Techniques for Building Cost-Effective Ultra-high-resolution Visualization Instruments

Luc RENAMBOT, Andrew JOHNSON, Jason LEIGH
renambot@uic.edu, ajohnson@uic.edu, spiff@uic.edu
Electronic Visualization Laboratory,
Dept. of Computer Science, University of Illinois at Chicago

LambdaTable (20 Mpixels) and LambdaVision (105 Mpixels) LCD-based displays at EVL

INTRODUCTION

Future situation-rooms and research laboratories will be designed with walls made from seamless ultra-high-resolution displays fed by data streamed over ultra-high-speed networks from distantly located visualization, storage servers, and high definition video cameras. It will allow local and distributed groups of researchers to work together on large amounts of distributed heterogeneous datasets. Scalable and high-resolution displays have been built in the past but it has only been affordable to average scientists more recently due to significant decreases in the cost of computers, networking, and especially displays.

Numerous scientists require new high-resolution displays to visually explore large datasets produced by large imaging devices (electron microscope, imaging satellite) or by newly deployed sensor networks (seismic sensors). For instance, geoscientists work with aerial and satellite imagery (365.000x365.000 pixels maps) and neurobiologists explore the brain with montages consisting of thousands of pictures from a high-resolution microscope (4Kx4K pixels sensor).

LAMBDAVISION

Past efforts have relied on the use of projectors with many problems. Color-balance and geometric alignment are difficult issues and their variations in time are problematic for practical use by scientists. These considerations have led us to use LCD screens as a building block for high-resolution displays. LCD panels are an extremely desirable solution for viewing large images because they are cheap, bright (viewable in standard office lighting), require no projection distance, are rather-well color-matched, and provide a wide-field of view. While it is possible to build tiled displays with projectors, the costs are prohibitively high for ultra-resolution screens. For example, a 1600x1200 20-inch LCD panel costs approximately $600. A 1024x768 2000 lumen projector costs about $2000. Hence, a 55 panel array of LCD panels costs approximately $33,000 whereas a projector-based display with the equivalent resolution will require about 134 projectors and cost $268,554- i.e. 8X the cost of an LCD-panel-based solution. Furthermore, the bulb-life of LCD panels is approximately 20000 to 30000 hours - roughly 3.5 years if the screen were left on permanently. Projectors have a bulb life of about 2000 hours, and each bulb replacement costs $400 - one complete bulb change for all the projectors will cost a total of $53,600 – more than the cost of the entire tiled LCD screen. Furthermore every bulb change requires color recalibration of the display.

LCD screens however have one minor drawback at the present time. They have borders around them that are about 10mm thick on all sides. We mitigate their impact by explicitly hiding the pixels under the borders in software- the net effect is akin to looking out of a set of French windows. This ensures that lines that cross borders appear to be continuous. We anticipate that over time border widths on panels will diminish. Furthermore, promising new display technologies such as Organic LEDs and optical devices are emerging that will aid in eliminating the borders altogether. This is one of the subjects of study in our LambdaVision MRI grant.

EVL's tiled display (LambdaVision) is built from 55 tiles in an 11x5 configuration, and provides over 100 million pixels of resolution. EVL has recently converted one of our first generation LCD tiled displays into a tabletop display (LambdaTable.) A prototype camera-based tracking system has been built to allow the tracking of position and orientation of an augmented mouse placed on the table. Infrared LEDs are mounted on the "mouse" so that the camera system can detect position, orientation and button presses wirelessly. We intend to develop the next generation of this system, where an array of cameras will provide higher resolution tracking, as well as an array of LEDs that can be used to uniquely identify and track multiple mice on the table, facilitating multiple simultaneous users interacting with the table

For smaller configuration than LambdaVision, multiple graphics cards can be inserted into a single PC providing a cost effective solution (new motherboard supports two 16x PCI-express slots for high-end graphics cards). For large configuration, multiple computers need to be ganged together- i.e. a cluster is needed. This introduces new problems- noise and heat, which means that the cluster needs to be separated from the displays.

As LCD resolutions increase, the cost of extending the video signals (DVI) increases. We can no longer use wire, so we need to use fiber. For lower resolution solutions, VGA or DVI extenders over CAT5 cable are economical. For high resolution (1600x1200 pixels and above), optical networking fiber makes the most sense, such as the OPHIT's DDL high-speed and long-distance transmission extender by LC-type multi-mode fibers where R, G, B, and clock signals are transmitted separately by four fibers. But the cost of cable extension is approaching the cost of computing.

