

Filtering Effect in Holographic Image Processing

Ferdous Ahmed*, Md. Sultan Mahmud**

*Electrical and mechanical Engineering Corps, Bangladesh Army, Bangladesh

**Professor and Head of the Department of Basic Sciences and Humanities, University of Asia Pacific, Dhanmondi R/A, Dhaka-1209, Bangladesh

Abstract— The most popular application of holography is using the technique to make three-dimensional images. This paper describes an algorithm for computationally generating holograms along with methods to fabricate the hologram. The phrase, “digital holography”, is common place in the optics community; it describes the methods used to reconstruct holographic images from physically recorded holograms as well as the methods used to construct holograms from virtual objects using a computer. In fact we have the ability to create digital holograms from imaginary objects and then recreate the image of those objects using the same digital holograms, the entire process performed on a single computer. A computer simulation technique for generating Fourier holograms using the Fraunhofer diffraction formula is applied. These generated Fourier holograms were analyzed for experimental reconstruction. A detailed analysis was done on the computation and numerical reconstruction. Filtering technique was used to analyze its feasibility to be used in image processing. Corresponding reconstructions were verified by MATLAB for computer simulation. The algorithm of the MATLAB program is discussed. Using this technique, computer generated holograms can be of great use in image processing field.

Index Terms— Computer generated hologram, Digital holography, Filtering technique, Fourier holograms, Fraunhofer diffraction, Holography, MATLAB

I. INTRODUCTION

The word holograph is derived from the Greek words ‘holos’ meaning whole, and ‘graphein’ meaning to write. A hologram, therefore, is something that records all of the information available in a beam of light, not just the amplitude, as in traditional photography, but also the phase of the light.

The wave theory of light is utilized in computer generated holography to represent both the object and reference waves mathematically. With this knowledge, the superposition of these waves at any point in space can be calculated to obtain the interference pattern required for the hologram. Computer generated holograms do not require actual objects to generate the hologram as long as the light scattered or diffracted off the object could be represented mathematically [2]. The light transmission and reflection properties of the object are no longer a problem since the ideal object wave can be computed mathematically, given its structure is properly described. Thus, a computer generated holographic image is computed by numerically simulating the physical phenomena of light diffraction and interference.

II. BASIC OF HOLOGRAPHY

A hologram is a recording of the optical interference pattern that forms at the intersection of two coherent optical beams [3]. Typically, light from a single laser is split into two paths, the signal path and the reference path. Figure-1 shows this holographic recording arrangement. The beam that propagates along the signal path carries information, whereas the reference is designed to be simple to reproduce. A common reference beam is a *plane wave*: a light beam that propagates without converging or diverging. The two paths are overlapped on the holographic medium and the interference pattern between the two beams is recorded.

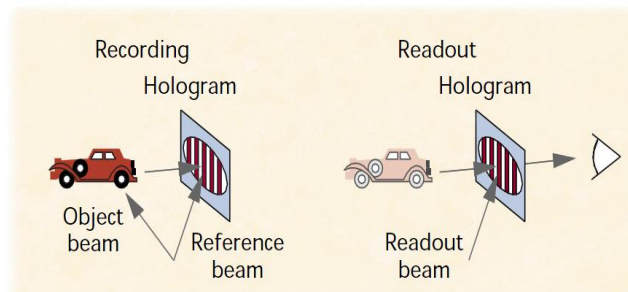


Figure 1: Hologram recording

and reading process

At the fundamental level, the difference between a hologram and a conventional photograph is that conventional photography

records intensity of light while a hologram records both intensity and phase. Holography is done by recording the interference pattern between coherent light and the incident light reflecting off an object.

III. FUNDAMENTALS OF COMPUTER GENERATED HOLOGRAPHY

A. Optical Holography Vs Digital Holography

The optical holography technique demands the presence of the real object (for which the hologram is to be made). In optical holography recording, light from a coherent laser source scattered from the object is made to interfere with a reference light derived from the same source. The recorded fringe pattern when illuminated by the same reference light generates the object wave front (3D image). Nevertheless, in computer simulated holography, the entire recording and reconstruction processes are simulated using diffraction formula. The first computer generated hologram (CGH) was made by A.W.Lohmann and D.P. Paris in 1967. Thereafter this technique has undergone many improvements and changes in both procedure and computational techniques. Once the choice of the diffraction formula has been made, then the choice of suitable computer implementation procedures should be made. The computing environment should be chosen such that it improves speed, accuracy and also cost efficiency for that type of simulation method. In our work, the Fraunhofer diffraction formula is used for simulation. The holograms thus generated using diffraction formula can be used for optical reconstruction.

