Advances in Large-scale Computer Holography

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Abstract

Traditional holography is not a modern digital technology because the holograms cannot be stored and transmitted with digital media. The nature of a hologram is the fringe pattern generated by optical interference with a reference wave. The origin of the concept of computer-generated holograms (CGHs), whose fringe patterns are calculated by computers, goes back to the days immediately after the realization of 3D imaging in optical holography. However, CGHs comparable to optical holograms were not realized until recently. This is entirely due to the extremely large space-bandwidth product (SBP) required for quality holograms. The viewing angle of a CGH is mainly determined by the pixel pitches Δx and Δy of the fringe image. As an example, when $\Delta x = \Delta y = 0.6$ µm, the viewing angle of the CGH is 48° in blue color (488 nm). As a result, when we create a CGH with the dimensions of a 40-inch high-definition television (88.4 cm × 49.8 cm), the number of pixels is approximately 1.22 T pix.

Over the past 15 years, we have developed computer holography to create quality CGHs for 3D imaging [1]. The maximum SBP has reached approximately 0.2 trillion as of August 2022 and is predicted to exceed 0.5 trillion within a year. These large-scale CGHs reconstruct not only monochromatic images but also full-color images. The impressive full-parallax 3D images give an amazing sensation of depth to the viewer, which has not been realized by other technologies.

We refer to full-parallax CGHs of more than 1 billion pixels as full-parallax high-definition CGHs (FPHD-CGHs). The first FPHD-CGH was The Venus created in 2009 [2]. The fringe of The Venus was comprised of 4.2 G pix and was printed adopting laser lithography (see Sec. 15.3 in [1]). The object field was calculated using the polygon-based method [3]; only mutual occlusion between separate objects was processed in this CGH using the silhouette method [4]. To realize FPHD-CGHs, although we have developed several numerical techniques in the field of wave optics [5–7], the computation time of The Venus was 48 h in 2009. Nowadays the same CGH can be calculated in 20 min and complicated self-occlusion can be properly processed using the switch-back technique [8]. CG-modeled 3D objects are reconstructed with not only diffusive surfaces but also specular surfaces [9,10]. Real objects can be incorporated into a 3D scene of virtual objects [11,12]. We can reconstruct FPHD-CGHs in full-color with the two methods [13,14]. Recently, we have developed a new technique to create flipbooks of FPHD-CGHs [15].

Figures 1 and 2 show examples of the latest monochrome and color FPHD-CGHs composed of more than 0.1 T pix, respectively. The latter is the full-color version of a monochrome CGH named Brothers, which was exhibited at the museum of the Massachusetts Institute of Technology in 2012 [16]. The RGB color filters are used for the full-color reconstruction [11].

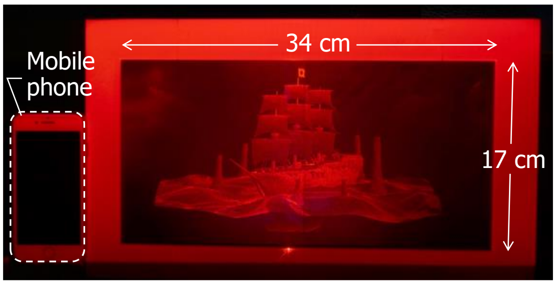

Fig.1 Monochrome FPHD-CGH composed of 425,000 × 425,000 pixels with a pixel pitch of 0.8 µm × 0.4 µm.

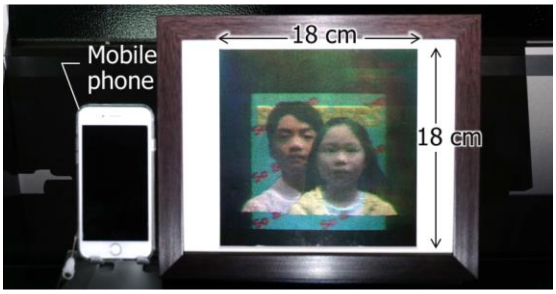

Fig.2 Full-color FPHD-CGH composed of 225,000 × 450,000 pixels with a pixel pitch of 0.8 µm × 0.4 µm.

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