Study of Environment for Stacked Pepper's Ghost Light Field Display

Hiroto Yamada
Department of Information Dydtems Engineering
Toyama Prefectural University
Totama, Japan
u020044@st.pu-toyama.ac.jp

Isao Nishihara
Department of Information Dydtems Engineering
Toyama Prefectural University
Totama, Japan
nishihara@pu-toyama.ac.jp

Takayuki Nakata
Department of Information Dydtems Engineering
Toyama Prefectural University
Totama, Japan
nakata@pu-toyama.ac.jp

***Abstract*— In this study, we developed an environment for evaluating the quality of stereoscopic images on the stacked Pepper's ghost light field display and identifying the causes of quality degradation. We achieved this goal by creating an ideal experimental environment in a virtual environment using Unity.**

Keywords—Autostereoscopic display, Light fields, Light transport matrix

I. Introduction

Many studies on autostereoscopic displays have been conducted in recent years, and one of them is a see-through additive light field display [1]. In this method, a screen onto which an image is projected from a projector is used as a layer to form a light field by superimposing light. However, the screen is made of holographic optical elements (HOE), which are optical devices requiring precision processing, making it difficult to produce larger images. Koike, Kuroda et al. proposed a stacked Pepper's ghost method [2] that combines a see-through additive light field display and the Pepper's ghost effect. This method does not require special optical equipment, and it is easy to produce larger stereoscopic images. In order to realize simultaneous viewing of stereoscopic images by multiple viewers, multiple viewpoint parallax images have been presented, but there was a problem that the quality of the images seen from each viewpoint deteriorated as the number of viewpoints increased. In this study, an ideal experimental environment using a virtual environment created with Unity is used to evaluate the quality of stereoscopic images and to identify the cause of the quality degradation.

II. Method and Experiments

In the stacked Pepper's ghost method, Koike et al. used multiple cameras to obtain the light transport matrix, which is the pixel correspondence between display and camera, to optimize the layered image and present a multi-viewpoint parallax image. The layered image is optimized by Equation (1).

$$\arg\min_{L} \|\boldsymbol{L_T} - \boldsymbol{L}\| \quad (1)$$

$\boldsymbol{L_T}$ is the desired target light field image, and $\boldsymbol{L}$ is the field image composed at each viewpoint direction. Using $\boldsymbol{I}$ as a column vector of $NM \times 1$ for a layer image of resolution $N \times M$ [pixel] and $\boldsymbol{L}$ as a column vector of $UV \times 1$ for a camera image of resolution $U \times V$[pixel], the light transport matrix $\boldsymbol{T}$ can be expressed as in Equation (2).

$$\boldsymbol{L} = \boldsymbol{TI} \quad (2)$$

When multiple cameras are used for a two-layer image, the light transport matrix calculation formula is expressed as shown in Equation (3) by adding the $\boldsymbol{L}$ and $\boldsymbol{T}$ columns to Equation (2). This calculates $\boldsymbol{T}$ and determines $\boldsymbol{I_R}$ and $\boldsymbol{I_F}$ so that (1) is satisfied.

$$\begin{bmatrix} \boldsymbol{L_{cam1}} \\ \boldsymbol{L_{cam2}} \\ \vdots \\ \boldsymbol{L_{camN}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{T_{cam1_R}} & \boldsymbol{T_{cam1_F}} \\ \boldsymbol{T_{cam2_R}} & \boldsymbol{T_{cam2_F}} \\ \vdots & \vdots \\ \boldsymbol{T_{camN_R}} & \boldsymbol{T_{camN_F}} \end{bmatrix} \begin{bmatrix} \boldsymbol{I_R} \\ \boldsymbol{I_F} \end{bmatrix} \quad (3)$$

In the experiment, a real environment was reproduced using Unity. Then, as shown in Figure 1, six cameras were set up at 6.0 cm intervals to capture the target light field image $\boldsymbol{L_T}$ presented to the viewer from each camera viewpoint. In addition, each layer image $\boldsymbol{I_R}$ and $\boldsymbol{I_F}$ were generated and displayed, and the field image $\boldsymbol{L}$ consisting of each viewpoint direction was captured. In Figure 1, it can be confirmed that stereoscopic view is possible by observing $\boldsymbol{L}$ using the parallel method. In addition, as shown in Figure 2, the same virtual environment was used to create a calibration standard in a real environment by displaying calibration images on each layer and photographing them.

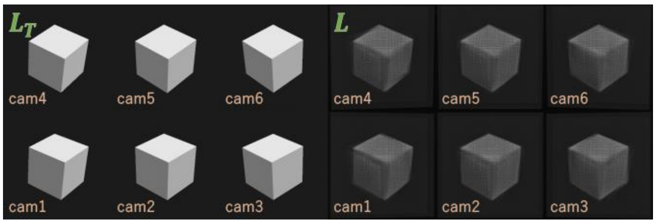

Figure 1. Experimental Results

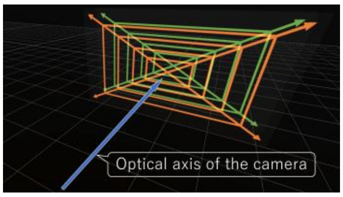

Figure 2. Creation of Calibration Standards

III. Conclusion

In this study, as an environment for evaluating the quality of stereoscopic images in the stacked Pepper's ghost method and identifying the cause of quality degradation, we generated stereoscopic images using an ideal experimental environment in a virtual environment created using Unity, and confirmed that images capable of stereoscopic viewing could be generated. In addition, as a preparation for calibration in the real environment, we were able to create calibration standards in the virtual environment.

References

[1] S.Lee, C.Jang, S.Moon, J.Cho, B.Lee, "Additive Light Field Displays: Realization of Augmented Reality with Holographic Optical Elements," ACM Trans. Graph., Vol.35, No.4, Article 60, 2016.

[2] Y.Koike, Y.Kuroda, T.Nakata, "Light Field Display using Stacked Imaginary Image Display," Proc. SPIE 11766, doi:10.1117/12.2591023, March 2021.