Reducing the Effect of Crosstalk Noise from Defocused Multi-Depth Holographic Image with a Rasterize Encoding Method

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ABSTRACT

Crosstalk noise from defocused light affects the image quality of target image in multi-depth holographic display system. In this study, we propose a defocused light noise reduction with the rasterize encoding method. With the objective image quality analysis, it proves that the proposed method could improve the image quality.

1. INTRODUCTION

In principle, computer generated holography can provide continuous parallax, depth perception, and can solve the basic problems of parallax 3D display technology, accommodation - convergence conflict. After the modified Gerchberg-Saxton algorithm (MGSA), we can generate multi-depth holograms are superimposed on the same axis. From the reconstruction results, we can observe that the multi-depth holograms are overlapped in one direction viewpoint. Then, the noise will be around the image. But, it is not the optical noise, it is the defocused images. Like our life experience, when we focus on one object, the other objects which are defocused will be blurred. However, since the objects in real world are solid, the out-of-focus objects will be blocked by the object which we focus on. Because of the holograms are optical information, the out-of-focus images will be diverging and disturb the reconstruction image.

Multi-depth reconstruction images are performed on axis, it is often interfered by defocused light, which causes problems in reconstructing image recording. Therefore, the rotating grating optical system is designed to reduce defocused light influence and effectively improve image quality. Root mean square error (RMSE), relative diffraction efficiency (RDE), signal to noise ratio (SNR) and speckle contrast (SC) [1-4] are used for image evaluation, and the image quality is significantly improved from the analysis results.

2. RELATED WORK

In recent years, computer-generated hologram (CGH) have developed rapidly. CGH can separate into phase modulation and amplitude modulation, and the phase-only CGH has higher diffraction efficiency, so phase-only CGH is used more than the amplitude-only CGH. Among them, only the most famous phase CGH is the Gerchberg–Saxton algorithm (GSA) proposed by R.W Gerchberg and W.O Saxton in 1972[5]. The GSA is a simple method that is easy to modify, but it uses a random phase in the initial state, resulting in strong fluctuations in the reconstructed image. These noises will reduce the quality of the reconstructed image, and in order to improve this problem, many people propose different algorithms to reduce noise [6-8]. The method used in this study is the modified Gerchberg-Saxton algorithm (MGSA) proposed by Hwang and Chang et al. in 2009 [9].

The difference between GSA and MGSA is that MGSA is based on Fresnel conversion instead of Fourier transform to omit the computational complexity, and in optical reconstruction, no lens can be used for imaging. MGSA can not only produces multi-depth images, but also effectively reduces noise after many iterations. However, the Crosstalk noise in this study is not a general noise, but a speckle caused by the defocus image. Therefore, it is proposed to use the grating mask and the rasterize images to effectively filter the defocused light.

3. EXPERIMENT

For the purpose of improving the problem of reducing image quality by defocused light, for the original image, we rasterized all of the original images as show in Fig. 1. And in the optical structure, we use the grating mask to filter the multi-depth rasterize images, the optical structure is designed as Fig.2.

We used monochromatic light (532nm DPSS laser) first. For the SLM, we used Jasper Display with model number Kit JD8554, the resolution and pixel pitch are 1920*1080 pixels and 6.4μm, respectively. The laser light source goes through spatial filter and a convex lens for adjusting to plane wave. Then, the optical wavelengths are incident to SLM for reconstructing POF, which could reconstruct image by diffraction. The grating mask is placed between the SLM and the imaging position. When the reconstructed rasterized image conforms to the grating mask, the multi-depth rasterize defocus image can be effectively filtered. We placed a charge-coupled device (CCD) in the reconstructed position to simulate the observer's eye, record the observed image and perform an image quality assessment.

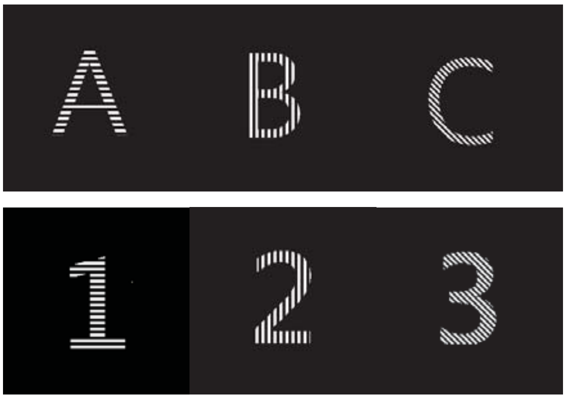


Fig.1 The rasterize images

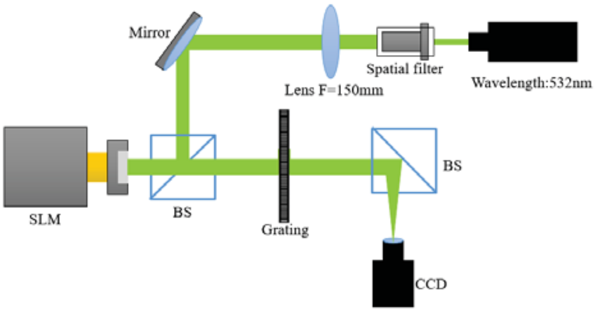
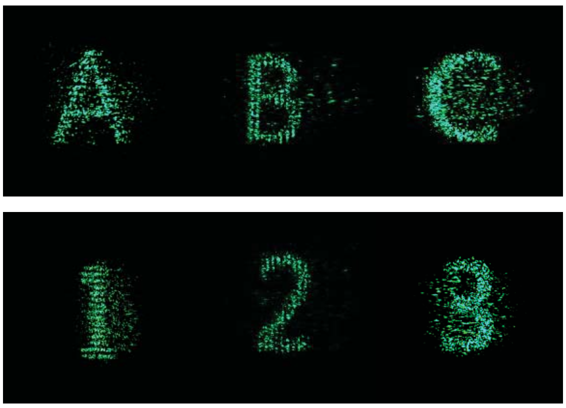


