A scalable, high-resolution tiled display system

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Abstract—**The common vision of a tiled display requires a very large, scalable range of display space and advanced visualization capabilities for high-resolution images, graphics primitives and video streams. This paper presents design criteria for making such a tiled display and describes our experience in building and utilizing a super high-resolution tiled display better than prior work. We show how our display can be effectively used as a powerful display technology by demonstrating some applications with four datasets, such as 2D images, 3D graphics data, movies, and real-time video streams.**

Keywords: tiled display, large-scale display, advanced visualization capability

1 Introduction

Recently, there has been a significant increase in demands for the interactive visualization of high-resolution life-sizing images and the rendering of complex models in various domains, such as scientific visualizations, virtual reality environments and visual simulation applications. Typical desktop-based display systems have intrinsic restrictions to meet those demands, because of their limited display capabilities and low graphics processing performance. Thus, recent research for meeting the needs of such a visualization community has been primarily focused on the development of large-scale high-resolution tiled display systems[3, 4, 14, 11, 10].

The main challenges for building a tiled display system are to support the needs for 1) driving a scalable high-resolution display; 2) scaling graphics performance; and 3) leveraging the potential benefits of commodity technologies. Much work has investigated and continues to happen on developing tiled display technologies and their use in the visualization community. Our primary concern here is to briefly introduce how to construct such a tiled display system that can fulfill all those challenges nearly better than those of previously accomplished similar work.

In this article, we present our experience in building and utilizing a super high-resolution tiled display system arranged in a 7 x 4 array projectors, producing a display of 6592 x 2784 pixels across a 5.6m x 2.4m size screen. More specifically, we focus on how the our display can meet the research challenges noted above by describing its scalable framework. Further, we describe how it can be effectively used as a powerful display technology by showing some applications.

This article is organized as follows. In the next section, we discuss how our display system is designed. The applications integrated into that system are demonstrated in Section 3. Finally a conclusion closes this article.

2 Design Scheme

First and foremost, in order to help understand how our display system is structured, we describe its main specification. It is a super high-resolution rear-projected display system, consisting of a unit of 7 x 4 projectors with a resolution of more than 20 million pixels. We configured it to be driven by a cluster of PCs to provide a more affordable, scalable architecture. The main specification includes (1) *arrangement*: 7 x 4 XGA Tiles (28 DLP Projector driven by commodity PCs to a Gigabit network); (2) *size*: 5.6m x 2.4m; (3) *resolution*: 6592 x 2784 pixels (28M pixels, dot pitch 0.78mm); (4) *ANSI*: 64,400 ANSI Lumen in total (2,300 ANSI Lumen per projector).

Our system is built with multiple low-cost commodity components and composed of three main parts: (1) hybrid screen for rear-projection; (2) projector frame and stages to correctly position the projectors; and (3) a cluster of PCs. We now describe how these main parts are designed and featured in brief.

2.1 Hybrid Screen

The most popular and frequently used methods for building a large display are using the composition of LCD panels[7, 16] and acrylic rigid screens[1]. In the former method, a screen is constructed by assembling a set of small-sized LCD panels. Such a screen of this kind generally gives high surface brightness. Since, however, it yields too many straight-line borders between adjacent tiles, it is inferior in the aspect of visualization effects[9]. Besides, this screen can be easily fragile due to its thin surface. In the latter method, a large acrylic screen can be built by composing several units of small-sized acrylic displays. This screen is rigid, but, it has an intrinsic limitation to expand its size (e.g., max-size is 340 inch[4]) in current manufacturing technology. In addition to this, it

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gradually tends to be getting bent according to the lapse of time.

For that reason, we designed a new rear projection screen, called a *hybrid screen* that can meet the shortcomings of those two approaches as shown in Fig.1(a). This screen is constructed by attaching a very high-quality non-rigid, white-colored screen to a large-sized transparent tempered glass (5.6m x 2.4m size). Its main features are brightness (gain 1.0), white uniformity, wide viewing angle, seamlessness, and firmness against vibration.

