Cylindrical Transparent Display with Hologram Screen

Tomoharu Nakamura, Akira Tanaka, Tsuyoshi Kaneko, Masanori Iwasaki, Takayuki Kurihara, Noriyuki Kato, Koji Kuramoto, Hidehiko Takanashi, and Yuji Nakahata

Sony Corporation, Atsugi Tec., 4-14-1 Asahi-cho, Atsugi-shi, Kanagawa, 243-0014, Japan
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ABSTRACT

We have developed a hologram screen with higher transparency and higher diffraction efficiency than conventional transparent screens. We have applied this screen to a cylindrical transparent display, and we propose a display system that creates a feeling of "actually there" reality with 2D images by combining sensing technology with multiple high-speed cameras.

1 INTRODUCTION

Augmented reality (AR), virtual reality (VR), and mixed reality (MR) provide novel experiences beyond those given by conventional flat-panel displays such as LCD and OLED. Several AR/VR/MR displays have been proposed and commercialized. For example, various VR head-mounted displays (HMDs) with a wide field of view (FOV) > 100° have been proposed and commercialized for VR applications [1]. The CAVE display proposed by C. Cruz-Neira *et al* is a display system with a wider FOV [2]. The CAVE display system is an immersive panoramic view display system that surrounds users with three to six display walls. A type of display technology that users surround with a cylindrical light-field display has also been reported [3]. This display creates reality with its displayed objects. We proposed and demonstrated a cylindrical transparent display as a new type of display that users surround in SIGGSRAPH 2019 [4].

In this paper, we will describe its technology and give examples of its applications. To embed realism in 2D video images in a novel way, we considered combining the cylindrical transparent display with a hologram screen and sensing technology using multiple high-speed cameras. Since the display is cylindrical, images can be viewed from any viewing angle up to 360°. In addition, a hologram screen with high transparency is difficult to sense, so the feeling that the image is floating increases as the background and the image blend. This feature is due to the great effects of motion parallax generated between the background and the image. Furthermore, the multi-camera sensing system can display a specific image for a specific observer in the surroundings. By imparting the motion parallax (calculated from the position of the observer) to 2D video images in real time, the image can appear to be located at the center of the cylinder. This feature makes it possible to further enhance the realism of the image.

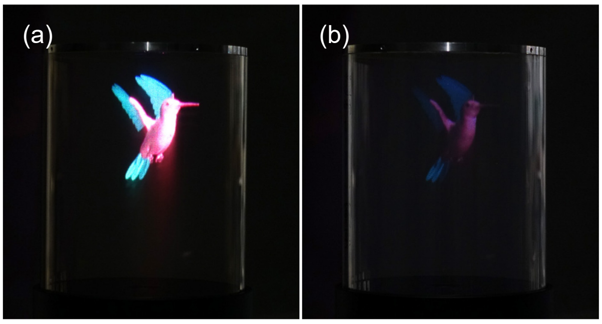

Figure 1: Brightness comparison between (a) the hologram screen and (b) the conventional transparent screen with scattering particles

2 OVERVIEW OF SYSTEM

2.1 Hologram Screen

We used our “holographic optical element” (HOE) technology to develop the hologram screen. HOE technology can impart various optical functions by preparing a diffraction grating by exposing a photopolymer with LASER (it is also used for smart eyeglasses) [5]. Since the hologram screen can diffract and scatter light of a specific wavelength at a specific angle, the projector light can be displayed brightly without affecting light in the background or the illumination. Furthermore, the hologram screen is designed so that the peak intensity of the scattered light emitted from the screen is directed upward from the horizontal plane, making the image look bright from the observer’s viewpoint. A significant advantage of the hologram screen is that it can arbitrarily change the direction of the peak intensity of the image light. We achieved the transparency and the brightness of the hologram screen by optimizing the HOE manufacturing process. As a result, bright and high-contrast images could be enjoyed even under bright lighting conditions, which typically is not the case with conventional transparent screens. Figure 1 compares the brightness of photographs between (a) the hologram screen and (b)

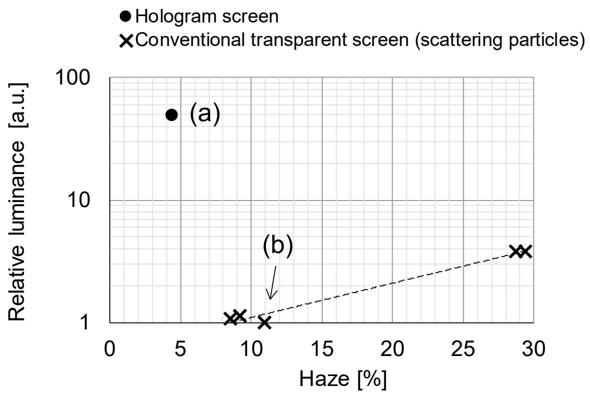

Figure 2: Haze vs. relative luminance at an angle of 10° upward from the horizontal plane

