LARGE DISPLAY RESEARCH OVERVIEW

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Abstract

As large displays become more affordable, researchers are investigating their effects on productivity, and techniques for making the large display user experience more effective. Recent work has demonstrated significant productivity benefits, but has also identified numerous usability issues with current software design not scaling well. Studies show that larger displays enable users to create and manage many more windows, as well as to engage in more complex multitasking behavior. In this overview, various usability issues, including problems around accessing windows and icons at a distance, window management, and task management, will be discussedSeveral novel interaction techniques that address these issues and make users more productive across multiple sizes of displays will be explored.

Keywords

Large displays, information visualization, interaction

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI), H5.2 User interfaces-Graphical user interface.

Introduction

The increasing graphical processing power of the PC has fueled a powerful demand for larger and more capable display devices. Despite the increasing affordability and availability of larger displays, most users' display space represents less than 10% of their physical workspace area. Similarly, many of our current interfaces are designed around the assumption of a relatively small display providing access to a much larger virtual world. How might users cope with and benefit from display devices that provide 25% to 35% of their physical desk area or perhaps one day cover entire office walls? This question has been an issue of interest for many researchers [2, 3, 4, 5, 10, 14, 19, 21, 22, 24, 29, 30, etc.]. To examine this issue, we evaluated usability issues for large displays and developed a series of research prototypes that address various issues we discovered.

Because the ability to work with multiple displays has been supported for some time in several operating systems (OS) and due to the advancements of graphic cards over the past ten years or so, a growing number of computer users take advantage of multiple monitor (multimon) capabilities. Our own survey research indicates that as many as 20% or more of the Windows™ OS "information workers" today run multiple monitors from one PC or laptop. Most users are aware that running multimon is an option. The top reason cited by participants in our survey for not running multiple monitors was a fear of not having enough physical desktop space. Display manufacturers have already addressed this concern for liquid crystal displays (LCDs) by building much smaller desktop footprints, and by developing wall-hung displays. A precipitous price drop has also occurred in the last few years, and the average computer consumer can now readily get 25% more pixels by buying dual 17" LCDs instead of one 21" LCD for approximately the same price. Since all laptop manufacturers are selling their products with built-in support for multiple monitors, we may see a dramatic increase in the number of users who will be opting for more screen real estate (pixels) by running multimon configurations when back in the office, and we need to develop user interfaces that take advantage of this possibility.

Grudin [13] documents the usage patterns of CAD/CAM programmers and designers running multiple monitors. Despite the limitations observed in current OS support, multimon users clearly love the extra screen real estate, and they adapt their windows and application layouts optimally for the number, size, orientation and resolution of their displays. Most current multimon users claim they would never go back to a single monitor. Robertson et al. [25] document a series of user studies demonstrating productivity benefits from using multimon or large displays with an eye toward novel software applications that might better support the way information workers multitask between their projects and applications. These studies showed a significant performance benefit as well as a satisfaction preference for large displays.

While these studies demonstrate the advantages of using large displays, we have found in our work that there are also serious usability issues with how current software systems behave on large surfaces. In the remainder of this overview, basic usability issues and proposed solutions will be described, including accessing distal windows and icons and managing multiple windows and tasks.

Cognitive Benefits of Large Displays

In addition to productivity benefits mentioned earlier, Czerwinski et al. [10] also document results showing that larger displays lead to improved recognition memory and peripheral awareness.Tan et al. [31] report a series of studies demonstrating the advantages of large displays on 3D navigation in virtual worlds. They show that while large displays increase performance for all users on average, females improved so much that the normal advantage male users have over females in virtual 3D navigation disappears when using large displays. These studies reveal that the wider fields of view provided by large displays lead to increased ability to process optical flow cues during navigation, cues that females are more reliant upon than males. They ran their studies on DSharp, a seamless wide screen multi-projector display shown in Figure 1, and found that the optimal field of view for the tasks tested was about 100 degrees, the equivalent of a triple monitor display. Thus, large displays actually serve to eliminate a gender bias, at least for the set of tasks tested. In separate studies, Tan et al. [33, 34] also found that large displays provide for a more immersive experience when performing spatial tasks, such as navigating 3D environments. This immersion allows the user to better perform navigation in 3D, in addition to building better cognitive maps of the virtual world.

