

# 3D Projector Corresponding to Four Parallaxes

Shohei Yamaguchi; Graduate School of Engineering, Tokyo City University; Japan;  
Yue Bao; Faculty of Knowledge Engineering, Tokyo City University; Japan;

## Abstract

An Immersive Projection Technology (IPT) has been noted as a display device for virtual reality. In this system, users enter a space surrounded by multiple screens, and it projects stereo images matching the position of one user. When multiple users observe them, images matched one user are projected. Therefore, all users observe the same images. Our aim of this study was to make two users observe different 3D images at the same time. In this research, we proposed a system that uses real-time tracking and four parallaxes projection corresponding to two users using LC shutter glasses and a 3D projector. We conducted experiments to confirm whether two users can observe different 3D images at the same time. In experimental results, it was confirmed that the corresponding parallax images could be seen with the eyes of two users and that it was possible to track the position of the two users. This made it possible for two users to observe different 3D images at the same time.

## Introduction

An Immersive Projection Technology (IPT) has been noted as a display device for Virtual Reality (VR) [1]. This is a technology to present a virtual world with a wide field of view with a high immersion feeling by using a high definition 3D projector and 3D glasses. HMD (Head Mounted Display) which is a typical display device of VR is attached to the head and used. On the other hand, the IPT surrounds the user with large screens and provides a high immersive feeling. The reason why this type of technology got noticed is that the system called CAVE (Cave Automatic Virtual Environment) developed at the University of Illinois in the USA has a big influence [2]. Much attention has been paid to research on IPT, not only in entertainment but also in various fields such as medical engineering field, manufacturing industry and urban planning [3-6].

## Previous Study

Conventionally some IPT acquire the viewpoint position of the user with either a magnetic sensor attached to the 3D glasses or a Kinect [7]. IPT work by drawing an image matching the viewpoint position of the user [8]. For instance, there is a CAVE that is an immersive virtual reality environment where projectors are directed to between three and six of the walls of a room-sized cube. A lifelike visual display is created by projectors positioned outside the CAVE and controlled by physical movements from a user inside the CAVE. A motion capture system records the real time position of the user. LC shutter glasses convey a 3D image. The computers rapidly generate a pair of images, one for each of the user's eyes, based on the motion capture data. The glasses are synchronized with the projectors so that each eye only sees the correct image. When multiple users observe, they observe the same images [10]. Although a method has been proposed to improve the distortion of images according to the observation position for multiple users to observe, each user can not observe the images matching their positions [9]. In other words, users can not simultaneously view different 3D images.

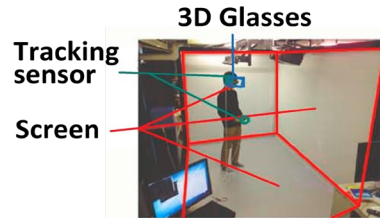


Figure 1. Immersive Projection Technology [2]

## Aim

Our aim of this study is to allow two users to observe different 3D images at the same time.

## Proposed Method

In this study, we propose a system that uses real-time tracking and four parallaxes projection corresponding to two users using LC shutter glasses and a 3D projector. Commercially available 3D projector projects images at 120 fps. Therefore, even with two users, 30 fps can be assigned per eye. This is the same frame rate as television broadcasting [11, 12].

## Projection System

We create four parallax images and project them in a time division sequence. In this system, the left parallax image of the user 1 (L1), the left parallax image of the user 2 (L2), the right parallax image of the user 1 (R1), and the right parallax image of the user 2 (R2) are projected in order. Figure 2 shows the projection image. Figure 3 shows a parallax image of Fig. 2 observed through the LC shutter glasses.

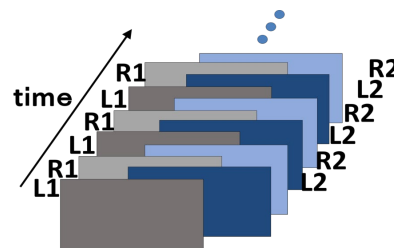


Figure 2. Projection order

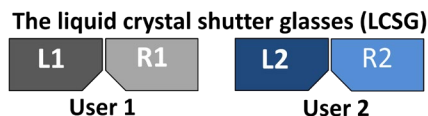


Figure 3. Correspondence

### Control of LCSG

We remodel the LC shutter to open and close arbitrarily according to the timing when the projected image switches. Accordingly, it is possible to show the corresponding four parallax images. Therefore, it is possible to give the parallax images to each of two users. In Fig. 4, the LC shutter control for each user is shown one by one in order. The white shows a state in which the shutter is open. Black shows a state of shutter closed.

