A Tangible Directional-View Display for Interaction

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***Abstract*—A tangible directional-view display system that can provide different perspective views without any special glasses is introduced. The proposed system can display perspective floating five images in the space in front of the system with the help of concave mirrors. In addition, the proposed system adopted an ultrasonic focusing technology in order to provide immersive experiences and deliver the sense of touch. We will explain our proposed method and provide theoretical analysis that supports it.**

Keywords-Interaction, Directional-View, Ultrasonicsound

I. INTRODUCTION

Since the successful development of a stereoscopic three-dimensional (3D) film, studies on autostereoscopic 3D display have been actively conducted recently. The ultimate goal of such a 3D display is to provide multiple viewers with a tangible 3D display. However, it is hard to implement such a 3D display because of several constraints, such as a lack of display panels that are usable commercially for ultimate 3D display [1-6]. Also, there are several reasons why some people are still against stereoscopic 3D displays; one of the reasons is the discomfort of wearing glasses.

For the ultimate tangible 3D display, there are several requirements. First, it is necessary to display different perspective images according to the users even though it is not necessary to provide such volumetric 3D display. Second, it should detect a hand gesture to identify the user's movements. Finally, a proper sense of touch should be provided to the viewer's fingertip in order to deliver immersive experiences [7].

In this paper, we propose a tangible directional viewable display for interaction using floating displays and ultrasound transducers. For providing high-definition directional-view images that can be viewed without any special gadgets by plural viewers, we integrated three lenticular lens displays and five floating displays into the proposed system. The proposed system has two attached infrared (IR) cameras as detectors. In addition, a number of ultrasound transducers are designed to feel tactile stimulation at a specific point. The paper is structured as follows. In Section II, we explain the proposed method by using floating displays and IR camera. In Section III, the experimental results that support the proposed method are provided, and, in Section IV, we conclude the paper.

II. PROPOSED METHOD

Figure 1 shows a schematic representation of our proposed system. The system consists of a display system in which three lenticular lens displays and five floating displays are combined, a hand gesture recognition system for interaction (IR camera), and a spatial tactile system that provides tactile expression. Various types of 3D displays, such as a holographic display and volumetric displays, can be considered to construct a tangible 3D display. However, each candidate has limitations, such as a massive amount of information to be processed and difficulty to interact with rotating screen. A floating display is a method of projecting clear two-dimensional (2D) images, which has been applied as a "Pseudo hologram" recently. Among the various abovementioned display methods, a floating display that provides vivid images and is suitable for interaction as a tangible display was selected.

Figure 1. Schematic diagram of the tangible directional-view display system

Three lenticular lens displays were adopted for delivering immersive experiences to the viewers. They located in an upper position for a number of viewers to observe images. These three lenticular lens displays were used for the selection of image contents, as shown in Figure 2. In the display system, viewers selected contents using a lenticular

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lens display, followed by touching the image contents directly. A floating display can be constructed by a concave mirror. This mirror is optically equivalent to the floating lens, so the location and the size of the floating image can be mathematically by the mirrors. For simplicity, a Jones transfer matrix of the floating display along the light propagation paths is expressed as follows:

$$\begin{pmatrix}x_4\\ \theta_4\end{pmatrix} = \begin{pmatrix}1 & d_3\\ 0 & 1\end{pmatrix}\begin{pmatrix}1 & d_2\\ 0 & 1\end{pmatrix}\begin{pmatrix}1 & 0\\ -\frac{1}{f} & 1\end{pmatrix}\begin{pmatrix}1 & d_1\\ 0 & 1\end{pmatrix}\begin{pmatrix}x_1\\ \theta_1\end{pmatrix} \quad (1)$$

where x_1, x_2, x_3, and x_4 denote the location of the original image, the lens, the floating image, and the viewer's eye, respectively [8]. θ_1, θ_2, θ_3, and θ_4 denote the angle of each optical component, and r represents the radius of the concave mirror. H_1, H_2, H_3, and H_4 denote the size of the original image, the floating lens, the floating image, and the distance from the viewers' eye, respectively. According to the equation, the location and the size of the floating image can be calculated. Because the horizontal viewing angle of each floating display is 45 degree, we choose five floating displays for covering five viewers simultaneously. This floating display is varied at the lower part for viewers to see only the floating images.

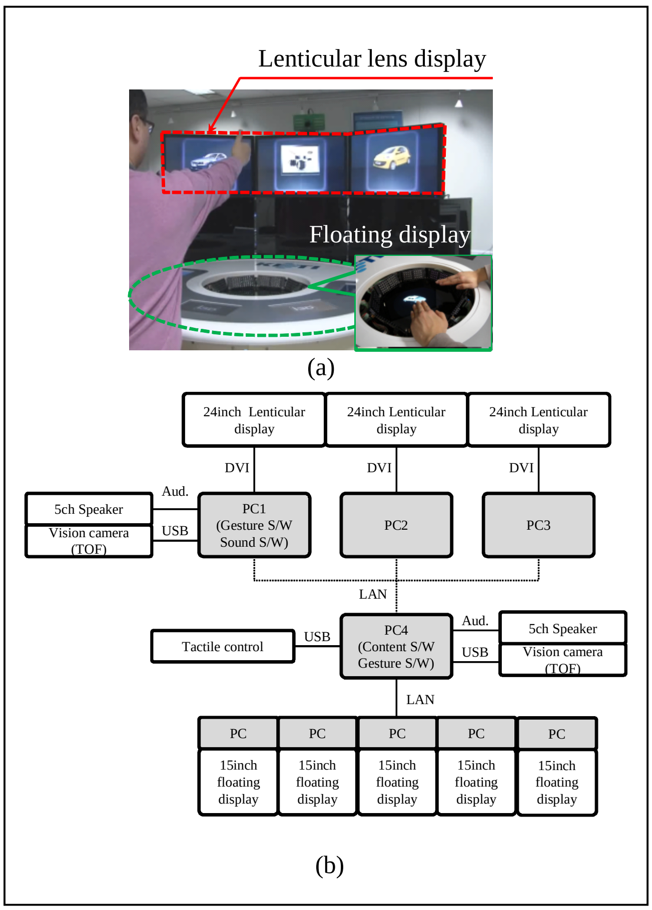

Figure 2. (a) a photo of our proposed system and (b) a system block diagram of our proposed system.

