Zooming Algorithms for Digital Holography

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Abstract. Digital Holography is an imaging modality made up of two parts: (i) Recording an interference pattern on a CCD, where an object wave field and a known reference wave are coincident and extracting the complex object wave field from this interference pattern and (ii) Replaying or reconstructing the hologram on a computer by simulating the propagation of the object wave field back to the object plane. Thus an image is obtained. We show how to adapt the reconstruction algorithm in a simple way to allow it to generate any output range and in any location making it far more versatile for zooming in on specific regions of our reconstructed image.

Digital holography [1], (DH) involves the use of discrete electronic devices, such as CCDs to record the hologram. In this case reconstruction is performed numerically by simulating the propagation of the wave field back to the plane of the object [2]. The most commonly used algorithms for the reconstruction algorithm are the direct method and the spectral method of calculating the Fresnel Transform which describes free space propagation in the paraxial approximation. These algorithms differ in the output range that they display. For the direct method the output image size is proportional to the propagation distance making it more appropriate for large objects at large distances. The spectral method has an output image size equal to the size of the CCD. In this study we have developed an algorithm that allows us to arbitrarily change the output pixel size and therefore the output window size as we see fit, we therefore can zoom in on particular features or areas of our reconstructed image.. The basic principle is based on the following property of the Fresnel transform, which is denoted by the operator F_{z_n}.

$$u_z(x/M) = \exp\left(j\frac{2\pi}{\lambda f_2}x'^2\right)F_{z_n}\{u(x')\exp\left(j\frac{2\pi}{\lambda f_1}x'^2\right)\} \tag{1}$$

where M is a magnification parameter that we are free to choose and this imposes the conditions;

$$z_n = zM, f_1 = z_n/\left(M-1\right), f_2 = z_n - f_1 \tag{2}$$

Equation 1 implies that to obtain a magnified image of our reconstructed image, our digital hologram can be multiplied by a discrete chirp signal with parameter f_1 and then reconstructed using the spectral method where we propagate a distance z_n and finally we multiply by another discrete chirp function. The user can define the output sampling interval arbitrarily, which will in turn define values for M, z_n, f_1 and f_2. In the case of the direct method we cannot apply this idea successfully to zoom because the terms cancel to reveal an output width that is a constant. We note that the relationship given in Equation 1 was first used to create a zooming algorithm for the Fresnel transform, known as the 'Rhodes Light Tube' in [3] where the output sampling interval was set to be a constant for all distances. When applying a large magnification to

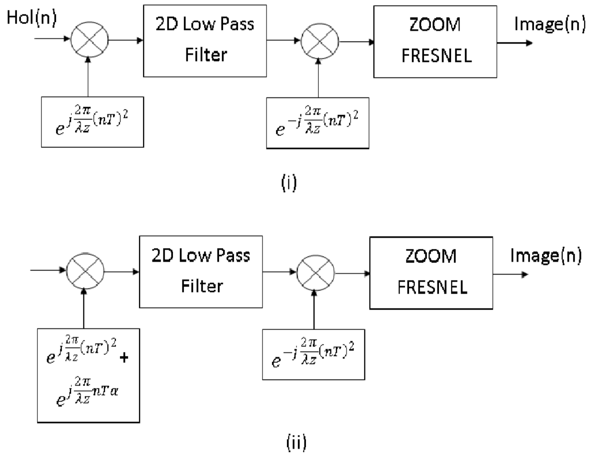

Figure 1. Flowcharts for adapting the zoom algorithm for magnifying the object: (i) Using a low pass filter between two chirps will mean that energy from the signal outside the magnified region that we wish to image will be set to zero and will no longer be a source of noise; (ii) we can introduce a linear phase to make the low pass filter into a bandpass filter and thus we can magnify different regions of the object

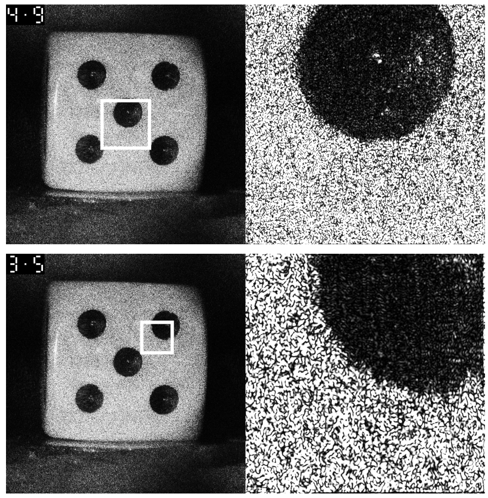

Figure 2. Zooming in with the adapted low pass filtering technique implemented before applying the zoom algorithm. In this case we also show the effect of using a linear phase at the input to scan the object. The numbers on the figure indicate the width of the image in mm

the algorithm such that we can view small parts of the object we find that the algorithm fails because those parts of the object that we are not interested in wrap around and invade the space of our field of interest. In order to overcome this we have developed a procedure shown in Fig. 1 and 2 where by applying an appropriate low pass filter we can eliminate this effect allowing to zoom into an object and view with any pixel size we wish. The actual resolution that we can still detect will be determined by the point spread function of the system. We believe this algorithm will have important application in digital holographic micrpscopy.

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