Large Display Usability Issues

Several of the usability issues we have identified and describe below were observed while evaluating the productivity benefits of large displays using formal laboratory studies [10]. Usability issues have been identified by developing and deploying windowing system logging tools to observe real Windows users in the field, and by analyzing product support calls.

Gathering Data

It is difficult to adequately design for large displays and multiple monitor systems without understanding how multimon users differ from, or are similar to, single monitor users. Therefore, a tool, called *VibeLog* [16], was deployed to a group of single monitor and multimon users to log window management activity. We focus on window management activity in order to discover higher-level patterns of activity for different sized displays (e.g., the number of opened windows, the frequency of window activation, and the frequency of window movement). Analysis of the data collected from this tool revealed that usage of interaction components may change with an increase in the number of monitors and that *window visibility* can be a useful measure of user display space management activity, especially for multiple monitor users. The results from this analysis begin to fill a gap in research about real-world window and task management practices, and have influenced the design choices for many of the prototypes discussed in this overview, as well as products in development.

Basic Usability Issues

The usability issues observed fall into six broad categories:

1. Losing track of the cursor. As screen size increases, users change mouse acceleration to compensate and it becomes hard to keep track of where the cursor is.

2. Distal access to information. As screen size increases, it becomes increasingly more difficult and

time-consuming to access icons, windows, and the Start Menu across large distances.

3. Window management problems. Large displays lead to notification and window creation problems, as windows and dialog boxes pop up in unexpected places. Window management is made more complex on multimon displays because users wish to avoid having windows placed so that they cross bezels (because of the resultant distortion).

4. Task management problems. As screen size increases, the number of windows that are open increases and users engage in more complex multitasking behavior – better task management mechanisms become a necessity.

5. Configuration problems. The user interface for configuring multimon displays is overly complex and hard to use. When a monitor is removed from the display configuration, it is possible to lose windows off-screen.

6. Failure to leverage the periphery. With larger displays a true periphery is available and could be leveraged for better, peripheral awareness in support of user activies.

In this overview, research prototypes will be described that address the problems raised by several of these categories of usability issues.

conclusions

There is a clear trend in the industry toward larger displays, either as a single display surface or in multiple monitor configurations. There is also evidence that larger displays increase user productivity, aid user recognition memory, and in some cases can eliminate gender bias (e.g., while navigating in 3D virtual environments). User studies have identified numerous usability problems that inhibit even more enhanced user productivity, including: keeping track of the cursor, distal access to windows and icons, dealing with bezels, window management, and task management. In this overview, a series of research prototypes will be presented that outline techniques for solving each of these problems. The work of integrating these various prototype solutions into one system remains to be done. Correcting each of these problems goes a long way toward improving the user experience on large displays.

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REFERENCES

1. Ballagas, R., Rohs, M. & Sheridan, J. (2005). Sweep and Point & Shoot: Phonecam-based interactions for large, public displays. In *Proceedings of CHI 2005 – the ACM Conference on Human Factors in Computing Systems*, pp. 1-4.
2. Baudisch, P., Cutrell, E., Robbins, D., Czerwinski, M., Tandler, P., Bederson, B., and Zierlinger, A. Drag-and-Pop and Drag-and-Pick: techniques for accessing remote screen content on touch- and pen-operated systems. In *Proceedings of Interact 2003*, pp.57-64.
3. Baudisch, P. Cutrell, E, and Robertson, G. High-density cursor: a visualization technique that helps users keep track of fast-moving mouse cursors. In *Proceedings of Interact 2003*, pp. 236-243.
4. Bezerianos, A.& Balakrishan, R. (2005). Canvas Portals: View and space management on large displays. *IEEE Computer Graphics and Applications, 25(4)*. pp. 34-43
5. Bezerianos, A. & Balakrishnan, R. (2005). The Vacuum: Facilitating the manipulation of distant objects. *Proceedings of CHI 2005 – the ACM*

Conference on Human Factors in Computing Systems. pp. 361-370.

