Glasses-Free Continuous 3D Displays

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Abstract

We have developed a front projection glasses-free continuous-3D display. We demonstrate that viewers see compelling 3D images naturally through binocular and motion parallax. The display prototypes consist of an array of up to 20 off-the-shelf mini-projectors and a flat or curved screen with asymmetrical scattering angles. The display has a maximum of 20 horizontal views and a horizontal angular viewing zone configurable form 10° to 40°. We demonstrate that our projection displays deliver well-behaved horizontal light field to enable a group of viewers anywhere in the within the angular field of view to observe simultaneously perspective-correct 3D imagery without having to wear special viewing glasses.

Introduction

It has been the Holy Grail for display researchers to invent and develop displays for showing life-like 3D still imagery and real-time video without the aid of special viewing glasses or restricting the viewers to a limited number of viewing positions. The current generation of 3D displays falls short of these goals. The 3D effects are achieved either with the use of special viewing glasses that provides only one viewing perspective or with a variety of auto-stereoscopic techniques that provide acceptable 3D effects at a limited number of viewing positions. The viewing glasses are also known to cause physical discomfort to a significant percentage of viewers. These shortcomings have impeded the wide acceptance of 3D displays. Commercial implementation of 3D displays nowadays is thus limited mostly to two views through the use of auto-stereoscopic techniques or special viewing goggles. There is also a need for multi-view displays in other applications such as the HALO Visual Collaboration Systems developed by Hewlett Packard.

Prior Solutions

Glasses-based 3D image viewing has been in existence since the mid-19th century. Recently, there is a resurgence of interests in the glasses-based 3D due to the box-office success of some popular movies, such as *Avatar*. These movies do provide stunning 3D effects. Baker, Li & Martin [1] presented an elegant technique to capture many views using arrays of closely spaced inexpensive, low-resolution cameras and projectors. They demonstrated a glasses-free continuous-view 3D (C3D) display using a screen consisting of a laminate of holographic diffusers and retro-reflectors. It is difficult to control accurately the light diffusion of the holographic diffusers. This leads to excessive cross talks and poor C3D image quality. Display manufacturers and researchers have also been showcasing various glass-free 3D displays with a limited number of sweet spots or limited number of viewers through eye-tracking[2,3]. Robust and inexpensive glasses-free 3D display technologies that deliver compelling 3D imagery simultaneously to all viewers in a contiguous viewing zone could help usher in a wider presence of multi-view displays and help accelerate the realization and acceptance of 3D displays in various segments of the markets.

Our solution:

We describe a glasses-free continuous-view 3D (C3D) front-projection display with a contiguous angular viewing region. Viewers located anywhere in the viewing region will naturally perceive perspective-correct 3D images and video without wearing special viewing glasses. The principles of projection C3D are illustrated by Figure 1.

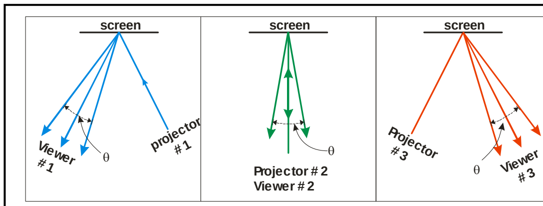

Figure 1. Principle of projection C3D display.

The display consists of a screen and an array of projectors. In the horizontal plan, projector illumination is reflected nearly specularly by the screen into a narrow angular spread (scattering angle), θ. An observer can see images from a specific projector only within a vertical stripe subtending an angle θ. Multiple projectors are needed to form a complete image. In addition, θ needs to be small enough such that the illumination from one projector is observable by only one of the viewer's eyes to provide 3D imagery observable with naked eyes. At a viewing distance of 2-3 meters, θ # ~0.5°. The scattering angle in the vertical direction needs to be large, >~40°, to provide a comfortable vertical viewing zone. An array of hundreds of projectors is needed to achieve a field of view of 100°.

Previously, we described a projection C3D display implementation consisting of a cylindrical brushed stainless-steel screen, shown in Figure 2A [4]. This optics of the system allows us to prototype C3D displays with only two projectors to provide a single-view-point glasses-free 3D. This implementation allows us to expand the view-points and the viewing zone gracefully. It also allows us to explore expediently the optimization of display configurations and components. We fabricated a system with 20 projectors and an angular viewing zone of ~10°.


Figure 2A


Figure 2B


Figure 2C

Figure 2A depicts a 20-projector system. Figure 2B shows a test image that we use to evaluate the characteristics of our C3D system. Figure 2C shows the banding artifact that we observed

Based on these findings we have constructed a two-tier 18-projector prototype as shown in Figure 3A. We use an aluminized holographic diffuser screen, placed at a distance of 60cm in front of the projectors. The effective horizontal spacing between the projectors is 2.5cm and an angular separation of ~2.5° between the projectors. The screen has a horizontal scattering angle of ~2.5°FWHM to match the spacing of the projectors. The vertical scattering angle of the screen is ~60°FWHM. We have also developed an automated alignment and calibration algorithm to compensate for geometrical distortions and to align the images from the projectors. This allows us to reconstruct the images for correct perspectives at all viewing locations. Figure 3B shows the composite image data for one of the projectors. Figures 3C and 3D show the projected image without and with the calibration.


Figure 3A


Figure 3B

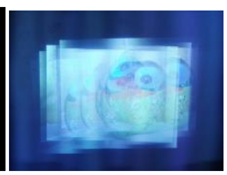
Figure 3C


Figure 3D

Conclusion

We have developed a front projection glasses-free continuous-3D display prototype. We have developed and demonstrated automated calibration and alignment techniques. We demonstrated that a group of viewers see simultaneously compelling and perspective-correct 3D images naturally without having to wear special viewing glasses through binocular and motion parallax within a contiguous viewing region.

Acknowledgement

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References

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