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A novel reconstruction method using the Phase only information of the Computer Generated Hologram

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***Abstract*—The studies that have been carried out so far, the reconstruction process of the phase hologram can be realized by a single phase hologram. In this study, on the basis of a single phase hologram, this process will be carried out with the phase information which is obtained from a single hologram. To reconstruct the test object image, two different methods will be used: (1) the image will be reconstructed with using single phase information of single hologram, (2) the image will be reconstructed with using single phase information of more than one hologram (In this study 4 holograms are used.) This method is same of the phase shifting hologram using with 4 holograms. In this study, only used numbers of holograms and also their expressions are different. This method is used in this study for the first time. To obtain the single phase value for holograms, with using different methods, the Fourier transform algorithm will be used. Consequently, the simulations will be achieved in Matlab and results of simulations are compared.**

***Keywords*—reconstruction, single phase, single hologram**

I. Introduction

In 2D imaging, only the wave intensity is recorded and the phase information having knowledges depth of image is lost. With holographic method, developed in the 1974s by Dennis Gabor, the information of the wave intensity and phase can be reconstructed [1]. Holography is a technique of recording and reconstruction of a three dimensional (3D) object field with its amplitude and phase [2, 3]. The 3D object hologram can be produced mathematically in computer and reconstructed as computer generated holograms (CGH) [8, 10]. There has been a great deal of application fields of holography like digital holographic microscopy, holographic tweezers, 3D- television and interferometry [4, 7]. There are two different kind of holograms: amplitude hologram and phase hologram. In this paper the phase hologram is used.

Computer generated phase hologram can also be processed directly in digital form by various methods. In optically, the phase hologram sent directly to the phase-modulated SLM (spatial light modulator) and calculated 3D hologram of the object image can be obtained [11, 13].

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With using complex field, calculated from digital holograms in the Fresnel or Fourier domain, the numerical reconstruction of 3D objcets can be obtained. Also by using phase-shifting techniques, the diffracted complex field of 3D object can be calculated. However, after sending obtained only-phase information of this complex field to SLM, the real time optical reconstruction is achieved, the phase shifting technique requires more than one hologram [14].

In previous study, the real time optical reconstruction is done with only-phase information calculated by continuous wavelet transform in computer [15].

In this paper, with using phase shifting methods [16] with four holograms and Fourier transform technique [17, 18] for the first time, the obtained phase hologram is reconstructed **(PS4HSP; Phase Shifting with 4 Holograms Single Phase Method).** PS4HSP method is compared with Single Hologram Single Phase Method **(SHSP)**. SHPS is a method of reconstruction of the phase hologram, which obtained by using the phase information found with Fourier Transform from single hologram. Finally, the results of the simulations are given.

Consequently, the reconstructed image, obtaining with PS4HSP method, is more bright and single. Whereas, the reconstructed image, obtaining with SHSP method, is noisy and double. Also its brightness is very low.

II. Theoretical Aspects and Simulations

A. *Reconstruction with SHSP method*

In this section, the single phase hologram, whose amplitude is one, is created from phase only information of constructed with computer generated hologram and reconstructed the object with taking an inverse fast Fourier transform (IFFT) of this phase hologram. For obtaining the phase information in this holography, the Fourier transform algorithm proposed by Takeda for the first time in 1982 is used.

$$g(x,y) = a(x,y) + c(x,y)e^{i2\pi f_0 x} + c*(x,y)e^{-2\pi f_0 x} \quad (1)$$

where, $c*$ is the complex conjugate of c.

$$c(x,y) = b(x,y)\frac{e^{i\psi(x,y)}}{2} \quad (2)$$

$$c^*(x,y) = b(x,y)\frac{e^{-i\psi(x,y)}}{2} \quad (3)$$

To find the phase information of this hologram, the Fourier transform is applied to (4).

$$G(f,y) = A(f,y) + C(f - f_0, y) + C^*(f - f_0, y) \quad (4)$$

Also fast Fourier transform is applied row by row for holography. Following this step, the maximum frequency point of collected phase is found. With using this finding frequency point, the filtering process has been applied. Finally, c(x, y) is obtained with taking an inverse fast Fourier transform (IFFT) row by row and the real and imaginary parts of c(x,y) are found. Using with this parts of c(x, y), the phase information is obtained:

$$\varphi(x,y) = \tan^{-1}\frac{\Re e\{c(x,y)\}}{\Im m\{c(x,y)\}} = \psi(x,y) \bmod \pi \quad (5)$$

With using this phase information, obtaining by Fourier transform method, the phase hologram is created. the amplitude value of this phase hologram is taken one.

$$h(x,y) = \exp(i\varphi(x,y)) \quad (6)$$

On the basis of the phase hologram *h(x, y)*, the image reconstruction process is fulfilled in (7).

$$\Gamma_p(\zeta,\eta) = \Im^{-1}\{h(x,y)\} \quad (7)$$

(ζ,η) is the coordinates of image plane. With taking an inverse Fourier transform of phase hologram, the reconstruction of 3D image is obtained digitally.

