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FrostWall: a Dual-Sided Situated Display for Informal Collaboration in the Corridor

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ABSTRACT
FrostWall is designed to support collegial communication and collaboration within a co-located work environment by facilitating and encouraging informal information exchange in the corridors of a workplace using large situated displays. FrostWall displays provide a flexible display area between the inside of a private office workspace and the public corridor outside it. FrostWall uses "frosting" of glass windows and partitions between private and public workspaces in combination with projectors to create a display area that is effectively dual-sided: readable and operable from both sides. In addition to facilitating informal digital communication and information exchange between co-workers, this situated display area also provides a venue for playfulness and personal expression enhancing social cohesion between colleagues. FrostWall is also a unique vehicle for future research into interaction design for dual-sided interfaces.

Author Keywords
Dual-sided interface, situated display, informal collaboration, ubiquitous computing

ACM Classification Keywords
H5.3. [Information interfaces and presentation (e.g., HCI)]: Group and Organization Interfaces – Collaborative computing.

INTRODUCTION
Advances in display and interaction technology and significant reductions in retail price have allowed interactive computing displays to move off the desktop and be embedded into the physical environment around us serving very different purposes and affording very different use. Within the field of Human-Computer Interaction, and in particular ubiquitous computing, there is an increasing interest in understanding the role that situated display technologies have on the varied environments in which they are embedded. Researchers are studying the way that these displays shape the behaviour of individuals located in that environment and in particular their social behaviour with others. Although many of these projects look at large situated displays in urban spaces several have also looked at interaction between workers and their colleagues involving small contextually specific situated displays in their work environments. Where media spaces and video conferencing systems provide connections between remotely located co-workers, situated displays in the workplace can facilitate collaboration amongst those that are located together.

The value of a situated display is determined by the relationship between the relevance of the information displayed to the behavioural context of the place in which it is located (O'Hara et al., 2003). At the same time, situating displays in context allows information to be provided "just in place" (Kjeldskov, 2002) and in a way that can be read and interpreted indexically. In the case of situated displays in the workplace, this means that the content and interaction design have to fit the specific areas of the workplace in which they are located, and that implicit meaning adding to the explicit content displayed can be drawn from this placement. For example, if situating a display in a corridor space, the content should fit the more informal and ad-hoc parts of collaboration and the serendipitous interactions that typically take place here. If situating displays in close physical relation to individual's offices or shared workspaces, it will be implied that the information displayed is related to and owned by those people and groups.

Figure 1. FrostWall set-up in an office corridor

In this paper we explain the design of the FrostWall system for facilitating informal collaboration in workplace corridors (figure 1). However, first we would like to outline the context of related workplace situated display systems reported in the literature. In particular, the systems that have inspired and contributed the most to our understanding of situated display systems in the workplace are Portholes, Clearboard, Notification Collage, OutCast, RoomWizard, and Hermes.

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RELATED WORK

Portholes is a distributed media space that supports awareness between distributed work groups through access to information such as who is around, what activities are happening, who is talking to whom (Dourish & Bly, 1992). Portholes gives a "porthole" view into the workspaces of collaborating colleagues by displaying many concurrent videos, in real-time, in offices and common areas. The leads to informal interactions, spontaneous connections and development of shared cultures - important aspects of the social cohesion in the workplace. From portholes we are interested in the strengthening of work group culture through being aware of what others are doing, and the facilitation of adhoc, informal "corridor" type meetings.

Clearboard, an early media space, was designed to integrate an interpersonal space with a shared workspace (Ishii et al., 1993). It is based on the metaphor of "talking through and drawing on a transparent glass window" for two remotely located co-workers. It does this by mirror reversing of video images between two Clearboards. From Clearboard we are interested in the use of glass as projection surfaces, as well as interaction with mirrored content and the use of mirror reversing techniques.

Notification Collage (NC) is effectively a digital bulletin board for maintaining contact between co-located and distributed colleagues through posting of media elements onto a shared surface (Greenberg & Rounding, 2001). It can be viewed on a large public screen and on individual desktop machines concurrently linking people in private places to those in public places. NC is primarily used for awareness of a colleague's activities and for prompting group members to communicate with each other with a strong social element through sharing of personal photographs. From NC we are particularly interested in the relationship between public and private places using the same displayed information, the variety of media being displayed and the sharing of personal information and interests with colleagues.

OutCast has a large display situated outside the office or workspace of its owner providing information about that person "that is intended for others to view" (McCarthy et al., 2001). It is connected to a computer situated inside their office, and it displays a variety of information such as calendars, messages and the current location of the owner. From OutCast our interest is in situated information intentionally shared with colleagues.

RoomWizard is a situated touch screen display mounted on the outside of a meeting or conference room for making reservations (O'Hara et al., 2003). The information on RoomWizard can be accessed on the situated display and remotely on a web page. Although RoomWizard displays rather limited and specific information, this information creates incidental awareness of ongoing activities in the workplace – by displaying to people as they move around the physical work place, who was where, meeting with whom, and about what. This indicates that peripheral awareness of people and activities can be gleaned from situated displays, such as FrostWall, embedded in a physical work environment.