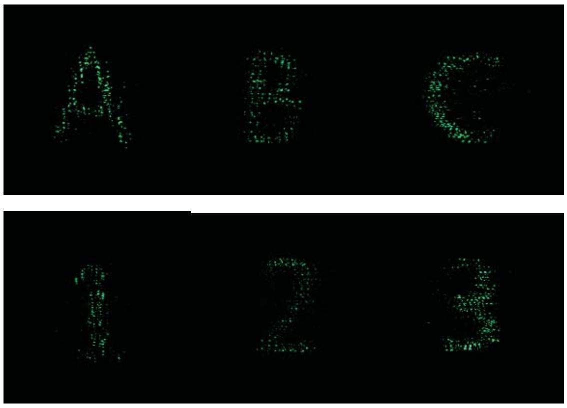
Fig.2 Optical system

4. RESULTS

In this study, we recorded two sets of multi-depth rasterized reconstructed images, one is "A", "B", "C" and the other is "1", "2", "3". Their reconstruction distances are "A", "1": 0.3m, "B", "2": 0.4m, "C", "3": 0.5m. The results captured by CCD are shown in Figure 3(a)(b). Figure 3(a) shows a multi-depth rasterized image without a raster mask. The object information will be calculated and output phase only function by MGSA. The calculation process of MGSA is shown in Fig. 4. The iteration number are 20. Fig. 3 (b) shows the reconstructed images which are filtered by rotating grating mask. The result is effective in reducing the effects of out-of-focus images.



(a)



(b)

Fig.3 The reconstruction results A、1: 0.3 m, B、2: 0.4 m, C、3: 0.5 m. (a) without grating (b) with rating

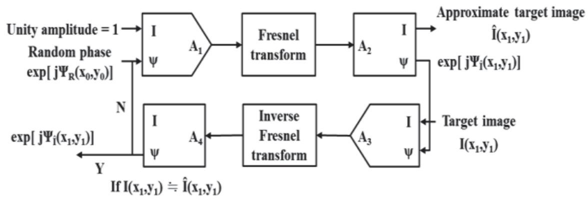


Fig.4 The flowchart of 3D MGSA

To effectively solve the effect of defocused light, a rotating grating mask and the rasterize of algorithm are used for the image reconstruction design to effectively separate non-image light and largely enhance the image quality as shown in Figure 2. Root mean square error (RMSE), relative diffraction efficiency (RDE), signal to noise ratio (SNR) and speckle contrast (SC) are utilized in this study for evaluating the image reconstruction [1-4]. The experimental result is captured by FLIR Blackfly S GigE with 85mm/F1.8-16 zoom lens equipped on the tripod to simulate the viewer's eyes, and the recorded images are further analyzed with RMSE, RDE, SNR, and SC, show in Table 1. With above image quality optimization, the reconstructed image is also analyzed and evaluated the quality, where the result appears remarkable enhancement.

Table 1 image quality assessment

	Without grating mask					
Word	A(0.3m)	B(0.4m)	C(0.5m)	1(0.3m)	2(0.4m)	3(0.5m)
RMSE	0.0191	0.0173	00.0226	0.0111	0.0141	0.0134
RDE	65.3685%	78.2783%	79.0397%	87.5125%	83.7531%	95.3977%
SNR	2.7590dB	5.5675 dB	5.7645 dB	8.455 dB	7.122 dB	13.165 dB
SC	24.94%	28.28%	29.77%	23.02%	30.31%	27.20%
	With grating mask					
Word	A(0.3m)	B(0.4m)	C(0.5m)	1(0.3m)	2(0.4m)	3(0.5m)
RMSE	0.0038	0.0032	0.0022	0.002	0.0011	0.0016
RDE	97.9443%	99.0860%	99.7472%	99.521%	99.8735%	99.9282%
SNR	16.780 dB	20.350 dB	25.961 dB	23.182 dB	28.972 dB	31.438 dB
SC	15.44%	19.32%	17.37%	16.65%	25.34%	16.54%

5. DISCUSSION

It can be seen from the experimental results that the image passing through the grating mask is darker than the image not passing through the grating mask because the grating sheet blocks half of the light and weakens the light intensity. But in the darkroom, this will not affect our viewing of the image.

In this experiment, multiple two-dimensional images are superimposed to form a multi-depth image. It can be seen in the experimental results that the interference of the out-of-focus image is significantly reduced. The 3D image is also a multi-depth image. If the image proposed by this experiment is rasterized for use on the three-dimensional image, the spot caused by the defocus image can also be reduced.

6. CONCLUSION

So far, the problem always encountered when reconstructing the multi-depth images by SLM is that the image quality will be affected by defocus light. The proposed system can reduce the SC 9 % than convention method. In this study, the characteristics of the grating are used to change the original image to reduce the influence of the defocused image. It proves that the proposed method could effectively enhance the three-dimensional computer-generated holography image quality.

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