Compact snapshot hyperspectral imager for fluorescence microscopy

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Abstract

Hyperspectral fluorescence microscopy is a growing field with applications in both biological research and clinical microscopy [1,2]. However, current hyperspectral fluorescence systems are bulky, expensive, or require scanning, thus limiting temporal resolution [3]. In this work, we present an architecture for a computational snapshot hyperspectral imager that can be attached to the output port of any traditional benchtop microscope. Snapshot hyperspectral methods eliminate scanning, in turn improving temporal resolution, but usually require a tradeoff between spatial and spectral resolution. Our architecture beats this resolution tradeoff by using a compressed sensing approach. The concept, based on our prior work for photography applications [4], is adapted here to microscopy to provide a substantially smaller form factor (~6 inches) and lower potential cost than hyperspectral confocal microscopes.

The imager consists of a diffuser and spectral camera (consisting of an image sensor with a 64-channel tiled spectral filter array) placed in the Fourier plane of the imaging system using a relay lens. The diffuser enables each spatial point from the object to map onto all the spectral filter channels at once and generates a spatially-varying caustic pattern, which encodes the lateral position of the point. Hence, we can computationally reconstruct the object's 2D spatial information and the full spectral information for each pixel using a sparsity-constrained inverse problem. We show results from both simulations and experiments and discuss limitations in throughput and reconstruction quality.

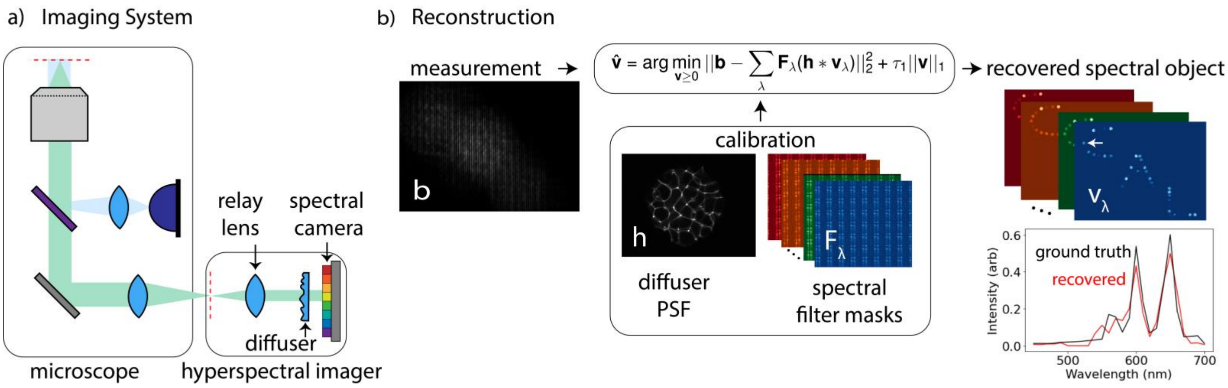

Figure 1: a) Optical diagram of our computational snapshot hyperspectral imager for microscopy. b) Here we show the reconstruction of spectral beads spelling "CAL" from a simulated measurement, **b**. The spectral object datacube, **v**(x,y,λ), on the far right is recovered by minimizing a cost function which reduces measurement error (L2-loss) and promotes sparsity (L1-loss) while enforcing non-negativity. Images of the diffuser's point spread function (PSF), **h**, and the spectral filter mask patterns, $\mathbf{F}_{\lambda}$, were acquired during calibration and used in the reconstruction. The spectrum of one of the recovered beads pointed out on the far right matches the ground truth.

References

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