B. Computer Generated Hologram

Computer Generated Holography is an optical numerical technique, which avoid the traditional light interference recording process by computer numerical calculation and record the hologram directly [4]. It does not require the actual light and the actual existence of the recording medium and reduces the difficulty of the realization of holography. Computer Generated Holograms has many applications in digital storage and display systems. Numerical generation and encryption of hologram are two important topics that have instigated abundant research and analysis works within the past twenty years. An important need for synthesizing computer generated holograms is to create optical wavefronts from objects that do not physically exist. The process of synthesizing a hologram usually consists of the following steps. The first step is to compute the propagation of the complex amplitude from the object to the hologram plane. The second step is to encode the complex amplitude as a real, nonnegative function from which the hologram can be generated on a graphic output device. The simulation of the interference fringes caused by interaction between the reference beam and object beam in conventional holography can be considered as an example for this. The next steps are to make the hologram and to reduce it to a reasonable size for diffracting light. The final photo reduction step could be eliminated by using special output devices such that hologram can be written directly in the desired size. An important property of hologram is that information about the object is spread over the entire image plane; therefore each and every portion of hologram contains the complete information of the object. This property can be utilized so as to make holograms effective for communication.

C. Computer Generated Hologram Vs Fourier Transform

According to scalar diffraction theory, the emanating wavefronts are spherical. The scalar diffraction theory at the end of Fresnel approximation reshapes the spherical wavefronts to parabolic wavefronts. Since the parabolic approximation is valid only for small diffraction angles this approximation is also called as paraxial approximation. The far field approximation of Fresnel diffraction formula yields the Fraunhofer diffraction formula [4]. The Fraunhofer diffraction formula is the Fourier transform of the aperture distribution. This formula greatly simplifies the calculations compared to Huygen – Fresnel diffraction formula. The simulation is employed using a simple algorithm in MATLAB language. The Fresnel diffraction formula is given by

$$U(x, y) = \frac{e^{jkz} e^{j\frac{k}{2z}(x^2+y^2)}}{j\lambda z} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \left\{ T(\xi, \eta) \exp \left[j\frac{k}{2z}(\xi^2 + \eta^2) \right] \right\} \exp \left[-j\frac{2\pi}{\lambda z}(x\xi + y\eta) \right] d\xi d\eta$$

IV. EXPERIMENTAL

In signal processing, particularly digital image processing, filtering has got significant effect on image quality [5]. A holographic image doesn't give out any meaningful image visually. But reconstructed image from the holographic image doesn't appear exactly as

the original image. Rather it is reconstructed along with some other spurious frequencies due to inherent properties of digital image processing. These unwanted signals which cause reconstructed image differ from its original image, can be negated by suitably applying filtering techniques namely Low Pass Filtering (LPF), High Pass Filtering (HPF) and Band Pass Filtering (BPF). The minimization is a criterion in filter design.

We know that Low Pass Filtering cuts off higher frequencies of certain level according to set parameter and High Pass Filtering cuts off lower frequencies of certain level. Filtering technique can be applied to a reconstructed holographic image if the image demands enhancing for its further use. Filtering technique can be applied to a holographic image through different image processing algorithms [6]. For our experiment, we used MATLAB program as our Computer Generated Hologram (CGH) is based on the same program. Depending on image class, processing algorithm and programming level, the applied filtering effect can vary from unnoticeable to annoying. Aggressive image filtering can also result to distortion in reconstructed image. Such as, the drawback of a low-pass filter is a ringing effect that occurs along the edges of the filtered spatial domain image. Multiplication in the Fourier domain corresponds to a convolution in the spatial domain. Due to the multiple peaks of the ideal filter in the spatial domain, the filtered image produces ringing along intensity edges in the spatial domain. Fraunhofer diffraction yields the Airy disk as point spread function, which has a ringing pattern. On the other hand, high pass filtering may generate sharp edges near the color transition within an image.

