Real-time Integral Photography Holographic Pyramid using a Game Engine

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Abstract: A new holographic pyramid system that can display an animation of integral photography images that appear to be floating is developed using a game engine and by writing its shader. An animation of the object, as viewed from the front, rear, left, and right, are displayed on the four surfaces of the pyramid. All animations are autostereoscopic and are provided in horizontal and vertical parallaxes. The user can rotate the object left or right by operating the keyboard. This system can be regarded as an autostereoscopic mixed-reality system because real and virtual objects can coexist in one pyramid.

1 INTRODUCTION

A holographic pyramid is a display that reflects the image displayed on a flat panel display, such as a liquid crystal display (LCD) on the surface of a quadrangular pyramid made of a half mirror, so that the image appears as an object floating in the pyramid. Normally, the flat panel display is 2D, thus the image displayed is a 2D image without depth, as shown in Fig. 1. However, by displaying 3D images in the flat panel, objects with depth can be manifested.

Among various 3D display systems, integral photography (IP), which was proposed by Lippmann (Lippmann 1908), is highly suitable for this purpose because horizontal and vertical parallaxes can be obtained without using stereo glasses. IP can be constructed simply by placing a fly's eye lens on top of the LCD, as shown in Fig. 2. Yamanouchi et al. (Yamanouchi et al. 2016) developed a holographic pyramid system using IP in which a fly's eye lens is integrated between the flat panel display and the pyramid, as shown in Fig. 3. Moreover, 3D CG animation of IP images can be played with the system, but images had to be pre-rendered because of the heavy processing. Another issue of the system is that only the same image can be displayed on the four surfaces of the pyramid. It would be better if the image of the object viewed from each direction is displayed on the side of the pyramid.

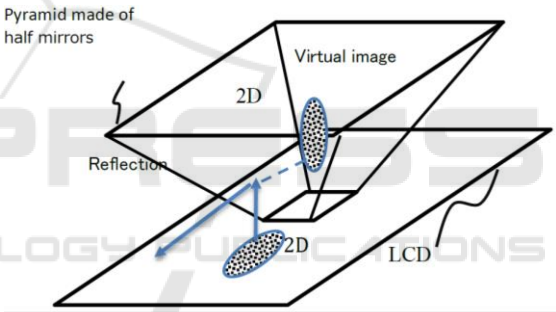

Figure 1: Conventional holographic pyramid system.

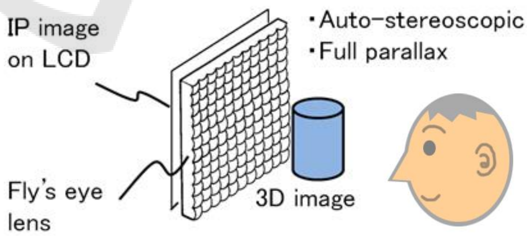

Figure 2: Simple integral photography system.

2 METHOD

2.1 Use of a Game Engine and Its Shader

We introduced a game engine (Unity 5) to solve these problems.

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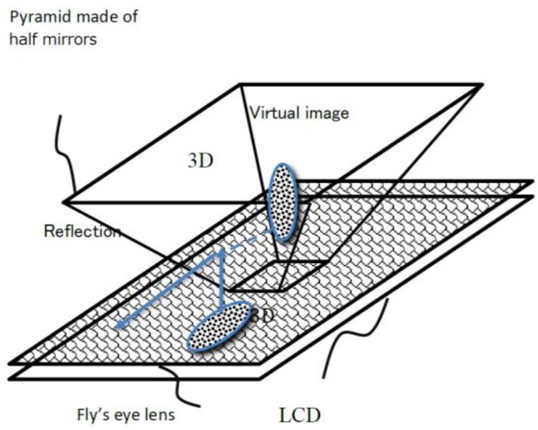

Figure 3: Holographic pyramid system using IP.

Game engines can reduce the time and labor of creating games, as well as most multimedia content. Moreover, IP multi-viewpoint rendering and IP image synthesis can considerably be accelerated by using a shader in general (Yanaka and Kimura 2013); and Anraku et al. reported that the shader of Unity is no exception. (Anraku et al. 2017).

Fig. 4 shows the IP image synthesis method using Unity. In the lower right of the figure, four camera arrays surround the subject. Each camera array consists of 8 ×8 = 64 virtual cameras placed in the front, back, left, and right of a subject that is to be displayed in the pyramid. A memory area called a render texture of 4096 × 4096 pixels is allocated to each camera array. Each render texture is divided into 8 × 8 = 64 viewports (512 × 512 pixels each) and images seen from different cameras are drawn.

