Using Overlays to Support Collaborative Interaction with Display Walls

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(a) The HIPerSpace Wall Display

(b) The Overlay interface[1]

Figure 1. Overlays enable collaborative interaction on ultra-scale wall displays

ABSTRACT
Large-scale display walls, and the high-resolution visualizations they support, promise to become ubiquitous. Natural interaction with them, especially in collaborative environments, is increasingly important and yet remains an on-going challenge. Part of the problem is a resolution mismatch between low-resolution input devices and high-resolution display walls. In addition, enabling concurrent use by multiple users is difficult — for example, how would this large workspace be managed for multiple users and what novel collaborative interactions could occur? In this paper, we present an overlay interface element superimposed on wall-display applications to help constrain interaction, focus attention on subsections of a display wall, and facilitate a collaborative multi-user workflow.

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Design; Human Factors; Experimentation

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INTRODUCTION
As graphics processing units (GPUs) become increasingly powerful and as the cost of displays continues to fall, large display walls are likely to become widely available. High-resolution displays are especially suited for analyzing and manipulating complex datasets in multi-user multi-device collaborative environments. One such example of a tiled wall display is the CalIT2 *Highly Interactive Parallelized Display Space* (or HIPerSpace[2] — Fig. 1(a)). It employs seventy 30" Dell LCD displays tiled together, creating a 31.8 foot by 7.5 foot wall, to provide a display resolution of 35,840 x 8,000 pixels (a total of 286,720,000 pixels).

However, as highlighted by the study conducted by Rogers and Lindley [10], there are multiple interaction challenges that must be addressed for such high-resolution displays to become more widely used — in the study, users found it awkward to collaborate around a vertical display, preferring the fluid interaction afforded by horizontal tabletop displays.

An obvious problem is the resolution mismatch between low-resolution input devices and the high-resolution wall which makes it difficult for users to accomplish fine-grained manipulation of small objects on the large display. This problem is often exacerbated by providing a low-resolution image of the wall's display on the input device itself, causing users to focus their attention on their input device rather than the wall.

Another limitation of current wall display systems is reaching distant objects [3, 8] — not only can it be a slow and tedious operation but, given the larger display area, users tend

[1]The background of the Overlay has been artificially saturated to make it more visible for publication purposes.
[2]http://vis.ucsd.edu/projects/hiperspace

to compensate by accelerating mouse movements, making cursor tracking difficult [8, 9].

Finally, although large display walls are inherently multi-user and can be a useful medium for collaboration, current interfaces do little to facilitate this type of behavior [12].

In this paper, we present an *Overlay* paradigm that builds on the *Magic Lens* metaphor [1] of a movable, see-through interface superimposed on information elements. We discuss the Overlay design, its use with multitouch surfaces, touch-capable mobile devices and digital pen and paper, and describe feedback we received from initial use and plans for future work.

THE OVERLAY INTERFACE

The Overlay is a small translucent rectangle[1] that appears superimposed on a wall display. By allowing a user to only interact with objects that appear directly underneath it, it helps to focus users' attention on a small subsection of the larger display [6], and aids allocation of display space across users. As highlighted in Fig. 1(b), objects — photos in this case — are visible through the Overlay.

Design Goals

Two design goals motivated the development of the Overlay interface:

Providing compatibility with diverse devices

A variety of input devices can be coupled with display walls in order to investigate natural ways of interacting with large display walls at a distance. In contrast to existing systems such as the Active Workspace [7], a design goal for the Overlay interface was to enable compatibility with a large number of diverse input devices for object-level manipulation. Every device, by default, maps to the dimensions of the Overlay rather than the entire display wall.

Supporting multiple users

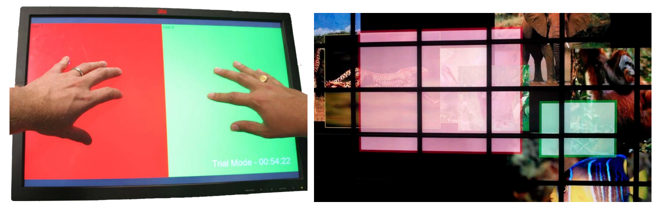
Although existing techniques such as Active Workspace and Shadow Reaching [11] discuss ways to extend the paradigm to support multiple users in collaborative environments as part of planned future work, we do not know of any concrete implementations. Our Overlay interface introduces one Overlay per user to facilitate multiple users working together and several new interaction techniques to encourage collaborative behavior.