Hermes is a small screen display system, located adjacent to an office door, supporting coordination amongst University staff and students through message posting (Cheverst et al., 2007). Hermes provides awareness about colleagues and teachers through messages left on the door display about where they are or when they will be back. Text or images can be sent from computers or mobile phones. By its location near an office door, the sender and the intended audience of the message are implicitly given by the physical context. From Hermes, we are inspired by the ideas of corridor displays defining both author and audience for information, and the ability to leave and receive messages both locally and remotely, as well as the appropriation of technology for sharing personal photos.

In all of these systems it is the peripheral nature of the information they are providing within the work context, and their support, either intended or appropriated, for facilitating social exchanges, that is of interest to us.

The FrostWall concept described in the following sections was inspired by the related work on situated displays outlined above, some informal observations of people's use of window space between their offices and the corridor as areas for posting information of various types and purposes, e.g. a poster of their favourite football team, and an interest in facilitating informal collaboration in a physical workspace. We also have an interest in the technical creation and interaction design for a dual-sided touch interface. The specific interface concept was conceived through a process of sketching user interfaces and widgets onto the glass window between the office of one of the authors and the corridor outside it and envisioning the use of this space for a dual-sided situated display.

THE FROSTWALL CONCEPT

FrostWall is a situated display where the graphical user interface is projected onto a glass window between an office and corridor that has been "frosted" with a special projection film developed for exhibition displays producing a perfectly viewable image on both sides at the same time. This creates a dual-sided interface with a private and a public face. Our idea was to use this dual-sided display as an electronic pin-up board where the inhabitant of an office can put up different kinds of information for colleagues to see (e.g. their calendar, pictures, interesting video clips, recent publications, etc) and where colleagues can leave notes etc. as they pass by.

As dual-sided situated displays FrostWalls facilitate informal aspects of co-located collaboration. FrostWalls can serve as a flexible, informal and expressive medium for people to present information about themselves, their interests, current activities, whereabouts etc for the use and enjoyment of colleagues, friends, visitors, and themselves. The placement of FrostWalls in the work environment, as a public face of someone's private workspace, makes them highly indexical through their physical location in the space between offices and surrounding public areas.

User interaction

User interaction with FrostWall is touch-based and can be either single or multi-touch depending on the specific hardware capabilities of the platform. The system can differentiate between touch-input on the inside and the outside of the glass screen. This means that, not only can two users interact with the FrostWall at the same time, they can also be assigned different levels of system-privileges depending on what side of the display they are standing. As an example, this allows content to be moveable and editable from inside the office only, while from the corridor users have access to functionality for browsing, leaving notes, downloading content etc. Hence, the *same* interface is given differentiated functionality depending on what side you use it from.

A dual-sided graphical interface

One of the key features of the FrostWall concept is that it explores the physical properties of a translucent display medium rather than treating these as limitations. Due to simple rules of optics, when projecting an image onto a semi-transparent display surface, the image will appear correct when viewed from the front, and mirrored when viewed from the back. However, if what is projected is *mirrored in the first place*, it would appear the other way around: correct when viewed from the back and mirrored when viewed from the front. Inspired by this optical feature and the graphical functionalities offered by modern composite windowing systems, individual screen elements on the FrostWall display can be graphically mirrored by means of software so that legibility of that screen element can be achieved from either side of the screen as desired. From a user point of view this effect creates an experience of a dual-sided interface with elements that can be "flipped around" to face away from you or towards you as illustrated in figure 2.

Figure 2. Graphically "flipping" interface elements on the FrostWall to face the user correctly

Private and public display areas of the FrostWall

Another optical property arising from creating a dual-sided interface by means of projection from one side of the screen is that some areas of the interface can be made visible from one side only. This is done simply by applying the translucent projection film to selected areas of the projection area while applying an opaque projection material to the rest. Placing the projector inside the office, an interface is created where content can be placed in either a "public" or a "private" area of the display. In the public area content is visible from both inside the office and from the corridor. In the private area content is visible from inside the office only. Figure 3 illustrates the projection set-up used to create a private and a public area within the FrostWall display. As another property of projecting from inside the office any area of the display surface can be made "private" simply by sticking a white piece of non-transparent material, of any shape, onto the glass surface. Any interface element placed in this area of the display can then only be viewed from inside the office, making the physical appearance of individual FrostWalls highly customisable.

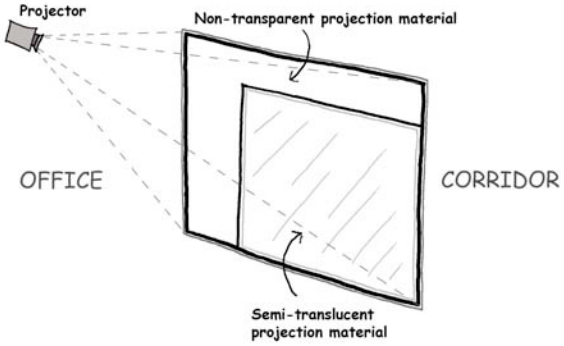

Figure 3. FrostWall projection onto a combination of opaque and semi-translucent projection material

Content and use

While dual-sided interfaces facilitate many novel use cases, our initial envisioned use of the FrostWall is as an electronic pin board for informal collaboration. In order to explore this we have designed a software system with some basic functionality that we believe would be useful for this scenario. This is described below.

