NAIC-ID(RS)T-0393-94

NATIONAL AIR INTELLIGENCE CENTER

Application of Computer Generated Holograms to Optical Transformations

by

Zheng, Shanfeng and Wang, Tianji

HUMAN TRANSLATION

NAIC-ID(RS)T-0393-94 08 March 1995

MICROFICHE NR: 95C000093

Application of Computer Generated Holograms
to Optical Transformations

By: Zheng, Shanfeng and Wang, Tiangi
English pages: 8

Source: Guangxue Xuebao, Vol 11, NR 7, July 1991

Country of origin: CHINA
This document is a Human translation.
Translated by: Scitran Company
Merged by: Nancy L. Burns
Requester: NAIC/TATE/Cpt. Joe Romero
Approved for public release; Distribution unlimited.

Accession For	
NTIS GRA&I	☑
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE NATIONAL AIR INTELLIGENCE CENTER.	PREPARED BY: TRANSLATION SERVICES NATIONAL AIR INTELLIGENCE CENTER WPAFB, OHIO

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

TABLE OF CONTENTS

APPLICATION OF COMPUTER GENERATED HOLOGRAMS TO OPTICAL TRANSFORMATIONS[1]

Zheng, Shanfeng and Wang, Tianji[2]

Abstract

This paper discusses how to use computer-generated holograms as a holographic lens to realize optical transformations of ring-to-line, line-to-point and ring-to-point, etc. By use of liquid crystal Television spatial light modulating devices one can fabricate computer generated holograms in quasi-real time.

Keywords: Computer generated hologram (CGH), Optical transformation, liquid crystal Television Spatial light modulator (LC-TV-SLM).

1. Introduction

Based on the basic principles of holographic recording, in 1965 Lohmann first used computers to come up with the first piece of computer generated holograms. When a computer generated hologram is being made, the presence of the actual material object is not necessary, but all one needs is the concrete mathematical expressions of material waves, which will allow one quite easily to build projection functions acting as some arbitrary 2-dimensional complex functional

---

1 Data of Receipt: June 4, 1990; Date of the revised version: November 5, 1990.

2 Guangzhou Institute of Electronics Technology, Academia Sinica Guangzhou 510075.

holographic lens, and such holographic lens can be fully utilized in some spatial transforming optical systems, in realizing a cerain kind of the required optic transformations.

Bryngdahl [2,3] used computer generated holograms as holographic lens to construct a spatial transformational system, which could realize some optic transformations: For instance, straight displacement, localized downsizing, etc., while Saito et al. [4] applied computer generated holograms to carry out the real-time optical ln(r) ~θ transformation, and then used this application to recognize optical shapes; Casasent [5] just used computer generated holograms to realize optical "marine" transformations.

Based on all these facts, what this paper would like to describe is how to use computer generated holograms as a holographic lens, to realize optical transformations of ring-to-line, line-to-point, and ring-to-point, etc., (below the transformations of ring-to-line, line-to-point and ring-to-point will simply be called as the ring-line, line-point and ring-point transformations). Now computer generated holograms are going to be worked out by 2 kinds of methods; the first kind is a commonly known one, namely letting computers sketch images to draw computer generated holograms and then carry out the optical downsizings, while the second kind is as follows: The computer would feed the encoded data of computer generated holograms into a liquid crystal television spatial light modulator, and thus on the liquid crystal television spatial light modulating device, computer generated holograms can be fabricated in quasi-real time.

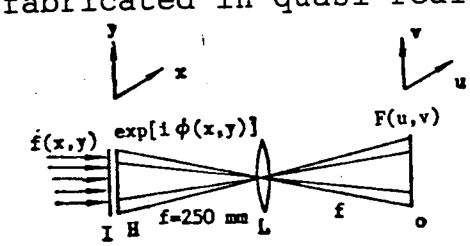


Fig. 1 Optical transformation system

1. Optical transformational systems

Fig.1 shows a realization of a spatial optical system for optic transformations, placing the amptitude distribution object f(x,y) at I the established input surface, while H the holographic lens (namely computer generated holograms) leans closely onto the I-surface, to get irradiated by the parallel coherent beams so that if H possesses phase function $\phi(x,y)$, then there will be a complex amplitude distribution F(u,v) at O the output surface as follows:

$$F(u, v)=\iint_{-\infty}^{+\infty} f(x, y)\exp[i\phi(x, y)]\exp[-ik(xu+yv)/f]\,dx\,dy, \tag{1}$$

where $k = 2\pi/\lambda$ and λ is the wavelength; if $h(x, y)=[\phi(x, y)/k]-[(xu+yv)/f]$, one can rewrite Eqn.(1) as

$$F(u, v)=\iint_{-\infty}^{+\infty} f(x, y)\exp[ikh(x, y)]\,dx\,dy。 \tag{2}$$

For a large K-value, one can use the phase-equalizing method [6] to find the approximate value of the integration of Eqn.(2) and can prove that whatever contributes to the integration are all in the vicinity of some saddle points and at these saddle points the following relationship is true:

$$\frac{\partial h(x, y)}{\partial x}=\frac{\partial h(x, y)}{\partial y}=0。 \tag{3}$$

