Embossing volume 3D effect by using DCRA plate

Shi-Hwa Huang[1], **Chih-Hao Chuang**[2], **Chien-Yu Chen**[1*]

chencyue@mail.ntust.edu.tw
[1] Graduate Institute of Color and Illumination Technology,
National Taiwan University of Science and Technology, Taipei, Taiwan
[2] Department of Photonics, Feng Chia University, 100 Wenhwa Rd., Seatwen, Taichung 40724, Taiwan
Keywords: DCRA, Embossing, Volume display, Ray tracing

ABSTRACT

Our research involves utilizing the DCRA to slice objects into multiple images, enabling us to display their volume. By leveraging the persistence of the visual effect in the human eye, we aim to achieve an embossed volumetric display.

1 Introduction

In today's consumer market, there is a growing demand for immersive sound, vivid lighting, and captivating audio-visual experiences. Achieving image immersion and interactive stereoscopic displays has become a focal point in the advancement of display technology.

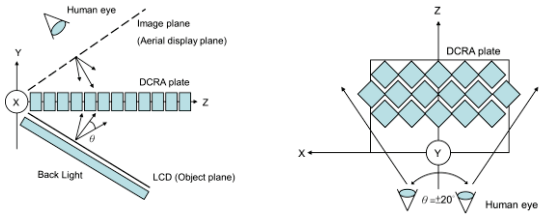
One unique approach in this field is the Dihedral Corner Reflector Array (DCRA) [1] proposed by S. Maekawa, which shows promising results in floating displays. DCRA is recognized for its high image resolution and has seen significant success in commercial applications. However, the ghosting caused by large-angle light in subsequent DCRA developments has hindered progress in volumetric displays.

This study aims to define the optimal imaging conditions for DCRA, focusing specifically on its application in volumetric displays. Through thoroughly examining system limitations and identified challenges, we propose a sliced display method to achieve an embossed volumetric display effect, utilizing the persistence of vision in the human eye.

2 Mythology

In this study, we begin by defining the use cases of DCRA, specifically focusing on the object image position and the range of light angles. DCRA functions as an imaging element where the object image corresponds to a specific element within the DCRA, and its position exhibits symmetry. Building upon Y. Osada's research [2], we discovered that by limiting the light distribution angle of the backlight panel in an LCD, we can reduce unnecessary reflections and mitigate ghosting issues. In Figure 1, we illustrate the object space as an LCD, and we set the light emission angle (θ) of the display to be θ<±20°.

To establish a coordinate system for our DCRA system, we present Figure 1(a), which provides a side view showing the YZ plane, and Figure 1(b), which offers a top view of the system.



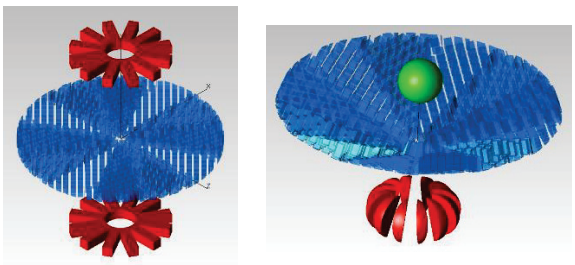
(a) (b)

Fig. 1 (a)Side View for the test system (b)Side View for the test system

To achieve the 3D display of floating volumes, we will modify and reorganize the structure of DCRA based on previous cases. For instance, in US Patent No. 8,702,252B2 [3], multiple sections of DCRA are cut into fan shapes, rotated along the Y-coordinate axis, and assembled to form a flat ring-shaped plate. This configuration creates a floating disk-like image, as Figure 2(a) depicts.

Another case, as seen in US Patent No. 8,434,872B2 [4], involves combining multiple fan-shaped DCRAs to form a horn-shaped plate, as shown in Figure 2(b). In this scenario, the object space consists of twelve individual luminous partial spheres, while the image space is combined to create a floating sphere-shaped image.

However, it is worth noting that due to the limited control over the light angle of the emitting object and the restricted effective light angle of DCRA, precise control of the light angle becomes challenging. Consequently, the displayed 3D image may appear blurry.



(a) (b)

Fig. 3 (a)Optical setup for the test system(b)XXX

The previous two cases mentioned focused on ring-shaped stereoscopic displays, where precise control of the light source angle proved challenging, resulting in a loss of the clear image advantage provided by DCRA.

Therefore, we propose an embossed volumetric display method that involves selecting content with relatively shallow depth, utilizing a high-definition flat-panel display, and incorporating a vibration device to generate displacement. By leveraging the persistence of vision in the human eye, we can generate stereoscopic images.

