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A two-sided collaborative transparent display supporting workspace awareness

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ABSTRACT

Transparent displays naturally support workspace awareness during face-to-face interactions. Viewers see another person's actions through the display: gestures, gaze, body movements, and what one is manipulating on the display. Yet we can design even better collaborative transparent displays. First, collaborators on either side should be able to directly interact with workspace objects. Second, and more controversially, both sides should be capable of presenting different content. This affords: reversal of images/text in place (so that people on both sides see objects correctly); personal and private territories aligned atop each other; and GUI objects that provide different visuals for feedthrough vs. feedback. Third, the display should visually enhance the gestural actions of the person on the other side to better support workspace awareness. We show how our FacingBoard-2 design supports these collaborative requirements, and confirm via a controlled study that visually enhancing gestures is effective under a range of deteriorating transparency conditions.

1. Introduction

Transparent displays are 'see-through' screens: a person can simultaneously view both the graphics on the screen and the real-world content visible through the screen. Our particular interest is how a transparent display can afford face-to-face collaboration between people situated on *opposite sides* of the screen. For example, consider the simple case of an off-the-shelf transparent display that allows touch interaction on one of its sides. If that display is positioned so that others can view its user through it, collaboration is afforded to some extent. Viewers can see that user's body movements, hand gestures, gaze, as well as what that user is actually manipulating on the display. Similarly, the user can see the viewers, as well as any gestures they make relative to their side of the display. This grounds awareness of mutual action as well as communication.

While an off-the-shelf transparent display affords the limited degree of collaboration as described above, we argue that transparent displays can provide even richer collaboration experiences if they were augmented with four particular features: allowing interactive input on both sides; allowing different content (albeit selectively) on either side; providing public, personal and private supporting the range of individual to group work; and visually augmenting human actions to make them more salient to viewers.

We will explain these ideas shortly. However, because the notion of transparent displays for collaboration is somewhat unusual and speculative, we begin by justifying why this is a fruitful research area worth pursuing.

1.1. The case for two-sided collaborative transparent displays

Almost all contemporary research on interactive surfaces for collocated collaboration situates people either side-by-side in front of a vertical display, or at various seating positions surrounding a horizontal tabletop display. Within this existing backdrop, it may seem unusual to suggest that collocated people may benefit from working on opposite sides of a single transparent display. Yet there are various reasons why such collaborative transparent displays should be added to our arsenal of techniques.

1.1.1. Reflects real-life practices

Collaborative transparent displays reflect real-life usage practices of people collaborating over glass. Dating back to the mid-20th century, for example, naval operators wrote field information (such as plotting ship direction) on both sides of glass plotting board, as illustrated in Fig. 1. This setup provided various advantages. Both operators had a clear view of the working area, as bodies were not in the way. It reduced interference between operators writing close to each other on the surface (as illustrated in Fig. 1). As operators could write on two sides of the glass, it doubled the space available for input.

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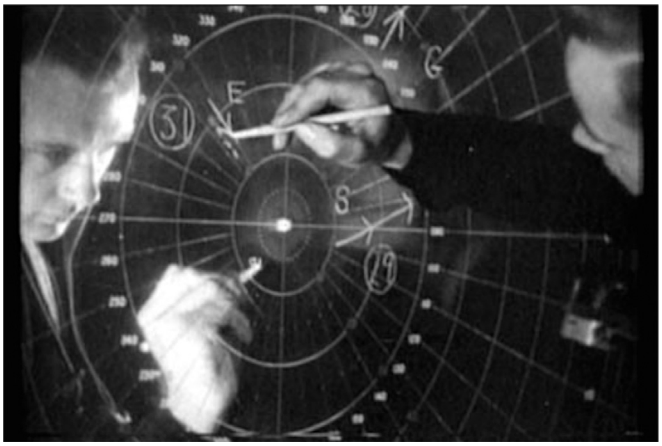

Fig. 1. Operators writing on both sides of a transparent plotting board. Source unknown.