As shown in the middle left of Fig. 1, four planes (front, left, right, and back) are present, and each render texture is texture-mapped to the corresponding plane.

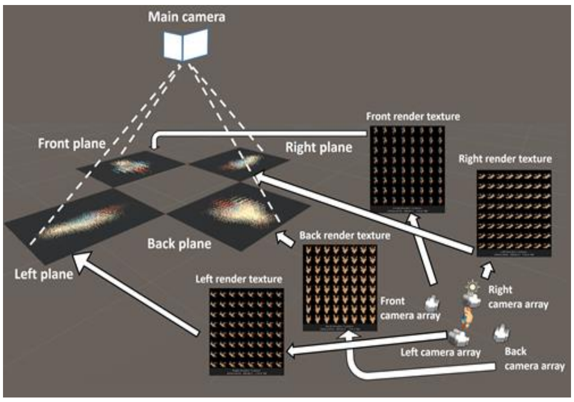

Figure 4: IP image synthesis method using Unity. ©UTJ/UCL.

A surface shader, which synthesizes the IP image from the multi-view image stored in the render texture, is assigned to each plane; thus, the IP image is produced on the plane surface. The synthesis algorithm is basically the same as written in previous studies (Yanaka 2008).

Four IP images obtained in this method are taken at once by Unity's main camera, shown in the upper left of Fig. 4. Fig. 5 shows an example of the image taken by the main camera and displayed on the LCD of the PC.

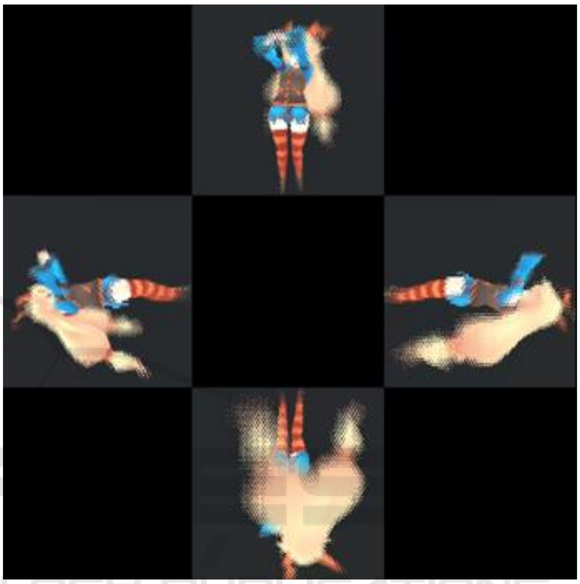

Figure 5: Image taken by the main camera and displayed on the LCD of the PC. ©UTJ/UCL.

2.2 Rotation and Flipping of the Image

Please note that the character's feet must point to the center of the pyramid so that the orientation of the character is correct when the image is reflected on one of the surfaces of the pyramid. For that purpose, the images on the left and right planes must be rotated by 90 degrees in opposite directions, and the image of the back plane must be rotated by 180 degrees, as shown in Fig. 5. IP images cannot be rotated, therefore, this rotation must be done before synthesizing the IP images.

Rotating the subject towards one direction and rotating the entire camera array in the opposite direction are equivalent. Thus, we rotated all the camera arrays, as shown in Figure 6.

Moreover, considering that the image displayed on the LCD is reversed left and right when it is reflected by the surface of the pyramid, the image is horizontally reversed in advance when drawing on the view port.

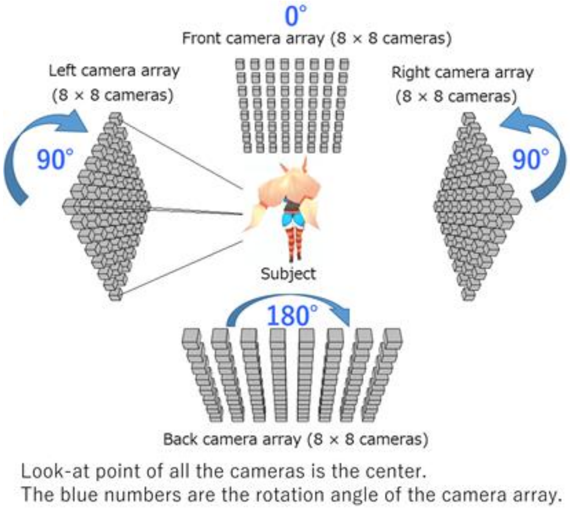

Figure 6: Rotation of each camera arrays. ©UTJ/UCL.