From Eqn.(3) one gets

$$u=\frac{\lambda f}{2\pi}\frac{\partial\phi(x, y)}{\partial x}, \quad v=\frac{\lambda f}{2\pi}\frac{\partial\phi(x, y)}{\partial y}。 \tag{4}$$

One selects a transformation from a certain X-Y plane to the U-V plane as follows:

$$\begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} u = u(x, y) \\ v = v(x, y) \end{bmatrix}. \qquad (5)$$

From Eqn.(5) and Eqn.(4) one can solve function $\phi(X,Y)$ (provided that the equation has solutions); from this, one can see that for the transformation from the X-Y plane to the U-V plane all one needs is to solve the phase function $\phi(X,Y)$ and one can fabricate computer generated holograms which have phases shown by $\phi(X,Y)$, and thus by use of the optical path of Fig.1, one can realize the desired transformations.

2. Discussion on several transformations

If the transformation is as follows:

$$\begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} u = x - y \\ v = y - x \end{bmatrix}, \qquad (6)$$

then it is a line-point transformation from the X-Y plane to the U-V plane, from which one can solve the phase-function as follows:

$$\phi(x, y) = \frac{\pi}{\lambda f}(x^2 + y^2 - 2xy). \qquad (7)$$

For a ring-line transformation, one assumes

$$\begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} u = \ln(x^2 + y^2)^{1/2} \\ v = \tan^{-1}(y/x) \end{bmatrix}, \qquad (8)$$

to solve the phase-function as follows:

$$\phi(x, y) = \frac{2\pi}{\lambda f}\left[-y \tan^{-1}\left(\frac{y}{x}\right) + x \ln\sqrt{x^2 + y^2} - x\right], \qquad (9)$$

If one combines the above 2 kinds of transformations, one can realize a ring-point transformation.

2. Experiments

1. Fabrication of computer generated holograms

A He-Ne laser is used as the light source, whose wavelength λ=6,328 nm; now the chosen lens focal distance f = 250 nm, and let a computer sketch the images to draw out computer generated holograms of Mr. Li type, then the original size of the computer generated holograms is 20 x 20 cm^2, but through an optical downsizing (reduction by 50 times) one fabricates a practical computer generated hologram.

The liquid crystal television spatial light modulater used in this paper was a modified version of "Citizen OBIA-OH" black-white liquid crystal television, purchased in the market, the screen size was 71 x 53 mm^2, and the number of pixels was 160 x 130 pixels; after some appropriate circuitry modifications, it could receive external visible frequency signals. The computer then passed the encoded data of computer generated holograms into the storage bank, and in the storage bank they were converted into some visible frequency signals to feed into liquid crystal television spatial light modulater to fabricate computer generated holograms in quasi-real time, as shown in Fig. 2.

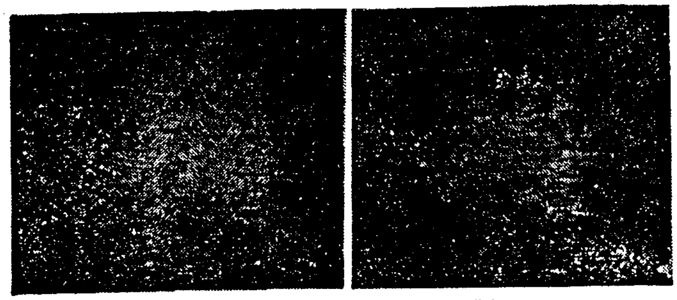
2. Use of computer generated holograms to realize some optical transformations

By following the optical path of Fig. 1, at input surface I, the input objects are separated into a ring group and a line group, in which the inner and outer diameters of the ring were, respectively, 2.5 mm and 3.0 mm, and the width of the line was 0.25 mm; then after a ring-line (line-point) transformation, the theoretical as well as the experimental outputs at output surface-O can be shown as in Fig. 3(b), (c) and Fig.4(b), (c). When the ring-line transformation and the line-point transformation are combined, one can carry out the ring-point transformation. The experimental optical path is as shown in Fig. 5, and the input object chooses Fig.3(a), while the actual transformed output can be seen in Fig. 6.

3. Concluding remarks

The experiment in this paper proved that computer generated holograms could realize an optical transformation, the fabricated computer generated holograms has fairly good vitality, thus the computer generated hologram can be readily applied as an optical transformational element, to achieve all kinds optical transformations for different needs.

