Exploring the Use and Affordances of Multiple Display Environments

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Abstract. We describe past and ongoing research in our two groups by briefly highlighting a few particularly relevant projects. Our research involves conducting evaluations of multiple monitor systems, developing new interaction techniques for distributed display environments, and inventing new applications for environments rich in computer displays.

1 Introduction

The notion of a computer as single-display, on-top-of-the-desk machine has been a fundamental aspect of the model of computing for decades. The recent introduction of slim, flat-screen displays coupled with reductions in display prices and improved video hardware support has begun to challenge that notion. In particular, multiple-monitor computers (*multimon*) are common today. Flat-panel, plasma displays and projected displays have likewise begun to appear in offices, homes, and public places such as airports, stores, and office break rooms. Researchers are beginning to push the limits of computer hardware by building more complex configurations (see Figures 1 and 2).

Grudin has perhaps the earliest and most foundational paper studying the use of multimon [2]. He contends that although operating systems and video cards increasingly support multiple monitor configurations, designers often create software with a one-monitor user in mind. Interviews of a group of multimon users illustrated that people strongly favor multimon after they use it, and often feel more productive despite various software foibles. Others, such as Czerwinski [1], demonstrated that the time-efficiency gain was indeed realized. Grudin also uncovered some properties specific to multimon. For example, multimon differs from single, large resolution monitors because with multimon the display space is less flexible; monitor bezels tend to discourage users from placing windows across monitor boundaries. He concludes with a call for designs that understand the availability of extra monitors, such as the development of specialized notification and awareness applications, and more careful consideration to the layout and adaptability of UI components.

Fig. 1. A multiple monitor computer backed by a projected wall display.

This position paper describes a collaborative effort between researchers at the Georgia Institute of Technology and Microsoft Research to answer this call in addition to researching more general distributed display environments (DDEs). Our uniting influence is Dugald Hutchings, a doctoral student at the Georgia Institute of Technology under the supervision of John Stasko and a summer intern at Microsoft Research working with Mary Czerwinski and Brian Meyers.

We are firm believers in the growing importance of DDEs and our research on such systems has taken on many different forms. First, we have been performing fundamental evaluations of multimon to broaden our understanding of its use. Our field work has demonstrated differences in window management behavior among single- and multiple-monitor users. Our lab work has demonstrated how multimon users can experience time-efficiency gains for multi-window tasks while also showing how this gain could be further improved. Second, we have been developing new interaction techniques for personal DDEs that attempt to allow users to explot the resource of additional physical display space. Finally, we are exploring the effects of more widely deployed DDEs, for instance on walls and in other public places, with an eye on understanding the kinds of applications that are well-suited for such display-rich environments. In particular, we are examining ways for using pervasive displays as peripheral information awareness aids.

In the next sections, we describe each of these three efforts in more detail, and describe our past and ongoing research in each domain.

Fig. 2. A computer with nine display monitors configured as one large workspace.

2 Evaluating Multi-Display Environments

We have already discussed Grudin's and Czerwinski's et al. work on multimon: Grudin's field study illuminated important characteristics of them and Czerwinski's lab study provided validation that multimon systems can significantly aid users. Following onto that work, we conducted a study that was a combination of the two: quantitative analysis gathered from a field study of multimon users.

The VibeLog project aimed to compare and contrast single-monitor and multiple-monitor users' window management habits and practices [6]. Forty volunteers, twenty of whom were multiple monitor users, ran a tool that we developed to gather a large amount of window management data on the Windows operating systems. Details about the tool and experiment are in the paper.

One difference in our user population was the use of the Windows TaskBar. Single-monitor users employed the TaskBar for 25% of their window switches and directly clicked on a window 65% of the time. Multiple-monitor users employed the TaskBar about 10% of the time and direct clicking about 80% of the time. There are a variety of probable explanations for this behavior, but we will focus on one in this paper: since the TaskBar is in a fixed location, it becomes increasingly difficult or tiresome to move the pointer to it. This hypothesis is loosely supported by previous work (Czerwinski et al.), but raises interesting implications for future work, such as the ability to have a window available in multiple locations (the beginnings of which are documented in Hutchings' and Stasko's Technical Report [3] and Tan's et al. work on WinCuts [10]), and dynamic placement of multiple windows.

A noteworthy result from our study is that as the number of monitors increases the percentage of time that the entire screen is being used decreases. This suggests that application design and window management capabilities discourage users from exploiting the additional space (this claim is bolstered by our work on general window management as well [4]). Based on this finding we are developing ways to allow users to have tighter control of displayed information, such as allowing the real-time cropping of on-screen windows [5]. We are planning a full implementation and several user studies around this operation.