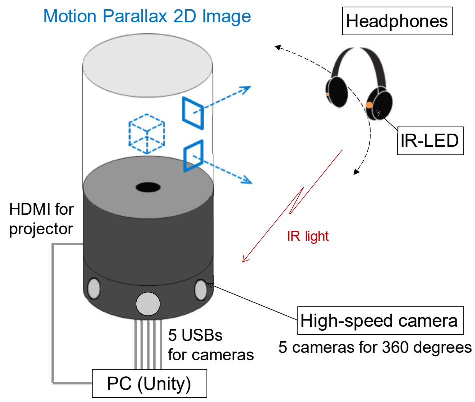

Figure 4: Overview of the 360-degree position tracking system

the transparent screen based on conventional technology using scattering particles. As for the hologram screen, bright images can be viewed from the top and the front according to the observation position. As for the conventional transparent screen with scattering particles, the images are dark and difficult to see, especially under the lighting conditions. To compare the characteristics of the hologram screen and a conventional transparent screen with scattering particles, Figure 2 shows a graph of haze and relative luminance at an angle of 10° upward from the horizontal plane. Compared to the conventional transparent screen with scattering particles, the hologram screen achieved high luminance in spite of low haze.

2.2 Cylindrical Transparent Display

As Fig. 3 shows, the cylindrical transparent display consists of a hologram screen, an acrylic cylinder, a projector, and a mirror. The hologram screen is attached inside the acrylic cylinder. The projector has RGB LASER light sources. The narrow wavelength width of light from LASER can maximize the utilization efficiency of the light projected onto the hologram screen. Adopting an original cylindrical-projection optical system (composed of a projector and a mirror) made it possible to create a high-

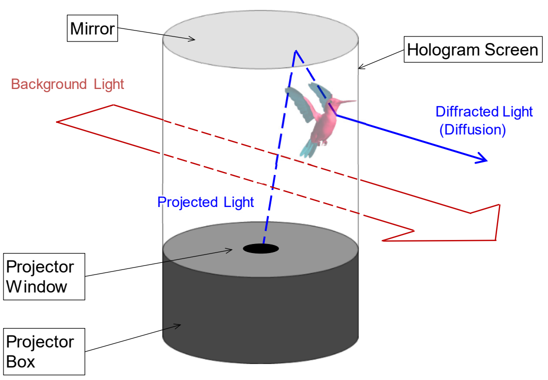

Figure 3: Overview of cylindrical transparent display with hologram screen

resolution image display on the entire cylinder. Since the hologram screen is optimally designed and fabricated based on the incident angle of the image light, bright images can be displayed on the entire cylindrical hologram screen. However, the light from the background and the illumination almost pass through the hologram screen because the angle of incident and wavelength do not satisfy the diffraction conditions.

2.3 360-degree Position Tracking System

As Fig. 4 shows, the 360-degree position tracking system consists of a cylindrical transparent display, five high-speed cameras with high-speed vision chips [6], headphones with an infrared (IR) LED with a wavelength of 840 nm, and a PC that controls the high-speed cameras. The frame rate of the high-speed camera is 1,000 fps. The camera angle is 87°. The camera has an 840 nm bandpass filter and a visible light cut filter that only detects light around 840 nm. The five high-speed cameras are embedded in the bottom of the cylindrical display. The PC controls both the projector via HDMI and the five high-speed cameras via USB. The video display tool uses Unity. The five high-speed cameras make it possible to sense the surroundings seamlessly. The high-speed cameras can extract the positional information of the surrounding observers wearing the headphones by recognizing the IR light and display content linked to the positional information on Unity in real time with fewer delays.

