Adaptive Filtering of Interference Fringes by Polar Transformation and Empirical Mode Decomposition

Hernando Altamar-Mercado,[1] **Alberto Patiño-Vanegas,**[1] **and Andrés G. Marrugo**[2]

[1] *Facultad de Ciencias Básicas, Universidad Tecnológica de Bolívar , Cartagena, Colombia.*
[2]*Facultad de Ingeniería, Universidad Tecnológica de Bolívar, Cartagena, Colombia.*

haltamar@utb.edu.co

Abstract: We designed an adaptive filter based on empirical mode decomposition for the removal of fringes in an interference microscopy image. Promising results show the possibility for extended depth-of-field imaging.

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1. Introduction

The limited depth of field (DOF) of conventional optical microscopes is a common problem in obtaining the image of an object with a height profile larger than the DOF. As a result, each acquisition shows certain parts of the object that are focused and others that are not focused. A standard approach to make a fully focused image [1] is to take multiple images corresponding to different focus positions of the object. The challenge is to segment from each image the focused area and fuse them. Interferometric objective lenses are the standard way to increase the resolution of microscopes. They add interference fringes to microscopy images visually indicating the DOF of the system. We incorporated interferometric fringes through a Mirau-type objective with a white light source. A Mirau-type optical system [2] does not allow an image to be recorded without the interference fringes which makes it difficult for the fusion of images. If the interference fringes vary in their orientation and spatial frequency, filtering in the power spectrum is difficult as shown in Fig. 1.

2. Experiments and Results

To estimate the intensity values in the focused points, we propose a solution that consists in eliminating the interference fringes employing a space-variant filter. We propose the following steps: 1) To make a representation of the image in polar coordinates. 2) The decomposition of the intensity signal in the radial direction in empirical modes [3]. 3) To subtract the residue from the signal. 4) To compute the 1D Fourier transform. 5) To filter in the band corresponding to the interference fringes. 6) To perform the 1D inverse Fourier transform, and finally, 7) To perform a transformation of the polar image filtered to a rectangular image. In Fig. 2 we show the polar representation of the interferometric image and the intensity signal through the red line. We carried out a numerical simulation of two optical systems. One system allows us to obtain a standard optical microscopy image for reference, and the other an image with interferometric fringes. We found values of the universal quality index [4] of an image around 0.9. The results both in the simulated images and in real images are shown in Fig. 3.

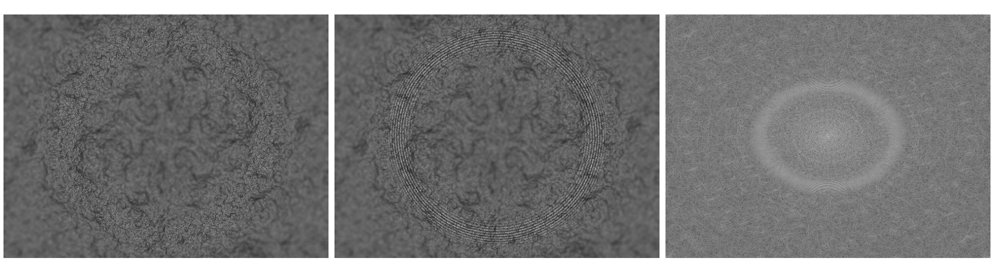

Fig. 1. (From left to right) A simulated microscopic images, interference microscopic image and its power spectrum.

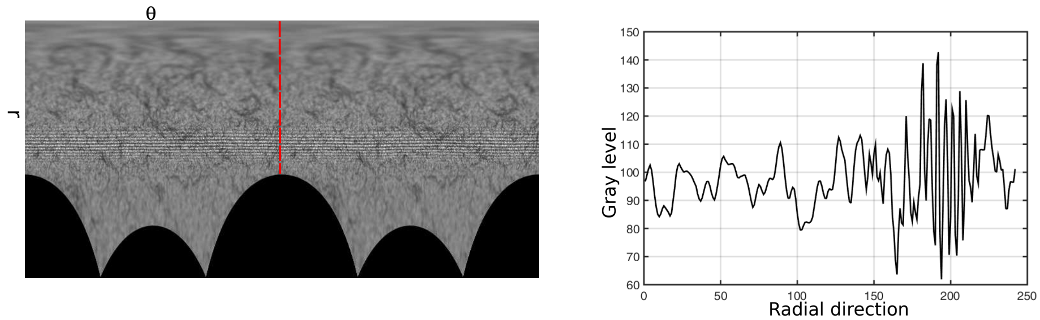

Fig. 2. (From left to right) Polar image and the intensity signal through the red line.

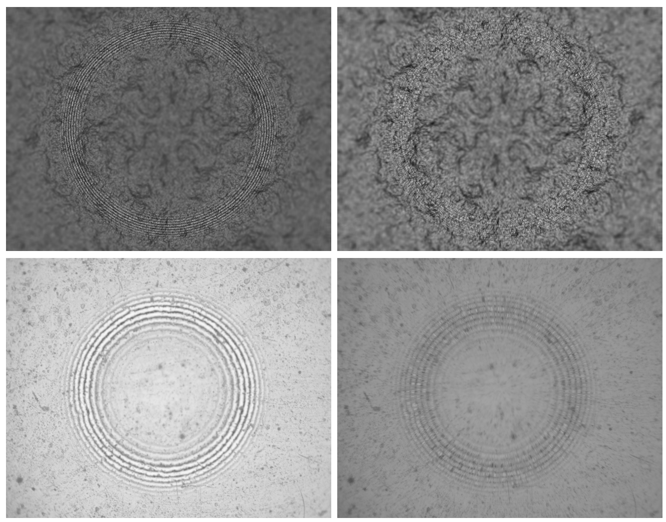

Fig. 3. (From left to right) Top-row: Simulated interference microscopic image and its filtered image. Bottom-row: Real interference microscopic image and its filtered image.

3. Conclusions

In this work, we designed an adaptive filter to remove interference fringes and to lose as little as possible the essential information of the focused points. With the polar representation, the filter is adapted to any orientation of the fringes while with the decomposition in empirical modes enables the filter to adapt to the frequency content of the fringes for each angular position in the polar representation.

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