Reconstruction of Holographic Microscopy Images Based on Matching Pursuits on A Pair of Domains

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Abstract: We propose a new reconstruction method of an object image from its digital hologram. The proposed matching pursuit on a pair of domains (MPPD) method employs spatial-domain bases and their (Fresnel) transform-domain pair. The transform domain bases are used to decompose the hologram, which yield a set of coefficients. Then, these coefficients are used to reconstruct the spatial-domain object image using the predefined spatial bases. We show the robustness of the proposed method against noise on a simulated hologram of spherical particles. By employing spatial-domain Gaussian bases and its transform pair, the image of these particles are recovered successfully. A possibility to extend the 2D (two-dimensional) case to a 3D (three-dimensional) one for slice reconstruction from a single hologram is also explored. The effectiveness of the proposed method is demonstrated by using a real microscopic-hologram of silica gel spherical particles, which shows promising results.

1. Introduction

Holography has been popularly known as an imaging technique that is capable of recording and reconstructing a 3D (three-dimensional) image by employing a laser. However, the first holographic device constructed by Gabor, was not intended for this purpose, but for correcting aberrations of an electron microscope by recording the interference of object wave with a reference one [1]-[3]. Leith and Upatnieks proposed significant improvements by proposing an off-axis hologaphic imaging method [4], which capable to separate a real image from its virtual and zero order ones. They also realized the relationship between holography and well-known signal processing techniques widely used in communication, i.e., the modulation, frequency dispersion, and square-law detection.

A digital holographic imaging (DHI) system is constructed by replacing the film in the analog holographic imaging (AHI) with a digital camera. Based on the digitally recorded hologram, the object image is then reconstructed numerically. Considering its central role, the numerical reconstruction of the object image is one of the most important issues in the DHI.

Previously, a digital holographic microscope imaging system capable to record and reconstruct images of microscopic organisms has been implemented by researchers [5], [6]. Various kinds of inline digital holographic imaging techniques have also been developed. In [7], the authors presented tile-superposition technique for in-line digital holography, which can be the basis of high-resolution wide-field imaging by multispot illumination with NA (Numerical Aperture) of 0.7. A single shot high-resolution imaging using partially coherent laser light illumination achieving NA of 0.8 has also been introduced in [**8**], where rearranging sample carrier enables one to get a hologram that is free from disturbing interference. The capability of imaging actual objects, among others are E-Coli bacteria, HeLa cells, and Fibroblast cells, have also been demonstrated in [**9**]. In principle, these devices will also capable to record and play a 3D (three-dimensional) movies of observed living microorganisms. Current progress on the DHI research was reported by Schnars and Juptner [10].

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