Eyestrain-free Bi-Focal 3D Projection Display System

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Abstract

A 3D projection display using stacked screens to display the near and far images, respectively, is developed. The front screen is made of a scattering polarizer film, and the far image on the rear screen is clearly visible through it. The image is perceived as three-dimensional, and no eyestrain is suffered.

1. Introduction

Although various types of three-dimensional (3D) display devices have been studied so long time, the technology is still far below the market requirements. The holographic display is seemingly infeasible for commercial applications due to the need for unrealistically large data bandwidth for motion picture applications. Even though the stereoscopic display based on binocular parallax is one of the most studied successful candidates, viewer's suffering from eyestrain is a genetic hurdle in the way of market penetration [1].

It has been reported that multilayered 2D images placed at different depths from the viewer can be perceived to be a three-dimensional image [2]. The 2D images form a 2D image when superposed. These two images, near and far images, stacked at different depths from the viewer as shown in Fig. 1 is perceived to be 3D, and it might be called Bi-Focal 3D (BF3D). It has been reported that a continuous depth perception is also achievable by assigning a proper luminance ratio between the stacked 2D images [3].

Since the 3D perception in the BF3D display method is based on most of the physiological processes to perceive depth, no glasses are needed and environment is friendly to the viewer. Unlike the stereoscopic display based on binocular parallax, the BF3D display results in no misfit between accommodation and convergence. Therefore, the BF3D display causes eyestrain only comparable to the conventional 2D display systems.

Although the basic principle of the BF3D is simple and well known for a long time, it has not been able to implement a system suitable for commercial applications. The main technical key to the BF3D display system is to have a front screen that forms the near image on it and is transparent to the far image formed on the rear screen. Most of the systems based on the method have used a half mirror and two 2D display panels of faces. Thus, the systems became inevitably bulky and the image planes locate remote from the viewer at the furthest part of the system. Although BF3D system using two transparent LCDs was proposed, it has not been shown feasible for large high-information-content display applications. In this paper, we present a new 3D projection display system based on the BF3D method using two vertically polarized lights.

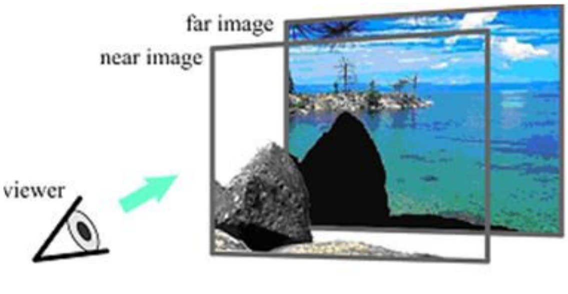

Fig 1. Principle of Bi-focal 3D (BF3D) display.

2. System Implementation

Since light waves with mutually orthogonal polarizations can be processed independently and human eyes are insensitive to the polarization of light, the BF3D display system can be implemented using polarization selective screens using a scattering polarizer film. The near and far images are projected using lights with mutually vertical polarizations onto the polarization selective screen as shown in Fig. 2. The near image is projected onto the front screen using a horizontally polarized light, and the far image is projected onto the rear screen using a vertically polarized light. The front screen consists of a scattering polarizer film and the rear screen consists of an ordinary polarization-holding screen. The polarizer axis of the front screen in this case should be vertical.

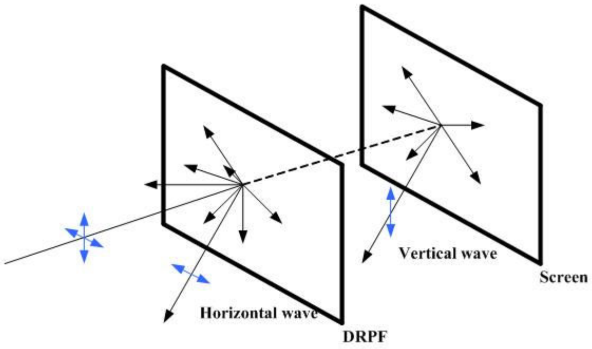

Fig 2. Operation principle of polarization − selective screen using scattering polarizer film.

This scattering polarizer film functions as an ordinary screen for light with a polarization that is vertical to the polarizer axis. It diffuse-reflects the horizontally polarized light back to the incident direction as shown in Fig. 2. On the other hand, since the scattering polarizer film is transparent to the light with a polarization parallel to the polarizer axis, the far image can be projected onto the rear screen through the front screen. The far image on the rear screen is visible from the projector side through the front screen. Consequently near and far image can be independently displayed on front and rear screens, respectively. Figure 3 shows the schematic representation of BF3D projection display system.

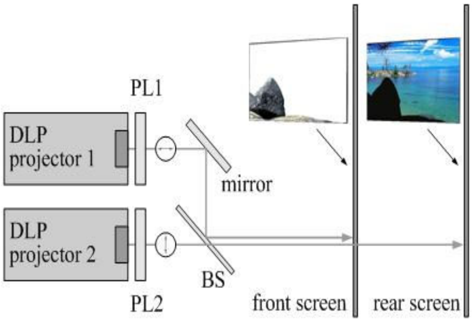

Fig 3. Schematic representation of BF3D projection display system (PL: linear polarizer, BS: beam splitter).

