OpenHolo Algorithm Guide

(WRP :: SingleWRP)

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1. Introduction

Generating a hologram takes a long time. To overcome those problems, Shimobaba et al. recently introduced a method that uses a wavefront recording plane (WRP) to reduce the calculation time. In this method, a virtual plane is placed near the object. The optical field from the object to the computer-generated hologram (CGH) plane is calculated on the virtual plane first and then propagated to the CGH plane by a fast Fourier transform (FFT). The calculation time is reduced because the optical field is generated on the WRP instead of directly on the CGH plane. The WRP is close to the object, so the wavefront area (active area) from one object point on the WRP is small. The calculation time is reduced further if every point is parallel processed in a GPU and a LUT is applied. Weng et al. presented an upgraded WRP method for recording a larger hologram. However, in a CGH, a scale factor could be used to rearrange the 3D object to any size that is suitable for the system parameters. More recently, Tsang et al. presented an interpolated WRP approach. In that paper, the authors noted that the resolution of the scene image was generally smaller than that of the hologram.

2. WRP Algorithm

2.1 Single WRP Method

The basic concept of the WRP method was first introduced in "Simple and fast calculation algorithm for computer-generated hologram with wavefront recording plane". A virtual plane (called the WRP) is placed close to the object point and parallel to the hologram plane. Instead of direct calculation of the optical field from a 3D object to the hologram plane, the optical field is calculated on the WRP and then the FFT is used to generate the optical field on the hologram plane. The pixel pitch of the WRP is set to the pixel pitch of the hologram. Thus, sampling theory is not violated.

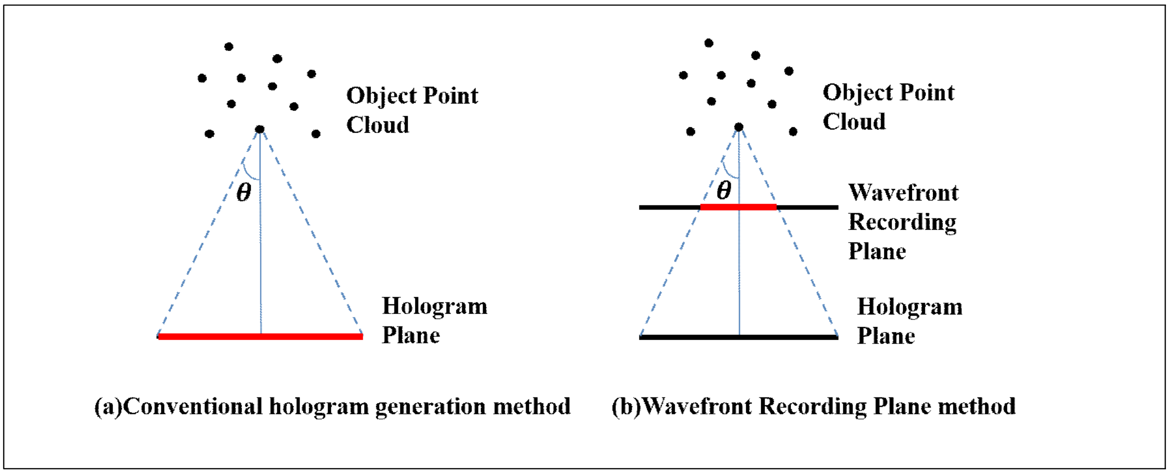

Fig 1. (a)conventional hologram generation method (b) Wavefront recording plane method

In the WRP, the intensity distribution of an object point located near the WRP may exceed that of object points far from the WRP. This problem reduces the quality of the reconstructed object. To enhance the quality, the WRP needs to be placed far enough from the object.

The WRP is placed parallel to hologram plane, so there is no violation of sampling theory.