2.2 Projector Frame Structure

When constructing a tiled display framework, one of the important problems is how to uniformly and accurately align the accumulated projectors not to distort the overall geometry of those projectors arrangement. In order to meet the issue with effective ways, we designed and implemented H/W frame which consists of two major elements: 1) a projector frame that can stably resist the weight of multiple projectors; 2) high-precision but small-sized stages designed to position the projectors.

2.2.1 Projector Frame

Most conventional approaches for building multiple projectors frame has been centered on a common method based on the *box-styled design*, assembled by many horizontal and vertical profiles as seen in the left of Fig.1(b). One drawback of this method is that it hinders the operators from accessing to the projectors, thus making it difficult to tune the process of projector arrangement. Therefore, we designed our frame to have a planar body with commodity aluminum profiles as shown in the right of Fig.1(b). This frame can allow the operators to easily access the projectors and help to minimize the tuning time for the arrangement task. Besides, our frame can be easily extended its volumetric size by simply adding a few aluminum profiles on the side of the main frame. Moreover, in order to increase its stability, we added footholds to both sides of each column pole to make a triangular structure being regarded as the most stable form for such a construction.

2.2.2 Projector Stages

We developed a very stable, high-precision 6 degree of freedom (DOF) stage that provides easier ways to adjust the position and orientation of the projector being mounted on the top of this positioning device. Some of earlier designs[4] have mainly two intrinsic problems from the aspects of positioning a heavy-weighted object and operating ranges: 1) it is sensitive to even a light touch, so that it requires frequent re-adjustment task manually;

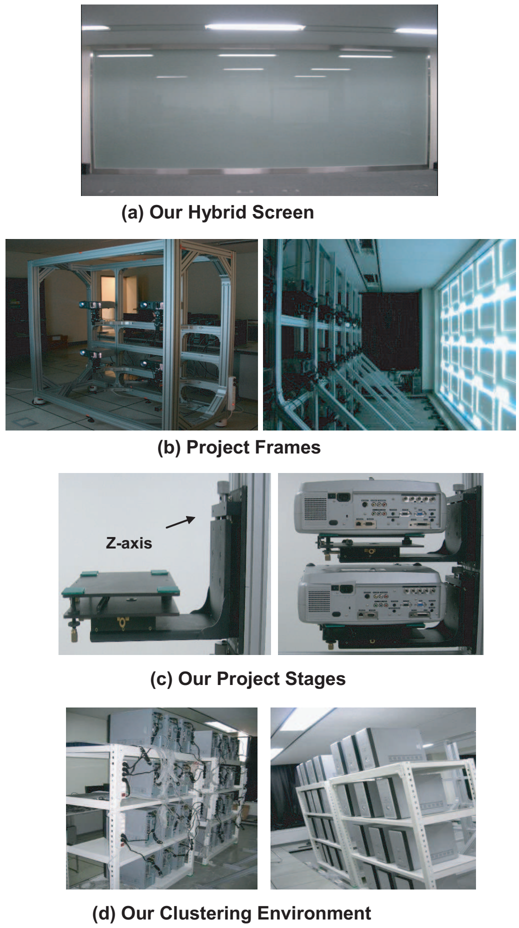

Figure 1: (a) The hybrid screen (5.6m x 2.4m size). (b) left: a typical projector frame having a box-styled design; right: our display frame - scalable, stable, easy-to-move, easy-to-use, and low-cost design. (c) Our projector stage with 6 DOF; left: a side view of our stage, right: when the stage is used for a stereo tiled display. (d) Our clustering environment for high-performance visualization using rich-featured graphics cards.

2) the operation ranges are too narrow especially to the z-direction.