B. *Reconstruction with PS4HSP method*

In this section, the phase hologram, whose amplitude is one, is reconstructed from phase information. The phase information is obtained with Fourier transform technique, proposed by Takeda for the first time, of four holograms created by using phase shifting methods in digitally. The image is reconstructed with taking an inverse Fourier transform of this phase hologram.

According to the phase shifting technique, by changing the phase of the reference *I(0), I(π/2), I(π), I(3π/2)* holograms are obtained. Equation (8) is used to obtain complex amplitude from four holograms [19].

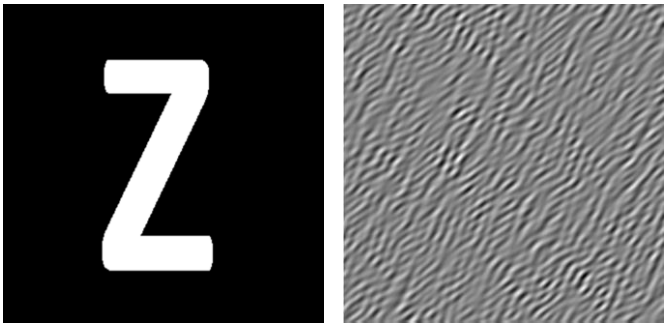
$$g(x,y) = [\{I(0) - I(\pi)\} + i\{I(\pi/2) + I(3\pi/2)\}] / 4G_r \quad (8)$$

G_r, is the amplitude of the reference beam and is taken one.

Consequently, according to the Fourier transform technique proposed by Takeda, the single phase value is obtained from g(x, y) by using (4) and (5) and with this phase information, the phase hologram is created. Also the amplitude value of hologram is accepted as one. Finally the reconstruction process is achieved by (6) and (7).

III. Simulation Results

In this section, the simulation results of the reconstruction methods are given. For reconstruction of 3D image with CGH in digitally, firstly the single hologram is created. In this study the Z letter with 256X334 dimensional is used and it is given in Fig. 1(a). The hologram of the Z letter is presented in Fig. 1(b).



(a) (b)

Figure1. (a) Test object, (b) the simulated digital hologram of test object

The reconstructed image of the hologram with using SHSP method in Fig. 1(b), is given in Fig. 2

Figure2. The image reconstructed by using SHSP method from the hologram in Fig. 1(b)

On the other hand, according to the phase shifting technique, obtaining 4 holograms *I(0), I(π/2), I(π), I(3π/2)* are given in Fig. 3(a), 3(b), 3(c) and 3(d) respectively. In addition, g(x, y), the complex field obtained from these holograms with phase shifting technique (see (8)), is presented in Fig. 3(e).

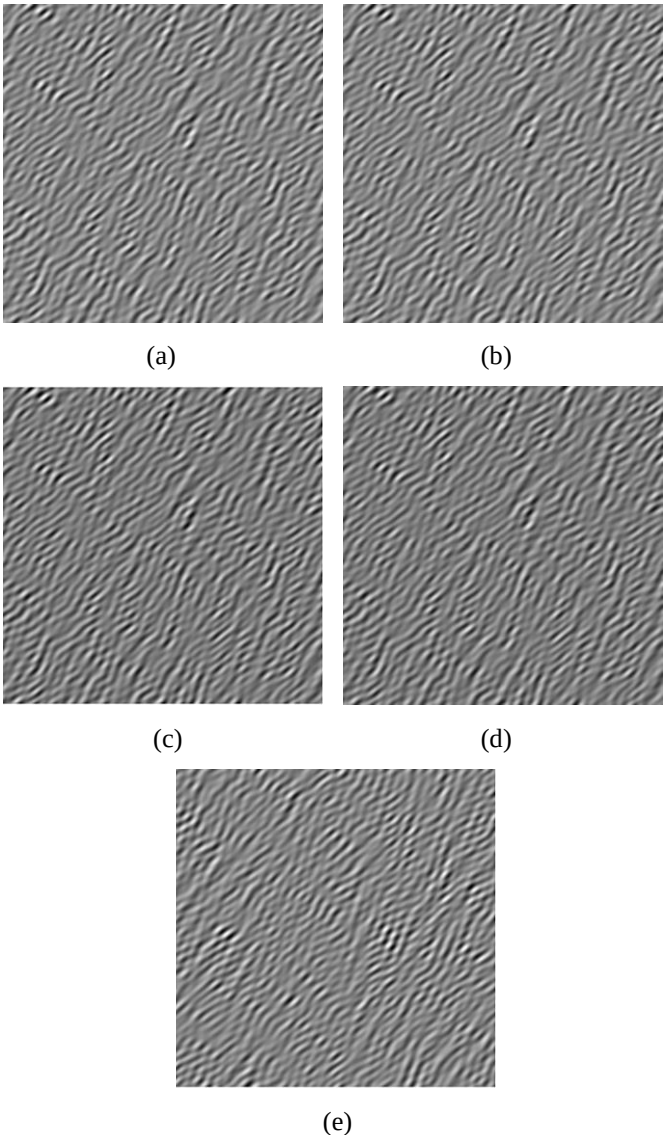


Figure3. (a) *I(0)* hologram (b) *I(π/2)* hologram (c) *I(π)* hologram (d) *I(3π/2)* hologram (e) g(x, y), the complex field of 4 holograms (see (8))

Finally, the reconstructed image obtained from g(x, y) complex field by using PS4HP methods is presented in Fig. 4.