3 Developing New Techniques for Multi-Display Environments

We developed some visualizations of users' window visibilities, and discovered not only a trend to keep windows within monitors, but to assign windows to specific monitors and refrain from further moving windows to other monitors. Following this observation, we are actively working on an idea that we are tentatively calling virtual monitors. Similar to Rooms and virtual desktops, virtual monitors allows a physical monitor to have several virtual monitors attached, and gives the user the ability to switch among those virtual monitors freely. Some virtual desktop systems have started to incorporate this ability (such as Vern http://www.oneguycoding.com/vern), but our work will focus on both providing a much more flexible use of multimon based on our user observations and looking at better ways to exploit and preserve spatial memory in a DDE.

Another possible direction for task management on a larger display surface, whether distributed across multiple monitors or unified as a single screen, is Scalable Fabric [8]. As shown in Figure 3, the user defines a focus region, where tasks are conducted (i.e. windows are displayed as normal), and a context region, where other tasks are stored for future completion but displayed visually to help maintain context (i.e. windows are scaled down but still how live content). One discussion point around this interface is screen space usage. Unlike a virtual desktop system, all tasks are shown, meaning that some of the screen is dedicated to task management rather than task completion. However, on a high-resolution display, the trade-off is likely to be marginalized and actually becomes an advantage: everything can be seen at a glance.

4 Exploring New Uses of Pervasive Display Environments

The decline in price and the much smaller footprint of displays has facilitated a more pervasive deployment of displays in offices, homes, and public places. While most offices have not become the equivalent of New York's Times Square with displays everywhere, it is not uncommon to see busy displays in lobbies, hallways, breakrooms, shared offices and laboratories.

We have been exploring ways to use displays throughout the environment as peripheral awareness aids. In one project, we have developed a system called The Buzz (www.cc.gatech.edu/gvu/ii/buzz) that helps people maintain awareness of community activities and of general information such as news, weather and traffic. Building on the earlier What's Happening system [11], the Buzz presents

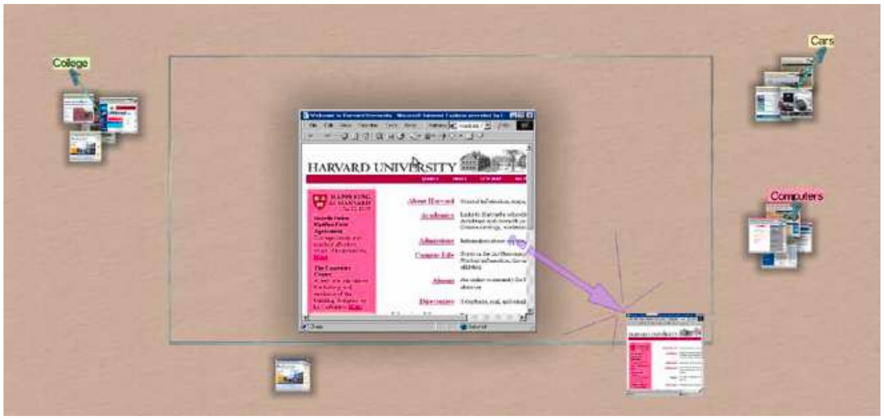

Fig. 3. An example display of a person while using Scalable Fabric.

collages of images taken from web pages. A new collage is displayed about every minute, and the system can be run as a screen-saver or on projected and plasma displays deployed ubiquitously. For promoting community awareness, the Buzz presents images taken from random web pages off our local web server. For general information, it scrapes local weather, traffic, etc., pages as well as pages like BBC World News and Technology News to create collages.

In another project, we have developed a system called InfoCanvas that provides a type of information art or electronic painting [9]. Figure 4 shows a deployed InfoCanvas mounted like a picture on a wall. It is an LCD display connected to a computer, but housed in a typical picture frame. Objects in the painting represent information of interest to a person. As that information changes, the objects change appearance accordingly. For instance, a bird flying in the sky might represent the stock market, flying higher when the market is up and lower when the market is down. An umbrella in a scene might represent traffic on a local road and be colored green when traffic is moving well, yellow when moving moderately, and red when moving slowly. This project shows how the pervasive presence of displays can enable new forms of communication and interaction.

In the projects described herein, we are investigating ways to help people be more efficient in DDE and we are exploring new forms of applications for DDE. This work is a major focus for both our groups, and we look forward to this workshop as an opportunity to describe more of our research and to learn more about what others are doing.

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Fig. 4. Using a computer display much like a picture hung on a wall.

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