Development of a Video Projection System using Multiple Projectors on a Directional Volumetric Display

Moeka Abe[1], Naoto Hoshikawa[2], Hirotaka Nakayama[3], Tomoyoshi Ito[1], Atsushi Shiraki[1]

Email: moe.a___5@chiba-u.jp
[1] Graduate School of Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan
[2] Department of Innovative Electrical and Electronic Engineering, National Institute of Technology,Oyama College, 771 Nakakuki, Oyama, Tochigi 323-0806, Japan
[3] Center for Computational Astrophysics, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
Keywords: Volumetric displays, Digital signage, Multi Projection, Media art.

ABSTRACT
Projecting a video from multiple projectors onto a directional volumetric display by applying threads and projectors necessitates that the display timing of the projected video is synchronized among the projectors. As a result, synchronous video projection was achieved in this study by synchronizing the projectors utilizing user datagram protocol communication.

1 INTRODUCTION

Digital signage that displays visual information in public transportation, commercial facilities, and other areas has recently gained popularity. Various display types, such as aerial displays that can project images through air and fog displays that project images through fog, have been developed [1,2].

Using a volumetric display, our research team proposes a display that can simultaneously show different two-dimensional information based on the viewing direction. Because the information is only visible from a specified angle, this display is known as a directional volumetric display. Volumetric displays applying three-dimensional crystals, as shown in Fig. 1, and those using threads, as shown in Fig. 2, have previously been developed [3,4]. By projecting images from a projector, the volumetric display applies threads, and a projector displays color images [5,6]. Interactive displays are also being developed, such as systems that display images while tracking people or images based on the language and position expressed by the observer. It is intended that these displays would be used for both functional and artistic purposes.

Because the volumetric display applies threads and a projector to display images by projecting images from a projector onto each thread, it is feasible to display motion pictures by switching images at a fast speed. Furthermore, this directional volumetric display currently has a limited horizontal resolution that can be visualized. Because it is constructed by hanging threads from an elevation, increasing the vertical resolution is simple; however, increasing the horizontal resolution necessitates the placement of more threads. Currently developed volumetric display using threads and a projector shows an image of 4–5 pixels per thread; therefore, a full high definition projector can only project onto around 400 threads, and the resolution is currently limited to 20 × 20. Furthermore, the existing method of arranging threads by squaring the horizontal resolution limits the number of threads that could be projected by a single projector, regardless of the projector's performance. Therefore, to achieve a higher resolution, multiple projectors must be considered. Furthermore, motion picture projection with multiple projectors necessitates synchronizing images between projectors.

Therefore, this research aims to develop a system that uses threads and projectors to synchronize PCs using a user datagram protocol (UDP) connection and to project videos from multiple projectors onto a volumetric display.

Fig.1 Directional volumetric display using a 3D crystal.

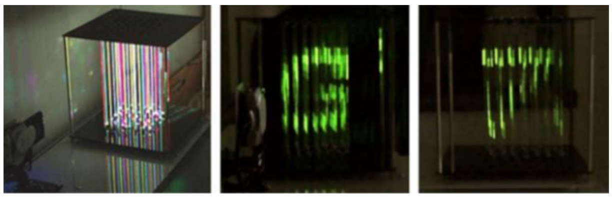

Fig.2 Directional volumetric display using threads and a projector.

2 METHOD

2.1 Volumetric display using threads and a projector

The volumetric display with threads and a projector generates one projected image from several different source images and projects it against the threads, as illustrated in Fig. 3, to ensure that several images can be observed from different directions. The body of the display is made up of sewing threads hung from a whiteboard and arranged in a sequence equal to the square of the horizontal resolution of the original images to be projected. Three constraints govern the thread positioning according to previous studies.