3 DISCUSSION AND CONCLUSIONS

By displaying bright images on a cylindrical transparent display with a hologram screen and imparting motion parallax according to the movements of the observers, a cylindrical transparent display with 360-degree position tracking system can apply a feeling of "actually there" reality to 2D images. If an observer moves around and sees the cylindrical display from different views (See Fig. 5), the motion parallax 2D image displayed at the center of the cylinder can follow

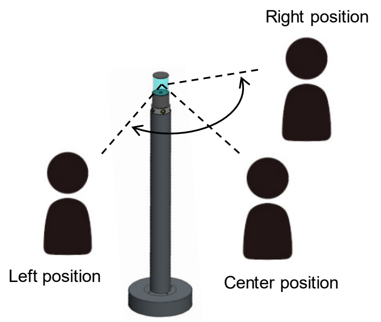

Figure 5: Observation of the cylindrical transparent display from different views

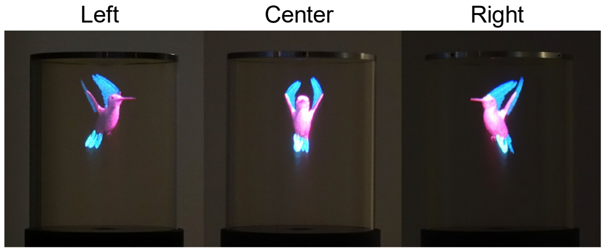

Figure 6: Motion parallax image from different views

the observer without delay (See Fig. 6). Therefore, the observer can feel as though a 3D image is inside the cylinder. An example of concrete use of a cylindrical transparent display with a 360-degree position tracking system is so-called “substantiation” of an artificial intelligence (AI) agent by an AI speaker displaying an image. This could make the human feel a measure of affection for the AI agent.

In addition, we propose two applications as new expression methods that make full use of the cylindrical transparent display. By using multiple cylindrical transparent displays and linking each image and sound, these applications can provide a new creation space that everyone can enjoy from 360 degrees at the same time (See Fig. 7(a)) and users can enjoy a new interactive experience by operating 360-degree video and sound and interacting with them in real time with hand-tracking sensors (See Fig. 7(b)).

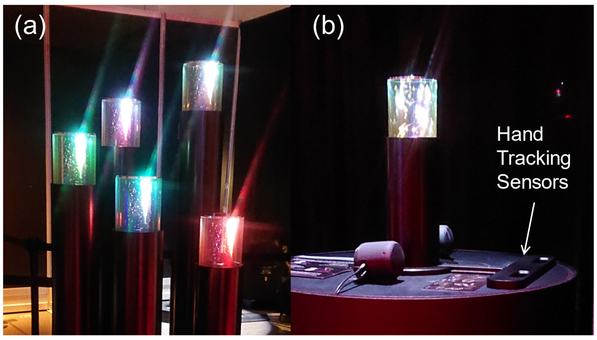

Figure 7: Other new applications, (a) new space creation with multiple displays and (b) new interactive experience with hand gesture operation

4 ACKNOWLEDGEMENT

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REFERENCES

[1] https://www.jp.playstation.com/psvr/

[2] C. Cruz-Neira, D. J. Sandin, and T. A. DeFanti, “Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE,” In Proceedings of SIGGRAPH 1993, pp. 135–142 (1993).

[3] K. Ito, H. Kikuchi, H. Sakurai, I. Kobayashi, H. Yasunaga, H. Mori, K. Tokuyama, H. Ishikawa, K. Hayasaka, and H. Yanagisawa, “360-degree autostereoscopic display.” In ACM SIGGRAPH 2010 Emerging Technologies, Article No. 1 (2010).

[4] T. Nakamura, T. Yano, K. Watanabe, Y. Ishii, H. Ono, I. Tambata, N. Furue and Y. Nakahata, “360-degree Transparent Holographic Screen Display,” In ACM SIGGRAPH 2019 Emerging Technologies, Article No. 1 (2019).

[5] T. Yoshida, K. Tokuyama, Y. Takai, D. Tsukuda, T. Kaneko, N. Suzuki, T. Anzai, A. Yoshikaie, K. Akutsu, and A. Machida, “A plastic holographic waveguide combiner for light-weight and highly-transparent augmented reality glasses,” In Proceedings of SID Symposium, Digest of Technical Paper, pp. 280–286 (2018).

[6] T. Yamazaki, H. Katayama, S. Uehara, A. Nose, M. Kobayashi, S. Shida, M. Odahara, K. Takamiya, Y. Hisamatsu, S. Matsumoto, L. Miyashita, Y. Watanabe, T. Izawa, Y. Muramatsu, and M. Ishikawa, “A 1ms high-speed vision chip with 3D-stacked 140GOPS column-parallel PEs for spatio-temporal image processing,” In Proceedings of the Conference on Solid-State Circuits, pp. 82–83 (2017).