The BF3D projection display system used in this work consists of two DLP (Digital Light Processing) projectors with polarizing filters, reflective mirror, beam splitter, and screens. The upper projector projects horizontally polarized near image on the front screen, and the lower projector projects vertically polarized far image on the rear screen. The gap between the screens is adjustable to select the optimal choice. A computer generated animation was used for the study because real taken images are not available at the moment.

Figure 4 shows the test setup of the BF3D projection display system using a Diffuse-Reflective Polarizer Film (DRPF) from 3M as the front screen. Two DLP projectors installed with polarizing filters (Kenko PL Filter) in front of the projection lenses to select a polarization state for each of the light outputs. The rear screen is a conventional polarization preserving screen for ordinary 3D display applications. The size of the image was 115mm/175mm (width/height) and the gap between the front and the rear screen was 7mm. The image size was limited by the DRPF film used in the study.

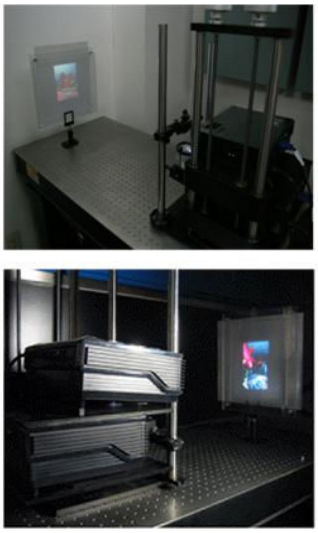

Fig 4. Photographs of BF3D projection display test setup.

3. Results and Discussions

Figure 5 shows the images displayed on the screens seen from the projector side. As can be seen from the figure, the near image projected on the front screen is formed as clear as on an ordinary screen. Furthermore, the far image projected on the rear screen is clearly visible through the front screen. It was also found that the viewing angle is comparable to that of an ordinary projection screen. Considering that the DRPF is not what is optimized for the projection display applications, the preliminary results are quite encouraging.

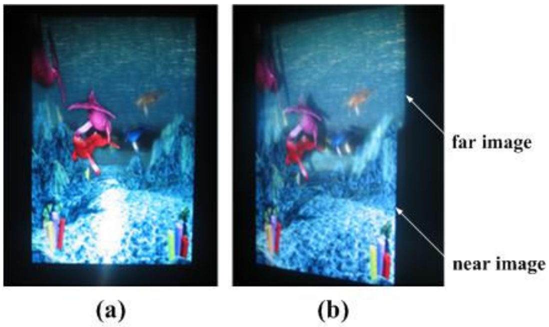

Fig 5. (a) Image seen from the front side of the screens. (b) Image seen from the tilted angle.

In order to study the visual impact of the BF3D display method, side-by-side comparison study of the images were performed using the system. Figure 6 shows an image projected on the screen. The image consists of a three-dimensional image (left) and a two-dimensional one (right) placed side-by-side. Although it is uneasy to visualize with a two-dimensional photo, it was observed that the three-dimensional depth perception is prominent. Meanwhile, as can be seen from the figure, the reflection of the rear image, which projected onto the rear screen, from the surface of the front screen is also noticeable. That is the reason why the three-dimensional image looks hazy compared to the two-dimensional counterpart.

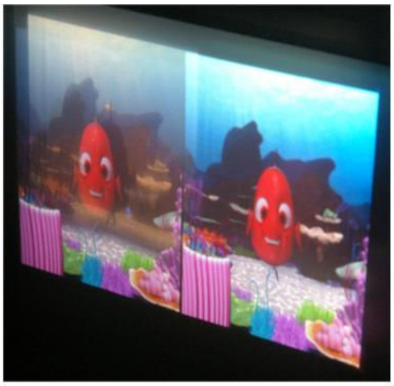

Fig 6. Three-dimensional (Left) and two-dimensional images.

Also seen from the figure are the shadow-like parts of the rear image on the back side of the objects displayed on the front screen. Although it was found that the shadow effect is not much disturbing to the viewer, the effect can be minimized by projecting the images of the front objects onto the rear screen as well as onto the front screen. Obviously, the clearness of the near image on the front screen would be jeopardized in some extent.

4. Conclusions

What is presented in this work is the first successful demonstration of the bi-focal 3D projection display system that causes no eyestrain. Since the viewer experiences no mismatch between accommodation and convergence of the eyes while watching the images, eyestrain only comparable to conventional 2D display is suffered. The front screen consisting only of a DRPF showed an excellent optical performance. Since the projection display system has already attained maturity, it is believed to be relatively easy to bring the new technology into the market. In addition, since only one extra bit of information per pixel is needed near/far identification, bandwidth requirement will be comparable to the conventional 2D system. Also integrated with the rapidly evolving 3D image processing technologies, the new eyestrain-free BF3D projection display method is believed to bring the 3D TV broadcasting earlier.

Acknowledgements

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