Chapter 6
Restoration and Enhancement of Digitally Reconstructed Holographic Images

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ABSTRACT

Holograms can be reconstructed optically or digitally with the use of computers and other related devices. During the reconstruction phase of a hologram by optical or digital methods, some errors may also be introduced that may degrade the quality of obtained hologram, and may lead to a misinterpretation of the holographic image data, which may not be useful for particular application. The basic common errors are zero-order diffraction and speckle noise. These errors have more undesirable effects in digital than in optical holography because the systems of recording and visualization used in the digital holography are extremely sensitive to them or inclusively increase them. The zero-order diffraction can be removed by using high pass filters with low cut-off frequencies and by subtracting the average intensity of all pixels of the hologram image from the original hologram image. Further, the speckle noise introduced during the formation of digital holographic images, which is multiplicative in nature, reduces the image quality, which may not be suitable for specific applications. As the range of applications get broader, demands toward better image quality increases. Hence, the suppression of noise, higher resolution of the reconstructed images, precise parameter adjustment, and faster, more robust algorithms are the essential issues. In this chapter, the various methods available in literature for enhancement and speckle reduction of digital holographic images have been discussed, and a comparative study of results has been presented.

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INTRODUCTION

The basic concept (Srivastava, 2010) of holography was first introduced by Gabor in 1948 to improve the resolving power of electron microscope for coherent imaging. After the advent of laser technologies, the Goodman in 1967 had conceived the basic idea of digital holography. Since one of the main drawbacks of electron microscopes is that the higher the spatial resolution, the lower is depth of focus which imposes restrictions in imaging for a specific application. This problem of microscopy can be resolved by holography. Holography is the science of producing holograms which is an advanced form of photography that allows an image to be recorded in three dimensions (3D) and the technique of holography can also be used to optically store, retrieve, and process information. Holography is related to measuring the wave field followed by reconstruction of the wave field, i.e. both the amplitude and the phase of the light wave scattered by the object. Due to advancements in digital optics, CCD and CMOS cameras and computers, it became possible not only to record the digital holograms but also to reconstruct them. Further, with the advancement and use of digital image processing and optical information processing methods for further processing of digital holographic images, nowadays it is possible to generate realistic digital holograms with no defects that may be used in different areas of applications. Holography which was originally invented to solve problems in electron-microscopy, now in its new form of digital holography, can be used to solve problems of optical microscopy. Holography is capable of recording 3-D information and optical reconstruction is then possible with visual 3-D observation. Since there are no wet chemical processing and other time consuming procedures, digital holography can be done in almost real time through numerical reconstruction which offers great flexibility on controlling some parameters, such as focusing, image size and resolution.

When image of an object is observed through a microscope or the object's diffraction pattern, the information about the phase of the emanated wave is lost. However, if one records the interference pattern of light coming from an object called the object beam with a reference beam which has the same wavelength as the object beam and of a known phase distribution such as a plane wave or a spherical wave then it is possible to reconstruct both the phase and amplitude of the object beam (See Figure 1) (Yaroslavskii & Merzlyakov, 1989). This reconstruction of the object beam can be done optically by taking the hologram, which is the recorded fringe pattern obtained from interfering the object and reference beam, and shining the reference beam at it and the hologram in turn diffracts the light so that an image of the object is visible. As an example, we can consider the recording of the hologram of a spherically scattered wave like the light scattered from a Rayleigh scatterer where the spherical wave coming from the object interferes with a plane wave and as result a pattern of concentric rings are formed which resembles a Fresnel zone plate and like a Fresnel zone plate, the fringes focus a plane wave illuminating it to a point. The holograms can be reconstructed optically or digitally with the use of computers and other related devices. Figure 2 shows the steps involved in digital reconstruction and image processing of holograms. The various components of the setup contain following components.

Hologram Sensor which captures original hologram in analog form; Analog-to-digital converter which converts the analog form of recorded hologram in digital form for further processing with computers; pre-processing of digital hologram which involves the preparation of hologram data in some specific desired format etc; image reconstruction is associated with Digital reconstruction of holograms by applying various steps such as use of transformations (DFT, Fresnel's) etc; followed by image processing step which is responsible for producing realistic

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