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**For a three-dimensional display using computer-generated holograms (CGHs), fast CGH calculations are required but calculation time can be reduced by introducing wavefront recording planes (WRPs). However the conventional multiple wavefront recording planes (M-WRPs) based full-color computer-generated hologram (CGH) have color uniformity problem caused by intensity distribution and high computation time due to the big distance between object points in the depth range and the WRPs. This paper proposes a method that creates WRPs based on the number of object’s point at each depth layer thus reducing the calculation time and also having higher intensity reconstructed images. The proposed method is confirmed by numerical and optical reconstruction.**

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1. Introduction

In recent years, advancement of hardware and technologies have created more demands for 3D television, AR, VR and many more 3D display technologies. Among all holography is the most prominent technique for reconstruction of all three dimensional (3D) information of an object in space and holographic projection can also achieve true 3D scene without wearable devices. In this technique, an object’s light field is recorded as interference fringes in the form of a so-called hologram. The physical process of light propagation in holography can also be simulated on a computer, called computer generated holograms (CGHs). However, an object consists of huge amount of three dimensional information; thus CGH generation is computationally costly.

To accelerate the generation of hologram many methods have been introduced so far. To reduce computational cost of holographic calculation Zhao et al. introduced a fast calculation method for point cloud gridding (PCG) method [1] where sub holograms are generated for each individual depths of the object and finally accumulated the sub holograms to form a complete hologram. Look-up table method [7-9] are used to store pre-computed calculation and use them later for faster generation of hologram but unfortunately, these methods require large memory for data storage.

Shimobaba et al. introduced wavefront recording plane (WRP) where a virtual plane, WRP, is placed close to the object point and parallel to the hologram plane [2-3]. Instead of direct calculation of the optical field from a 3D object to the hologram plane, the optical field only calculate the active area of the WRP, as shown in Fig. 1, and then propagate to the hologram plane by the Fast Fourier Transform (FFT).

Rj

WRP

Hologram

Active Area

P1(x,y)

Fig. 1. Hologram generation using WRP

The light field of each pixel of the WRP is calculated by summing the contribution of each point of the object according to equation (1),

, (1)

Here *Rj* is the distance between *j*th point and the WRP, shown by equation (2), *N* is the number of object points, *λ* is the wavelength of the light and *Aj* is the intensity of the *j*th object point.

 (2)

However, for long depth objects, due to large distance between the object points and WRP the active area size is also large; thus computation time is still high. Later Anh-Hoang et al proposed double WRP to reduce the calculation further [4] where they introduced two WRPS at two different distances from object. The usage of GPU and lesser distance between object and the WRPS lowered the calculation time. Arai et al. proposed acceleration of CGH generation using tilted WRP which uses “Least Square Tilted WRP method” and “RANSAC Multi-Tilted WRP method.” to maintain the minimum distance between the WRP and curved sides of the object [5]. Later, Hasegawa et al proposed a multiple WRP (M-WRPs) method to optimize the number of WRPs and their arrangements automatically [6]. Recently, Piao et al proposed a method for image quality enhancement for M-WRPs [11]. In this method WRP is set at each layer using fixed active area size. However, fixed activation area might over-estimate or under-estimate the color uniformity and for objects with few object point at different depths computation would be slower. Moreover, in conventional M-WRPs object is divided into several parts based on fixed depth range and a WRP is set in the middle of each depth range, as shown in Fig. 2.

Depth

Range 1

Hologram

Fig. 2. Hologram generation using conventional M-WRPs

Depth

Range K

WRP 1

WRP k

**Point cloud object**

Unfortunately, for each depth range, higher the distance between the object points in the farther depth and the WRP the higher will be calculation time for CGH generation.

Therefore, in this paper, a fast and efficient method is proposed for reduced multiple wavefront recording plane (RM-WRP). The proposed method creates WRP based on the number of object points in each depth layer and neighbor. Due to prioritizing depth layers with higher number of object points and optimum distance between the objects points and WRP faster calculation with higher reconstructed image can be achieved.

2. Proposed Reduced M-WRP method

A. CGH generation of non-uniform objects with Reduced M-WRPs method

In the proposed Reduced M-WRPs (RM-WRPs) method, point cloud object is considered as sub-layers and WRP is set based on the number of object points in each depth layer, as shown in Fig 3. Firstly, WRP is set closer to the farthest layer. Onwards each depth layer is iterated and number of object points is counted. A new WRP is set, if and only if, the next layer has more number of object points than the previous layer, *Nk+1>NK,* otherwise wavefront of all object points from the current depth layer is propagated to the previous WRP.

Hologram

Fig. 3. Hologram generation using RM-WRPs

**Point cloud object**

N1, 2 = 6

N3 = 2

N4 = 4

N5, 6 = 6

Nk = 4

WRP 1

WRP 2

WRP 3

WRP 4

WRP k

B. CGH generation of uniform objects with Reduced M-WRPs method

In the proposed Reduced M-WRPs (RM-WRPs) method, point cloud object is considered as sub-layers and WRP is set based on the number of object points in each depth layer, as shown in Fig 3. Firstly, WRP is set closer to the farthest layer. Onwards each depth layer is iterated and number of object points is counted. A new WRP is set, if and only if, the next layer has more number of object points than the previous layer, *Nk+1>NK,* otherwise wavefront of all object points from the current depth layer is propagated to the previous WRP.

Hologram

Fig. 3. Hologram generation using RM-WRPs

**Point cloud object**

N1, 2 = 6

N3 = 2

N4 = 4

N5, 6 = 6

Nk = 4

WRP 1

WRP 2

WRP 3

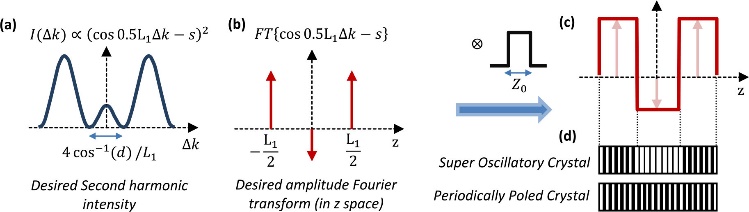
WRP 4

WRP k

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 (1)

 Fig. 1. Caption text with descriptions of (a), (b), and (c).

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(1) 2D and 3D image files and video must be labeled “Visualization,” not “Movie,” “Video,” “Figure,” etc.

(2) Machine-readable data (for example, csv files) must be labeled “Data File.” Number data files and visualizations consecutively, e.g., “Visualization 1, Visualization 2….”

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**Sample dataset citation**

1. T. Ireno and R. Tadaa, "Chemical and mineral compositions of sediments from ODP Site 127-797" (Geological Institute, University of Tokyo, 2009), [**http://dx.doi.org/10.1594/PANGAEA.726855**](http://dx.doi.org/10.1594/PANGAEA.726855).

**Sample code citation**

1. Zima Engineering, ZIMA-CAD-Parts: Application for management of CAD files and projects (version 0.5.0-beta1) [software] (2013), [**http://sourceforge.net/projects/zima-cad-parts/**](http://sourceforge.net/projects/zima-cad-parts/).

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