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Fast Distance detection by using Lock-in-amplifier in Optical Scanning Holography

Munseob Lee[1] , Gihyeon Min[1], Nacwoo Kim[1],Byung-Tak Lee[1], and Je-Ho Song[2]

[1] ETRI, 1110-6 Oryong-dong, Buk-gu, Gwangju, 61012, Republic of Korea
{mslee21, ghmin, nwkim, bytelee}@etri.re.kr
[2] IT applied system engineering dept., Chonbuk national univ., 567 Baekje-daero, deokjin-gu, Jeonju-si, Jeollabuk-do 54896 Republic of Korea
songjh@jbnu.ac.kr

Abstract. We propose simple distance extraction algorithm for hologram reconstruction in optical scanning holography. By measuring the time-of-flight of the heterodyne beam in optical scanning holography, we can extract the depth information from the object apart by an arbitrary distance. For the time-of-flight, we has constructed the scanning holography and then, we extracted the phase information by using lock-in-amplifier without an additional changes in basic scanning holography setup. Finally, we have reconstructed the reflection-type complex hologram about 10.4mm x 10.4mm object apart from 426mm by this method.

Keywords: Holography, Lock-in-amplifier, Phase shifting method, depth detection.

1 Introduction

The optical scanning holography is one of holography methods for recording three-dimensional information of the object. [1] The merits of the optical scanning holography can record the digital holography by using inexpensive single photodiode without the CCD camera and provide the hologram images with speckle free.

The optical scanning holography is obtaining the complex hologram by using pixel-by-pixel scanning the 3D object with that heterodyne beam.

To restore the hologram obtained from the optical scanning holography, we need the focal distance of hologram. To know the focal depth, some researcher proposed the conventional imaging filtering [2], the auto-focusing technique based on the Wigner analysis [3], axis transform method [4], and so on. Unfortunately, these method are time consuming and difficult for real-time reconstruction because of the post-processing of hologram image.

In this paper, we propose the depth detection algorithm to be able to obtain from the time of flight calculation of the interfered beam in optical scanning holography. In order to calculate the time of flight, we measured the phase shift from lock-in-amplifier without adding some device to the basic scanning holographic architecture.

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2 Experimental Setup and Analysis

Optical scanning holography configuration is shown in Fig. 1. [1] The light from the laser (He / Ne Laser) divides two beam paths through the 50:50 beam splitter. Then, the each beam is modulated by acousto-optic phase modulation with frequency ω and $\omega_0 + \Omega$, respectively. These beams are enlarged through each beam magnifier, BE1 and BE2, respectively. To create the well-known interference pattern, one of the two beam transmit the spherical lens (L1). In the 50:50 beam splitter (BS2), these beams produces the interference pattern, called the time-dependent Fresnel zone plate (TD-FZP) [10].

The one of interfered beam from beam splitter (BS2) is scanning the object by using 2D scanner and the other beam is used for reference for lock-in-amplifier. The scattered beam from object is collected by the area integrating photodetector. In this setup, the each photodetector is used Si detector with about 5kV/A Gain at 50ohm load, respectively.

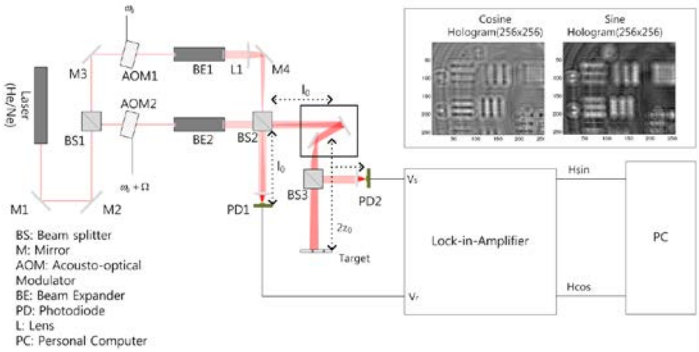

Fig. 1. Experimental setup (subset: the sine and cosine hologram)

The voltage output from the photodetector PD2 has been converted the sine hologram $\mathrm{H}_{\sin}$ and the cosine hologram $\mathrm{H}_{\cos}$ through the lock-in-amplifier.

$$\mathrm{H}_{In-Phase} = \mathrm{H}_{\cos} = I(x, y; z) \otimes h_z(x, y) \cos(\phi_s(x, y) - \phi_r) \quad \textbf{(1)}$$

$$\mathrm{H}_{quardaruple-Phase} = \mathrm{H}_{\sin} = I(x, y; z) \otimes h_z(x, y) \sin(\phi_s(x, y) - \phi_r) \quad \textbf{(2)}$$

where ϕ_s and ϕ_r is represented by the phase change caused by optical length l_0 to the PD1 and $l_0 + 2(\delta z(x, y) + z_0(x, y))$ to the PD2, respectively. The free-space propagation impulse response $h_z(x, y)$ given by $h_z(x, y) = j/_{\lambda z} \cdot \exp\left(-j\pi/_{\lambda z} \cdot\right)(x^2 + y^2)$

Finally, the complex hologram is given by following equation.

$$\mathrm{H}_{complex} = \mathrm{H}_{\cos} + j \cdot \mathrm{H}_{\sin} = I(x, y; z) \otimes h_z(x, y) \exp(j \cdot \phi_s(x, y) - \phi_r) \quad \textbf{(3)}$$

To reconstruct the hologram image in arbitrary distance, we can use the convolution method.

$$I(x, y; z) = \Im^{-1}\left(\Im\left(\mathrm{H}_{complex}(x, y; z)\cdot\right)\Im\left(h_z(x, y)\right)\right) \quad (4)$$

In order to reconstruct the hologram image of the object $I(x, y; z_0)$ in the focus area, it is necessary to obtain the distance z_0.

