Synthesis algorithm of wide-viewing angle full-color depth-map computer-generated holograms

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Abstract: Wide-viewing angle full-color computer-generated hologram has been actively developed and studied by many researchers because it can display realistic and high quality holographic 3D images. In this paper, we propose synthesis algorithm of the wide-viewing angle full-color depth-map computer-generated hologram, and present key technologies such as field mapping, color matching, and filtering method for realistic and accurate calculation.
Key Word—*Color holography, Computer holography, Digital holography, Holographic display.*

1. Introduction

Full-color wide viewing angle Computer-generated holograms (CGHs) can improve narrow viewing angles and limited resolution, which are the disadvantages of conventional holograms, and are being researched and developed by many researchers because these technology can represent 3D objects realistically [1-3]. Typical calculation methods for CGH that can represent 3D objects very realistically are point cloud, polygon, and depth-map method. The depth-map has the advantage of reducing computation time and memory when calculating complex objects which have a lot of curves compared to other methods of calculating CGH [4]. The key factors in wide-viewing angle full-color CGH design are algorithm to synthesize after segmentation calculation, several techniques for realistic representation, and combination technique of R/G/B CGH components. In this paper, we are suggesting synthesis algorithm of CGHs with full-color wide viewing angle and key technologies for realistic representation of 3D objects.

2. Large-scale CGH segmentation

In this section, we will explain how to segment and synthesize large-scale and high-definition CGHs. General segmentation method and our method are compared in the Fig. 1. For the calculation, large-scale high-definition CGH, the general method performs division in the object plane as shown in Fig. 1(a), while the approach we propose is the division in the viewing zone as shown in Fig. 1(b). Using the proposed method, many techniques such as occlusion culling and rendering can be easily applied to improve the quality of CGH.

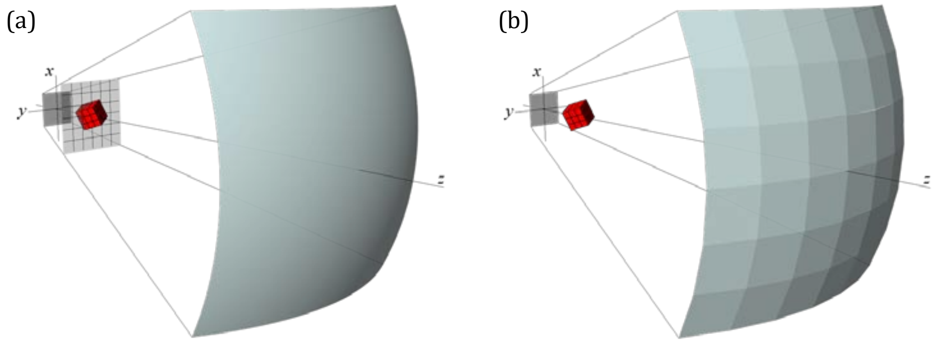

Fig. 1 (a) Segmentation of object plane to observe from various angles, (b) Segmentation of viewing window to observe from various angles

The key to the proposed synthesis method is to multiply the carrier waves by CGH for each direction and combine them. More precisely, calculation of the CGH for each direction and multiplication the result by the carrier wave in that direction are carried out. Finally, we combine these results. The formula for this is represented as

$$total\_CGH = \sum_m \sum_n \exp\left(j\left(k_{m,n,x}x + k_{m,n,y}y + k_{m,n,z}z\right)\right)F_{m,n}(x,y) \cdot \tag{1}$$

where m, n are the indices of viewing direction and $F_{m,n}(x,y)$ and $\exp\left(j\left(k_{m,n,x}x + k_{m,n,y}y + k_{m,n,z}z\right)\right)$ are complex signal and carrier wave terms, respectively. Numerical simulation result is shown in Fig. 2. Methods for obtaining simulation results are as follows. First, calculate the CGH for the segmented area (low resolution) of the observation area. The next step is the same as Eq. (1), change the calculated CGH (low resolution) to the original resolution and multiply the carrier wave. Finally, we synthesize the results for all viewing angles.