For the tactile impression, we developed a technology that can focus stimulation on a specific location using an ultrasound transducer technology [9]. The focus where a floating image is projected over a space is set up followed by obtaining a distance difference from the focus to the corresponding ultrasound transducers as shown in Figure 3. Since the distance is different according to the corresponding ultrasound transducers, a phase difference is generated per ultrasound transducer. Therefore, we should adjust this difference by using phase differences. We use 5 by 10 transducers per module and 8 ultrasound transducer modules in total were used for increasing the tactile pressure.

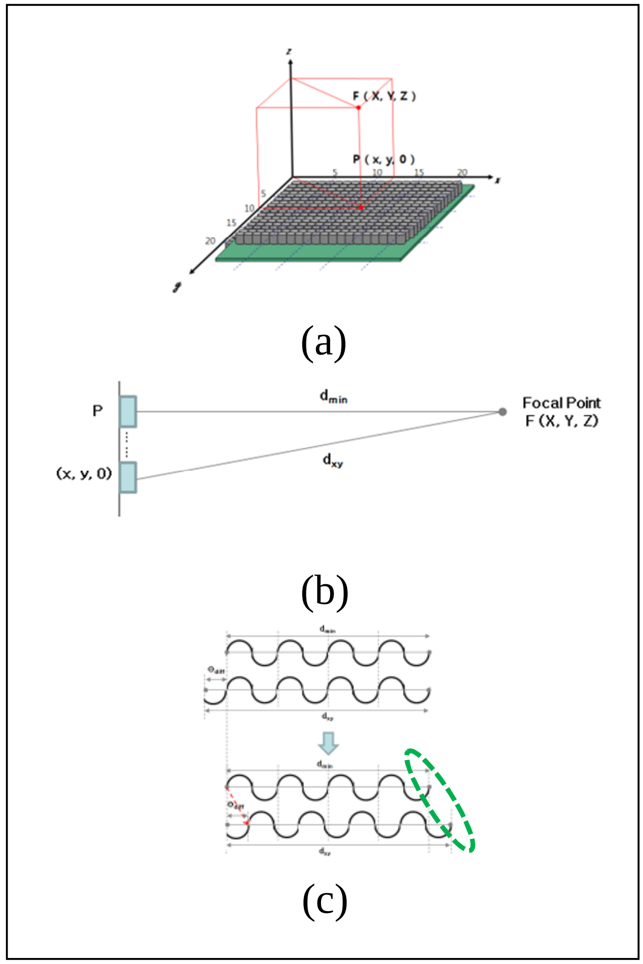

Figure 3. Focusing of ultrasound wave by ultrasound transducers: (a) a schematic of ultrasound transducer system, (b) distance estimation between focal point (x, y, z) and each transducer, and (c) phase alignment of ultrasound wave by considering phase difference among transducers.

Lastly, a detecting system using IR emission units was used for applying tactile stimulation by the location of the fingertip of users. The system was designed to find out user's fingertip using general time-of-flight (TOF) mode. Four of predefined hand gesture (left, right, enter, and backward) were selected according to the user's gesture.

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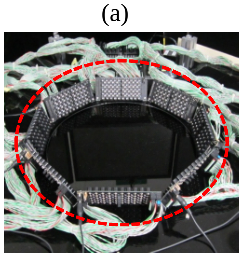
III. Experimental Results

To verify our proposed system, we integrated three lenticular lens displays, detecting camera systems, floating displays, and tactile devices using ultrasound transducers, as shown in Figure 4. Figure 4 (a) depicts the configuration of the proposed system, and Figure 4 (b) depicts the mounted ultrasound transducers in the system. A 24 inch lenticular lens display with 9 views was used as the frontal display device. Each unit was connected with a 5-channel speaker and a TOF camera. For floating displays, 15 inch high brightness LCD monitors were used as a display panel, whose images were viewed by viewers through the polarization glass located in the center of the system. A 37 inch parabolic mirror a focal length of 9.3 inch and diameter of 35 cm in the central area was cut, and five 15 inch LCD monitors were used. Each floating display had a 45 degree field of view, and the diameter of the lower system was 90 cm, while that of the polarization glass was 30 cm. Five 10 inch tablet PCs (Samsung Galaxy note) were used and three types of scenarios were displayed by the system.

(a)



(b)

Figure 4. (a) a photo of experimental setup and (b) ten sets of ultrasound transducer module.

IV. Conclusion

We proposed a tangible directional-view display system for providing a user interaction experiences. The system was constructed by three sets of lenticular lens displays, five sets of floating displays, a designed ultrasound transducer system, and two TOF cameras using IR units. Integrated systems are presented to verify the validity of the proposed method, and the experimental results show that the proposed system provides different perspective view images and tactile expressions according to the predefined positions. We expect our system to have a number of applications, such as advertisement, game, e-training, and immersive digital signage industries.

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