A NEW METHOD FOR BUILDING LARGE-FORMAT TILED DISPLAYS SYSTEMS

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Abstract: Large-format tiled display is a new emerging technology for constructing large scale，high-resolution, immersive multi-projection virtual environment systems, which can present high-resolution stereo images. A PC-cluster, five-display-channel tiled display system is built in this paper. It produces a 5120x768 stereo image. The software infrastructure has been designed using a retained mode sort-first parallel rendering paradigm. This paper discusses development issues including selecting on projectors and projection surface to support passive stereo, synchronization tiled displays, geometric correction and color calibration etc. Finally, overall display performance is given and future work is mentioned.

1 INTRODUCTION

In the past decades, large format displays provide impressive visuals, high cost and technical expertise are required to own, operate and maintain these displays. This restricted their usage only to a few large institutions and universities and limited the application of virtual reality technology.

Recently, high-performance PC graphics cards become available with low cost. This development enables us to build clusters of high-performance graphics PCs with reasonable cost. Now, building Large-format tiled displays based on PC-cluster become a trend (Michael, 2005. Raij, 2004. Raskar, 2003. Humphreys, 2002). It offers a large field of view and resolution, and affords a strong immersion. Wall-sized tiled displays are more supportive for collaboration than regular monitors. Users stay longer in such displays, move and discuss the datasets more, and treat such displays as “murals” that they repeatedly touch, inspect, walk around and see from different viewpoints.

Following problems come out in designing large-format tiled displays systems, including the design of systems infrastructure framework, stereo display implementation, geometric and color calibration etc. The existed systems infrastructure framework mainly had master-slave mode and synchronism execution mode (Oliver, 2003). Geometric correction methods mainly include hardware-based correction, software-based correction and software automation correction method. How to accomplish geometric correction automatically and rapidly is currently a hot researched field (Michael, 2003).With regard to color calibration, the representative methods are Luminance Attenuation Map (LAM) method (Aditi, 2002), the gamut-matching method (Grant, 2003) and perceptually seamless luminance balancing method (Aditi, 2003).The LAM method is simple but it decreases the dynamic range of displays. The theoretical disadvantage of the gamut-matching method lies in the fact that there is no practical method to find the common color gamut. The perceptually seamless luminance balancing method uses expensive light measuring instruments to address various photometric issues.

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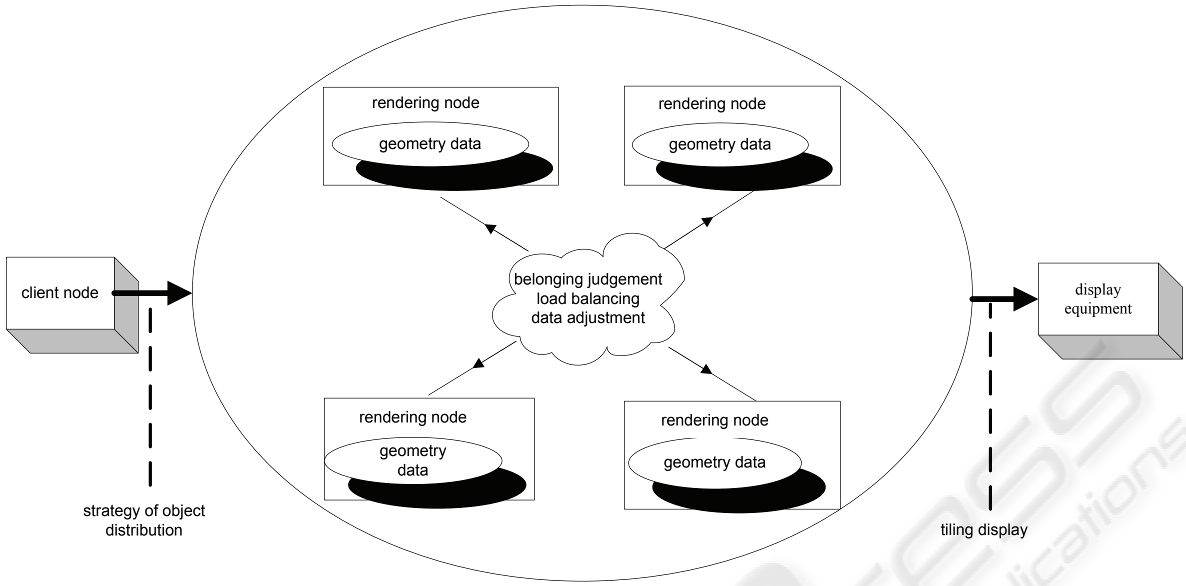


Figure1: Diagrammatic representation of the software infrastructure.