In Figure 3, we present our experimental device, a box with a beveled design measuring 200mm in height and a base of 150 x10mm. A DCRA measuring 160x133mm is installed on the beveled surface, while inside the box is a reciprocating shifter and an LCD. Through the inclined plane of the DCRA, the human eye can perceive the 3D floating image composed of several frames.

To illustrate this method, let's consider the example of displaying five colored spheres. We utilize a 5.6-inch high-brightness LCD panel with a resolution of 1920x1080, ensuring that each sphere visually occupies no more than 1 inch in diameter. Hence, we set the movable distance of this LCD panel to be 1 inch, which provides a rough representation of the spatial depth of the spheres.

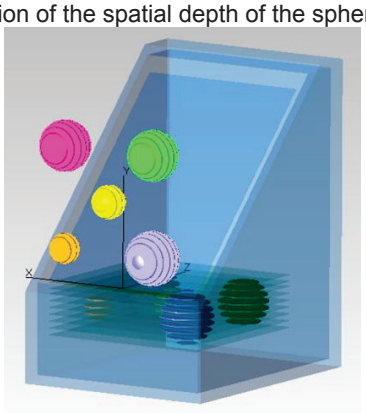


Fig. 3 The embossing volume display system

In our setup, we utilize a separate LCD module with increased backlight luminous intensity of 4000 nits. Additionally, we incorporate an optical film to restrict the luminous angle of the backlight module. As experimental equipment, we utilize DCRA provided by Askanet company. To ensure the stability of each slice's position in the air, our system requires a synchronization device that connects the video display (LCD) and the displacement device. This device controls the reciprocating frequency of the displacement. For the experiments, we use an LCD with a resolution of 1080p and vary the video frame rates.

In the first experiment with a 60 frames per second (fps) update rate, each image is displayed for 1/60 second. The stereoscopic image display for the eight positions during the outbound journey requires a total display time of 8/60 second. The reciprocating cycle time for the back and forth displacement is 2 * 8/60 second, equivalent to a required frequency adjustment of 3.75 Hz. In the second experiment, we changed the frame rate to 30 fps, resulting in a displacement frequency of 3.75 Hz / 2 = 1.9 Hz.

3 Discussion

The experimental results demonstrate that higher video frame rates and a larger number of slices contribute to a more visually pronounced image and improved 3D effect. Based on previous experiments outlined in [5], we acknowledge that 3D graphics algorithms can enhance image quality. Therefore, we continuously strive to optimize these algorithms to alleviate the software and hardware burden on playback devices.

Ensuring the repeatability of the synchronization device within the system is crucial. It is essential to consistently reproduce the image corresponding to its position in space. Otherwise, the visual disorder may occur, leading to visual fatigue.

The impact of showcasing human faces is particularly remarkable regarding the displayed content. Facial expressions have the power to surprise individuals, which further highlights the potential of our product.

4 Conclusions

Building upon developing a practical volumetric display device, this research proposes an embossing volume display method utilizing DCRA. This method leverages sliced image display and the persistence of the vision effect of the human eye to generate volumetric stereoscopic images. The synchronicity between the video and the reciprocal displacement device is crucial in achieving optimal results.To ensure a smooth viewing experience, the video specifications should meet specific criteria, including at least 1080p resolution, a frame rate of 60 fps, and the utilization of more than eight sliced images.

While hardware improvements can enhance the display effect, we also recognize the potential for optimizing image content to achieve similar results. In the future, we will focus our efforts in this direction.

References

[1]. Maekawa, Satoshi, Kouichi Nitta, and Osamu Matoba. "Transmissive optical imaging device with micromirror array." Three-dimensional TV, video, and display V. Vol. 6392. SPIE, 2006.

[2]. Osada, Yuto, and Yue Bao. "Design of Ghost-free Aerial Display by Using Polarizing Plate and Dihedral Corner Reflector Array." *2021 5th International Conference on Imaging, Signal Processing and Communications (ICISPC)*. IEEE, 2021.

[3]. Otsubo, Makoto. "Optical imaging apparatus and optical imaging method using the same." U.S. Patent No. 8,702,252. 22 Apr. 2014.

[4]. Maekawa, Satoshi. "Multi-viewpoint floating image display device." U.S. Patent No. 8,434,872. 7 May 2013.

[5]. Navarro, Fernando, et al. "Perceptual considerations for motion blur rendering." *ACM Transactions on Applied Perception (TAP)* 8.3 (2011): 1-15.