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Development of a Multi-Projection System for High-Resolution Directional Volumetric Display

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ABSTRACT

The resolution of directional volumetric display can be improved using threads and a projector by increasing the number of threads. However, the number of threads that may be projected from a single projector is limited. In this study, we developed a system to project images from multiple projectors.

1 INTRODUCTION

Recently, a surge in interest in digital signage that provides image and video information in commercial and transportation facilities is seen, and various displays have been developed, including aerial and fog displays that operate images in the air and into fog, respectively [1,2]. In addition, owing to their security and creative features, directional volumetric displays, which display different information depending on the viewing direction, can be used in encryption and digital art.

Previously, we developed volumetric displays; using three-dimensional (3D) crystals and thread as shown in Figs. 1 and 2, respectively [3,4]. Color images and moving images can be displayed through projecting images from a projector in a directional volumetric display using threads and a projector [5,6]. A directional volumetric display using threads and a projector, which can trace a person and display directional images solely to that person, has also been developed. [7].

A volumetric display using 3D crystals can display high-resolution images. However, because the information of the image to be projected on the volumetric display must be recorded in advance, it is confined to still images and cannot display moving images. Further, using threads and a projector, a volumetric display may project moving images by projecting images from the projector onto each thread and switching between them quickly. In addition, because the threads are hanging from the top, increasing the resolution in the vertical is simple.

The currently developed volumetric display using threads and a projector projects an image of 4 or 5 pixels per thread, limiting a full high definition (HD) projector to only approximately 400 threads, and a resolution of 20 × 20. Even with a projector with a 4K resolution, the maximum number of threads that can be projected is approximately 800. In the current method, where the number of threads is the square of the horizontal resolution, increasing the number of threads is necessary to display a higher resolution image. In addition, projectors with 4K resolution are often more expensive than those with full HD resolution. Therefore, multiple projectors are used to attain is high resolution.

Therefore, the purpose of this study is to develop a system that uses thread to project images from multiple projectors onto a volumetric display.

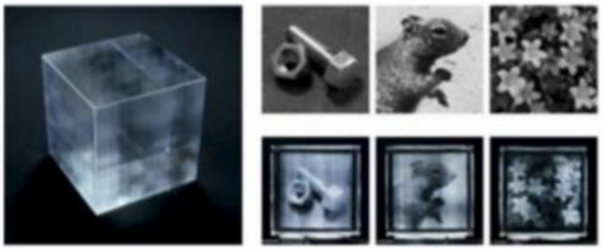


Fig.1 Directional volumetric display using a 3D crystal.

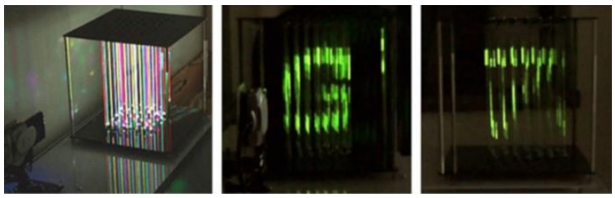


Fig.2 Directional volumetric display using threads and a projector.

2 METHOD

2.1 Volumetric display using threads and a projector

As shown in Fig. 3, the volumetric display using threads and a projector creates one projected image from several different original images, and projects it against the thread using projection mapping, allowing multiple images to be recognised from different directions. The center of the display consists of a sewing thread hanging from a whiteboard. A washer is attached to one end of the thread and a nut to the other end. The end with the washer is attached to the whiteboard using a magnet, and the thread is hung using the nut as a weight. The square of the horizontal resolution of the original image to be projected should be used to determine the number of threads. There are three constraints on the placement of thread, as shown in Fig. 4, as follows:

- Constraint 1: When observing, each thread must not overlap in the direction of observation.

- Constraint 2: All rays from the projector must correspond one-to-one with all threads.
- Constraint 3: When viewed from above, the overall shape of the thread arrangement must be square.

In this study, the placement of threads was determined according to the above constraints.

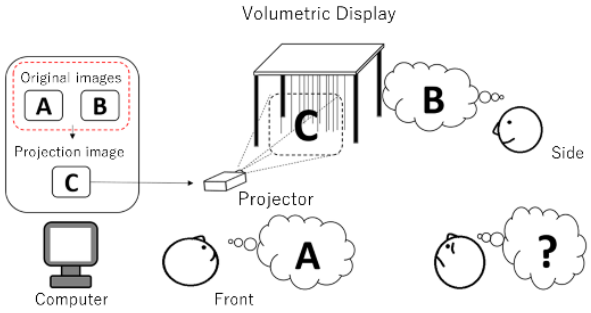


Fig.3 Overview of a directional volumetric display using threads and a projector.