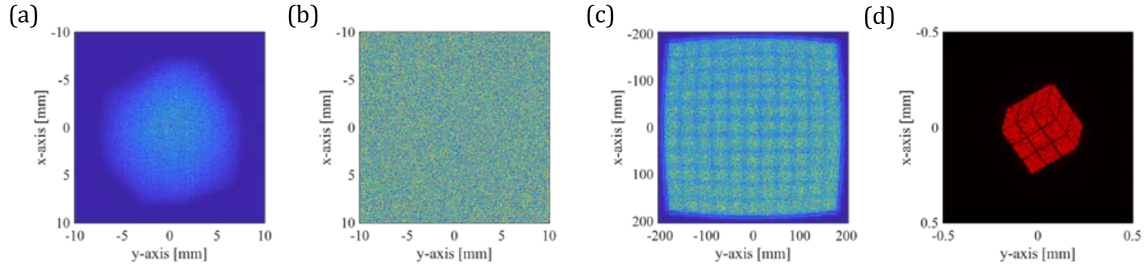

Fig. 2. (a) Amplitude profile and (b) Phase profile of total CGH. (c) Signal distribution in the viewing zone. (d) reconstructed holographic image

3. Field mapping, Color CGH, and Filtering

The field mapping method as shown in Fig. 3(a) is mapping field using the rotation transformation matrix and the gridded interpolant method to represent the correct observation image at the off-axis. This method is applied to low resolution CGH with division computation. The CGHs with the field mapping method are multiplied on each carrier wave. At this time, since the diffraction angle varies depending on the wavelength, it is necessary to multiply this by one standard carrier wave to match signals of all colors at the same position, as shown in Fig. 3 (b). Otherwise, in the view of wide angle, the more severe color separation will occur when you observe that. The full-color holograms can be designed by applying the carrier wave calculated by the blue wavelength with the smallest diffraction angle to the CGH of red and green components. Finally, when synthesizing the results for all viewing angles, the low resolution CGH is changed to the original resolution and noise is included. This problem could be solved by applying the signal filtering method shown in Fig. 3(c). By filtering each resized red, green, and blue signal to the blue wavelength signal size, it is possible to reduce the cross talk phenomenon with the adjacent signals divided viewing window and improve the quality of the reconstructed image.

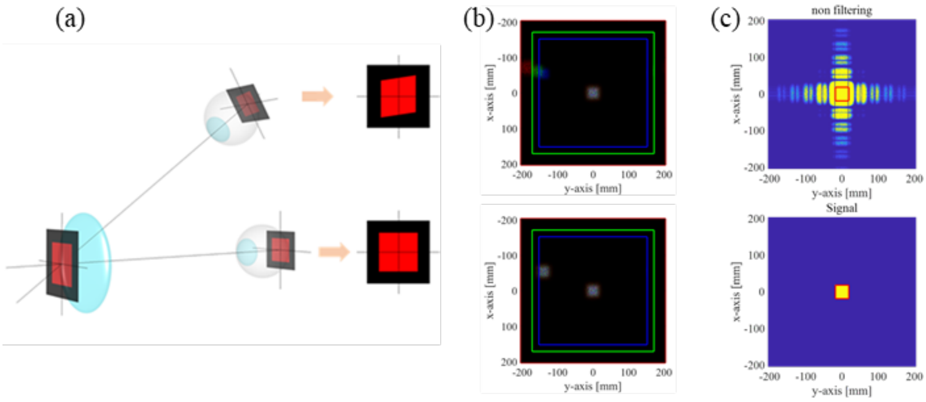

Fig. 3. (a) Schematic of field mapping method for two different observed angles. (b) Full-color signal distribution before and after color matching with central and side views. (c) Signal distribution before and after filtering method.

4. Conclusion

We proposed the viewing zone segmentation method for the wide-viewing angle full-color CGH. We also introduced technologies such as field mapping, color matching and filtering method for representation of 3D object more realistically and accurately. Based on these techniques, we have established the efficient calculation method for the full-color wide viewing angle CGHs with high resolution and small pixel pitch. Our future works will be focused on research for the algorithm to improve the quality of the efficient color filter for the color implementation of the designed CGH.

5. References

[1] 1. J. Hahn, H. Kim, Y. Lim, G. Park, and B. Lee, "Wide viewing angle dynamic holographic stereogram with a curved array of spatial light modulators," Opt. Express 16, 12372-12386 (2008).

[2] Y. Tsuchiyama, K. Matsushima, S. Nakahara, and Y. Sakamoto, "Full-Color High-Definition CGH Using Color Filter and Filter Design Based on Simulation," in Imaging and Applied Optics 2016, OSA Technical Digest (online) (Optical Society of America, 2016), paper DW5I.4.

[3] K. Matsushima and N. Sonobe, "Full-color digitized holography for large-scale holographic 3D imaging of physical and nonphysical objects," Appl. Opt. 57, A150-A156 (2018).

[4] J. Roh, K. Kim, E. Moon, S. Kim, B. Yang, J. Hahn, and H. Kim, "Full-color holographic projection display system featuring an achromatic Fourier filter," Opt. Express 25, 14774-14782 (2017).