Fast Generation of Binary Phase-only Hologram

Peter Wai Ming Tsang

Dept. of Electronic Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong
Tel.:852-3442-7763, E-mail: eewmtsan@cityu.edu.hk

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 SOPH 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 SOPH, 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

\[
S(x, y) = \begin{cases} 
1 & \text{if } (x \mod M) = 0 \text{ or } (y \mod M) = 0 \text{ or } (x \mod M) \text{ or } (y \mod M) = (M - x \mod M - 1) \\
0 & \text{otherwise}
\end{cases}
\]

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

\[
I_D(x, y) = I(x, y) \times S(x, y).
\]

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

\[
H(u, v) = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} I_D(x, y) \exp \left[ i2\pi \frac{\lambda}{\delta^2} (x-u)^2 + (y-v)^2 + d_{x,y}^2 \right],
\]

where \( \delta \) is the pixel size and \( \lambda \) is the wavelength. A binary SOPH (BSOPH) is obtained by setting the magnitude of the hologram to a constant value of unity, and binarizing the phase component, i.e.

\[
H_{BSOPH} = \exp \left\{ i \text{Tr} \{ \text{arg} \{ H(u, v) \} \} \right\}, (T[A] = \pi/4 \text{ if } -\pi/4 \leq A < 3\pi/4, \text{ and } 5\pi/4 \text{ otherwise})
\]

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 \( 1024 \times 1024 \) 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 SOPH 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)-1(c) Reconstructed images of the binary SOPH based on \( M=12, 16, \) and 20, respectively

References

IMID 2015 DIGEST