Split-Lohmann Computer Holography: Fast generation of 3D hologram in single-step diffraction calculation

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Supplementary Material

1. Parameters relations in holographic display system

In this section we discuss the parameters relations in the CGH calculation including an eyepiece for our holographic near-eye display prototype, such that the hologram reproduces correct 3D images. As illustrated in Fig. S1, the hologram reconstructs 3D volumetric images around the focal plane of the Fourier lens. We then place an eyepiece lens between the reconstructed images and human eyes. This eyepiece functions to magnify the real reconstructed scenes into virtual counterparts and forming the final light signals on the retina. Suppose that the eyepiece with focal length f_e is placed at a distance z_e from the focal plane of the Fourier lens (focal length f_0). The eye is usually placed at a distance of f_e from the eyepiece which ensures that the axial shift of a display pixel does not change its viewing direction. Assuming that an image point is reconstructed at a displacement z_0 from the focal plane of the Fourier lens, then we can deduce that this real point is magnified and relocated by the eyepiece to the distance d_0 from the eye such that

$$\frac{1}{z_e - z_0} - \frac{1}{d_0 - f_e} = \frac{1}{f_e} \tag{S1}$$

In near-eye displays, we usually replace the distance of d_0 to the diopter representation as D_0=1/d_0, So in holographic near-eye display prototype, we firstly render the 3D scene points location $d(x, y)$ from the quantized depth map, and reversely calculate the axial displacement map $z(x, y)$ for all the target points from Eq. (S1) to

$$z(x,y) = z_e - \frac{\left[d(x,y) - f_e\right] f_e}{d(x,y)} \tag{S2}$$

Subsequently the phase slop profile $v(x, y)$ and the hologram can be calculated from $z(x, y)$ using Eq. (7) and Eq. (5) in the main text.

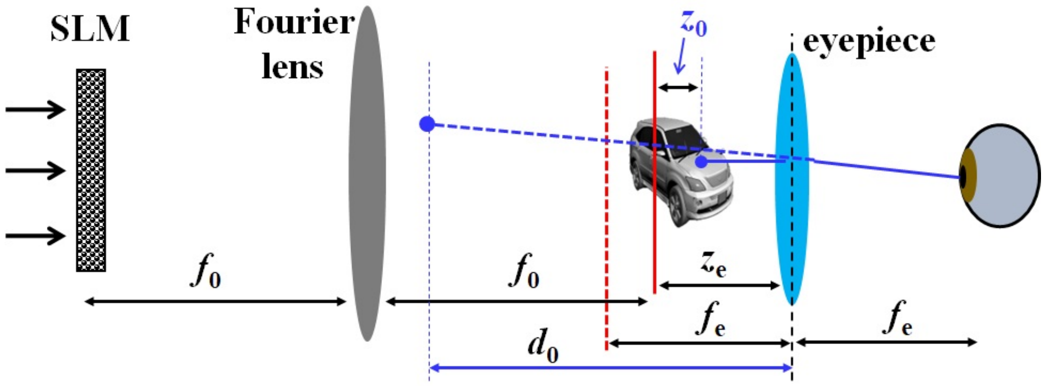

Fig. S1. Illustration of the calculation parameters involved in holographic near-eye display. The eyepiece magnifies the real holographic images into virtual contents that are perceived by the eye with accommodation cues.

2. Initial phase assigned to the target object

In our work, we finally generate a phase-only hologram which is loaded into the phase-only spatial light modulator (SLM) for phase modulation of the incident light. In order to generate such "phase-only" hologram, we simply extract the phase component from the complex wavefront at the hologram plane while discarding the amplitude component. So the employment of total random phase to the target image is physically equivalent to simulate the object as diffusive light emission/reflection. As a result, all of the information from the object can effectively distributed everywhere in the spectrum domain (which is the hologram plane), the image can still be successfully reconstructed using only the phase component. To validate this point, we compare the simulated results by using different initial phase to the target object. We assign four different types of initial phase, named random phase, uniform phase, spherical phase and smoothed compensation phase, to the target object. Figure S2 show the simulation results from the phase-only holograms with different initial phase. The first column shows four types of initial phase. The second and third column show the amplitude and phase distributions of the complex wavefront at the hologram plane, where the third column are the phase-only holograms. The fourth column shows the reconstructions from these phase-only holograms. We can see that the random initial phase guarantees complete spectrum information (see second column) over the hologram area and therefore the success reconstruction from phase-only hologram.

