Fast Generation of Binary Phase-only Hologram

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Past research has proven that if the intensity profile of an object image is down-sampled and converted into a Fresnel hologram, the phase component of the hologram alone will be sufficient to reconstruct the object image favorably. A phase-only hologram derived with such method is known as the sampled phase-only hologram (SOPH) [1]. Generation of the SPOH is faster than techniques based on iteration [2], and the reconstructed image is brighter than that derived with error diffusion [3]. This paper provides a review on the method, and demonstrates with numerical simulation that it can be extended to the generation of binary phase-only hologram.

The proposed method for generating a binary SPOH, based on the parent method in [1], is outlined as follows. Let $I(x,y)$ and $d_{x;y}$ denote the intensity of a pixel at location (x,y) on a three-dimensional (3-D) surface, and its perpendicular distance to the hologram, respectively. A grid-cross lattice $S(x,y)$ is defined as

$$S(x,y)=\begin{cases}1 & (x \bmod M)=0 \; or \; (y \bmod M)=0 \; or \; (y \bmod M)=(x \bmod M) \; or \; (y \bmod M)=(M-x \bmod M-1) \\ 0 & otherwise\end{cases}, \quad (1)$$

where M is the down-sampling factor, and mod is the modulo operator. Next, $I(x,y)$ is down-sampled as given by

$$I_D(x,y)=I(x,y)\times S(x,y). \quad (2)$$

The 3-D surface is then converted into a Fresnel hologram $H(u,v)$ based on Fresnel diffraction. Assuming the size of both the hologram and the intensity image is $N\times N$, we have

$$H(u,v)\big|_{0\le u,v<N}=\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} I_D(x,y)\exp\left[i2\pi/\lambda\sqrt{(x-u)\delta^2+(y-v)\delta^2+d_{x;y}^2}\right], \quad (3)$$

where δ is the pixel size and λ is the wavelength. A binary SPOH (BSPOH) is obtained by setting the magnitude of the hologram to a constant value of unity, and binarizing the phase component, i.e.

$$H_{BSPO}=\exp^{iT[\arg(H(u,v))]}, \; (T[A]=\pi/4 \text{ if } -\pi/4\le A<3\pi/4, \text{ and } 5\pi/4 \text{ otherwise.}) \quad (4)$$

The standard image "Lena" is employed to illustrate the proposed method. The image is first down-sampled with the grid-cross lattice $S(x,y)$, and a 1024×1024 Fresnel hologram of the down-sampled image is generated with Eq. (3). The hologram is parallel to, and at an axial distance of 0.3m from the image. The wavelength of the optical beam is $633nm$. Subsequently, Eq. (4) is applied to obtain the binary hologram. The reconstructed image of the binary SPOH for *M*=12, 16, and 20 are shown in Figs. 1(a)-1(c). We observed that with larger values of *M*, the contrast and visual quality of the image is increased, while the resolution is jeopardized.

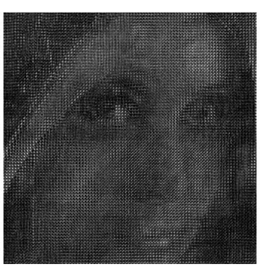
Fig. 1(a)

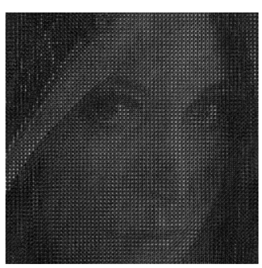
Fig. 1(b)

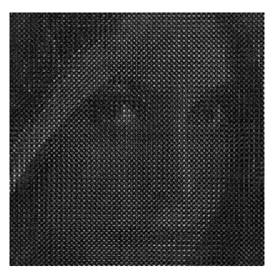
Fig. 1(c)

Fig. 1 (a)-(c) Reconstructed images of the binary SPOH based on *M*=12, 16, and 20, respectively

References

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3. P.W.M. Tsang, T.-C. Poon, "Novel method for converting digital Fresnel hologram to phase-only hologram based on bidirectional error diffusion," Opt. Express 21(20), 23680–23686 (2013).