6. Biehl, J.T. & Bailey, B.P. (2004). ARIS: An interface for application relocation in an interactive space. In *Proceedings of Graphics Interface 2004*, pp. 107-116.
7. Brignull, H. & Rogers, Y. (2003). Enticing people to interact with large public displays in public places. In *Proceedings of Interact 2003*, pp. 17-24.
8. Buxton, W., Fitzmaurice, G., Balakrishnan, R., Kurtenbach, G. (2000). Large displays in automotive design. *IEEE Computer Graphics & Applications*, July 2000.
9. Cao, X. & Blakrishnan, R. (2003). VisionWand: Interaction techniques for large displays using a passive wand tracked in 3D. *Proceedings of UIST 2003 – the ACM Symposium on User Interface Software and Technology*. pp. 173-182.
10. Czerwinski, M., Smith, G., Regan, T., Meyers, B., Robertson, G. and Starkweather, G. (2003). Toward characterizing the productivity benefits of very large displays. In *Proceedings of Interact 2003*, pp. 9-16.
11. Elrod, S., Bruce, R., Gold, R., Goldberg, D., Halasz, F., Janssen, W., Lee, D., McCall, K., Pedersen, E., Pier, K., Tang, J. & Welch, B. (1992). LiveBoard: A large interactive display supporting group meetings, presentations and remote collaboration. In *Proceedings of CHI 1992 – the ACM Conference on Human Factors in Computing Systems,* pp. 599-607.
12. Grossman, T., Balakrishnan, R., Kurtenbach, G., Fitzmaurice, G., Khan, A. & Buxton, W.. (2001). Interaction techniques for 3D modeling on large displays. *Proceedings of the ACM Symposium on Interactive 3D Graphics (I3DG2001)*, pp. 17-23. New York: ACM.
13. Grudin, J. (2002). Partitioning digital worlds: Focal and peripheral awareness in multiple monitor use. In *Proceedings of CHI 2002 – the ACM Conference on Human Factors in Computing Systems,* pp. 458-465.
14. Guimbretiere, F., Stone, M., and Winograd, T. (2001). Fluid interaction with high-resolution wall-size displays. In *Proceedings of UIST 2001,* pp. 21-30.
15. Huang, E.M., Russell, D.M. & Sue, A.E. (2004). IM Here: Public instant messaging on large, shared displays for workgroup interactions. In *Proceedings of CHI 2004 – the ACM Conference on Human Factors in Computing Systems,* pp. 279-286.
16. Hutchings, D., Czerwinski, M., Smith, G., Meyers, B., Robertson, G Display space usage and window management operation comparisons between single monitor and multiple monitor users. In *Proceedings of AVI 2004*, pp. 32-39.
17. Khan, A., Fitzmaurice, G., Almeida, D., Burtnyk, N. & Kurtenbach, G. (2003). A remote control interface for large displays. *ACM UIST 2003 Symposium on User Interface Software & Technology,* pp. 127-136.
18. Khan, A. Matejka, J. Fitzmaurice, G. & Kurtenbach, G. (2005). Spotlight: Directing users' visual attention on large displays. *Proceedings of CHI 2005 – the ACM Conference on Human Factors in Computing Systems* pp. 791 – 798.
19. MacIntyre, B., Mynatt, E., Voida, S., Hansen, K., Tullio, J., Corso, G. (2001). Support for multitasking and background awareness using interactive peripheral displays. In *ACM UIST 2001 Symposium on User Interface Software & Technology,* pp. 41-50.
20. Malik, S., Ranjan, A. & Balakrishnan, R. (2005). Interacting with large displays from a distance with vision-tracked multi-finger gestural input. *Proceedings of UIST 2005 - the ACM Symposium on User Interface Software and Technology.* pp. 43-52.
21. McCarthy, J.F., Costa, T.J. & Liongosari, E.S. (2001). UniCast, OutCast & GroupCast: Three steps toward ubiquitous, peripheral displays. In *Lecture Notes in Computer Science*, Vol. 2201, pp. 332-*, Germany: Springer-Verlag.

