Basic Study of Scalable Autostereoscopic Display for Haptic Interaction in Mixed-Reality

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Abstract. This paper gives a basic study how to design scalable autostereoscopic display for building large size 3D image. The autostereoscopic display can show 3D images in mid-air to user for haptic interaction. Users can interact using their hand directly with 3D image projected by this system. Each autostereoscopic display module shows only small size 3D images, life-size 3D images that span across the modules can be displayed by stacking multiple modules so that it can be easily installed in public places.

Keywords: autostereoscopic display, mixed reality

1 Introduction

Our concept is to realize the possibility for users to interact collaboratively in a public display setting with virtual objects as is commonly seen in science fiction movies. To realize this concept, we are developing a 3D display and haptic device. The development is been undertaken with the following device requirements in mind:

- The 3D display should show floating 3D image in mid-air to enable the direct interaction with real objects.
- The 3D display should show autostereoscopic images for use in public spaces.
- It should be easy to move and build in public space like digital signage.
- The haptic device should provide haptic feedback to users when real objects touch the floating 3D image.
- The haptic device should provide haptic feedback without special wearable devices for using in public space.

In this paper, we propose a scalable autostereoscopic display. Here we define scalable as being the ability to increase the scale of the display by stacking multiple display modules. By stacking the autostereoscopic 3D display modules, larger objects can therefore be displayed. Each module can show only a small-sized 3D image in the air. By stacking and building a multi-module display, life-size3D images can be displayed seamlessly across multiple modules. The modular design increases the ease of set up, transport and storage of the display.

adfa, p. 1, 2011.

Various autostereoscopic display systems for interaction with real objects have been proposed so far. RePro3D [1] showed a multi view 3D display that can superimpose 3D images onto real objects. fVisiOn [2] showed a tabletop auto-stereoscopic display for multiple users. Ueda et al. [3] showed an auto-stereoscopic display for multiple users comprising three autostereoscopic display units. However, these proposed methods cannot show seamless large-size 3D images by tiling multiple displays, and preclude the display of life-size 3D images. On the other hand, recent large-size digital signage in public spaces consist of multiple LCD panels. NexCAVE [4] proposes a multi-tile large-scale stereoscopic 3D display arranged with multiple regular 3D panels that require active shutter glasses. It is a reasonable method for builing a large-scale 3D display in public spaces for digital signage, however, the users need special 3D glasses. To solve this problem, Kooima et al. [5] showed a large-size autostereoscopic display by tiling multiple lenticular 3D displays. This system can show the autostereoscopic image to multiple viewers, although multiple displays have bezels which preclude seamless 3D images. To solve this problem, Takaki et al. [6] proposed a multi-tile bezel-less autostereoscopic display. This system can generate seamless life-size 3D images to users, although it cannot generate floating images in mid-air. Therefore, it is impossible to combine the interaction of real objects with virtual objects directly.

In the method presented here, the modules make box sized autostereoscopic images in mid-air with a narrow bezel. The 3D images generated by modules can move from one module to the next smoothly. Moreover, the modules are cube-shaped, which allows them to be easily stacked and tiled. The proposed system allows users to interact with 3D images with multimodal feedback through a large stereo image of arbitrary size.

2 System Description

To achieve our concept, we used a display method called Active-shuttered Real-Image Auto-stereoscopy[7] as shown in Figure 4. It has an LCD, an active shutter and a Fresnel lens. The user eye position is calculated with a motion capturing system. The image projected by LCD is blocked by active shutter and the image can reach only user's single eye. The Fresnel lens projects the image from LCD in mid-air.

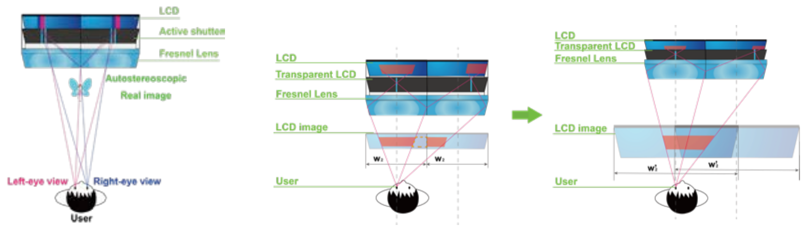

Fig. 1. System overview **Fig. 2.** Gap between images produced by the display modules

In this paper, we aim to solve two main issues in order to archive our concept.

1. Gap between images produced by the display modules: Common displays have a frame that holds the system. In addition, common autostereoscopic displays using a Fresnel lens tend to be set up such that the image is smaller than that on the surface of the display to enhance the apparent resolution and reduce apparent aberration. However, it means that if multiple such displays are used in a modular fashion side-by-side, there is a gap precluding a seamless 3D mid-air autosterioscopic image, as illustrated in figure 2(a).
2. Aberration on display edge: Autostereoscopic displays using the Fresnel lens' tend to have image distortion due to the lens. In most previous works, users need to observe 3D images from front of lens to reduce lens distortion. However, in our system an undistorted image at larger viewing angles is required.

To solve those issues, we have designed and developed a scalable autostereoscopic display module using the following method.

1. Reduction of gap between display modules: The autostereoscopic display module has a large Fresnel lens covering from edge-to-edge of the device with no frame. In addition, we position the lens such that the image is larger than the object (the image at the LC panel). This allows the image to spread over the entire field of view with no gap between modules, as illustrated in figure 2(b).
2. Reduction of aberration on display edge: We calibrate the Fresnel lens aberration from multiple viewpoints by hand in order to correct for large distortions at oblique angles.

In current prototype we used a DELL E2011H 22inch 1680x1050 for the LCD, a SAMSUNG LTI220MT02 22inch 1680x1050 for the active shutter and a custom-made Fresnel lens. These modules are designed to be surrounded by a cube for ease of stacking. Figure 4 illustrates an example of presented 3D image with our developed system. Observers could see the large-scale autostereoscopic image without wearing special glasses.

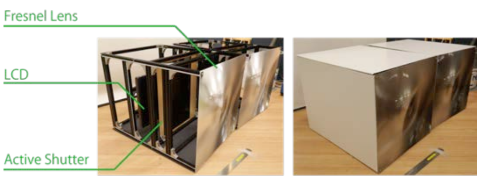

Fig. 3. Developed module overview

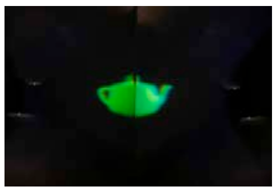

Fig. 4. A 3D image displayed astride on two modules

3 Discussion

As a result of implementation, we have shown that our method allows a continuous image with no gaps between display modules, and we have reduced aberration on the display edge. Moreover, we have confirmed that the scalable autostereoscopic display can produce different images to each of the user's eyes. However, the current implementation allows the users to scale up to a maximum of four displays as the display area is limited to in between the axis of the lenses. Therefore, we consider users can build large size autostereoscopic display constructed by the above system, up to four displays. In addition, we confirmed projectable real image size is limited by the F-number. If the display module has a small F-number, the light rays produced by the LCD cannot converge at one point. Therefore, we should open the active shutter's width widely in order to produce the image produced by the LCD on the edge of the Fresnel lens. However, a part of the image produced by the LCD can reach both eyes, which means it cannot make binocular disparity.

In future work, we will design and simulate the correction of aberration for a Fresnel lens in order to build a larger size autostereoscopic display. In addition, we will implement the interactive contents with floating 3D images with haptic feedback.

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