By using front-projected passive stereo displays, commodity Personal Computers (PC), low-end projectors, 100M Ethernet equipment, and surround sound system, we build a low-Cost 220^0 curved display System, which can provide interactive graphics application for multi-projector displays.surround sound system, we build a low-Cost 220^0 curved display System, which can provide interactive graphics application for multi-projector displays.

The key problems of the presented system including system infrastructure framework and its parallel rendering architecture, stereo displays method, synchronism tiled rendering control, geometry correction, intensity blending and colour calibration, etc. are detailedly discussed in this paper.

2 OVERALL FRAMEWORK

Unlike most display wall systems today, which use high-end graphics workstations and high-end projectors, our immersive curved display systems are built with low-cost commodity components: a cluster of PCs, PC graphic accelerator card, consumer video and sound equipment, portable presentation projectors and 100M common network equipments. It relies on a PC-based distributed rendering tiled design using a number of light projectors operating together to form a single logical display. The screen space is partitioned (virtually) into a rectangular grid of tiles, each of which is produced by one projector. The prototype system consists of projection subsystem, graphics generation subsystem and human-computer interaction subsystem. Diagrammatic Representation of the PC-Driven Curved Display system is as figure 1. The software architecture has been designed using a retained mode (master-slave) sort-first parallel rendering architecture (see figure 1). A copy of the application runs on each display server. The client handles user-interface events, and sends control commands, including synchronization events, or changes in view to each rendering node, i.e. rendering server. This kind of parallel rendering system architecture brings lower network bandwidth load than the immediate-mode systems brings.

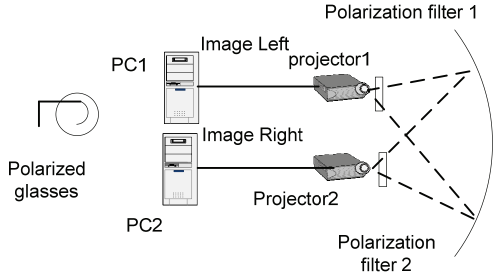
We have successfully developed solutions in several research areas as outlined in this article , including alignment of projectors, blending of overlapping projected images, tiling output , synchronization of displays, etc. we use front projection passive stereo display technology to produce the virtual environment economically , and the tiled wall integrates a high resolution image " tiles" into a seamless whole better.

3 DESIGN AND IMPLEMENTATION

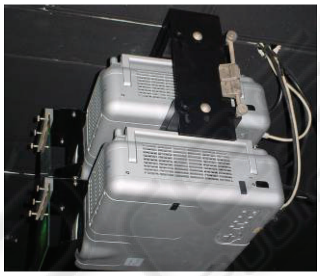
3.1 Passive Stereo Display

One of the feature of our PC-driven display system is that it uses front projection passive stereo display technology to produce the virtual environment economically. As it is known that there are two feasible methods in implementing stereo display. The first uses active shutter glasses synchronized with the display refresh, which alternately block each eye, allows successive images to be passed to each eye in turn. The polarized glasses are lightweight and cheap, and using passive stereo method also avoid having to genlock all of the render machines. The second, passive stereo, displays two separate images at all times and uses polarizing filters and glasses to pass the desired images to the two eyes. To achieve the same effective frame rate relative to a standard display, the first method requires doubling the frame rate, and the second method requires doubling the number of graphics pipes and projectors. Moreover, projectors with an extra high refresh rate are very expensive. So we selected passive stereo instead of active shutter glasses.

