A Practical Inverse Problem Approach to Transport-of-Intensity Equation for Phase Imaging

Emrah Bostan*, Masih Nilchian, Daniel Sage and Michael Unser

Biomedical Imaging Group, EPFL, Lausanne, Switzerland

* *Corresponding author: emrah.bostan@epfl.ch*

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Abstract

We propose a new optical phase retrieval algorithm for imaging unstained transparent objects that are thin. In fundamental terms, our approach is guided by the transport-of-intensity equation (TIE), which relates the phase of an optical field to the derivative of its intensity along the direction of propagation [1]. Since TIE requires recording a set of defocus images to approximate said derivative, we first analyze the implications of using finer and coarser approximations. Based on the analysis, we identify reliable frequency ranges in the phase image as the defocus distance changes. We then formulate a variational problem where the sought phase is specified as the minimizer of an energy function. In designing the energy, we utilize weighted-norms and sparsity-based regularization principles. The eventual framework is a joint model that nonlinearly combines the spectral information of different defocus distances within a regularized reconstruction framework. As for the computation of the solution, we propose an iterative solver that efficiently handles the consequent minimization problem. We apply our method to real microscopy data of HeLa cells, where we choose to operate with both bright-field and differential interference contrast (DIC) images [2]. For reconstructing the phase, we use four defocus images that are symmetrically acquired at "small" and "large" defocus distances. The final phase images are compared with the ones acquired using a digital holographic microscopy (DHM). The latter confirms that our computational phase imaging technique renders the morphology of the cells faithfully.

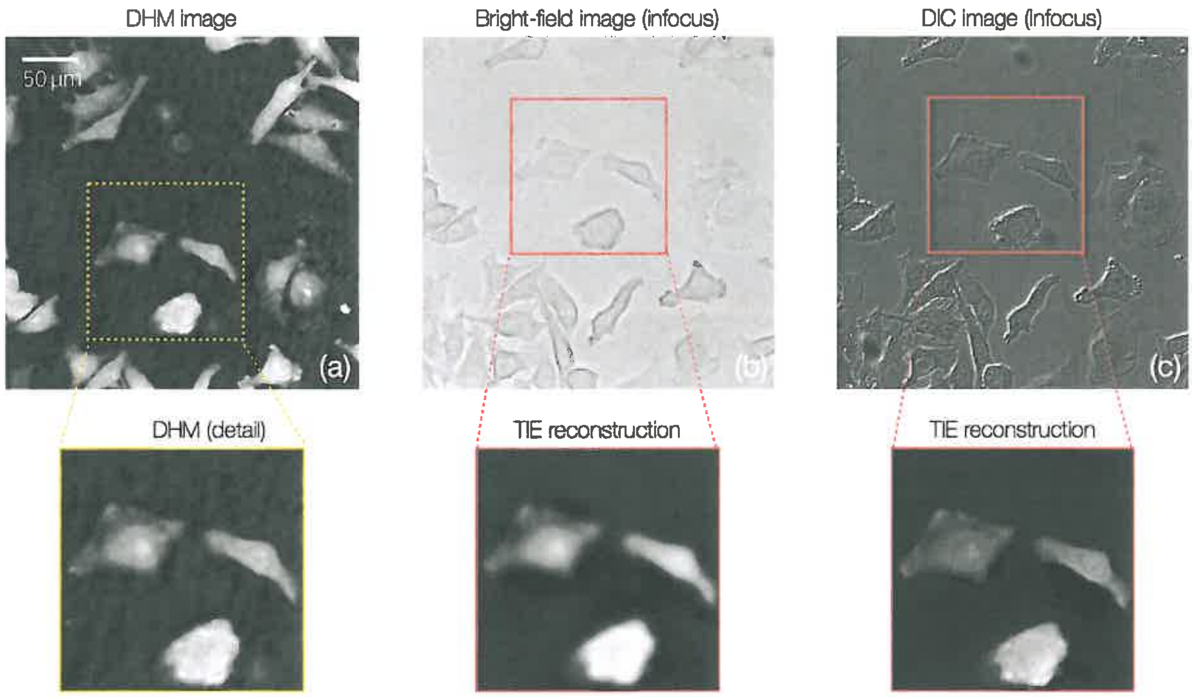

Figure 1: Validation of the proposed TIE reconstruction method on the same sample: (a) Reference digital holographic microscope (DHM) image of HeLa cells, (b) result of our TIE reconstruction using bright-field images, and (c) result of our TIE reconstruction using differential interference contrast (DIC) images.

References

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