As demonstrated in Fig. 4, voxel data are collected to generate the display image by considering the volumetric display as a virtual object that records information. Let

$V(x, y, z)$ be the voxel value at coordinates $(X, Y, Z) = (x, y, z)$. The voxel values are calculated by multiplying the pixel values of the source image. They are obtained via Equation (1) for displaying an image in any N direction. Where λ denotes a constant for normalizing the voxel values, $P_i(u_i, v_i)$ denotes the pixel value in the i-th original image, and θ_i denotes the angle between the (X, Y, Z) coordinate system and the i-th coordinate system (u_i, v_i, w_i).

$$V(x, y, z) = \lambda \prod_{i=1}^{N} P_i(x \cos\theta_i + z \sin\theta_i, y) \qquad (1)$$

Because the projector rays are elevated at an angle, the projected image must be corrected by reducing and dropping the corresponding rays based on the depth information of the thread.

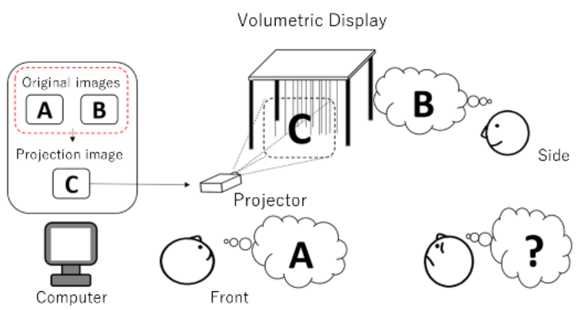

Fig. 3 Overview of a directional volumetric display using threads and a projector.

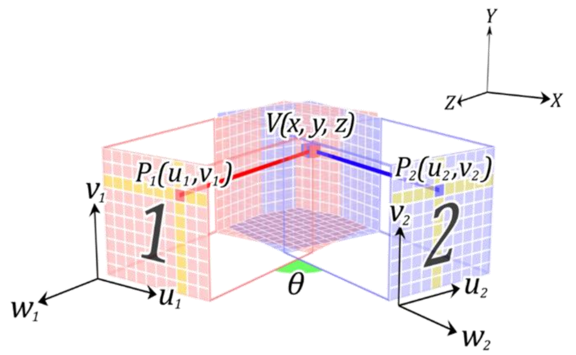

Fig. 4 Creation of projection image algorithm.

2.2 Projection method using multiple projectors

In previous studies, thread placement is determined by its constraints; some threads cannot be placed among the squared threads at the horizontal resolution. To obtain higher density and resolution, threads placed in locations that do not meet the thread placement constraints should be projected from a different projector. However, because this research is in its early stages and aims to establish that video projection using multiple projectors is conceivable, the volumetric display is divided into left and right halves, as shown in Fig. 5, for projection to be performed. When viewed from the front of the volumetric display, the left half is projected from the front-facing projector, and the right half is projected from the back–facing projector.

In this work, as shown in Fig. 6, the direction from the center of the volumetric display where the projector is installed is 0°, and each PC individually generates the projected image to present three images of 10 x 10 pixels at 0°, 45° and 90°, respectively. The projector on the rear side projects the projected image generated from the original image flipped left and right, and the projected image can be seen from the projector on the front side from the directions of 0°, 45°, and 90°.

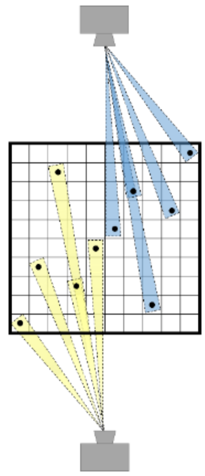

Fig. 5 Placement of projectors.

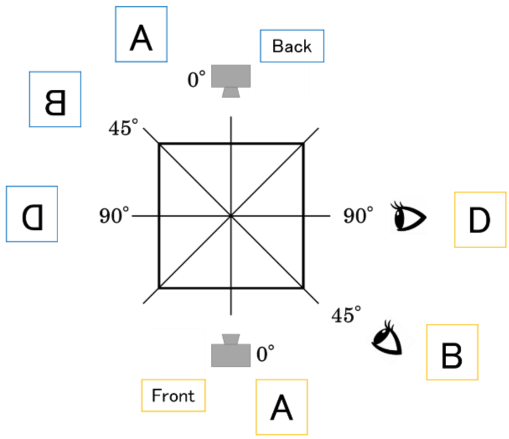

Fig. 6 Direction of image display.