The projector display systems are divided into five render nodes. Each render node consists of two PCs, two projectors and polarizing filters (see figure2). For passive stereo to work, it is important that the two eyes receive two non-interfering images at the same time. To achieve this, two arrays of projectors project the image for the left and right eye simultaneously to the screen. The light from each projector is polarized with a polarization filter in such a way that the image on the screen for the left eye consists only of linearly polarized light at –45 degrees, whereas the image for the right eye is polarized at 45 degrees. Inexpensive glasses using the same polarization filters allow each eye to see only light that is correctly polarized. The -45 degree light arrives at the left eye and is blocked at the right eye and vice versa. The dissimilarities between the images received by the two eyes create an illusion of dimension. This technique allows a large audience due to the low cost of the glasses.



(a) The passive stereo display principle.



(b) the passive stereo display projectors.

Figure 2: The passive stereo display of one render node.

3.2 Synchronization Tiled Displays

The software infrastructure of our system has been designed using a retained mode (master-slave) sort-first parallel rendering paradigm. It runs an instance of the program on every PC in the render clusters. To control these programs, a client node application runs on the console PC, which is used to transmit the user's inputs and viewpoint information to each render server node. Every render server node renders a different part of the screen from its own copy of the scene database according the global scene view frustum partition.

Obviously, a synchronization mechanism must be integrated into the system for getting a logical coherent display image. It ensures that the geometric, viewpoint, and other graphics properties are consistent to all of the tiles over time. It is mandatory to fulfill two functional requirements intrinsic to multi-projector tiled environments: swaplock and datalock. Swaplock is the frame buffers swaps synchronization and datalock consists in maintaining coherent views of the scene on all the render nodes.

Figure 3 shows the synchronization process of frame buffer swap. The direction network message reply methods by socket UDP communication is adopted in our systems. When one of server nodes has finished rendering task, it notifies client node and ready for swap buffer. The client node controls every process of each server node. After all server nodes have sent their signals to the client, it is the client node's turn to broadcast each node to proceed and swap buffers.

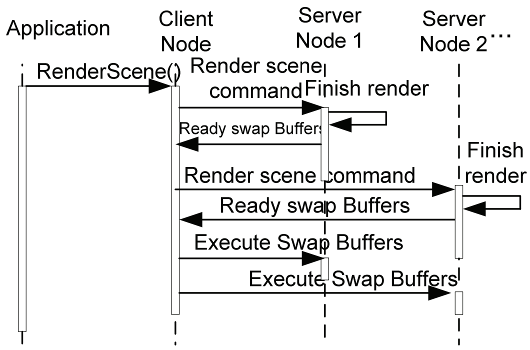


Figure 3: Synchronization process of frame buffer swap.

Data synchronization is performed implicitly through a mechanism that keeps multiple local replicas of a scene graph synchronized without exposing this process to the application programmer or user. Our own implementation of this conception is to propagate scene graph changes using reliable multicast. Using customer defined data structure, the client node multicast the scene change information to all render server node when one event arise such as viewpoint change or mouse motion events. The server render nodes receive the messages from the client node and update its local scene immediately. As a result of synchronization, the program instances generate logical correct scene image.

3.3 Geometric Correction

Geometric correction is to address the image on curved screen distortion in the single projection plane and the geometric continuity of image from adjacent projection plane. This paper applies two-pass rendering techniques to do geometric correction. Figure 4 shows the image distortion calibration process of single projection plane. Let the projector plane coordinates be denoted by (x_p,y_p) and the screen space coordinates be denoted by (x_s,y_s). The image calibration algorithm is as follows:

Step1. Project the regular grid pattern consisted of sample points (x_p,y_p) onto the ring screen ;

Step2. Compute the map: (x_p,y_p) → (x_s,y_s) according to these parameters such as sreen radius, projection center etc;

Step3. For each frame image from framebuffer, perform the nonlinear warp by piecewise texturing in accordance with the map in step;

Step4. The preprocessed image is sent to render pipeline and appears on screen correctly.

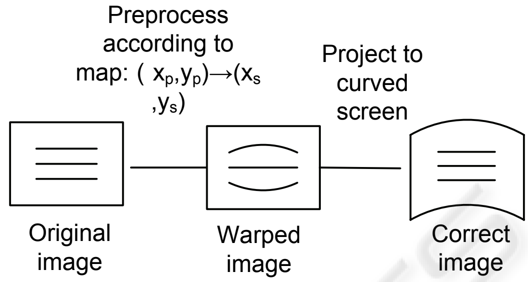


Figure 4: Image distortion warp process.

