

MICROSCOPE IMAGING CAPABILITIES IMPROVE USING COMPUTATIONAL OPTICS

Carol J. Cogswell, Sharon V. King, S. R. Prasanna Pavani, Donald B. Conkey
and Robert H. Cormack

Department of Electrical and Computer Engineering
University of Colorado at Boulder
Boulder, CO 80309-0425 USA
E-mail: cogswell@colorado.edu

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ABSTRACT: We will present a brief overview of our recent work in the rapidly growing field of computational optical sensing and imaging (COSI) which is a new acronym that describes several older, well-established techniques for optical imaging systems design. These include such approaches as so-called “wavefront coding,” “point-spread-function (PSF) engineering,” “pupil plane masking,” and others, all of which share a central theme: *that the optical system is designed and optimized with the expectation that some type of digital image computation or processing will be required to produce the final resulting image.*

When applied to the world of optical microscopy, COSI designs allow us to install optical components and devices that, for example, alter the phase of the image-forming wavefronts in ways that can capture or encode more information in the recorded image than is found in a traditional microscope image. One goal is to speed up image acquisition so that closely-spaced time points can be recorded of a moving, live biological specimen by acquiring only one (or possibly two) images per time point rather than a multi-focus stack of images. Another of our novel techniques increases the sensitivity and accuracy of a DIC microscope for imaging small variations in phase produced by sub-cellular features within the cell volume, without loss of lateral resolution.

In this talk, we will present some recent results that illustrate COSI techniques applied to fluorescence, bright field and quantitative phase (including DIC) microscopy. We will describe how optimization techniques are applied to both (1) the design of *optical* components installed in the microscope (e.g. pupil plane masks, illumination and detection path manipulation) and (2) the design of *digital signal processing* techniques (e.g. image noise, artifact removal) in order to extend the information content of microscope images.

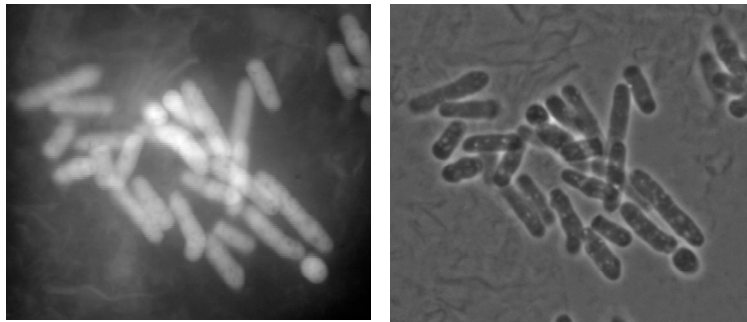


Fig. 1: Example of one COSI technique that uses optical system modifications and digital processing to provide quantitative phase information (left) of fixed yeast cells. At right is a traditional Zernike phase contrast image of the same cells for comparison. Intensity in the left image increases linearly as the optical path length through the cells increases, making it easy to distinguish regions where cells overlap (brightest features). This is much less obvious in the phase contrast image at right, which is also further degraded by halo artifacts at cell boundaries.

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