Interactive Devices

Although our design supports compatibility with a variety of input devices, for the purposes of this paper, we will discuss using the Overlay interface with three types of devices: multitouch surfaces, touch-capable mobile devices, and digital pen and paper.

Multitouch Surfaces

Research has long demonstrated the benefits of touch-based interaction [2] and with the current proliferation of multitouch devices we expect this to be an increasingly important form of interface. We experimented with two types of multitouch surfaces. The first is the 3M M2256PW display[3], a 22-inch display capable of differentiating up to 20 touch points. One of the limitations of this display is that it is incapable of differentiating between different users. As a result, to support multiple users with the 3M display, we partition the touchscreen into multiple regions depending on the number of users (Fig. 2(a)) and each region is mapped to the correspondingly colored Overlay on the wall display (Fig. 2(b)).



(a) Touch-based interaction (left:red, right: green) (b) Multiple Overlays (left: red, right: green)

Figure 2. Multi-user touch-based interaction with the Overlay

The DiamondTouch table[4] is the other multitouch system we used to explore use of the Overlay. It employs an array of capacitive transmitters and receivers to distinguish between multiple users [4]. Thus, we are able to easily assign one Overlay per user without manually dividing the touch surface.

Touch-capable Mobile Devices

One of the inherent limitations of the devices above is that they are positioned at a fixed location and thus restrict the movement of users. We thought mobile devices would promote different forms of interaction and exploration with the HIPerSpace wall. In order to test the use of mobile devices, we built an iOS 4 application[5] for the Apple iPhone and iPod Touch. Given that these devices are personal, likely to be only used by one user at a time and rarely shared, and given their size, we assigned one Overlay per device (shown in Fig. 3).

Figure 3. The Overlay interface: the translucent rectangle[1] is superimposed on part of the three photos displayed on the wall

Digital Pen and Paper

We conjectured that digital pen and paper interfaces might be uniquely suited for interactions with the display wall — they are mobile, offer the affordance of paper including ease of taking notes and existing user familiarity, and numerous additional interface elements may be directly printed on the paper itself.

[3]http://www.3m.com

[4]http://www.circletwelve.com

[5]http://developer.apple.com/devcenter/ios

To explore their suitability in this space, we modified the HIPerPaper interface [13] by adding an Overlay widget as as shown in Fig. 4 — the upper region of the interface maps to the entire wall display whereas the lower region represents and maps to the Overlay.

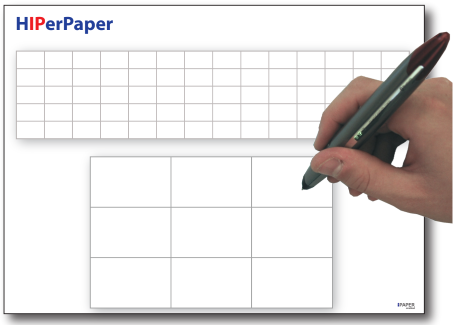


Figure 4. The HIPerPaper Overlay

Using the Overlay

The Overlay works by intercepting events transmitted to the underlying application and normalizing the event coordinates such that interaction occurs relative to the Overlay's position and dimensions rather than the entire display — i.e. the input device maps to the dimensions of the Overlay and a user is constrained to only interacting with objects that appear, at least partially, underneath their Overlay. This makes the Overlay compatible with any events that contain (x, y, z) coordinate information including selecting, dragging, zooming and rotating events.

Selecting and Zooming within the Overlay

We support the natural grammar of multitouch devices with the Overlay. When the user taps a point on the device, they select the object that is underneath the corresponding point of the Overlay. Similarly, pan, pinch and rotation gestures can be used to move, scale or rotate any selected objects. We have also implemented a two-finger double-tap gesture to be able to select multiple objects with the Overlay; the selection is then treated as a group and manipulated together. HIPerPaper's Overlay widget works in a similar fashion and maps to the dimensions of the on-display Overlay as well — users can tap an area to select an object, drag the pen to move it, trace a circle to scale it and vary the pressure with which they press the pen to select multiple objects.

We intentionally provide no local feedback on input devices as a form of (in)direct manipulation designed specifically to focus a user's visual attention on the high resolution wall over the low-resolution input device. Rather, we display interactions on the Overlay itself through small colored circles which help to orient a user and offer feedback comparable to that offered by a cursor. For example, Fig. 1(b) shows one colored circle when a finger makes contact with a touch-sensitive surface, or if a user performs a pinch gesture to zoom the selected photo, two circles would represent the motion of the user's fingers and move away from each other.