To reduce these problems, we separated the z-axis from the other transformation axes in the main body of our stage. Then, we located such a separated z-axis control part to be attached to the project frame (see the left of Fig.1(c)). This method also made it possibly to have a relatively thin structure compared to the former design methods. The right of Fig.1(c) even shows how our stage can be easily extended to the situation where it is used for generating stereo visualization effects.

2.3 Cluster of PCs

For several years now, high-performance and rich-feature PC graphics interfaces have been increasingly popular and available at relatively lower cost. This trend enabled

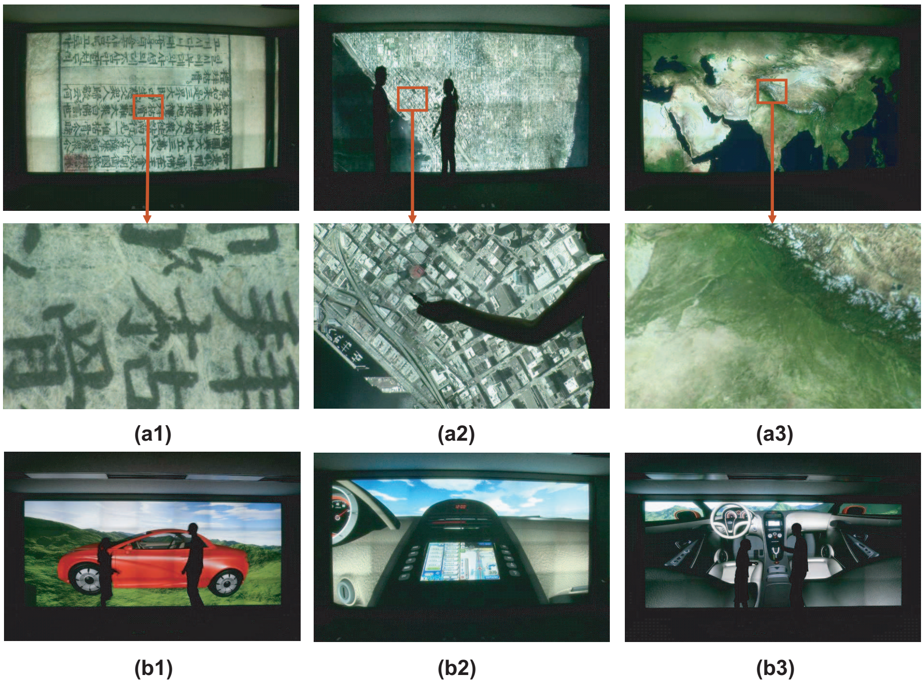

Figure 2: (a1) A high-resolution picture having ancient Korean characters written in an ancient paper. We can see even the pattern of the delicate weaves of the paper. (a2) A high-resolution picture taken from a satellite displayed on our display. We can look into it in depth, even identify the shape of a fingernail-size object in the image. (a3) A picture taken from a satellite. We can get a view of whole map at a look in detail. (b1) A 3D rendered graphics model composed of about 3 millions polygons with background. (b2) A snapshot of the certain region of the inner body of the automobile model seen in (b1). (b3) This application is effectively applied in the situation when reviewing and simulating designed objects.

us to build a clustered tiled display environment at a reasonable cost. The main purpose of our system's clustering is to enable the real-time visualization of 3D graphics images or video streams with high-performance in a tiled display environment. Its main characteristic is to have *master-slave model*[15] in which all of the visualization applications are executed in collaboration with all the clustered slave PCs. Such executions can be synchronized to insure consistency among those slave nodes. Fig.1(d) shows our clustering structure in which 28 PCs harnessed with high-end graphics card (i.e., NVdia GT6800) are interconnected via a gigabit LAN.

3 Applications

In this section, we show our experiments. The goal is to answer the question of whether our display system is appropriately enough as a powerful display technology for high-resolution graphics applications consisting of massive datasets. We briefly describe four applications which have been integrated into this environment.

