Computer-generated Hologram Algorithm to Expand Eyebox in the Waveguide Type Near-Eye Display

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Recently, with the expansion of applications using augmented reality (AR) technology, there has been a growing interest in near eye displays (NED), a key device in this field. In particular, waveguide type NEDs have been widely commercialized and studied with a depthless Maxwellian view which is employed to achieve a wide eyebox. When using a Maxwellian optical system, the virtual images remain consistently sharp regardless of the user's focus, leading to a lack of depth perception. Another problem is that each virtual spatial light modulator (SLM) replicated from the waveguide causes holographic restoration, leading to the presence of multiple images when observed by the user. In this presentation, we propose an anamorphic computer-generated hologram (CGH) algorithm that leverages the structural characteristics of waveguide type NED to simultaneously expand the eye box and allow the user to perceive the depth of the image without multiple images being seen in the waveguide.

Figure1(a) illustrates the schematic of the anamorphic CGH algorithm proposed in this research when applied to the waveguide. The proposed algorithm was created by synthesizing CGH with an infinite focal length on the vertical axis and appropriate focal length for specific depth on the horizontal axis using the characteristics of an anamorphic lens, which has a different focal length of each axis in one lens. From this approach, horizontal direction image exhibits Maxwellian view and the vertical image has depth, and it can be enabling the reconstruction of hologram in the waveguide that users to perceive depth based on their focus. The numerical analytical simulations of the proposed algorithm for target images with two different depths were conducted. The results showed the accommodation effect of virtual images based on the observer's focal distance. Additionally, for horizontal direction images, a thin virtual slit aperture was applied in front of the observer's retina to achieve an all-in-focus effect. The previously calculated anamorphic CGH passes through a slit in front of the observer's retina, and the reversely redesigned CGH is restored from waveguide. This redesigned CGH can be displayed in-focus on horizontal direction.

If the waveguide is designed to replicate a rectangular-shaped SLM without seams in the horizontal direction, the replicated SLMs would overlap in the vertical direction. Figure 1(b) represents the simulation results of how the reconstruction of anamorphic CGH in the waveguide appears to the observer. Applying the proposed CGH with an infinite focal length along the vertical axis prevents the visibility of multiple images when observed. By proportionally increasing the number of vertically replicated SLMs, it was possible to expand the vertical eyebox, allowing for upward and downward eye movement. Within this eye box, the accommodation effect of vertical direction images with changes in focal distance and the all-in-focus of horizontal direction images were verified. In conclusion, this research proposes an anamorphic CGH algorithm that enables both the expansion of the vertical eyebox and the restoration of holograms with variable depth in a waveguide type NED. Furthermore, the validity of the algorithm was verified through simulations and optical experiment.

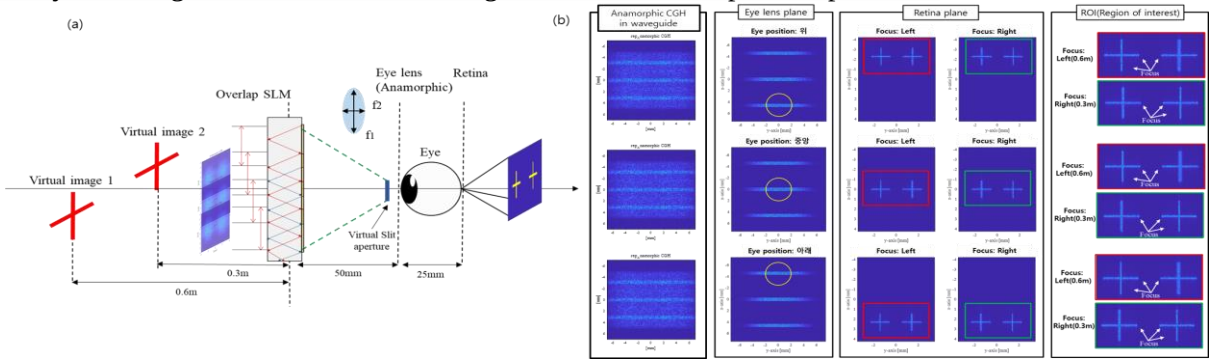

Fig. 1 (a) Schematic of Anamorphic CGH in waveguide. (b) Numerical simulation results for Anamorphic CGH algorithm