22. Mynatt, E., Igarashi, T., Edwards, W., and LaMarca, A. (1999). Flatland: new dimensions in office whiteboards. In *Proceedings of CHI 1999 – the ACM Conference on Human Factors in Computing Systems*, pp. 346-353.
23. Paradiso, J.A., Leo, C.K., Checka, N. & Hsiao, K. (2002). Passive acoustic sensing for tracking knocks atop large interactive displays. In Proceedings of the IEEE Sensors 2002 Conference, pp. 1-6.
24. Pedersen, E., McCall, K., Moran, T., Halasz, F.G. (1993). Tivoli: An electronic whiteboard for informal workgroup meetings. In *Proceedings of CHI 1993 – the ACM Conference on Human Factors in Computing Systems*, pp. 391-398.
25. Robertson, G.G., Czerwinski, M., Baudisch, P., Meyers, B., Robbins, D., Smith, G., and Tan, D. (2005). Large display user experience. In *IEEE CG&A special issue on large displays, 25(4),* pp. 44-51.
26. Robertson, G., Horvitz, E., Czerwinski, M., Baudisch, P., Hutchings, D., Meyers, B., Robbins, D., and Smith, G. (2004), Scalable Fabric: Flexible Task Management. In *Proceedings of AVI 2004* pp. 85-89.
27. Russell, D. M., Drews, C. & Sue, A. (2002). Social aspects of using large interactive displays for collaboration. In *Proceedings of UbiComp 2002: Ubiquitous Computing: 4th International Conference*, pp. 229-236.
28. Smith, G., Baudisch, P., Robertson, G., Czerwinski, M., Meyers, B., Robbins, D., and Andrews, D. (2003). GroupBar: The TaskBar Evolved. In *Proceedings of OZCHI 2003*, pp. 34-43.
29. Streitz, N.A., Geiler, J. & Holmer, T. (1998). Roomware for cooperative buildings: Integrated design of architectural spaces and information spaces. In *Lecture Notes in Computer Science*, Vol. 1370, pp. 4-*, Germany: Springer-Verlag.
30. Swaminathan, K. & Sato, K. (1997). Interaction design for large displays. In ACM's *Interactions* (4), pp. 15-24.
31. Tan, D., Czerwinski, M., and Robertson, G. (2003). Women Go With the (Optical) Flow. In *Proceedings of CHI 2003 – the ACM Conference on Human Factors in Computing Systems*, pp. 209-215.
32. Tan, D.S. and Czerwinski, M. (2003). Information Voyeurism: Social impact of physically large displays on information privacy. *Proceedings of CHI 2003 – the ACM Conference on Human Factors in Computing Systems.* pp. 748-749.
33. Tan, D.S., Gergle, D., Scupelli, P. & Pausch, R. (2003). With similar viewing angles, larger displays improve spatial performance. In *Proceedings of CHI 2003 – the ACM Conference on Human Factors in Computing Systems*, pp. 217-224.
34. Tan, D.S., Gergle, D., Scupelli, P. & Pausch, R. (2004). Physically large displays improve path integration in 3D virtual navigation tasks. In *Proceedings of CHI 2004 – the ACM Conference on Human Factors in Computing Systems*, pp. 439-446.
35. Tan, D.S., Meyers, B. & Czerwinski, M. (2004). WinCuts: Manipulating arbitrary window regions for more effective use of screen space. In *Extended Abstracts of Proceedings of CHI 2004*, pp. 1525-1528.
36. Vogel, D. & Balakrishnan, R. (2005). Distant freehand pointing and clicking on very large high resolution displays. *Proceedings of UIST 2005 - the ACM Symposium on User Interface Software and Technology.* pp. 33-42.
37. Vogel, D. & Balakrishnan, R. (2004). Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users. *Proceedings of UIST 2004 – the ACM Symposium on User Interface Software and Technology*. pp. 137-146.