Reconfigurable Displays

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Abstract. Modular Ambient Display boxes provide a modular high-resolution display system that makes experimentation with the physical configuration of the display surfaces relatively simple. MAD Boxes have flush floated rear-projection screens that cause a mere 2 mm inter-screen gap. They can be stacked and reorganized into many possible configurations.

1 Introduction

Over the last ten years as computers move into our everyday living and working environments, interest in variant types of displays has been growing. This is in part because we have new needs and tasks and in part because we want them to blend into rooms, halls, and furniture. New displays range from the very large to the very small and from the totally portable to those built into buildings as they are constructed. Usually researchers have to decide on a configuration or two that relate to their research. In turn, once built, the chosen configuration's display parameters will influence the research. As we work towards discovering how to best merge information technology into our everyday environments it is difficult to decide a priori what the right configuration will be.

To minimize the limitations caused by having to make display decisions up front we decided to try and support different types of display configurations by paralleling the *Lego*[tm] concept. With *Lego*[tm] a child can build trucks and boats and bridges that are quite good though perhaps less than perfect. The advantage is that a truck can become a boat. With this in mind we have built Modular Ambient Display (MAD) Boxes.

2 Related Work

Since MAD Boxes support the creation of many different types of displays, there is a considerable amount of related work, which is only briefly mentioned here.

A significant amount of research has been directed towards building large-scale high-resolution display systems. The typical configurations are either adjacently mounted screens [6, 11] or a single display surface illuminated by tiled LCD or DLP projectors.

A key problem with tiled projector display walls is image alignment. Early display wall projects [11] were manually positioned to avoid gaps in the output image. Various methods [1, 2, 4, 7, 10, 12] have been devised to avoid manual positioning. These systems generally use scalable camera-based calibration algorithms to perform geometric and photometric registration.

Another issue inherent in multi-projector displays is application support. Existing systems generally use a cluster of rendering machines, one per projector. Rendering is controlled by applications on a host a computer, either using specialized parallel rendering libraries or by forwarding system API calls to the cluster nodes [5, 7, 14, 15].

3 MAD Box System

We have three principle goals for the MAD Box project:

Modular. To create a modular high-resolution display system that allows us to experiment with the physical configuration of the display surfaces. Tiling existing plasma and LCD displays do not meet our needs because the frames on the individual screens create large discontinuities in the display surface.

Regular Software Environment. To provide a software environment that permits other researchers to use the MAD Box environment with minimal effort. These researchers must be able to run their software written for single-display machines on our multi-display configurations without any modification.

Interactive. To support interaction research on various display configurations where multiple users interact with the display simultaneously in close proximity.

3.1 Display Hardware

Each MAD Box consists of a 29x22x34 inch steel frame (Figure 1). The projector is mounted on an adjustable platform (Figure 2) that is bolted inside the frame. We are using NEC MT1060 LCD projectors that provide 1024x768 resolution. A 36 inch diagonal-back projection screen is hung at the front of the frame. This acrylic screen is affixed to the 9 inch deep floating mount (Figure 3) using plastic sheets less than 1mm thick. This screen mounting technique causes only a very small inter-screen gap. As shown in Figure 4, when the screens are properly aligned the gap is approximately 2mm. In our experience this very small gap is barely noticeable. This may

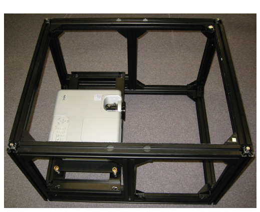

Figure 1 Box Frame

Figure 2 Projector Mount

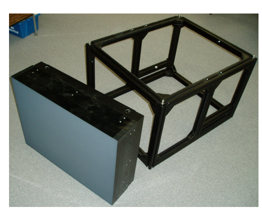

Figure 3 Floating Screen

parallel evidence gathered in [8] showing that removing the gap pixels largely mitigates any discomfort for users.

The MAD Box projector alignment system is manual. However, because each projector is inside a fixed frame and only needs to be aligned to its individual screen, alignment is not time consuming. An added benefit is that once a MAD Box is aligned it should not need realignment if the physical configuration is changed. While MAD Boxes are essentially independent display modules, the thin mount for the screens makes them stackable and quite versatile.