- The number of pixel in active area is much smaller than that in hologram.
- Fresnel transform could be done by FFT

- Conventional point cloud hologram

$$U(x, y) = \sum_j^N \frac{A_j}{R_j} \exp(jkR_j)$$

- Wavefront recording plane

$$U_{WRP}(x, y) = \sum_j^{N_{WRP}} \frac{A_j}{R_{WRP\_j}} \exp(jkR_{WRP\_j})$$

$$U(x, y) = F^{-1}\left[F\left[U_{WRP}(x, y)\right]F\left[h(x, y)\right]\right]$$

$$h(x, y) = \frac{\exp(jkz)}{j\lambda z} \exp\left[\frac{jk}{2z}\left(x^2 + y^2\right)\right]$$

2.2 Computational complexity of WRP method

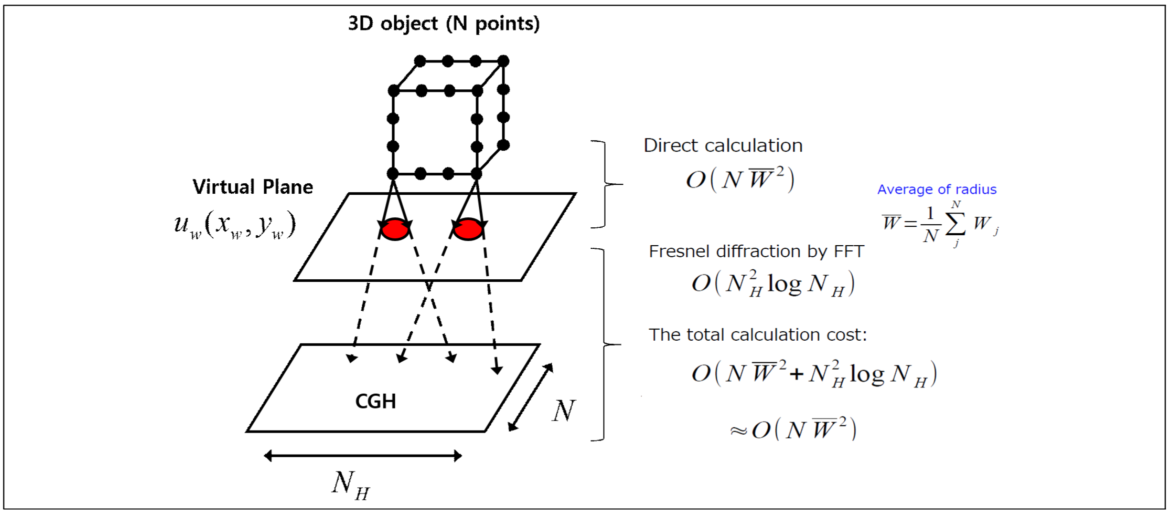

Fig 2. Computational complexity of WRP method

Algorithm Name	
Input	object, hologram_resolution, SLM_pitch
Output	Hologram
	for i=1: object_number $N = \lvert z_{object} - z_{wrp} \rvert \tan\left(\frac{\lambda}{2p}\right)$ **, is the radius of object point on the WRP,** $u_w(x_w,y_w) = \sum_{j}^{N} \frac{A_j}{R_w} exp(i\frac{2\pi}{\lambda}R_w)$, **is the complex amplitude of all points of 3D object on the WRP** $f(x,y) = \frac{\exp(ikz_{wrp})}{j\lambda z_{wrp}} exp\left[\frac{jk}{2z_{wrp}}(x^2+y^2)\right]$, **is the impulse response** $wrp = wrp + u_w(x,y)*h(x,y)$ **end** $Hologram(x,y) = F^{-1}[F[u_w(x,y)] \cdot F[h(x,y)]]$, **is Fresnel diffraction to Hologram**

Code 1. Algorithm 2.1.1. Pseudo Code

3. Reference

[1] Tomoyoshi Shimobaba, Nobuyuki Masuda, and Tomoyoshi Ito *“Simple and fast calculation algorithm for computer-generated hologram with wavefront recording plane"*, Optics Letters, 34, 3133-3135, 2009

[2] Anh-Hoang Phan, Mei-lan Piao, Sang-Keum Gil, and Nam Kim *“Generation speed and reconstructed image quality enhancement of a long-depth obejct using double wavefront recording planes and a GPU”*, Applied Optics, 53, 4817-4824, 2014