3.1 High-resolution 2D Image Viewer

As our basic application, we developed a distribute image viewer (DIV) that can display high-resolution life-sizing images. Previous work on high-resolution cameras has led to the availability of very large and accurate images of fine art acquired from various areas, such as VR environments, manufacturing industries, entertainment/advertisement industries, and GIS areas. Some examples are shown from Fig.2(a1) to Fig.2(a3). The master node handles user interactions and then distributes the control data (i.e., the size of portion that each DIV on a slave must display and the size of overlapped regions to be blended between adjacent tiles). By this experiment, we found that our display system presents an ideal medium for visualizing the image that itself is quite rich at high resolution.

3.2 3D Graphics Renderer

Originally, our work is motivated to support *Virtual Engineering Process* which allows engineers to review and simulate designs created during manufactural real processes in a more efficient way. With regard to this motivation, our 3D graphics renderer was made not only to provide better 3D immersion effects, but also to help reduce manufactured cost, explore creativity, and lead to a better final product quality. It can let many off-the-shelf 3D graphics formats run and simulate according to the triggering events of user interactions in real

Figure 3: Some snapshots being displayed on our display: (a) Movie Player (High-resolution movie); (b) Real-time Video Stream Player (HD News Broadcasting);

time. The master node controls the rendering process of all the slaves, distributes only control data (e.g., view frustums), and has a responsible for synchronizing that process. Each slave renders its own partial scene region when receiving the control data from the master. Fig.2(b1) shows a complex 3D automobile model created by our virtual manufacturing process. As shown in Fig.2(b2), we can manipulate this design and even have a feeling how the inner leathers of the car are characterized in detail. Through the renderer, we were able to enhance the sense of immersion like shown in Fig.2(b3).

3.3 Movie Player

We developed a movie player for playing high-resolution frames of digital movies and for scientific data on our tiled display. Currently, high-resolution digital movies having abundant high-quality of effects have been increasingly created through various off-line cinematic techniques. Those kinds of movies exceed the resolution that a single desktop video player cannot afford in general. Moreover, in order to improve the sense of immersion and the feeling of reality on those movies, we certainly believe that a high-resolution movie player is required. The objective here was to produce a movie player that can meet these demands and plays the movies at the greatest possible resolution, capable of adapting the frames for playback on our display with any arbitrary resolution. Our movie viewer is separated into main two parts: 1) *Movie Controller* running on the master node, and 2) *Movie Player* running on each of the slaves. We first segmented a high-resolution movie image into the number of slave nodes, considering the size of resolution to be displayed on each of the slave nodes and overlapped regions to be blended between tiles. Then, we placed these segmented images on all the slaves before playing the movie. The Movie Controller synchronously transfers an introduction how to run all these Movie Players together, and periodically distributes a timestamp (i.e., frame number) to them to synchronize the execution. After then, each Movie Player performs its blending process and finally plays its own segmented portion of the movie image, being controlled from the master. Fig.3(a) shows a 3555 x 2000 resolution movie with 30 FPS on our display.

3.4 Real-Time Video Stream Player

We developed a real-time video stream player for MPEG-2 which is the current standard format for delivering a high-quality video stream. Our goal is to bring MPEG-2 or even higher resolution video streams to our scalable display with high-performance. We applied this technique to HDTV playing by using our rendering strategy. The HDTV signal (ATSC aerial signal) is captured via UHF antenna and it is converted into a MPEG-2 stream by HDTV card attached to the master. The master then separates the signal into two parts (i.e., video and audio) and it splits each frame of the stream into small portions according to the numbers of slaves. All those segmented images are distributed to all the slave nodes along with the control data. If those are reached to the slaves, they carry out its own blending process and display the blended images synchronously according to the control data, with the the audio stream. Fig.3(b) shows some snapshots of real-time domestic HD News broadcastings in Korea displayed on our display.