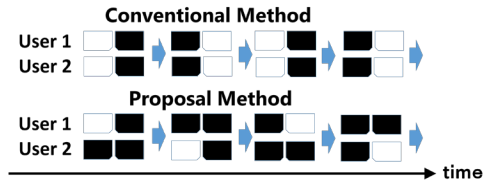


Figure 4. LC shutter control

### Creating Parallax Images

As shown in Fig. 5, we prepare four cameras corresponding to the left and right eyes of two users in CG space. Each camera captures an object in the CG space to create parallax images corresponding to the two users. As shown in Fig. 6, Kinect is used to acquire two users' head coordinates in real space. We use the head  $x, y, z$  coordinates as the coordinates of the cameras. We move the position of the cameras in the CG space accordingly.

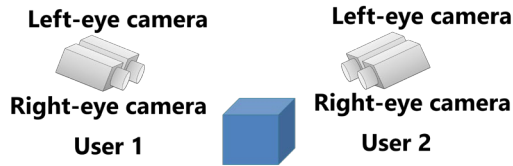


Figure 5. In CG space

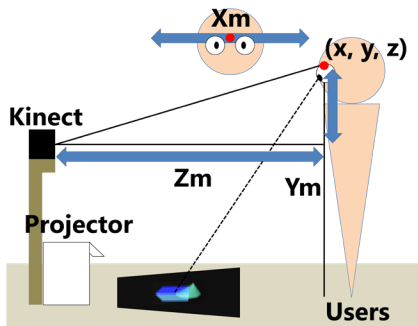


Figure 6. In real space

### Experimentation

We confirmed that two users can observe different 3D images through remodeled LC shutter glasses. Also, we compared with a commercially available system and conducted a qualitative evaluation.

### Devices Development

We prototyped an experimental system that enables the proposed method. A signal received from the control board is input to an Arduino, and the LC shutter is controlled by using it. Figure 7 shows the actual prototype system. Figure 8 shows the LC shutter glasses (LCSG) used, and Fig. 9 shows the Arduino. Specifications of the equipment used in the development are listed in Table 1 and Table 2.

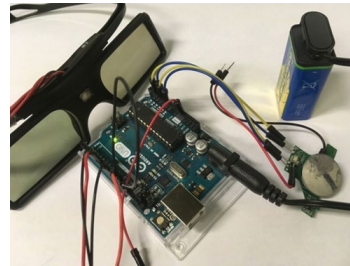


Figure 7. LC shutter glasses



Figure 8. LC shutter glasses

Table 1. LC shutter glasses “RV-3DGBT2BX2”

Specs	Details
Glass Type	LC Shutter
Compatibility	DLP-LINK
Frequency	96-144Hz
Drive Voltage	5V
Response Speed	2.0 ms



Figure 9. Arduino UNO

Table 2. Arduino Uno Rev3

Specs	Details
Microcontroller	ATmega328P
Operating Voltage	5V
Clock Speed	16 MHz

### Disassembled LC Shutter Glasses

As shown in Fig. 10, we disassembled commercially available LCSG. We used both LC shutter and control board to create a device. The control board receives the DLP signal and applies voltage to the LC shutter. We confirmed opening and closing of liquid crystal shutter. As shown in Fig. 11, it was able to become opaque by applying 5V.

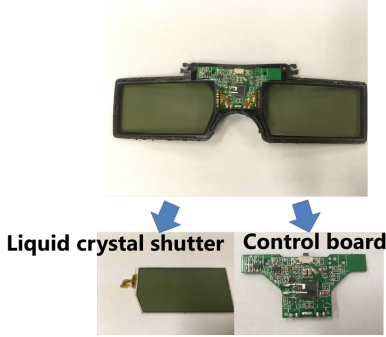


Figure 10. Disassembled LC Shutter Glasses

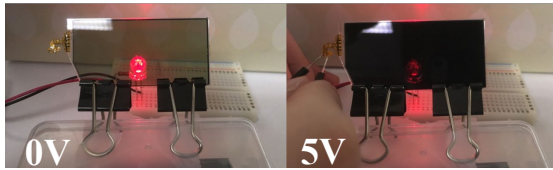


Figure 11. Operation check

### Experimental Environment

The equipment used for experiment is listed below. We used a Kinect v2 (Fig. 12) and a DLP projector (Fig. 13). Specs of the equipment used in the experiments are listed in Table 3 and Table 4.