The image align implement among multiple projection plane is as follows:

Step1.The regular grid pattern consisted of sample point are projected onto every channel of screen;

Step2.Adjust the position and shape of each channel grid pattern by using our special application program, make all channel grid pattern aligned;

Step3. Triangulate the aligned grid mesh, compute the triangle vertex coordinates and save them as the geometric vertex of texturing for next step;

Step4.During the render process of each channel, use the image from each framebuffer as texture, warp the image by piecewise texturing and then send it to pipeline again. Lastly, get the correct aligned project image.

Our align calibration process adopting the manual interactively align adjustment makes a more exact calibration result than the camera based calibration methods.

3.4 Color Calibration

Color calibration is to blend the luminance between the abut projection plane and keep the color continuity of the display. The effect of intensity blending and color correction decides the equality of displays. For intensity blending, we adjust it using software method with handwork interactive input. This method attenuates the luminance of overlap area by adjusting its alpha value. Using the special software, the alpha value is modulated by controlling the shape of associated NURBS curve. Recurring to the susceptivity of human eye to luminance, the method can achieve a preferable blending effect and its algorithm is as follows:

Step1. Make the two abut projection plane *Plane1*、*Plane2* project white display simultaneously;

Step2. Attenuate the overlap area luminance of *Plane1*、*Plane2* by manually adjusting control curve of alpha value until achieve a satisfied blending effect;
Step3. Save the last results(Luminance attenuation Map, LAM) adjusted in step 2 as the bitmap files on PC of *Plane1*、*Plane2*；
Step4. Repeat step 1,step 2,step3 to accomplish the intensity blending of rest of all overlap;
Step5. During the rendering process of each channel, call its LAM and perform intensity blending operation using mulit-texturing.
The color continuity adjustment mainly is to solve the color difference brought by the different gamut of projectors. The automatic software calibration method is designed to perform the color calibration as follows:
Step1. Input projector *P1* a series of input, im with scheduled RGB value, then feedback the response luminance by a camera and according to it, compute the gamma response curve of *P1*;
Step2. For the projector *P2* which is abut with *P1* , by modifying the input of *P2*, let the gamma response curve approach to the one of *P1* and compute the gamma curve amend function of *P2*;
Step3. Repeating step 1, step 2, accomplish the rest gamma response curve approach of all abut channel, and get the corresponding gamma curve amend functions of each projector;
Step4. During the rendering process of each channel, load the gamma curve amend functions of each projector using color look-up table function of OpenGL. Last, the display attains color continuity by modifying and adjusting input of each projector.

4 IMPLEMENTATION AND RESULTS

We conducted experiments on our front-projection ring screen display systems which have a 220 degree view field angle. It's hardware consists of 10 P4 2.4G PC with 512MB RAM, 10 Quadro4 750 XGL 128MB graphic cards, 100 Mbps Ethernet Switch, 10 projectors of NEC MT1065 + etc.(see figure 5).

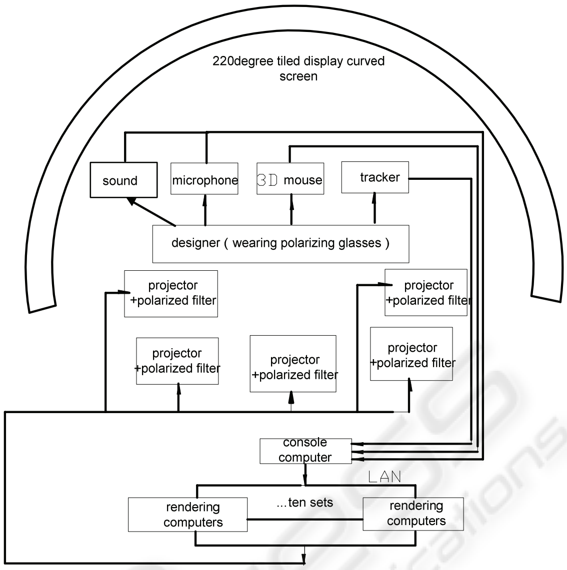
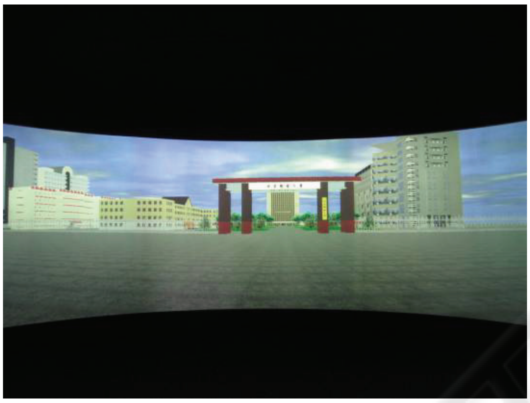