If object are very thin ($\delta z << z_0$), we can obtain the depth information of object from the phase difference which is ` we can easily calculate the distance from 2D scanner to object.

$$z_0 = c\cdot\left[\left(\phi_s - \phi_r\right) / \ 4\pi\cdot\Omega\right] = c\cdot\left[\mathrm{atan}\left(\mathrm{H}_{\sin} / \ \mathrm{H}_{\sin}\right) / \ \right]4\pi\cdot\Omega \quad (5)$$

where c is the speed of light and Ω is modulation frequency difference between the each acousto-optic modulator. When modulation frequency Ω is determined, the non-ambiguity range is $z_{\max} = c / 2\pi\cdot\Omega$, and the resolution of distance measurement can be expressed as $\delta z_{\min} = c\cdot\Delta\phi_{\min} / 4\pi\cdot\Omega$. For example, measurement distance is 37.5m and the measurement resolution $\delta z_{\min}$ is about 5mm, when Ω=4MHz and $\Delta\phi$=0.05 degree.

3 Results

The sin and cosine hologram are depicted in Fig. 1. The each modulation frequency of the acousto-optic modulator was used at 40MHz and 44MHz, respectively. USAF 1951 positive was used as an object and scanning angle of 2D scanner was 0.40 degree. Beam diameter is 10mm, and data pixels is 128 by 128 points. For detection, we use Si-detectors for each reference and signal beam. In this holograms, we can observe the traces of the Fresnel time zone plate without speckle noise.

Figures 2(a) shows a variation of the distance according to the phase difference between the signal and the reference signal. While moving the object to about 50.0mm intervals, we measured the phase change of lock-in amplifier by using an oscilloscope. We showed the 2-dimensional contour map about distance apart from object in Fig. 2(a). The blue region means the distance to the object, and the yellow refers to the portion of the transmitted region, respectively.

In this study, the distance to the object was 460.1mm in average. Also, with the distance from 2D scanner to an object and the angle of 2D scanner, we can calculate the width and height of the object by using triangulation method. According to this calculation, the measurement area is 10.4mm x 10.4mm. Based on above depth information, we carried out the reconstruction of this hologram image in Fig. 1. Figure 2(b) shows a reconstruction image of the measured complex hologram in the focus areas.

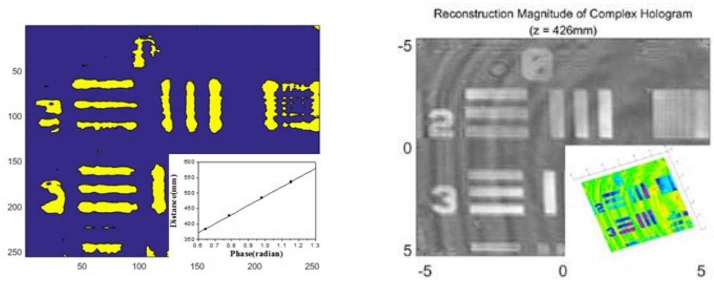

Fig. 2. (a) Distance extracted the phase difference (subset: Phase map) (b) Reconstruction hologram (subset: phase hologram)

4 Conclusions

In this study, we propose an algorithm based on the phase shift measuring method for the reconstruction of the complex hologram obtained from the optical scanning holography. By applying this proposed algorithm, we can easily extract the distance to object without the complicate calculation. Also, this method can be possible for the real-time processing for reconstruction of holography by measuring the phase of a pixel.

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References

1. Poon. T –C.: Optical Scanning Holography – A Review of Recent Progress. Journal of the Optical Society of Korea, vol. 13, no. 4, pp. 406--415 (2009)
2. Xin Zhang, Edmund Y. Lam, and T. –C. Poon: Reconstruction of sectional images in holography using inverse imaging. Optics express, vol. 16, no. 22, pp. 17215--17226 (2008)
3. T. Kim and T. -C. Poon.: Extraction of 3-D location of matched 3-D object using power fringe-adjusted filtering and Wigner analysis. Opt. Eng., vo.l. 38, no. 12, pp. 2176--2183 (1999)
4. Kim, Y. S. Kim, W. S. Kim, and T. Poon: Algorithm for converting full-parallax holograms to horizontal-parallaxonly holograms, Opt. Lett. 34, 1231--1233 (2009).
5. Pengcheng Hu1, Jiubin Tan, Hongxing Yang, Xiping Zhao and Siyuan Liu: Phase-shift laser range finder based on high speed and high precision phase-measuring techniques, The 10th International symposium of measurement technology and intelligent instruments, Deajeon, Korea, pp. 1--5 (2011)