2.3 Communication between PCs for video projection

The projection of motion pictures on a volumetric display utilizing threads is accomplished by displaying many static images in quick succession and switching between them at high speed. However, when projecting a video with multiple projectors, the images from each projector must be synchronized. The proposed method synchronizes display time by communicating and synchronizing PCs. Because the displayed image cannot be seen if there is a delay in the projected image, UDP, which can handle one-to-many communications, was utilized for synchronization and can be used even if the number of projectors is increased further.

Figure 7 depicts an overview of the communication. In this projection, two PCs were used as the transmission and receiving devices for communication and synchronization. When data are communicated, the transmitting device projects the images, and when data are received, the receiving device begins projecting. Since multiple still images are continuously switched and exhibited as motion pictures, synchronization between the PCs is performed periodically when a certain number of images are switched to avoid the projected images from falling out of synch.

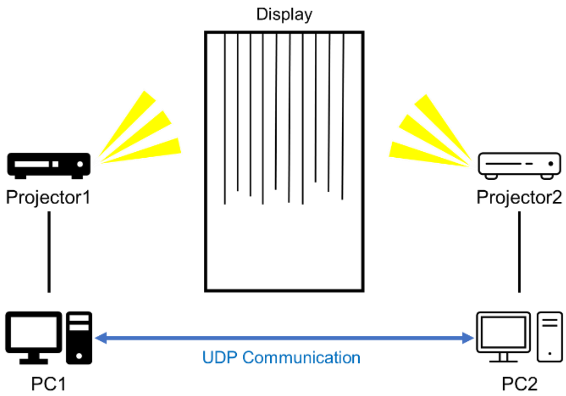

Fig. 7 Communications Overview.

3 RESULTS AND DISCUSSION

Figure 8 depicts the final volumetric display and projector positioning. Based on the thread placement constraint, the display built in this study has 96 threads. Figure 9 depicts the display image, whereas Fig. 10 depicts the simulation results. We projected motion pictures of the English alphabet from right to left, as illustrated in Fig. 9. The source images utilized are 12 that were displayed sequentially to create the animation.

Fig. 8 Overview of development system.

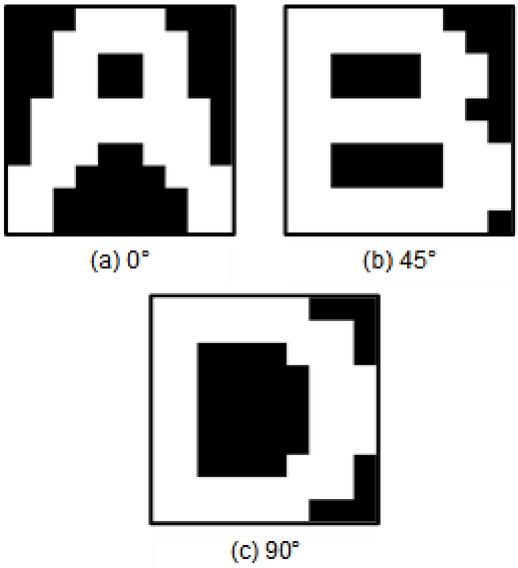

Fig. 9 Original image.

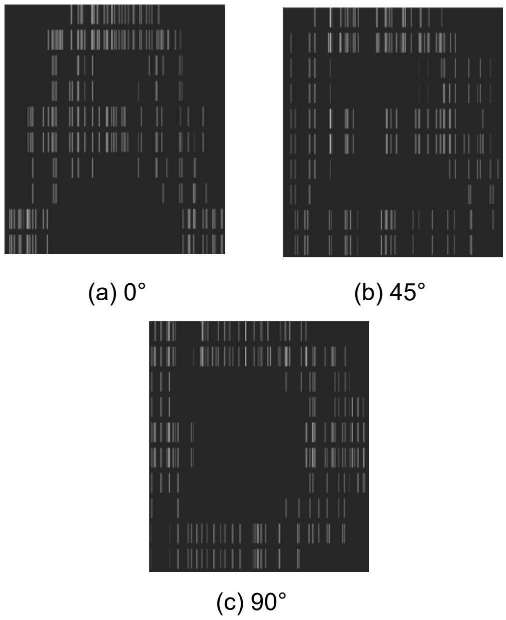

Fig. 10 Simulation results.

