Applying Geometry and Color Correction to Tiled Display Walls

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Introduction

Tiled displays systems built by combining the images from arrays of projectors can provide a huge number of pixel elements to applications needing to visually represent a large amount of information, including a range of scientific visualization applications and high-fidelity collaborative environments. With commodity projectors and COTS rendering clusters, these large-area displays have the potential to provide very high performance and high resolution at low per pixel cost. But it is difficult to create the illusion of a unified seamless display for a variety of reasons. These include small misalignments of the projectors, optical distortion of the individual projector images because of imperfections in the lenses, intensity variation from projector to projector and across the field of each single projector, and color differences between projectors. Argonne has been researching methods for addressing these limitations, in particular, geometry and color. These methods are briefly discussed below. Both methods produce correction values that can be applied to the projected images to create a single seamless image. For these techniques to become truly useful, however, they must be integrated into existing infrastructure so that all applications and users can benefit from them. Such integration is the subject of the rest of this paper.

Geometry and Color Correction Techniques

Hereld et al. have developed a technique for quickly and accurately assessing and correcting the alignment and distortion of the tiled array using a commodity digital camera [1]. In our approach we take a few pictures of test patterns covering of the entire display. Automatic analysis of these extracts a detailed geometrical mapping to subpixel accuracy of projector pixels to the display surface coordinates. We use the mapping to remove the distortions from the image by applying a piecewise bilinear warp.

Majumder et al. have solved the second piece of the calibration puzzle by introducing a camera-based method for correcting the luminance field of the entire display [2-4]. Camera images of the display projecting constant color values are analyzed to produce two quantitative measures of the system. First, for each projector of the color output is remapped as a function of intended input value, to correct the projector to projector color differences. Second, a smooth attenuation map is generated in the form of an alpha mask. This mask balances the brightness of the display, and it provides smooth blending across overlapping projected subimages.

Real-Time Geometry and Color Correction

Using the correction tables provided by the two systems described above as input, we have developed a set of functions for applications that use OpenGL. One solution is for application developers working directly with tiled displays. This library of functions for developers is currently implemented to work only with OpenGL and NVIDIA extensions [5] but could easily be extended to work with other extensions and DirectX. The second solution uses the functions just described to construct a Chromium SPU. Chromium is a system for controlling and modifying streams of OpenGL API commands [6] and is commonly used for the displaying of OpenGL applications in a tiled display environment.

To implement a solution that does not adversely affect the frame rate of the application, we use the latest in OpenGL extensions. The process is as follows:

1. The scene is rendered as it normally would be, including the use of vertex programs, texture shaders, and register combiners.
2. The framebuffer is then copied by using glCopyTexSubImage2D to texture memory for the color correction step.
3. Color correction is then applied by using texture shaders and register combiners, with the color correction represented as a texture map and alpha mask applied for overlapped projection systems (the alpha mask step does not need to be applied for nonoverlapped tiled displays).

4. The resulting image is then texture mapped to surface where the geometry correction is applied by manipulation of texture coordinates.
5. The final image appears on an individual tile of the tiled display.

This approach as been applied to a number of test cases. Table 1. shows the results of the various stages of the process, as well as the overall impact on the system.

Table 1 Results for three different applications, showing the unmodified frame rate, render to texture (RT), render to texture with color correction (RTCC), render to texture with geometry correction (RTGC), and complete system with render to texture with color correction and geometry correction turned on (RTCCGC). These tests all have the alpha mask step turned on.

Application	Unmodified	RT	RTCC	RTGC	RTCCGC
Solar System	89.3 fps	55.5 fps	48 fps	54.5 fps	45 fps
Atlantis	78.5 fps	63.2 fps	56.0 fps	61.5 fps	54 fps
Teapot	153 fps	91 fps	72 fps	89 fps	70 fps

Conclusion

This work has demonstrated that it is possible to correct both geometry and color errors in a tiled display environment without severe impact on the applications performance. This work has also demonstrated that it is possible to construct a Chromium SPU that allows users of the Chromium toolkit to benefit from color and geometry correction without having to modify existing applications. Future work will include testing the system with graphics adaptors that have similar capabilities to those of the NVIDIA adaptors, as well as extending it in the lower level library to support DirectX in addition to OpenGL.

Acknowledgment

References

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