Figure 12. Kinect v2

Table 3. Kinect v2

Specs	Details
Color	1920×1080 @30
Range	0.5m-4.5m
Angle of View Horizontal / Vertical	70° / 60°



Figure 13. DLP projector

Table 4. BenQ MH856UST

Specs	Details
Projection System	DLP Single 0.65" 1080P
Resolution	1920x1080 pixels
Brightness	3,500 ANSI Lumens
Contrast Ratio	10000:1
Vertical Scan Rate	23 - 120Hz

### Four Parallaxes Confirmation

We were able to confirm that the two users were able to observe different 3D images at the same time. We created parallax images of two users in the CG space and projected them in order. We showed a blue cube to user 1 and showed a green cube to user 2. As shown in Fig. 15, the different images could be seen from the four LC shutters. Figure 14 shows an actual projection plane.

We could confirm that the left and right parallax images of a blue cube could be photographed at the positions of left eye and right eye of the user 1 respectively. Also, the left and the right parallax images of the green cube could be photographed at the positions of left eye and right eye of user 2 respectively.

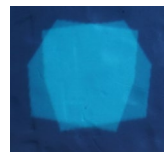


Figure 14. Projection plane

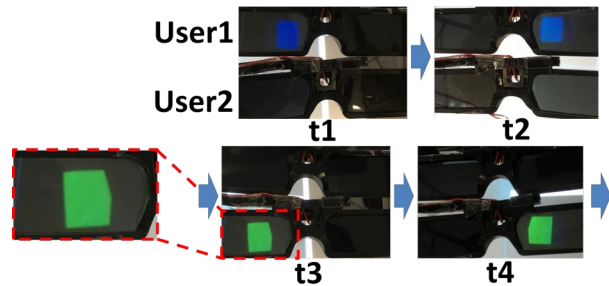


Figure 15. Result

### Qualitative Evaluation

We conducted qualitative evaluation using a survey based on questionnaires given to 15 students (21-24 years old). They evaluated the flicker and stereoscopic impression as compared with the conventional system. We changed the image to a 3D image of a cube and a cone. User 1 observed a cube, User 2 observed a cone 3D image. The two users watched while moving freely. User1 is the evaluator. The evaluator observed both the proposal method and the conventional method.

Figure 16 shows an experimental environment, and Fig. 17 shows an actual projection plane.

The qualitative evaluation questions and results are shown below. Figure 18 shows the results of "Do you think the stereoscopic impression is equivalent to the conventional system?". As the result, "Strongly agree" was 67%, "Agree" was 27%.

Therefore, 94% answered almost the same as the conventional method. Figure 19 shows the results of "Do you feel flickering?". As the result, "Strongly agree" was 14%, "Agree" was 50%. Accordingly, 64% answered feel flickering.

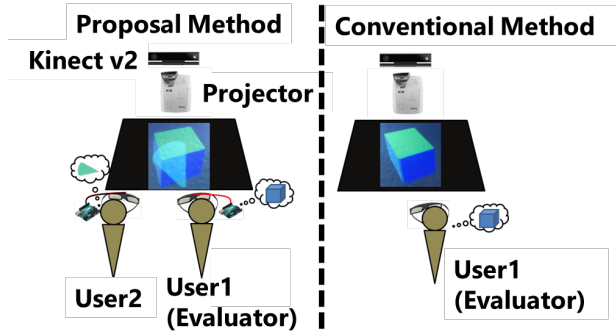


Figure 16. Experimental environment

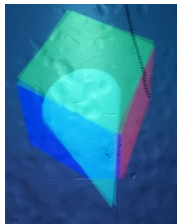


Figure 17. Projection plane

**Do you think the stereoscopic impression is equivalent to the conventional system? :**

- 1. Strongly agree. 10 votes
- 2. Agree. 4 votes
- 3. Neutral. 1 vote
- 4. Disagree. 0 votes
- 5. Strongly Disagree. 0 votes

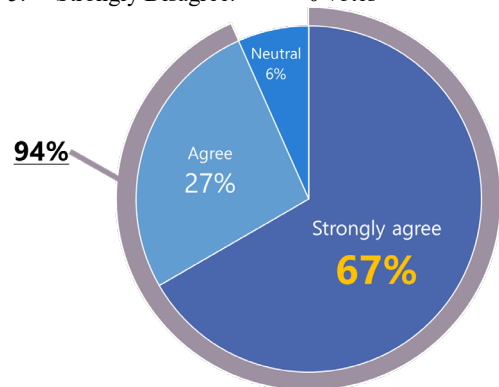


Figure 18. Result

**Do you feel flickering? :**

- 1. Strongly agree. 2 votes
- 2. Agree. 7 votes
- 3. Neutral. 5 votes
- 4. Disagree. 0 votes
- 5. Strongly Disagree. 0 votes

