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High-Definition Image CGH Created by the Polygon-Based Method and its Reconstruction by White Light

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1. Introduction

Recently, we presented polygon-based high-definition CGHs (PBHD-CGH) that reconstruct brilliant 3D images of occluded virtual 3D scenes [1]. These PBHD-CGHs are fabricated using a laser lithography system available on the market. All PBHD-CGHs created so far were Fresnel-type holograms, i.e. all objects comprising the 3D scene were set in the position of several centimeters behind the hologram. If we would place the objects too close or so as to overlap the hologram plane, the shade and texture of the objects could be lost in the optical reconstruction. This is generally caused by image-type binary holograms not only in use of the laser lithography system. Binary-amplitude fringe patterns are commonly unable to reconstruct object shading and texture-mapping, because amplitude information of the object field is removed by the binarization if the object is too close to the hologram.

In this paper, optimized error diffusion is applied to encoding binary-amplitude image-type CGHs in order to improve reconstruction of surface shading and texture-mapping. In this technique, a set of coefficients of error diffusion are iteratively optimized so that brightness of a test pattern is reproduced in simulated reconstruction. We will demonstrate some actual image-type high-definition CGHs created by the proposed technique and verify that the CGHs can be reconstructed by white light source without much chromatic aberration.

2. Technique of optimized error diffusion

The 3D scene used to optimize diffusion coefficients is shown in Fig. 1. In the scene, a test pattern of 2D image is placed in front of the hologram. The fringe pattern is generated by numerical interference between the calculated object wave and reference wave, and then the binary fringe of the image CGH is produced by binarization employing error diffusion. Reconstruction of the CGH is numerically simulated by a numerical image formation technique based on wave-optics. Reproducibility of brightness of the test pattern is evaluated by root mean squared error (RMSE) between the defined and measured brightness of the test pattern. The diffusion coefficients are iteratively modified employing simultaneous perturbation algorithm (SPA) [2] so that the RMSE decreases. These coefficients optimized for the test pattern are applied for binarization of the CGH fringe pattern for 3D object.

Figure 2 shows examples of simulated reconstruction of the image-type binary CGH encoded by a simple threshold in (a) and the optimized error-diffusion in (b). It is verified that brightness of the test pattern is reproduced better with the optimized error-diffusion than that with the simple threshold.

3. Creation of image-type high-definition CGH

We created an image-type high-definition CGH named “i-Shion” by the error diffusion technique using the coefficients optimized for the test pattern. The total number of pixels of the CGH is more than 4 G pixels. The 3D scene of the CGH is shown in Fig. 3. Simulated reconstruction of the CGH encoded by a simple threshold is shown in Fig. 4 (a) and the optimized error-diffusion in (b). Shading of the object is obviously

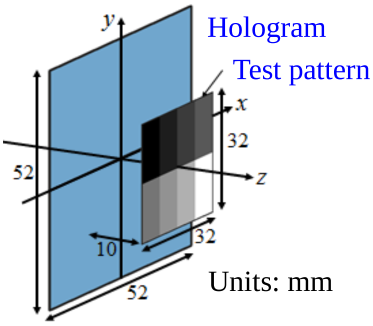


Fig.1 The 3D scene used for optimization.

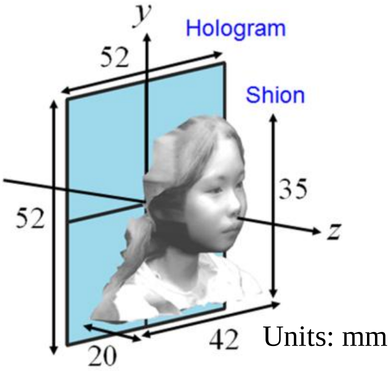
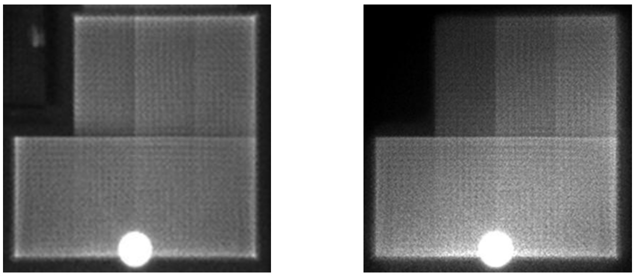
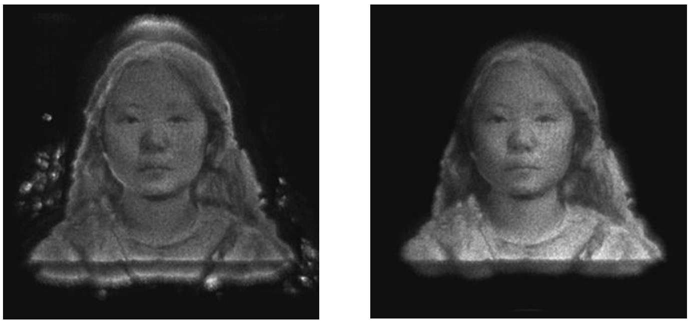


Fig.3 The 3D scene of “i-Shion”.



(a) (b)

Fig.2 Simulated reconstruction of the binary CGH of the test pattern encoded by a simple threshold (a) and the optimized error-diffusion (b).



(a) (b)

Fig.4 Simulated reconstruction of “i-Shion” with a simple threshold (a) and the optimized error-diffusion (b).

improved by employing the proposed error diffusion technique.

4. Optical reconstruction and conclusion

Optical reconstruction of “i-Shion” by using a white light source is shown in Fig. 5. It is verified that the 3D surface with shading and texture-mapping is clearly reconstructed. However, it was also shown that the shade and texture are not completely reconstructed in every viewpoint.

References

1) K. Matsushima and S. Nakahara: “Extremely high-definition full-parallax computer-generated hologram created by the polygon-based method”, Appl. Opt. **48**, H54-63(2009).

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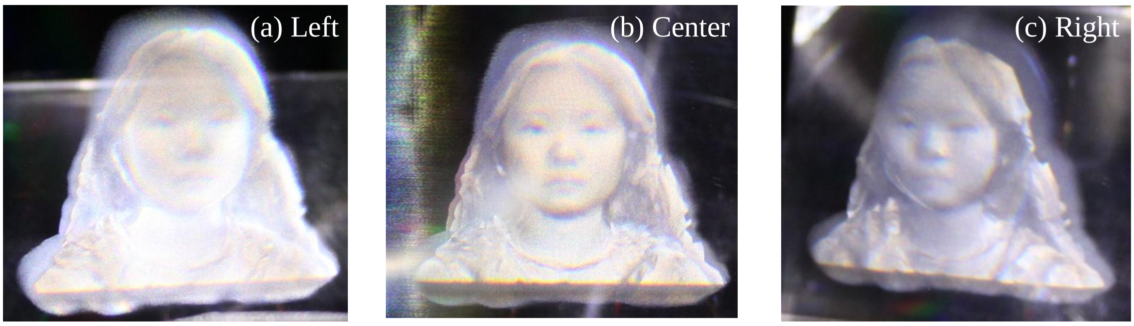

Fig.5 Photographs of optical reconstruction of the image-type high-definition CGH “i-Shion” by white light. Photographs (a) – (c) are taken from different viewpoints.