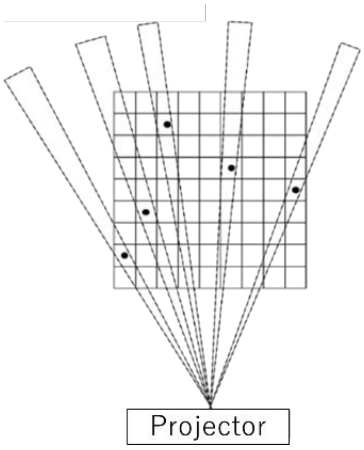


Fig.4 A placement of threads.

2.2 Creating a display image

Consider the volumetric display as a virtual object that records information as shown in Fig. 5 and generates voxel data. Let $V(x,y,z)$be the voxel value at the coordinates $(X,Y,Z)=(x,y,z)$. Voxel values are obtained by multiplying the pixel values of the original image. When the image is displayed in any N direction, it is obtained by equation (1). where λ is a constant to normalise the voxel value, $P_i(u_i,v_i)$ is the pixel value in the i-th original image, and θ_i is the angle between the (X,Y,Z) coordinate system and the ith coordinate system (u_i,v_i,w_i).

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

Since the rays from the projector have an elevation angle, if the created projection image is projected directly onto the volumetric display, the vertical size of the displayed image will change depending on the depth where the thread is placed. Therefore, as shown in Fig. 6, the projected image is corrected by reducing and lowering the corresponding rays based on the depth information of the thread.

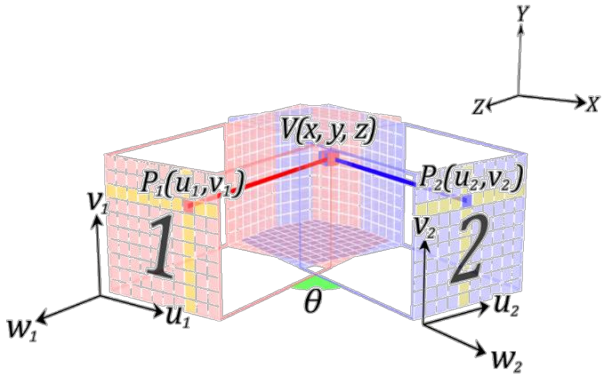


Fig.5 Creation of projection image algorithm.

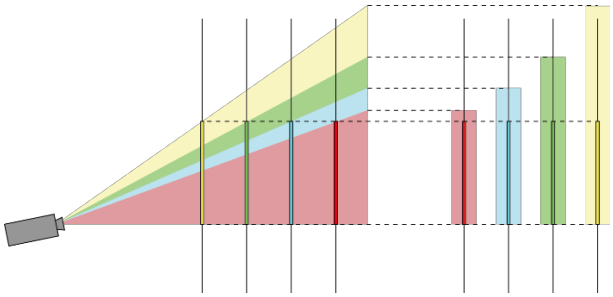


Fig.6 Adjusting height of rays.

2.3 Projection method

Previously, the placement of thread was determined based on the constraints shown in Section 2.1, therefore, some threads cannot be placed among the squared horizontal resolution threads. Ideally, achieving high density and high resolution should be possible via projecting from a different projector for the threads that are placed in places where the constraint on thread placement cannot be met via projection with a single projector. However, since this study to confirm that multiple projectors can be used, the volumetric display is divided into left and right halves when viewed from the direction where the projectors are installed, as shown in Fig. 7, and projected. When viewed from the front of the volumetric display, the left half is projected from the projector installed in the front, and the right half is projected from the projector installed in the back.

In this study, as shown in Fig. 8, the direction in which the projector is installed from the centre of the volumetric display is set to 0°, and voxel data is generated separately on each PC so that three 10 × 10pixel images are displayed at 0°, 45° and 90°, respectively. The voxel data is generated using the original image flipped left and right from the back projector, and the displayed image can be observed from the front projector at 0°, 45° and 90°.

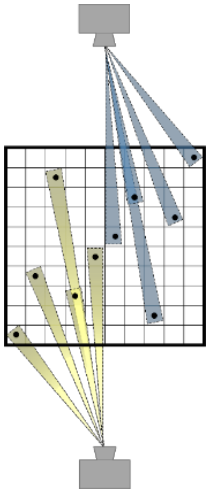


Fig.7 Placement of projectors.