2.3 Character Rotation by Keyboard Operations

In this holographic pyramid, autostereoscopic images of a character viewed from four different directions are displayed on four surfaces of the pyramid. Therefore, the image of the character viewed from that direction can be seen if the user moves to another surface. However, if the observer can rotate the character in the pyramid, the user does not have to walk around the pyramid to see the character from various angles. Therefore, we added an interactive function to rotate the character by the following keyboard operations.

As shown in Fig. 7, the character rotates counter-clockwise when the user presses “4” on the numeric keyboard and rotates clockwise when “6” is pressed.

3 EXPERIMENTS

Fig. 8 shows an outlook of the system. Here we used LowPolyUnityChan (Unity Technologies Japan 2016), which is distributed by Unity Technologies Japan. The personal computer used in the experiment is a Microsoft Surface Book equipped with 13.5-inch high definition LCD of 3000×2000 pixels. The fly’s eye lens used is by Fresnel Technology and is a 360, a hexagonal convex lens array whose lens pitch is 1 mm. Despite the number of renderings being increased by 256 times compared with the normal CG, the frame rate was about 4 fps. It will be improved by using a high performance GPU.

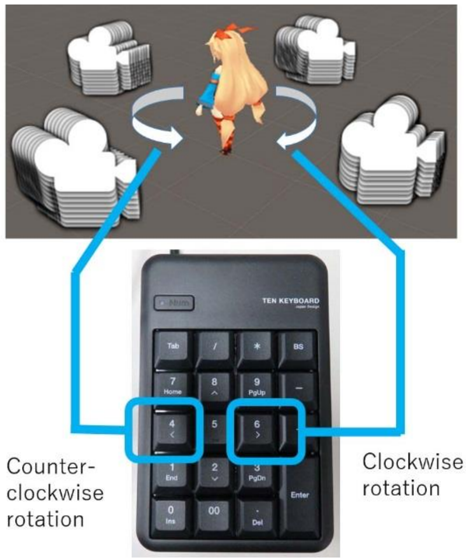

Figure 7: Character rotation by keyboard operations. ©UTJ/UCL.

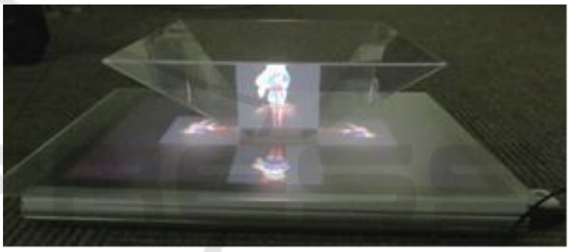

Figure 8: Appearance of new holographic pyramid. ©UTJ/UCL.

Figs. 9, 10, 11, and 12 show the front, back, left-side, and right-side views of the character displayed on the surface of the pyramid, as seen from a user by rotating the character by the user's own keyboard operation.

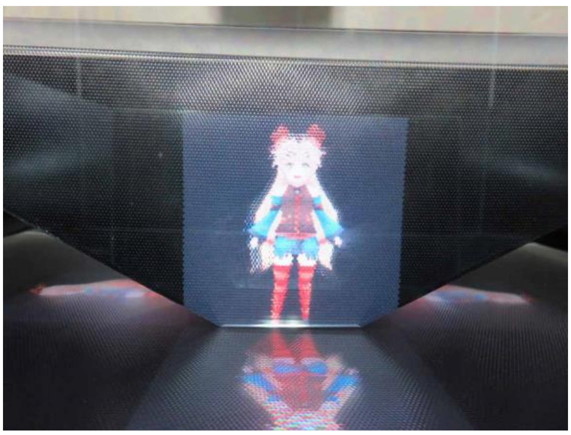

Figure 9: Character seen from the front. ©UTJ/UCL.

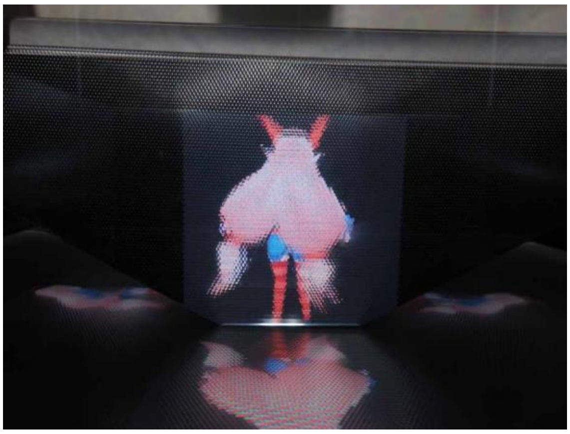

Figure 10: Character seen from the back. ©UTJ/UCL.