A. *Effect of Low Pass Filtering on Holographic Image*

```
a1=imread('image location.jpg');  
%Provide image location%  
a=rgb2gray(a1);  
%size(a)  
% size(a1)  
af=fftshift(fft2(a));  
%size(af)  
figure, imshow(af);  
fftshow(af)  
[x,y]=meshgrid(-512:511,-512:511);  
z=sqrt(x.^2+y.^2);  
  
c=z<12;  
%size(c)  
af1=af.*c;  
fftshow(af1)  
af11=ifft2(af1);  
ifftshow(af11)  
  
c=z<64;  
af1=af.*c;  
fftshow(af1)  
af11=ifft2(af1);  
ifftshow(af11)
```

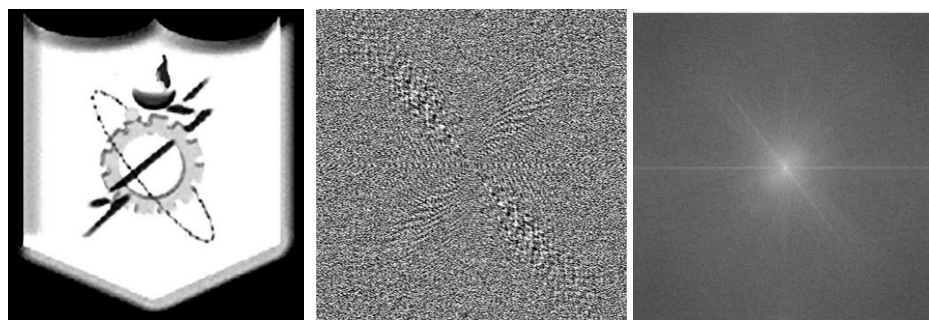
B. *Effect of Image Enhancing Technique on Holographic Image*

```
a=imread('image location.jpg');  
%Provide image location%  
a1=rgb2gray(a);  
af=fftshift(fft2(a1));  
figure, imshow(af);  
fftshow(af)  
  
[x,y]=meshgrid(-512:511,-512:511);  
z=sqrt(x.^2+y.^2);  
  
c=z>15;  
%size(a)  
hp=af.*c;
```

```
fftshow(hp)  
hp1=ifft2(hp);  
ifftshow(hp1)  
c=z>2;  
hp=af.*c;  
fftshow(hp)  
hp1=ifft2(hp);  
ifftshow(hp1)
```

V. RESULTS AND DISCUSSIONS

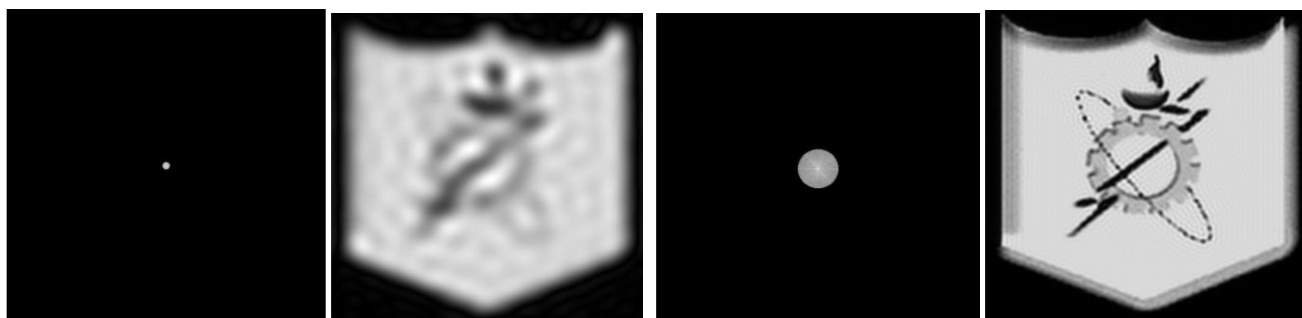
The quality of reconstructed image with respect to original image is visible from Figure - 2. Low pass filtering effect and high pass filtering effect on reconstructed image with different filtering level are shown in Figure - 2 and Figure - 3 respectively. The filtered images vary depending upon the filtering level applied on reconstructed holographic image which is evident from the properties discussed [7, 8].