4 Conclusion

In this paper, we presented our experience in building and utilizing a scalable, super high-resolution tiled display system. In particular, we described how our overall system is designed and what its main characteristics are in brief. Then, we demonstrated how our tiled system can be appropriately enough as a powerful display technology by showing four popular visualization datasets integrated into our display. Future work will include building a completely immersive display system that could support multi-modal interaction functionalities by deriving intelligent hybrid tracking mechanisms in our display space.

References

[1] N. Bordes, W. P. Bleha., and B. Pailthorpe. Compact tiled display with uniform illumination. *Journal of Electronic Imaging*, 12(4):682–688, 2003.

[2] Glenn Bresnahan, Raymond Gasser, Augustinas Abaravichyus, Erik Brisson, and Michael Walterman. Building a large-scale high-resolution tiled rear-projected passive stereo display system based on commodity components. In *Proceedings of SPI*, volume 5006, pages 19–30, 2003.

[3] M. Czerwinski, G. Robertson, B. Meyers, G. Smith, D. Robbins, and D. Tan. Large display research overview. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems*, 2006.

[4] M. Hereld, I.R. Judson, and R.L. Stevens. Introduction to building projection-based tiled display systems. *IEEE Computer Graphics and Applications*, 20(4):22–28, 2000.

[5] Mark Hereld, Ivan Judson, Joseph Paris, and Rick L. Stevens. Developing tiled projection display systems. In *Proceedings of the Fourth International Projection Technology Workshop*, 2000.

[6] M. Ibrahim and S. Smullen. Cost-effective parallel tiled display. *Computing Sciences in Colleges*, 21(2):273–280, 2005.

[7] B. Jeong, R. Jagodic, L. Renambot, R. Singh, A. Johnson, and J Leigh. Scalable graphics architecture for high-resolution displays. In *Proceedings of IEEE Information Visualization Workshop*. IEEE Press, 2005.

[8] D.S. Jo, H. Kang, G.A. Lee, and W.H. Son. Xphere: A pc cluster based hemispherical display system. In *Virtual Reality Conference*, pages 312–313, 2006.

[9] C. Krumbholz, J. Leigh, A. Johnson, L. Renambot, and R. Kooima. Lambda table: High resolution tiled display table for interacting with large visualizations. In *Proceedings of 5th Woekshop on Advances collaborative Environments*. ACM Press, 2005.

[10] K. Li, H. Chen, Y. Chen, D. Clark, P. Cook, S. Damianakis, G. Essl, A. Finkelstein, T. unkhouser, A. Klein, Z. Liu, E. Praun, R. Samanta, B. Shedd, J. Singh, G. Tzanetakis, and Zheng. J. Building and using a scalable display wall system. *IEEE Computer Graphics and Applications*, 20(4):29–37, 2000.

[11] Tao Ni, Greg S. Schmidt, Oliver G. Staadt, and Mark A. A survey of high-resolution display technologies, techniques, and applications. In *Proceedings of IEEE Symposium on Information Visualization*. IEEE Press, 2006.

[12] PowerWall. http://www.msi.umn.edu/projects/woodward/powerwall/powerwall.html.

[13] L. Renambot, B. Jeong, R. Jagodic, A. Johnson, J. Leigh, and J. Aguilera. Collaborative visualization using high-resolution tiled displays. In *CHI 06*, 2006.

[14] D. Schikore, R. Fischer, R. Frank, R. Gaunt, J. Hobson, and B. Whitlock. High-resolution multiprojector display walls. *IEEE Computer Graphics and Applications*, 20(4):38–44, 2000.

[15] O. G. Staadt, J. Walker, C. Nuber, and B. Hamann. A survey and performance analysis of software platforms for interactive cluster-based multi-screen rendering. In *Workshop on Virtual Environments 2003 (EGVE '03)*, pages 261–270. ACM Press, 2003.

[16] VisWall. High resolution display wall, http://www.visbox.com/viswall.html.