Variable-depth Computer Generated Holograms Algorithm in Curved Holographic Waveguide Display

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Holographic near-eye displays (NEDs) are emerging as immersive displays that can enhance the user's visual experience in augmented reality (AR) [1]. We need to consider human-friendly optical factor such as high resolution, variable-accommodation, field of view (FOV), and eye box. Additionally, we should be a thin and lightweight optical combiner for comfortable wearing experience. In a waveguide-type AR display based on exit pupil expansion (EPE), a virtual spatial light modulator (SLM) is replicated through total reflection guiding within a waveguide, thereby simultaneously delivering the real scene and the replicated SLM to the user. This approach is considered an appropriate method to extend the FOV with optical see-through.

However, waveguide-type displays face several fundamental problems for realizing holographic three-dimensional (3D) images. It can only generate virtual 2D images in infinite distance, and virtual images in finite distance cause multiple images by pupil replication. Computer-generated hologram (CGH) can help to mitigate the challenges of generating variable-depth holograms in finite distance [2]. In terms of eye relief of AR NEDs, if the user's eyes are close to the display, the flat waveguide display limits the EPE by the diffraction angle of the replicated virtual SLM. This does not allow fully observation of the optical wave field from waveguide, resulting in a narrow FOV. On the other side, curved waveguide displays can mitigate the limitations of EPE and have an extended FOV beyond flat waveguide displays.

In this presentation, we propose variable-depth CGH synthesis in curved waveguide displays. This synthesis algorithm can generate holograms with an extended FOV from a waveguide-type pupil-replicated display in a finite plane. Figure 1 (a) and (b) show the numerical observation results of holographic images located 50mm away from the flat and curved waveguide displays, respectively. We assumed a single super-resolution display with replicated virtual SLM eight times by the waveguide. The observer's eye relief from waveguide is approximately 38.43mm. In flat waveguide display, the holographic image is locally observed in the retina plane by limited EPE in Fig. 1(a). Conversely, in curved waveguide display, the holographic image is entirely observed in the retina plane in Fig. 1(b). Consequently, we demonstrated hologram generation with extended FOV through the proposed variable-depth CGH synthesis algorithm in curved waveguide display.

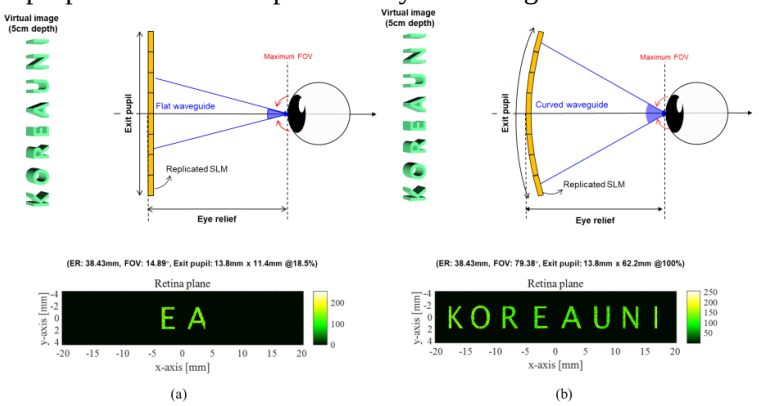

Fig. 1 Numerical simulation results of human eye observation of holographic image field in (a) flat and (b) curved waveguide display.

References

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[2] B. Lee, D. Kim, S. Lee, C. Chen, and B. Lee, "High-contrast, speckle-free, true 3D holography via binary CGH optimization," Sci. Rep. **12**(1), 2811 (2022).