Figure 11 shows the results of the video projection using the proposed method. The projection was visible from every angle. No discernible difference in projection timing between the projectors was found; hence, it is assumed that the error due to communication latency or lag is insignificant.

The light from the projector positioned on the opposite side of the screen was excessively bright when viewed from 0°, making it impossible to see the displayed image. This could be rectified by adjusting the projector's installation position and angle. Furthermore, there is a height difference between the left and right halves of the projected image. This is assumed to be because the two projectors were set symmetrically in relation to the display, but the threads and projectors were all installed manually, resulting in inaccuracies; thus, the thread height correction could not be performed accurately.

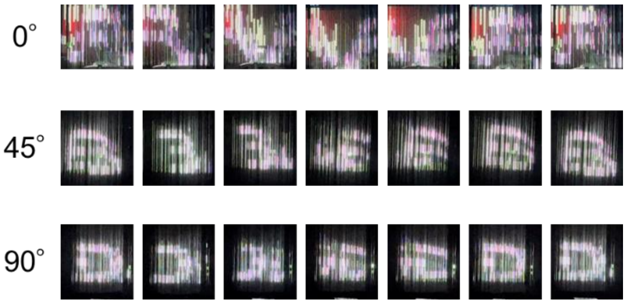

Fig. 11 Projection image of proposed method.

4 CONCLUSION

We developed a system for projecting a video from multiple projectors to a directional volumetric display using threads and projectors by synchronizing them with UDP communication. Future objectives include measuring communication time, verifying image defects, and enabling projection onto threads that cannot be projected due to thread placement constraints. We also intend to increase the display density to ensure that images with resolutions of 20 × 20 pixels or larger can be exhibited to boost display resolution.

ANCKNOWLEDGEMENT

This work was partially supported by Yazaki Memorial Foundation for Science and Technology.

REFERENCES

[1] H.Yamamoto, “Aerial Display with Aerial Imaging by Retro-Reflection(AIRR)” “, Journal of the Imaging Society of Japan, Vol.56, No.4, pp.341-351, 2017(in Japanese).

[2] Rakkolainen, I., DiVerdi, S., Olwal, A., Candussi, N., H¨ullerer, T., Laitinen, M., Piirto, M. and Palovuori, K.: The Interactive FogScreen, ACM SIGGRAPH 2005 Emerging technologies (2005).

[3] H. Nakayama, A. Shiraki, R. Hirayama, N. Matsuda, T. Shimobaba and T. Ito, “Three-dimensional volume containing multiple two-dimensional information patterns”, Scientic Reports, vol. 3, article number 1931, pp. 1-5, 2013.

[4] R. Hirayama, H. Nakayama, A. Shiraki, T. Kakue, T. Shimobaba and T. Ito, “Image quality improvement for a 3D structure exhibiting multiple 2D patterns and its implementation”, Opt. Exp. 24(7), pp. 7319-7327, 2016.

[5] A. Shiraki, H. Nakayama, R. Hirayama, T. Kakue, T. Shimobaba and T. Ito, “Volumetric Display Containing Multiple Two Dimensional Information Patterns”, 22nd International Display Workshops (IDW'15), PRJ1-1, pp. 1038-1040, 2015.

[6] A. Shiraki, M. Ikeda, H. Nakayama, R. Hirayama, T. Kakue, T. Shimobaba, and T. Ito, "Efficient method for fabricating a directional volumetric display using strings displaying multiple images," Applied Optics, Vol. 57, Issue. 1, pp. A33-A38, 2018.

[7] D. Matsumoto, R. Hirayama, N. Hoshikawa, H. Nakayama, T. Shimobaba, T. Ito, and A. Shiraki, "Interactive directional volumetric display which keeps displaying directional image only to a particular person in real-time," OSA Continuum, Vol. 2, Issue. 11, pp. 3309-3322, 2019.