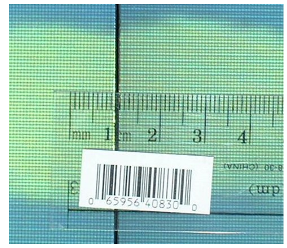

Figure 4 Screen Gap

3.2 Display Software Environment

Since it is our intention that the multi-display environment be transparent to as many user applications as possible, we have looked for solutions that use a single computer to render the display. Several off-the-shelf display adapters exist that support 4 separate RGB outputs on a single PCI card. Using two of these cards we can drive 8 MAD Boxes with one computer (Figure X). Recent versions of Microsoft Windows can be configured so that all 8 outputs are merged into a single desktop. Existing applications can be stretched across the entire 8-output desktop and used normally.

This off-the-shelf hardware solution has some limitations. We are using display adapters with NVidia Quadro4 NVS 400 chips. These 4-output adapters cannot support video playback that spans an arbitrary number of displays. In addition, both Direct3D and OpenGL are not hardware accelerated in a window stretched across more than one display. To support Direct3D 9 we intercept Direct3D calls using a custom d3d9.dll. These intercepted calls are forwarded to individual rendering contexts created for each display that the full Direct3D window covers. This technique is sufficient to support hardware acceleration for many Direct3D applications in both full-screen and windowed modes.

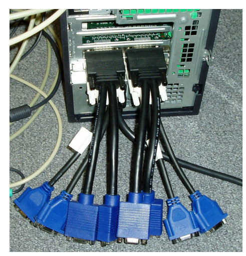

Figure 5 Video Outputs

We have also tested an engineering sample of the 4-output Matrox QID Pro board. This board supports OpenGL and Direct3D acceleration across all 4 outputs. We have still to confirm that this will hold across more than 4 displays.

This architecture will scale to support the four times number of PCI slots available in a single machine. A system with 6 PCI slots can support at most 24 MAD Boxes, assuming no other hardware or driver issues arise. This may be sufficient for the types of display configurations we wish to experiment with. Increased scalability can be achieved by resorting to a cluster-rendering system [5, 14, 15].

3.3 Interaction Systems

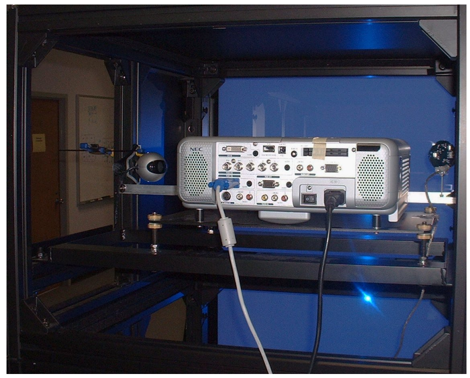

Figure 6 Webcams mounted inside frame

We are exploring several techniques for collaborative interaction with the MAD Boxes. Primarily we have experimented with vision-based systems. Off-the-shelf webcams can be mounted inside each MAD Box to track "blobs" that can be seen through the screen. This configuration avoids any physical occlusion issues. Laser pointers [9] can be used to interact at a distance or up close. The systems described in [3, 13] can identify individual laser pointers based on brightness modulation.

Colored LEDs can also be used in place of laser pointers to interact with our MAD Boxes. Users must physically touch the LEDs to the display surface, like a whiteboard pen. This restriction may be desirable since it closely parallels touch. In addition, determining pointer ID by colored LED is relatively simple compared to the laser pointer modifications required to modulate laser spots. We are developing an interaction system that supports identifiable pointers based on both brightness-modulation and color recognition.

4 Conclusions and Future Plans

The MAD Boxes have satisfied some of our design goals. They are modular, stackable and reconfigurable. Figure 7 shows several configurations including an 8 box 3 foot by 10 foot wall, two 3 box towers – one starting at floor level and one elevated and used as a bulletin board at an art gallery showing, a 4 box table, and a 4 box counter. One could imagine such a counter in one's breakfast nook and eating cereal while surfing current news.

The floating screens should not be difficult to align, however, with our current construction this is not always the case. Due to assembly errors the floating screen mounts do not always sit in the same position if they are removed and replaced. We have plans to improve this in future design iterations. Also, the current steel frames weigh approximately 70 pounds, making reconfiguration a two-person job. We plan to reduce this weight significantly through design and construction material improvements.

Figure 7 A variety of display configuration

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