user's local cubicle is an augmented computing environment ([4]) containing both physical and virtual objects, while the physical and virtual objects in the remote cubicles appear locally only as rendered models. For this work, we assume a simple model of privacy: public objects can be experienced (e.g., seen) by other users, while private objects cannot.

Contributions from virtual environments and CSCW

While research in multi-user virtual environments is a growing area, most of the focus is on friendly collaboration, assuming equal accessibility and visual appearance of the environment to all users. This uniformity is designed to ensure a strong sense of presence and interaction in the shared environment. The exception is Bullock and Benford [2], who discuss access restrictions based on restricted subspaces of the environment. Most desktop CSCW systems take an opposite point of view [1], assuming that only explicitly shared things are public, while all other things on a user's computer screen are private by default, because most items on the screen inherently have nothing to do with the collaboration. Our scenario requires an approach between these two extremes. We clearly need private information in a collaborative context, and therefore must remove some objects from other people's views. On the other hand we want the different views of the shared space to be as similar as possible to enhance spatial orientation and provide common reference points. Therefore, we set objects to be public by default.

Managing privacy in augmented environments

Users need to be able to modify the privacy state of objects and to review the state of all objects quickly. We want visual and interaction metaphors that support these tasks simply and efficiently. At the same time, we want these metaphors to enhance the user's sense of a natural physical space. We excluded standard UI components (e.g., menus and dialog boxes), on the grounds that they were not part of the real world. Similarly, we discarded methods such as encoding privacy state with shadows cast by colored light sources, which, though based on physical reality, are not at all intuitive. In general, we feel it is wise to be very careful when overloading rendering properties with application semantics. For example, we decided that marking privacy state by coloring objects would interfere with other semantics attached to object colors. We also considered screens local to each object that could be placed manually and would hide objects in a way similar to Japanese folding screens, but decided that though this was very natural, it would produce a great deal of visual clutter in close vicinity to the objects. Finally, although in the initial scenario there is a maximum of four users, we have tried to keep in mind the scalability of the metaphors to many users and groups.

Privacy and publicity lamps

One idea with which we are experimenting, that meets most of the above requirements is to use virtual spot lights to mark private areas. Such a *privacy lamp* can naturally be picked up and positioned over arbitrary objects. Raising the lamp increases the area of light on the desktop, allowing more objects to be selected. The effect of the light source on virtual objects becomes clearly visible by just including it in their lighting calculations. In an augmented reality system, the technique can also be applied to physical objects by rendering the light beam as a transparent volume or by rendering

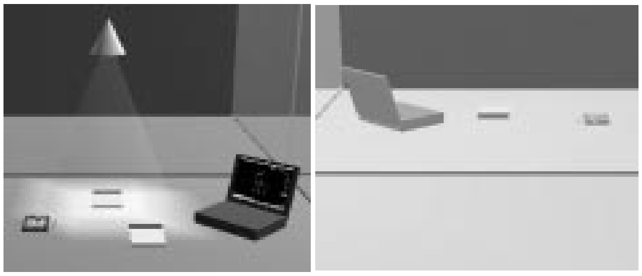

Figure 1: (left) A private *privacy lamp* shining on an object and (right) the view from another cubicle.

highlighted overlays on the objects it affects. The objects within the beam will then be omitted in remote views of the environment. (Recall that physical objects in the local cubicle are rendered in the other cubicles and thus can be omitted just like virtual objects.) If the lamp and its beam are visible to other users, then the objects under it may be private, but their existence will not be a secret, so we allow for the lamp itself to be marked public or private. Alternatively, if the user chooses to make objects private by default, *publicity lamps* can be used to make objects public. Privacy and publicity lamps may even coexist, with privacy lamps used to hide selected objects from an otherwise trusted colleague, and publicity lamps used simultaneously to reveal selected objects to an otherwise untrusted adversary. Because the lamps can be moved around in the same way as the other objects in the environment, they allow a user to manipulate privacy state without new interaction techniques. Their light beams give a clear visualization of private (or public) areas of space and thus allow a quick review of the privacy state of the local part of the environment.

Vampire Mirrors

Another approach that we are exploring uses a selective mirror, which we call a *vampire mirror*, because it reflects public objects, but not private ones. If a user places the mirror so that all objects of interest are reflected, she can review their privacy state at a glance: if she cannot see an object in the mirror, then others cannot see the object either (see Fig. 2). Searching for objects in a mirror is something we do in daily life, so this is a metaphor that doesn't require new skills. The privacy state can be modified by interacting with the mirror itself. Objects can be made private by touching their image in the mirror, and they can be made public again by grasping them and touching the mirror with them. We have also considered reflecting a faint image of private objects. This might make the visual search for an object faster, and making an object public could be done by touching the object's ghost image in the mirror. Note that the mirrors obstruct the user's view in the figure. We can either make the mirrors transparent, or make them pop-up from the table when needed.

Conclusions

The methods presented in this paper take simple metaphors from the physical world to visualize and manipulate the privacy state of virtual and physical objects in an augmented reality environment. They allow users to review and change privacy of objects in a natural way, without learning new interaction methods. The methods were first implemented in animated VRML'97 worlds available on the web at http://www.cs.columbia.edu/˜butz/vrml/ and are being explored in a augmented reality system currently under development in our lab as a virtual prototype for the physical tele-cubicle environment.

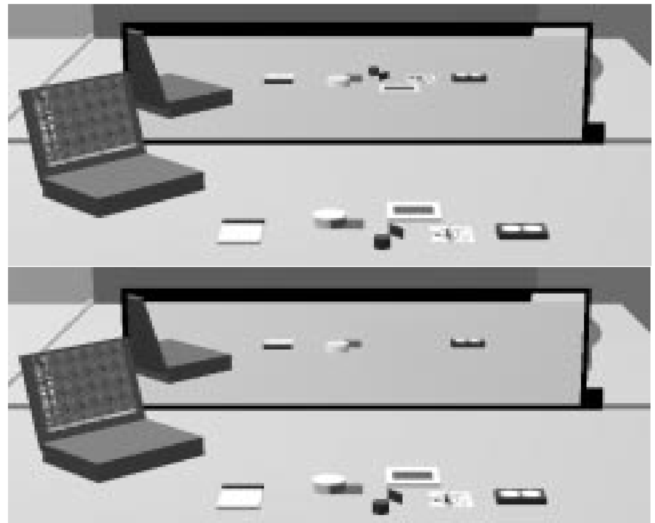

Figure 2: A *vampire mirror* (above) with all objects public and (below) with selected objects made private.

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