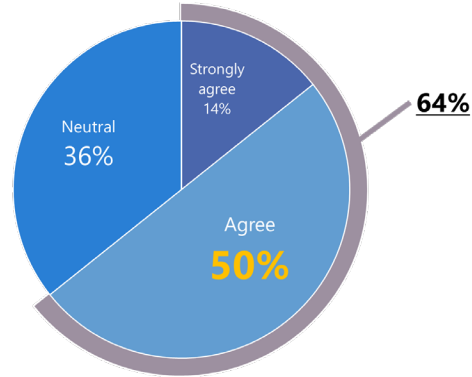


Figure 19. Result

**Conclusion**

In the conventional 3D projector, there was a problem that only a single user can observe a correct stereoscopic image because only 2 parallaxes can be projected. Therefore, we proposed a 4 parallaxes 3D images system by time division multiplexing method. In the experiment, we observed the 4 parallax images through the liquid crystal shutter glasses, and we confirmed whether two users can observe different 3D images. As a result, we enabled a 3D projector for two users just by changing the shutter pattern using a commercially available 3D projector and 3D glasses. But there were many users who feel flickering. Accordingly, it is necessary to suppress flicker in the future.

**References**

- [1] Bullinger,H., Riedel,O., Breining,R, " Immersive Projection Technology-Benefits for the Industry," International Immersive Projection Technology Workshop Proc. 1, 13-25 (1997).
- [2] Tetsuro Ogi, "Characteristics of Immersive Projection Displays and their Applications," Journal of Human Interface Society 1(4), 43-49 (1999).
- [3] Hitomi Anzai, Kazuhiro Watanabe, Mingi Zhang, Narendra Kurnia Putra, Yuriko Takeshima, Makoto Ohta, "Application of CAVE System for Biomedical Engineering," Journal of the Visualization Society of Japan 143(36) 20-24(2016).
- [4] Mie Sato, Satoru Sugawara, Masao Kasuga, Kenji Honda, Naoki Hashimoto, "Comparison of Immersive Feeling Effects between Three Wide-angle Image Projection Techniques," International Journal of Affective Engineering 14(1), 73-78 (2015)
- [5] Peng SONG, Shuhong XU, Wee Teck FONG, Ching Ling CHIN, Gim Guan CHUA, Zhiyong HUANG, "An Immersive VR System for Sports Education," IEICE Transactions on Information and Systems 95(5), 1324-1331 (2012)
- [6] Naoki Hashimoto, Koichiro Kimura, Makoto Sato, "Human-Scale Assembly Simulator with Haptics Interface," The Journal of The Institute of Image Information and Television Engineers 62(6), 880-888 (2008)

- [7] Hidemaru Nakamura, Kiyooki Yoshida, Yasumasa Sujaku, "An input method for HoloStage to obtain natural immersion by using Kinect," Joint Conference of Electrical and Electronics Engineers in Kyushu 03-2A-09(2013).
- [8] Bullinger,H., Riedel,O., Breining,R, " Immersive Projection Technology-Benefits for the Industry," International Immersive Projection Technology Workshop Proc. 1, 13-25 (1997).
- [9] Peng SONG, Shuhong XU, Wee Teck FONG, Ching Ling CHIN, Gim Guan CHUA, Zhiyong HUANG, "An Immersive VR System for Sports Education," IEICE Transactions on Information and Systems ,vol.E95.D(5), 1324-1331 (2012).
- [10] Andrew Woods, Joshua Hollick, Jesse Helliwell, "Image distortions in large-scale immersive display systems - Cylinder and wedge displays", [SD&A-110] (2017).
- [11] Y. Omori, T. Onishi, H. Iwasaki, and A. Shimizu, "A 120 fps high frame rate realtime HEVC video encoder with parallel configuration scalable to 4K," COOL Chips 20, Yokohama, Japan, April (2017).
- [12] standupmaths, 3 October (2016), "Why is TV 29.97 frames per second?," Online video. YouTube, <<https://www.youtube.com/watch?v=3GJUM6pCpew>>, Accessed 8 April (2019)

## Author Biography

*Shohei Yamaguchi was received the B. E degrees in Computer Science from Tokyo City University, Tokyo Japan, in 2018.He is now a master course student of Tokyo City University His research interest includes 3D system development.*

*Yue Bao received Ph.D. degrees from Kanazawa University, Japan, in 1996. He has been a professor at Tokyo City University since 2004. His research interest includes 3D display, image processing and mobile robot.*



**JOIN US AT THE NEXT EI!**

IS&T International Symposium on

# Electronic Imaging

SCIENCE AND TECHNOLOGY

*Imaging across applications . . . Where industry and academia meet!*



- **SHORT COURSES • EXHIBITS • DEMONSTRATION SESSION • PLENARY TALKS •**
- **INTERACTIVE PAPER SESSION • SPECIAL EVENTS • TECHNICAL SESSIONS •**

[www.electronicimaging.org](http://www.electronicimaging.org)