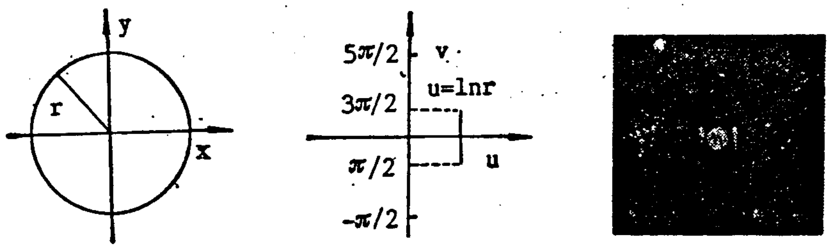
The time needed in fabricating a computer generated hologram is not some problem that can be overlooked. This paper used a liquid crystal television spatial light modulater to fabricate computer generated holograms in quasi-real-time, but such a method is rarely seen in our country, and it can skip some complex processes for the computer to sketch images or to carry out optical downsizing, and thus it not only saves time, but it allows easy preservation and revisions, and thus brings down the cost of frabricating computer generated holograms; it is a very practical experimental method; the liquid crystal television spatial light modulater used in this paper had a low resolution power, but the present authors are convinced that by use of some similar methods, it should not be too difficult to fabricate computer generated holograms of the spatial band-width multiple of 1,024 x 1,024 or of some even higher ones.



(a) (b)

Fig. 2 CGH generated by LCTU. SLM

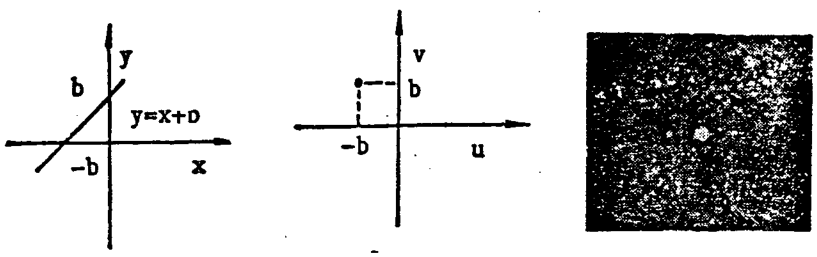
(a) For ring-to-line (b) For line-to-point



(a) (b) (c)

Fig. 3 Ring-to-line transformation

(a) I plane input distribution; (b) O plane theoretical output distribution; (c) O plane practical output distribution, center: 0-order diffraction, both sides: ± 1-order diffraction.



(a) (b) (c)

Fig. 4 Line-to-point transformation.

(a) I plane input distribution; (b) O plane theoretical output distribution; (c) O plane practical output distribution, center: 0-order diffraction, both sides: ± 1-order diffraction

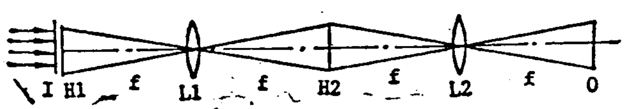


Fig. 5 Ring-to-point transformation diagram

Focus of L1 and L2: f=250mm, H1 and H2: CGH for ring-to-line and line-to-point transformations respectively, I and O; input and output planes.

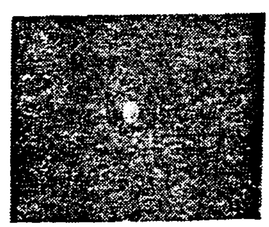


Fig. 6 O plane practical output distribution in ring-to-point transformation

References

[1] A. W. Lohmann and D. P. Paris; *Appl. Opt.*, 1976, **6**, No. 6 (Mar 15), 1739.

[2] O. Bryngdahl; *Opt, Commun.*, 1974, **10**, No. 2 (Feb), 164.

[3] O. Bryngdahl; *J. Opt. Soc. Am.*, 1974, **64**, No. 8 (Aug), 1092.

[4] Y. Saito *et al*; *Opt. Commun.*, 1983, **47**, No. 1 (Aug 1), 8.

[5] D. Casasent *et al.*; *Opt. Commun.*, 1976, **19**, No. 2(Nov), 217.

[6] M. 玻恩, E. 沃耳夫著;《光学原理(下册)》, (科学出版社, 北京, 1981), 1002.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
B085 DIA/RTS-2FI	1
C509 BALLOC509 BALLISTIC RES LAB	1
C510 R&T LABS/AVEADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
Q592 FSTC	4
Q619 MSIC REDSTONE	1
Q008 NTIC	1
Q043 AFMIC-IS	1
E051 HQ USAF/INET	1
E404 AEDC/DOF	1
E408 AFWL	1
E410 AFDTC/IN	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
P050 CIA/OCR/ADD/SD	2
1051 AFIT/LDE	1
P090 NSA/CDB	1
2206 FSL	1

Microfiche Nbr: FTD95C000093
NAIC-ID(RS)T-0393-94