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Ringing Effect In Holographic Image Processing

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Abstract

The most popular application of holography is using the technique to make three-dimensional images [1]. This paper describes the basic of computationally generating holograms along with integral effect of image processing on 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. Computer generated holograms being an image processing technique is prone to certain effects of typical image processing caused due to filtering effects [2]. The effect of image processing on the computer simulation technique for generating Fourier holograms using the Fraunhoffer diffraction theory is discussed. A detailed analysis was done on the computation and numerical reconstruction. Corresponding reconstructions were verified by MATLAB for computer simulation. Understanding this technique, further image enhancement technique can be applied on holographic image.

Keywords: Holography, digital holography, Computer generated hologram, Fraunhoffer diffraction, Filtering Effect; MATLAB, etc.

1. Introduction

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. It does not require the actual light and the actual existence of the recording medium and reduces the difficulty of the realization of holography. 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 minimize specific filtering effects appear due to few inherent properties of signal processing [3].

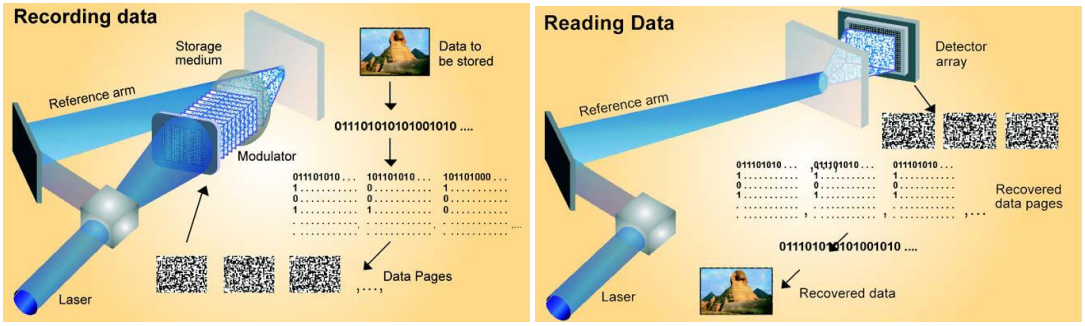


Figure-1 Holographic data/image processing (Recording and retrieval)

In signal processing, particularly digital image processing, ringing artifacts are artifacts that appear as spurious signals near sharp transitions in a signal [4]. Visually, they appear as bands or "ghosts" near edges; audibly, they appear as "echos" near transients, particularly sounds from percussion instruments; most noticeable are the pre-echos. The term "ringing" is because the output signal oscillates at a fading rate around a sharp transition in the input, similar to a bell after being struck. As with other artifacts, their minimization is a criterion in filter design.

2. Experimental

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. The far field approximation of Fresnel diffraction formula yields the Fraunhoffer diffraction formula. The Fraunhoffer diffraction formula is the Fourier transform of the aperture distribution [5]. If G(x,y) is the Fourier transform of F(ξ,η) – Object and reference beam plane, then

$$G(x+pN, y+qN) = \frac{1}{N}\sum_{\xi=0}^{N-1}\sum_{\eta=0}^{N-1} F(\xi,\eta)$$

$$\exp\left\{\frac{-2\pi i}{N}(x\xi + y\eta)\right\} \times \exp\{-2\pi i(p\xi + q\eta)\}$$

for $x, y = 0, 1, \ldots N-1$

In signal processing ringing effect occurs as an effect of low pass frequency filtering. Computer Generated Hologram is no exception to this effect as it works on the principle of Fast Fourier Transform method where all the low frequencies of an image are centered towards the reference beam (zero position at x, y plane). The simulation algorithm used is shown below.

```
[x,y]=meshgrid(-128:127,-128:127);
z=sqrt(x.^2+y.^2);
c=(z<15);
figure, imshow(c)
cf=fftshift(fft2(c));
cf1=log(1+abs(cf));
m=max(cf1(:));
figure, imshow(im2uint8(cf1/m));
b=1./(1+(z./15).^2);
figure, imshow(b)
cf=fftshift(fft2(b));
cf1=log(1+abs(cf));
m=max(cf1(:));
figure, imshow(im2uint8(cf1/m));
```

Ringing effect so known as Gibbs phenomenon in mathematical methods of image processing is the annoying effect in images and video appeared as rippling artifact near sharp edges. This effect is caused by distortion or loss of high frequency information in image. It can be found in images of different classe s: MRI images, compressed images, over sharpened images, images transmitted over analog channel, holographic images etc.

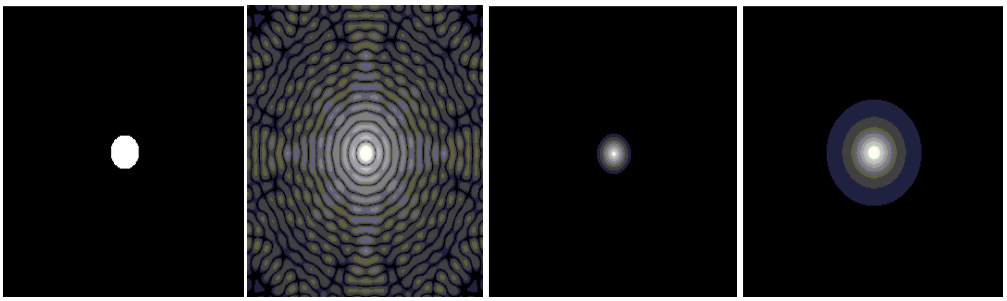
3. Results and Discussions

These generated Fourier holograms were verified from simulated image (a circle in this case) [6]. Computer Generated Hologram being an image processing technique, ringing effect occurs due to inherent properties as explained before. Holographic image technique works on the principle of taking a reference beam at center point of the image and considering all other frequencies as zero and converging the lower frequencies of the image towards the reference point, thus a low pass filtering effect is implied on the generated holographic image. Fraunhoffer diffraction yields the Airy disk as point spread function, which has a ringing pattern. This effect is reduced by suitably applying frequency distribution technique here. Some other techniques may also be applied to reduce this effect.

Ringing effect is usually introduced to image after different image processing algorithms. The most often it appears after image and video compression. Depending on image class, compression algorithm and compression level, this artifact can vary from unnoticeable to annoying. Aggressive image sharpening can also result to false edges near sharp edges. 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 [7]. 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.

The presence of ringing effect depends on the presence of sharp transition in frequencies in an image. The generated holographic image with respect to original image is visible from Figure-2. The reconstruction image quality varies depending upon the techniques used to minimize the ringing effects within a hologram.



(a) (b) (c) (d)

Figure-2 (a) Image to be processed (b) Ringing effect in Holographic image (c) Frequency distributed image (d) Ringing effect in modified image

4. Conclusion

This paper discussed the inherent drawback in signal / image processing. Implementing Computer Generated Holograms complied with that property. A simple algorithm for simulation of computer generated holograms was presented through Fourier transform operation and corresponding ringing effect was observed. Frequency distribution technique was used to minimize this ringing effect and corresponding effect was also observed. A concept to understand and eliminate a very basic drawback of signal / image processing was discussed in the paper. An important property of this concept is to broaden ideas for implementation in future Computer Generated Hologram construction and image reconstruction out of it.

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