We believe that an electronic pin board like FrostWall should facilitate a high level of expressiveness and freedom. Therefore we wanted the FrostWall to support displaying of range of rich media content such as text files and images in different formats. Inspired by Apple's Dashboard and Widgets, we also wanted to allow similar small programs with specific functionality to be put on the display, and allow users to find and add such components themselves as they wished. In relation to this we also wanted to create a system where we could relatively easily develop specific widget-type components ourselves to study their use and usefulness in the context of dual-sided situated displays for informal collaboration. Finally, we wanted to create a display that is simple to use and easy to put new content on to.

These aims led to a design where the owner can control the layout of the display using the inside touch surface or from their desktop computer. New content can be put on the FrostWall by "dropping it" onto a desktop icon and then placing and flipping it as desired afterwards by walking over to the display and rearranging it. Alternatively, a VNC connection can be established to the FrostWall allowing the user to interact with everything on the display from their desktop. A "box of widgets" is provided by default but others may be downloaded from the Internet and put on the wall. Some widgets may be non-interactive; reflecting the status of an online dataset (e.g. the weather forecast) or present a web clipping (e.g. a daily cartoon strip from an online newspaper). Others may have more interactivity such as letting people browse an online calendar or leave a note. Its up to the owner!

As an example of a customised widget for the project, we designed a status list for the activity of colleagues (e.g. out of office, do not disturb, on the phone, etc) to be put in the private (inwards facing) area of the display. Another widget shows a live video feed from a remote collaborator's lab. From the corridor-side colleagues can flip all elements placed in the publicly visible area of the display to face outwards for legibility. They can leave messages on the wall by writing with an electronic pen, typing on a virtual keyboard, or by sending an SMS from their mobile phone to a number specified on the display. Finally, they can browse the content displayed (e.g. the calendar) and operate the widgets set by the owner to be publicly interactive (e.g. the video player).

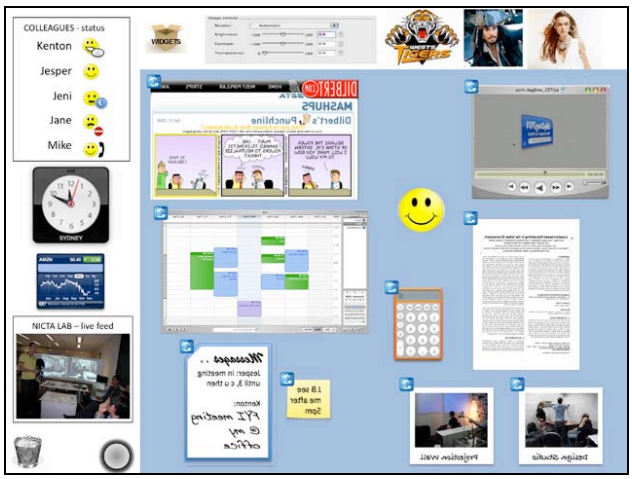

Figure 4. Example FrostWall - viewed from inside an office with some elements mirrored for readablity from corridor.

FUNCTIONAL PROTOTYPE

We have built a functional prototype of the FrostWall concept to allow further research into interaction design and use of dual-sided graphical interfaces and to facilitate user studies of the FrostWall situated display. On the hardware side our first prototype offers a dual-sided interface projected onto a sheet of Plexiglas with an area of 22" covered by MirrorVu semi-translucent projection film (using a half silvered mirror technology). On both sides of the Plexiglas are mounted a 22" capacitive touch screen providing two separate single-touch inputs.

Figure 5. FrostWall prototype system using Compiz

On the software side, the prototype is developed as a Compiz plug-in to the X window system that allows any window to be mirrored so that the correct orientation can be achieved from either side of the display. Compiz is a compositing window manager for the X window system that uses 3D graphics to support desktop effects. Combining the FrostWall Compiz plugin with the multi-device capable windowing system MPX (Hutterer and Thomas, 2007), developed as part of a parallel project, allows system level separation between touch inputs on the two sides of the display. To provide access to a broad range of content for the FrostWall, the prototype supports using Google Gadgets (figure 5).

DISCUSSION AND CONCLUSIONS

Of interest to us with the FrostWall, and not yet addressed in current HCI research into situated displays, is an understanding of the dichotomy of private/public information that exists when both types of place are accessing the same information at the same time. Further more, adding a level of interactivity with this information from both sides of a shared display gives us an interaction situation to explore that is truly novel.

FrostWall provides users with the ability to use the window area of their office adjoining a corridor as a collegial information exchange facility. At the same time, providing them with additional display space away from their work computer for those more peripheral and social activities that are an important part of a balanced and productive working life.

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