1.1.2. Overcomes environmental separation

Collaborating through the display can overcome particular environmental constraints that require participants to be separated by a divider, i.e., where side by side collaboration is infeasible. For example, Corning Inc (2012) portrays a surgeon in a sterile operating room consulting with a distant colleague through a display wall (Fig. 2). However, we can easily imagine that colleague is standing in an adjacent non-sterile viewing room, where the wall between the rooms comprises display-enabled transparent glass. In this co-located situation, the surgeon can collaborate across this wall with his non-sterile colleague in the other room, where both can study and interact with the displayed medical imagery. Similarly, transparent displays can work as a collaborative yet protective barrier by people separated for security reasons, such as between prisoners/visitors in a jail, between clerks/customers in a bank or jewelry store, and between a taxi driver and her back-seat customers.

1.1.3. Supports opportunistic casual interaction

Transparent displays readily support awareness leading to casual interactions. For example, many contemporary envisionments about near-future work involving a team of collocated people depict various team members working behind transparent displays of various sizes (Shedroff and Noessel, 2012). Co-workers get a sense of what others are doing as they glance around, as they can see the worker's face and hands through the screen as well as what they are working on. In turn, this increases overall situation awareness and creates opportunities for co-workers to interact. An example is one worker noticing another having difficulty with their on-screen work, and coming to their assistance.

Fig. 2. A mock-up scenario showing a surgeon in the sterile operation room asking for advice from his colleague in the other non-sterile room, while studying medical imagery displayed on the transparent wall between them. Source: Corning Incorporated (2012), with permission.

1.1.4. Supports the switch between individual and joint work across desk partitions

If the display can be switched between opaque and transparent modes, it could be used by co-located workers to rapidly switch between individual and joint work across desk partitions. To explain, Danninger et al. (2005) created an LCD glass partition separating the abutting desks of two office workers. To minimize distraction and safeguard privacy, the glass was fully opaque when both were turned away from it. However, if one co-worker knocked on the glass and the other turned to face it, the glass became fully transparent to afford face to face conversation. If this glass was replaced by an interactive display that allowed both opaque and transparent settings (Lindlbauer et al., 2014a, 2014b; Li et al., 2014), that same partition could afford individual work in opaque mode (each working on their own side), and shared work in transparent mode (both working over the common work surface visible to both).

1.1.5. Supports true face to face interaction

A fifth opportunity is suggested by gaming. Console games using vertical displays currently require its players to be in front of the display, where they usually stand or sit side by side. Yet certain console games involve activities normally done through direct face to face play, where the scene and the other person are simultaneously in view (e.g., boxing and tennis games). Games designed for a collaborative transparent display could thus allow players to directly face each other, giving an entirely different feel to game play. This benefit could be applied to any situation where true face to face interaction is desired. In contrast, tabletop and non-transparent vertical displays require participants to either look at the surface or at each other (when face to face) and/or to assume alternate positions (e.g., side to side).

We are not suggesting that collaborative transparent displays should supplant existing digital surface technologies. Indeed, we believe that tabletops and non-transparent wall displays will remain appropriate for a large majority of common situations. Rather, we see collaborative transparent displays as an addition to the repertoire of available surface types, where they are a good match to particular situations such as the samples listed above. We are not the only ones holding this view, as a small community of other researchers are actively researching collaborative transparent displays (e.g., Olwal et al., 2006, 2008; Heo et al., 2013; Kuo et al., 2013; Lee et al., 2014; Li et al., 2014; Lindlbauer et al., 2014a, 2014b).

1.2. Structure of the Paper

In this paper,[1] we contribute to the design of transparent displays supporting collocated collaboration, thus adding to the repertoire of existing collaborative display mediums. Our goal is to elaborate upon a digital (and thus potentially more powerful) version of a conventional glass dry-erase board that currently allows people on either side to draw on the surface while seeing each other through it (e.g., contrast Fig. 1 with Fig. 2). Our methodology (and the paper structure) roughly follows a multi-step process as detailed below, each offering a particular contribution.

First, we lay the theoretical foundation – drawn from related work – that we use motivate our design ideas (§2). We know from prior work that seeing the displayed artifacts in the workspace, along with people's bodily actions relative to the artifacts, is critical for efficient collaborative interaction, as it helps communicate and coordinate mutual understanding. This is known as *workspace awareness,* defined as the "up-to-the-moment understanding of another person's interaction with a shared workspace" (Gutwin and Greenberg, 2002). We also

[1] This paper reflects a complete archival report of our multi-year project on collaborative transparent displays. The first part - our theoretical foundation, implementation and related work – expands considerably upon the initial work reported in (Li et al., 2014). The second part – the study – has not been previously published.