

# A large-scale display system based on multi-projector

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## Abstract

A large display system usually consists of many projectors, whose projections are merged together to form a large screen. Such system has been used in many fields, such as entertainment, exposition, and education. In this paper, we discuss technologies to join multiple projections into a large display for multimedia entertainment and virtual reality applications. In contrast to use expensive hardware-based seamlessly merging modules, we adopt a software-based seamlessly merging solution. Our hardware platform consists of three projectors, and each projector is controlled by a PC, so projectors are controlled by a PC cluster. Many technologies are adopted in our software system. Our software merge system can run on a variety of large display platforms. And in order to enlarging its application, we adapt technology to several kinds of screens, like a plane screen, camber screen or spheroid screen. The experiment shows our system obtain the satisfying results. It can seamlessly play videos with different encoding formats, such as AVI, wmv, rm etc, and can seamlessly render 3D scenes in real time.

**Keywords:** large-scale display, seamless tiling, color matching, OSG, DirectShow

## 1 Introduction

This paper presents a large-scale video display system in which commercially available projectors are tiled to create a seamless, high-resolution display surface. A simple yet effective scheme is proposed for synchronizing video playing across different PCs.

According to the requirement of large-scale displaying system and the methods we have had [4] [5] [6], we devise our more effective way to seamlessly tile images from multiple projectors. Our goal is constructing a scalable display wall system to play videos and do some virtual reality applications, like virtual walkthrough a scene. Our approach is using a cluster of PCs with commodity graphics accelerators to drive an array of projectors. First we use DirectShow methods to play videos. Then we use the network to eliminate the joining of pictures from different time-frames synchronization. We use OSG technology [7] to render 3D graphics. At last we use geometry splicing way and color blending method to solve the problem of luminance and color variations between color channels of each projector.

We can use the Camera-Based way for calibration. But if there are only several projectors [1][2][3], this way is more troublesome. So we introduce an easy way for seamless display systems.

## 2 The Multi-projector Seamless Display System

### 2.1 Hardware facilities

The screen for the multiple projections could be a plane screen, camber screen or spheroid screen. The plane screen could be used for video conferences as well as the camber screen or the spheroid screen could be used to playback videos or to provide exhibit halls with large visual content. For example, according to the vision area of the normal people, we can build a camber screen of  $150^\circ$  by putting three screens side by side.(Figure 1)

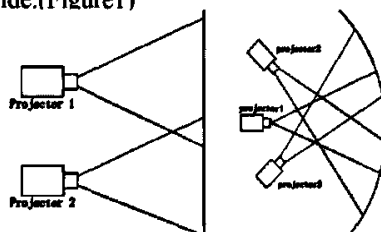


Fig.1 Plane screen and camber screen

## 2.2 Playing videos using DirectShow and synchronization

DirectShow simplifies the video- and audio playback. At the same time it provides function of controlling these streams. We can use DirectShow to read streams from the DVD player. It makes use of a model called Filter Graph to manage the process of handling entire data stream.

While displaying large-screen movie, we must let each computer to display one part of the entire picture. During this process, the movies picture is changing all the time and each computer also needs to renew the displaying content unceasingly. To eliminate the joining of pictures from different time-frames synchronization through the network is used. During movie playback the times between both movies playback position are checked unceasingly. When the time interval (so called lag) between both movies time-frames exceeds the critical level of

$$|t_1 - t_2| \geq \lambda \quad (1)$$

The frames are reordered due synchronization over the network. This prevents the movies from departing from each other. If the chosen  $\lambda$  is too large, then the slave machine might be delayed in playback or the display of the pictures will not seem smoothly. If the chosen  $\lambda$  is too small, the machines will adjust too often and seek the frame from the streams constantly. This also results in a waste of CPU time. A good choice is  $\lambda = 0.1s$ .

But the best results can be obtained by the following setup: Only one computer (the master) is responsible for reading the film. It delivers the picture information to the other computer(s) (slaves). All the slaves need to do now is to receive the picture and display it.

To do so, we think of using a router with one Gbit/s network speed. There are two kinds of packets transmitted over the network when using this method. The first kind carries the frame (the image). The second one carries the display matrix.