So the new model being investigated in the OptIPuter [1] and LambdaVision projects are to plug cheap PCs to the back of displays and drive them as large frame buffers from remote computers- such as the TeraGrid. We do not expect this as the final solution. It is a temporary solution to illustrate its viability so that display manufacturers will incorporate more intelligence into the display and connect it via Gigabit Ethernet rather than DVI.

Another research topic is user interaction in such environments [2]. As the screen size increases interaction paradigms need to change in order for the displays to be useful to real users. One no longer just shows one large picture but many smaller ones- allowing multiple users to work with various visualizations simultaneously. This is currently not possible under the current design of window managers in the operating system and so this needs to be carefully rethought. Instead, a variety of peripheral input devices need to be used: for example TabletPCs and laptops; or cameras for LambdaTable.

These displays are currently being controlled by a software system called SAGE (the Scalable Adaptive Graphics Environment) [4]. SAGE acts as a scalable display manager to enable real-time high-resolution content to be routed, under user control, to any region of a tiled display or table. SAGE is based upon a graphics streaming architecture for supporting collaborative scientific visualization environments with potentially hundreds of megapixels of contiguous display resolution. In collaborative scientific visualization, it is crucial to share high-resolution visualizations as well as high definition video among groups of collaborators at local or remote sites. Our network-centered architecture allows collaborators to simultaneously run multiple visualization applications on local or remote clusters and share the visualizations by streaming the pixels of each application over ultra high-speed networks to large tiled displays. This streaming architecture is designed such that the output of arbitrary M by N pixel rendering cluster nodes can be streamed to X by Y pixel display screens allowing for user-definable layouts on the display. This dynamic pixel routing capability of our architecture allows users to freely move and resize each application's imagery over the tiled displays in run-time, tightly synchronizing the multiple visualization streams to form a single stream. Experimental results show that our architecture can support visualization at multi-ten-megapixel resolution with interactive frame rates using gigabit networks.

Content such as 2D mapping and 3D bioscience imageries is generated by JuxtaView and Vol-a-Tile - software systems designed for rendering high-resolution 2D and 3D data sets, respectively [3]. Both JuxtaView and Vol-a-Tile run on a cluster of computers whose graphics are streamed to SAGE for display. A next generation rendering system (called Ethereon) that will merge the capabilities of JuxtaView and Vol-a-Tile is currently under development- a first prototype will be operational in Fall 2005. Lastly, hardware/software systems called TeraVision and Scalable Video Consumer (SVC) enable the streaming of HD, HDV, and MPEG2 video signals over a high-speed wide-area network. Legacy applications (OpenGL and VNC) are also supported. Software and documentation available at: http://www.evl.uic.edu/cavern/sage

ACKNOWLEDGMENTS

These projects are made possible by major funding from the National Science Foundation (NSF), awards CNS-0420477, CNS-0115809, CNS-0224306, SCI-9980480, SCI-0229642, SCI-9730202, SCI-0123399, ANI-0129527 and EAR-0218918, as well as the NSF Information Technology Research (ITR) cooperative agreement (SCI-0225642) to the University of California San Diego (UCSD) for "The OptIPuter". This project is further facilitated by funding from the Office of Naval Research.

REFERENCES

1. Larry L. Smarr, Andrew A. Chien, Tom DeFanti, Jason Leigh, Philip M. Papadopoulos "The OptIPuter" Communications of the ACM, Volume 46, Issue 11, November 2003, pp. 58-67.
2. Park, K., Renambot, L., Leigh, J. and Johnson, A., "The Impact of Display-rich Environments for Enhancing Task Parallelism and Group Awareness in Advanced Collaborative Environments", In Workshop on Advanced Collaboration Environments, June 22-24, 2003, Seattle, WA.
3. OptIPuter visualization: www.evl.uic.edu/cavern/optiputer/
4. Renambot, L., Rao, A., Singh, R., Jeong, B., Krishnaprasad, N., Vishwanath, V., Chandrasekhar, V., Schwarz, N., Spale, A., Zhang, C., Goldman, G., Leigh, J., Johnson, A., "SAGE: the Scalable Adaptive Graphics Environment", in the proceedings of the Workshop on Advanced Collaborative Environments 2004, Nice, France, September 23, 2004. http://www.evl.uic.edu/luc/Research/papers/WACE2004.pdf