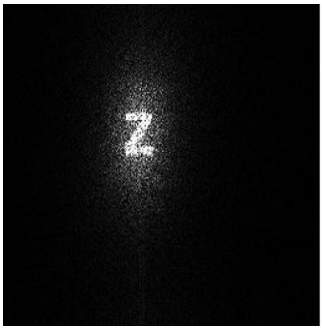


Figure4. The reconstructed image obtained from g(x, y) complex field in Fig. 3(e) by using PS4HSP method

IV. Conclusions

Consequently, the reconstructed image obtaining with PS4HSP method is more bright and single. Whereas, the reconstructed image obtaining with SHSP method is noisy and double. Also its brightness is very low. According to these reconstruction results, PS4HSP method is more useful than SHSP method. In addition to these, diffraction efficiency for each method will be represented in presentation.

References

[1] M. Bayraktar, M. Özcan, "Surface Deflection and Vibration Analysis Using Holographic Interferometry,"Eleco, 2008.

[2] H. J. Caulfield, Handbook of Optical Holography, Academic, New York, 1979.

[3] P. Hariharan, Optical Holography, Cambridge University Press, Cambridge, 1984.

[4] L. Bouamama, M. Bouafia, G. Wernicke, S. Krüger, and H. Gruber, "Real time opto-digital holographic microscopy," Catalysis Today 89 2004, pp. 337-341.

[5] G. Sinclair, J. Leach, P. Jordan, G. Gibson, and E. Yao, "Interactive application in holographic optical tweezers of a multi-plane Gerchberg-Saxton algorithm for three-dimensional light shaping," Opt. Express, vol.12, 2004, pp.1665-1670 .

[6] Y. Bitou, "Digital phase-shifting interferometer with an electrically addressed liquid-crystal spatial light modulator," Optics Letters, vol. 28, ıssue 17, 2003, pp. 1576-1578.

[7] L. Ahrenberg, P. Benzie, M. Magnor, J. Watson, Opt. Express, vol.14, 2007, p. 7636.

[8] O. Ripoll, V. Kettunen, and H. P. Herzig, "Review of iterative Fourier-transform algorithms for beam shaping applications," Optical Engineering, vol. 43, num. 11, 2004, p. 2549.

[9] D. Abookasis, J. Rosen, "Three types of computer-generated hologram synthesized from multiple angular viewpoints of a three-dimensional scene," Applied Optics, vol. 45, ıssue 25, 2006, pp. 6533-6538.

[10] U. Schnars, W.P.O. Jüptner, "Digital recording and numerical reconstruction of holograms," Meas. Sci. Technol, vol.13, 2002, R85-R101.

[11] Thomas Kreis, Handbook of Holographic Interferometry, Optical and Digital Methods, second ed. Wiley-VCH, Germany, 2005.

[12] M. Sutkowski, M. Kujawinska, "Application of liquid crystal devices for optoelectronic of digitally stored holograms," Opt. Lasers Eng. vol 33, 2000, pp.191-201.

[13] Z. Huadong, Y. Yu, C. Dai, "A novel three-dimensional holographic display system based on LC-R2500 spatial light modulator," Optik 120, 2009, pp. 431-436.

[14] O. Matoba, T. J. Naughton, Y. Frauel, N. Bertaux, and B. Javidi, "Real-time three-dimensional object reconstruction by use of a phase-encoded digital hologram," Applied Optics, vol. 41, ıssue 29, 2002, pp. 6187-6192.

[15] D. Önal Tayyar, Z. Saraç, and F. N. Ecevit, "Real-time optical reconstruction of the diffused 3D object using phase information calculated by continuos wavelet transform," Optics Communications, vol.284, 2011, pp. 5460-5465.

[16] O. Matoba, T. J. Naughton, Y. Frauel, N. Bertaux, and B. Javidi, "Three-dimensional object reconstruction using phase-only information from a digital hologram," Photonics,Boston, 2002.

[17] M. Takeda, K. Mutoh, "Fourier transform profilometry for the automatic of 3-D object shapes, " Appl. Opt. vol.22 (24), 1983, pp.3977-3982.

[18] H. Kaya, Z. Saraç, M. Özer, and H. Taşkın, "Optical signal processing of interference fringes by Hartley transform method, "*Proc. SPIE* 7746, 17th Slovak-Czech-Polish Optical Conference on Wave and Quantum Aspects of Contemporary Optics, 77461W, December 14, 2010.

[19] Y. Awatsuji, T. Tahara, A. Kaneko, T. Koyama, K. Nishio, S. Ura, T. Kubota, and O. Matoba, "Improving image quality of parallel phase-shifting digital holography, " Journal of Physics: Conference Series 139, 2008, 012009.

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