## 2.3 Image Overlapping

A perfect projector does not exist. However, we need to find a way to balance between performance, features, and cost. Our system is built with low-cost commodity components: a cluster of PCs and portable presentation projectors. The first problem when the normal projectors meet is that these projectors differ from those expensive models, they don't support the graphics seamless tiling inside. When two projectors are used side by side, the most casual observer notices that the images do not align, their colors do not match, and they are probably not the same brightness. Besides, the tiles overlap slightly, causing the bright lines or seams (Figure 2).



Fig.2 Bright seam

It is better to keep the overlapping areas at about ten to 25 percents of the whole projection area. Edge blending techniques overlap the edges of the projected and tiled images to blend the overlapped pixel to smooth the luminance and chromaticity transition from one image to another.

## 2.4 Geometry splicing

The goal of the geometry splicing technique is to guarantee that there are no double images of the object in the projections overlapping regions. Because in software splicing, each projector projects a part of the image, the overlapping regions from both projectors should show the same content.

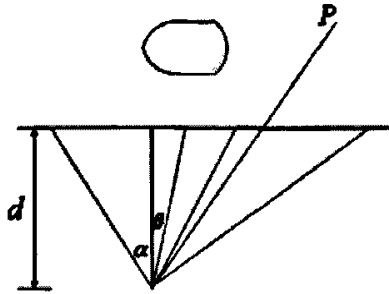


Fig.3 The right projector

The projection screen is a plane one and two projectors are used to build the overall-screen.

According to the figure which shows the position of projector and the screen (figure 3), we need to transfer the content of green area to the red area.. Make the right projector for example, here is a formula to calculate P's position on the windows.

$$P^* = PM_v M_p M_s \tag{2}$$

and

$$M_s = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \frac{tg(\beta)}{tg(\alpha)} - 1 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

In this way we can transfer the point of

$$x = d * tg(\beta) / (d * tg(\alpha)) = tg(\beta) / tg(\alpha) \tag{4}$$

to -1. In another words, the content is moved by the distance of  $-\left(\frac{tg(\beta)}{tg(\alpha)} + 1\right)$ .

As well as the arc length of the projecting area corresponding to a single projector and the length of the joined area needs to be measured manually. Be aware that the contents have to be rotated in order to fit the curved screen perfectly.

## 2.5 Color Blending

If the neighbor projection screens are put together, the overlaying area in the middle would leave a bright lane. So it is necessary to use a method of mixing the overlaid parts together to adjust the luminance and color variations. The mixing technique is applied to the every pixel in the overlapping region(s).

This can be realized by defining a function

$$f(x) = 1 - x^p \tag{5}$$

with  $x \in [0,1]$  (Figure 4). To adjust the brightness levels of two given pixels on both sides of the lane, multiply the right pixels brightness level with  $f(x)$  and the left pixels level with  $1 - f(x)$ .

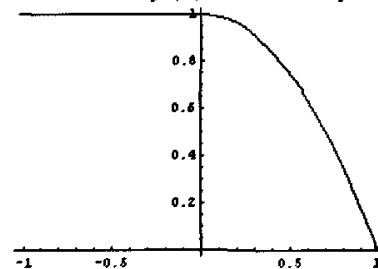


Fig.4 The function of left projection

Now the important thing is to choose the right parameter  $p$ . When  $p = 1$ , the accurate curvature lies on the parameter  $p$ . When  $p = 2$ , the mixing is quadratic. When increasing of the value of  $p$ , the curve keeps the same brightness level for a more pixels, while then lowering it very fast. So a high  $p$  is a good choice for sharp crossings.

### 3 Result

Using our Multi-projector seamless display system, we can watch the films just like in the cinema (Figure 5). We almost remove the bright lines at the seams and display the same frame of the film at the same time.

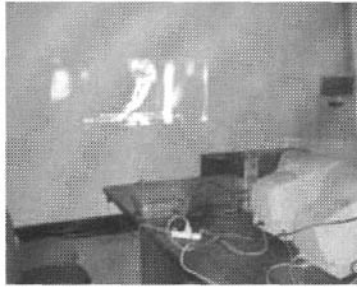


Fig.5 Use two PCs to play a film

### 4 Conclusion

This paper introduces some general thoughts on seamless display systems. It shows how to adjust the geometry model as well as color and brightness, so that the sub-screens fit perfectly together. A way to provide a large scaled screen with a high resolution was presented. It is highly variably, since more and more projectors could be added to the setup easily. As an advantage it is cheap, since normal-priced projectors could be used.

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