Figure 5: The structure implement of systems.

The ring screen is 19.19 meter wide and 2.81 meter high and has a 5 meter radius. It gives a wall resolution of 5120 x 768 stereo image.
The system runs on Windows 2000 operation system and its application development environment includes such as MultiGen Creator, VC++, OpenGL，Vtree and so on.
During the systems running, users can interact with the virtual scene in real time and we obtain a performance over 30 fps. The geometric continuity, intensity blending and color continuity of the display is satisfied and present a strong self-presence sense as shown in Figure 6.

(a) the effect of a application example running.



(b) the near display effect of another example

Figure 6: Result of systems executing.

Our system adopted the human-machine interactive software method to adjust the geometry registration and the intensity blending, which had more exact geometry correction precision and more consistent intensity blending effect than the existed tiled displays systems such as the MSPR (Zefan Jin, 2003, see figure 7, it has a "bright slot"), the system of UNC (Aditi, 2005, see figure 8).

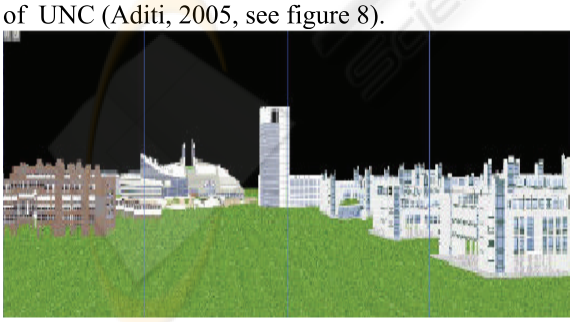


Figure 7: Result of MSPR systems executing.

Figure 8: The correction effect of UNC's system.

5 CONCLUSION

The approach using a multiplicity of commodity parts to construct a scalable display-wall system works well, it provides a large scale , high-resolution immersive visualization environments capable of presenting high-resolution stereo images. We have addressed these tradeoffs and developed solutions in several research areas relating to screens, projectors, synchronization tiled displays, and integration into seamless systems.

Tiled display technologies offer a range of opportunities for exploring scalable, high-resolution, large-format displays, for applications ranging from virtual manufacturing to collaboration walls to high-resolution scientific visualization. These technologies should increasingly become affordable and useful in additions to the range of next -generation displays for building active spaces.

This work suggests several areas for future research:

1. Load balancing: Load balancing algorithms are designed to optimize the performance of parallel systems by distributing work as evenly as possible across each node in the system. In this paper, we only consider scenarios in which one rendering processor is dedicated to each display device. But, then, if the rendering load is not uniformly distributed over all display devices, or if we have more graphics processors available than there are display devices, this simple, static allocation does not achieve optimal performance. In related work, we will develop dynamic load balancing algorithms for PC clusters driving a display wall. Moreover, further work is required to develop effective load balancing methods for remote applications.

2. Compression. In order to use this display environment for remote computing, we need to provide the accompanying dynamic compression scheme, and incorporate it into the rendering pipeline. When the source of the pixels is 2D or 3D primitive rendering, there may be further opportunities for efficient compression, either based

on compression of primitives or based on primitive-guided pixel compression.
3. Evaluate metric. Currently we get the results from different algorithms visually, which is subjective. For more objective evaluation, we need a sophisticated perceptual metric.

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