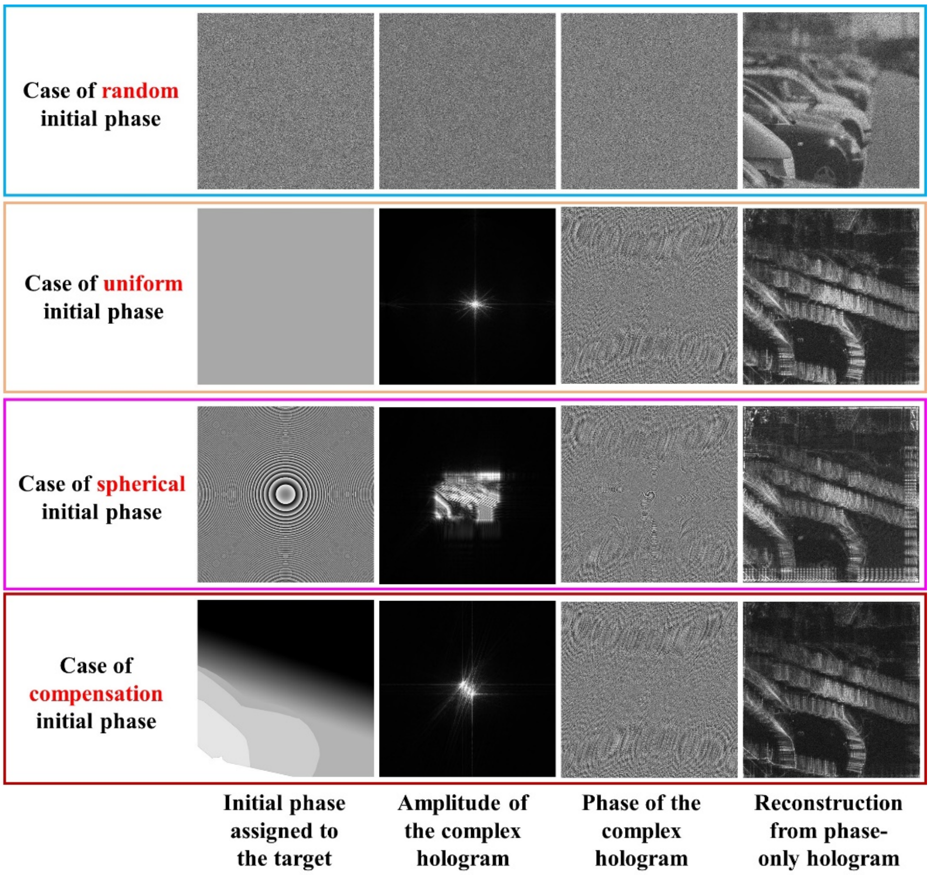

Fig. S2. Illustration of the influence of reconstruction from phase-only hologram by assigning different initial phase to the target object. The case of compensation initial phase is a smoothed phase distribution calculated according to the depth map.

3. Comparison of quality in reconstruction with NS-WRP method

Similar to our method, the CGH can also be generated in single backward diffraction calculation from the RGB-D data by using the algorithm based on nonuniform sampled wavefront recording plane (NS-WRP) [32]. However, since the manipulation of sampling always corresponds to a certain area of pixels rather than single pixel, it is difficult to achieve accurate depth control of single object point. In addition, since the sub-area of hologram with different pixel size has different frequency bandwidth, the aliasing artifacts may occur at those areas where the depth has discontinuity. Figure S3 shows the simulated reconstructions from Split-Lohmann CGH and NS-WRP based CGH. Compared with our method, we can find obvious aliasing artifacts (marked by yellow-dotted lines) in the reconstructions from NS-WRP based CGH.

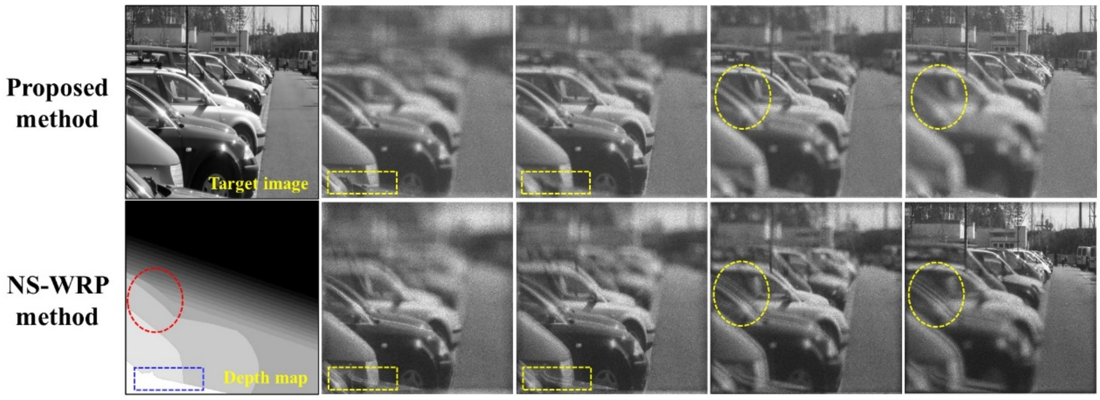

Fig. S3. Comparison of reconstructions between our method and NS-WRP method.