(a) Original Image

(b) Hologram

(c) Hologram-FFT Show



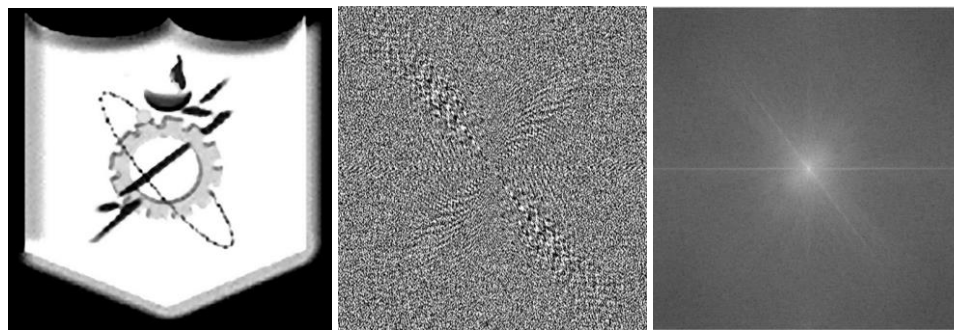
(d) LPF-Z<12

(e) Filtered Image

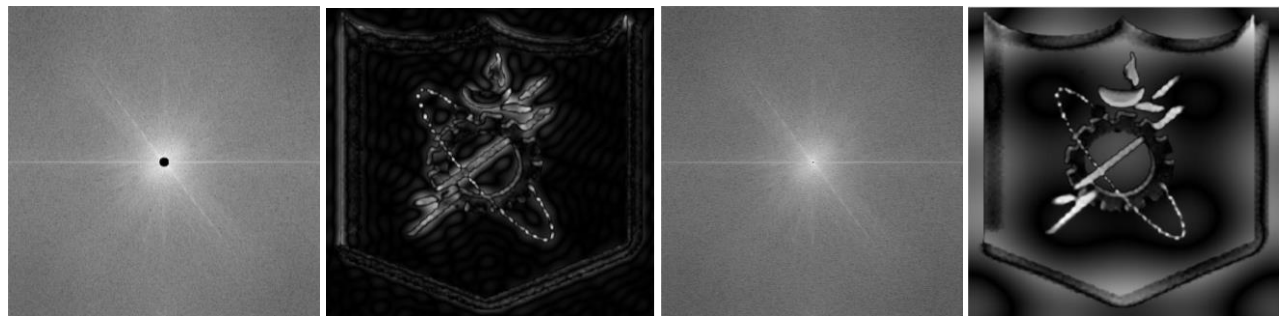
(f) LPF-Z<64

(g) Filtered Image

Figure 2: Low Pass Filtering Effect



(a) Original Image (b) Hologram (c) Hologram-FFT Show



(d) HPF-Z<15 (e) Filtered Image (f) HPF-Z<2 (g) Filtered Image

Figure 3: High Pass Filtering Effect

It is observed from the above result that reconstructed image from its hologram when low pass filtered, gives out blurring effect and sharp edges are minimized. Again, reconstructed image from its hologram when high pass filtered, gives out reverse color effect.

VI. CONCLUSION

This paper discusses the basic principles of hologram and implementation of computer generated holograms along with filtering effect on generated hologram. A simple algorithm for simulation of computer generated holograms was presented. Fourier transform operation was utilized to obtain the hologram of the object. The reconstruction of object image from the computer generated hologram was done. The image reconstructed from hologram after applying filtering effect contains portrays different response to the filtering parameter technique applied. A method to observe the output image by suitably modifying the hologram was discussed in the paper. An interesting property of hologram is that every portion of the hologram contains information about the object. The hologram was filtered at different levels and dimensions and overall filtered portions were reconstructed to get the object image. It was found that the reconstructed image depend on the position and size of filtering of the hologram.

ACKNOWLEDGMENT

The author wishes to thank Jawaharlal Nehru Technological University for rendering support in doing research on Holographic Technology and grateful to Professor P. Syam Prashad for proper guidance.

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AUTHORS

First Author - Ferdous Ahmed has completed Masters in Technology in Communication Engineering from Jawaharlal Nehru Technological University, India, PH-+8801769011945. E-mail: rasselbd99@gmail.com

Second Author - Md. Sultan Mahmud has done PhD in Nano Technology from KUET, Bangladesh and Sweden. He is the head of the department of Basic Sciences and Humanities, University of Asia Pacific, Bangladesh, PH-+8801916974628. E-mail: head.bsh@uap-bd.edu

Correspondence Author - Ferdous Ahmed, Electrical and mechanical Engineering Corps, Bangladesh Army, Bangladesh, Cell: +8801769011945, E-mail: rasselbd99@gmail.com