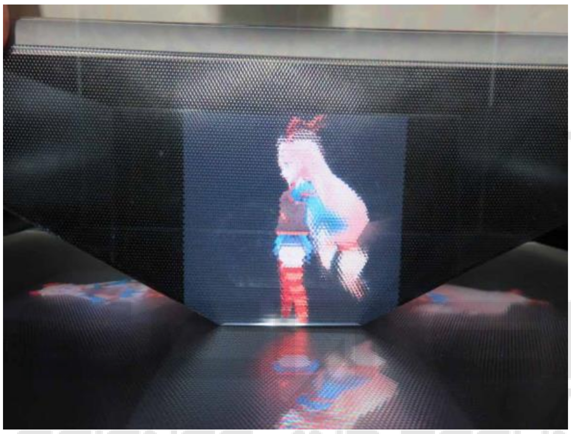

Figure 11: Characters seen from the left side. ©UTJ/UCL.

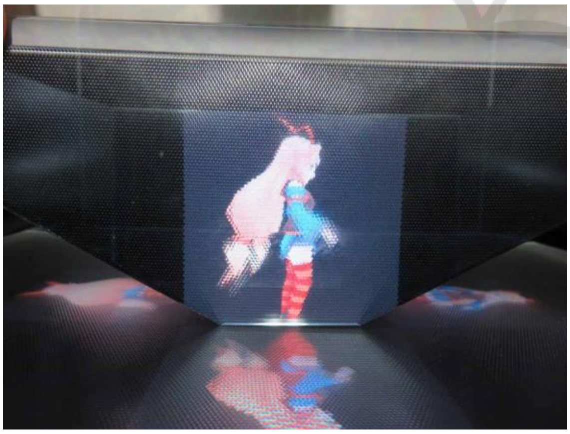

Figure 12: Character seen from the right side. ©UTJ/UCL.

Naturally, the images of the remaining three faces also change in conjunction with it. In either case, an autostereoscopic effect of the IP method is obtained. IP provides parallax in the horizontal and vertical directions. Therefore, when the head is moved vertically, the image changes accordingly.

For comparison, Fig. 13 shows an image of a conventional holographic pyramid system in which IP is not used. Even in this case, the character looks like being inside the pyramid. However, the depth of the object is not perceived because the surface of the pyramid reflects the 2D image on the LCD. The image seen around the center of the pyramid is not 3D, but 2D, as if in a billboard.

On the other hand, the holographic pyramid using IP reflects the light from 3D image produced by the IP system consisting of a LCD and a fly's eye lens. Therefore, the viewer feels that the 3D character really exists inside the pyramid.

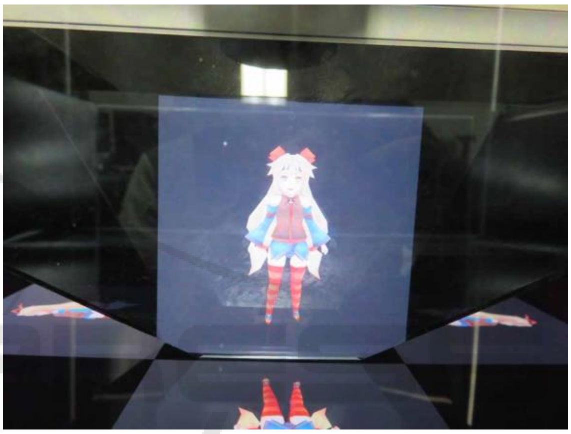

Figure 13: Normal H\holographic pyramid without IP. ©UTJ/UCL.

4 CONCLUSIONS

In summary, we developed a new holographic pyramid system that can display autostereoscopic objects that appear to be floating and are animated around the center of the pyramid using a game engine and developing its shader to synthesize integral photography images at high speed. On each of the four surfaces of the pyramid, the scene which should be seen from the direction is displayed.

In this system, real and virtual objects can coexist in the pyramid. In this sense, this is a kind of autostereoscopic mixed-reality system, which can be applied in various situations, such as sales promotions inside stores.

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