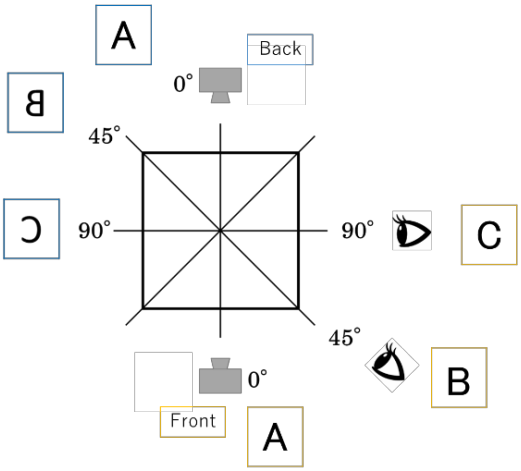
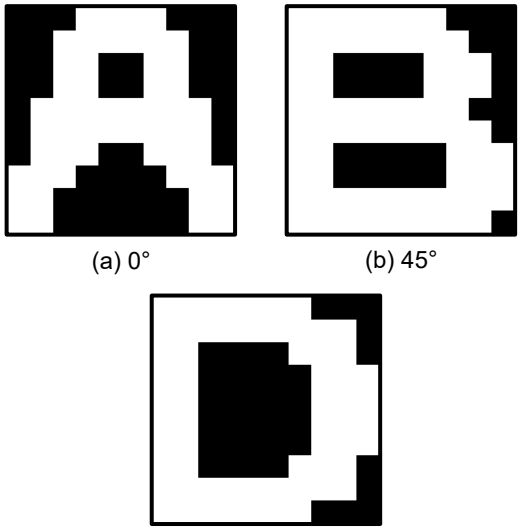


Fig.8 Direction of image display.

3 RESULTS AND DISCUSSION

Figure 9 shows the actual arrangement of the volume display and the projector. The display image and the simulation result of the proposed method are shown in Figs. 10 and 11, respectively. In the simulation results, the display image can be seen from each direction.

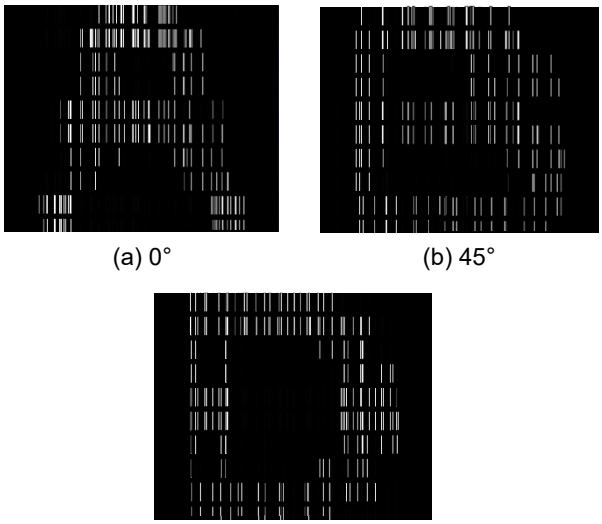
Fig.9 Overview of development system.



(a) 0° (b) 45°

(c) 90°

Fig.10 Original image.



(a) 0° (b) 45°

(c) 90°

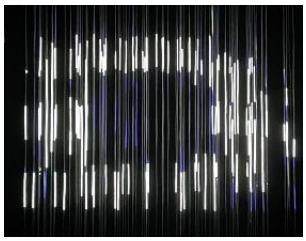
Fig.11 Simulation results.

Figure 12 shows, the results of actual projection using the proposed method on a directional volumetric display with threads and projectors. The displayed image is visible from every direction in the actual projection. Fig. 13 also depicts the outcome of projection using the previous study's method, which uses a single projector. When compared with Fig. 12, this proposed method produces findings that are comparable to those obtained in the previous study.

Figure 12(a) shows that the height of the right half of the image projected from the back projector is slightly off. The volumetric display was created using the proposed method by placing two projectors in symmetrical positions to the volumetric display, assuming that each projector can project the identical thread arrangement. However, the height adjustment of the threads was not accurate owing to the errors in the manual installation of the threads and projectors.

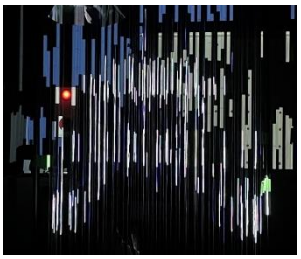
(a) 0°

(b) 45°

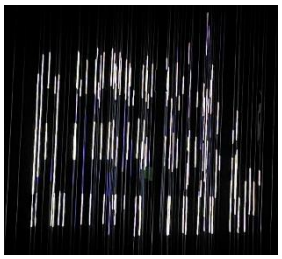


(c) 90°

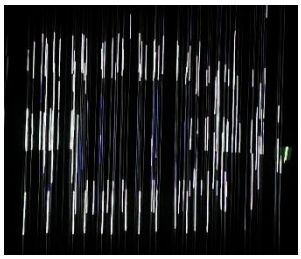
Fig.12 Projection image of proposed method.



(a) 0°



(b) 45°



(c) 90°

Fig.13 Projection image of previous study.

4 CONCLUSION

We developed a system for projecting images from multiple projectors and proposed a novel projection method for higher resolution volumetric displays.

In the future, we will use User Datagram Protocol (UDP) communication and other methods for synchronizing among PCs for video projection. In addition, we would like to achieve a higher density of displays to show images of 20 × 20 pixels or more for the original purpose of higher resolution.

ANCKNOWLEDGEMENT

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