Positioning and Scaling the Overlay

To allow users to manipulate any area of the large display, the Overlay itself can be positioned at an absolute point on the display, dragged across it or scaled to take up a larger or smaller area of the display.

With touch-capable devices, the following five-finger gestures manipulate the Overlay:

- *Five-finger tap*: causes the Overlay to snap to an exact position on the display.
- *Five-finger pinch*: scales the Overlay up or down while maintaining its aspect ratio.
- *Five-finger drag*: moves the Overlay across the display, corresponding to the drag gesture.

Note that with these gestures, there is an implicit change of state — whereas previously the device mapped to the confines of the Overlay, these interactions cause the device to map to the entire display instead.

In the case of mobile devices, however, five-finger gestures may be awkward to perform and thus, we are exploring other modalities they offer to manipulate the position and size of the Overlay — for example, tilting the device towards or away from the screen to move the Overlay vertically and tilting it to either side to move it horizontally.

With HIPerPaper, users can use the main interface (top part of Fig. 4) to position the Overlay by tapping or dragging their pens to a position. By tracing a circle on this area, users can scale the Overlay up or down.

If any objects within the Overlay are selected when it is moved, they move along with it, i.e. their position remains fixed relative to the Overlay (Fig. 5).

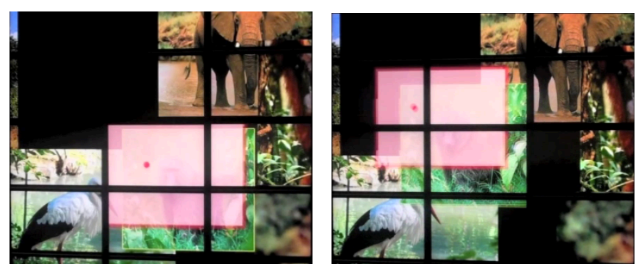


Figure 5. Dragging the Overlay with a photo selected

Collaborative Interactions

The first step towards supporting multiple concurrent users was introducing one Overlay per user. We differentiate each user's Overlay with differently colored borders — as shown in Fig. 2(b). However, several questions remain with regard to the behavior of multiple Overlays. What happens if multiple users wish to interact with the same section of the large display? Will their Overlays intersect and overlap, or should they remain distinct? What novel collaborative interactions will multiple Overlays enable?

We are exploring two approaches to address the issue of overlapping Overlays. The first examines prohibiting overlapping Overlays by establishing a "sphere of influence" around each Overlay. An Overlay is not be able to enter another's sphere of influence, but a moving Overlay can temporarily

Figure 6. Sphere of influence

push other Overlays out of its way in a repelling fashion (see Fig. 6). Spheres of influence are only displayed when two Overlays are in danger of overlapping).

An alternative approach is to use "drop shadows" to layer Overlays. In this case a user's precedence is determined by the position of their Overlay in the pile, with the Overlay at the top having the highest precedence. Thus, if multiple users were to simultaneously interact with an object under a pile of Overlays, the user with the highest precedence would win, and other interactions would be ignored. We are also investigating allowing users to toggle between these behaviors.

CONCLUSION AND FUTURE WORK

We informally tested the Overlay interface with graduate students and researchers in our lab to gather early feedback. Each user was given a brief introduction and then given time to freely experiment with a photo application to determine if they were able to perform simple tasks including selecting, dragging, zooming and rotating photos.

Users reported that the overlay immediately drew their attention and that mappings between devices and the Overlay felt natural, noting the importance of matching the aspect ratios of the Overlay and input device. They also reported that manipulating the overlay was easy, but remarked that dragging or scaling the overlay to reach distant objects still felt tedious. None of the users expressed concerns about the (in)direct interaction, with input-only devices to control the wall display, and seemed to naturally attend to what was displayed on the wall.

Although multi-user support, particularly collaborative interaction, is still in its infancy, this early feedback suggests that introducing one overlay per user is effective — users immediately understood that they each controlled an individual overlay, and were able to work on separate tasks simultaneously. In the context of the photos application, future work will explore how the Overlay interface can support more high-fidelity collaborative interaction — for example, if one user grabbed the top-left corner of a photo while another grabbed the bottom-right and then dragged their Overlays in opposite directions, this could stretch the selected photo. To test this interface with more complex objects and data, we are also working to integrate the Overlay interface with "Shared Substance" [5], a general application framework for large display walls.

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