DIFFERENTIABLE MULTI MODE MICROSCOPE SIMULATOR

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The vast majority of confocal microscopes use physical or mechanical elements for both generating the excitation patterns and filter out-of-focus light. Our group has developed a fully programmable array microscope (PAM) using a novel technique of digital holography using acousto-optic deflectors (AODs) that allows the user to decide between a host of illumination configurations, scanning protocols and filtering methods within the same device.
Here we present a multi-mode microscope simulator that reproduces the behaviour of most existing confocal modalities, especially the ones using multipoint schemes to achieve higher imaging speeds. Our simulator considers all the optical phenomena including the interference along the optical axis when using a coherent light source or the AODs behaviour, directly impacting the sectioning capability and photo-bleaching of the sample. We also model the scanning scheme to ensure uniform illumination and the final image acquisition with a camera model. Finally, we reconstruct the image using custom algorithms that reproduce different microscopy modes, such as epifluorescence, confocal filtering (with variable virtual pinhole) or even a photon reassignment approach providing improvement in lateral resolution [1]. The simulator gives us the possibility to do an exhaustive study of advantages and disadvantages among different configurations and due to its differentiable capability is able to model explicitly the relationship between changes in model parameters and the generated images.
Our simulator program is coded in Python with Kornia [2] library, an open-source differentiable computer vision library for PyTorch. This allows us to include a fast and easy to use image formation module into a deep learning or optimization pipeline scheme for several purposes such as super-resolution or optimal parameter search.

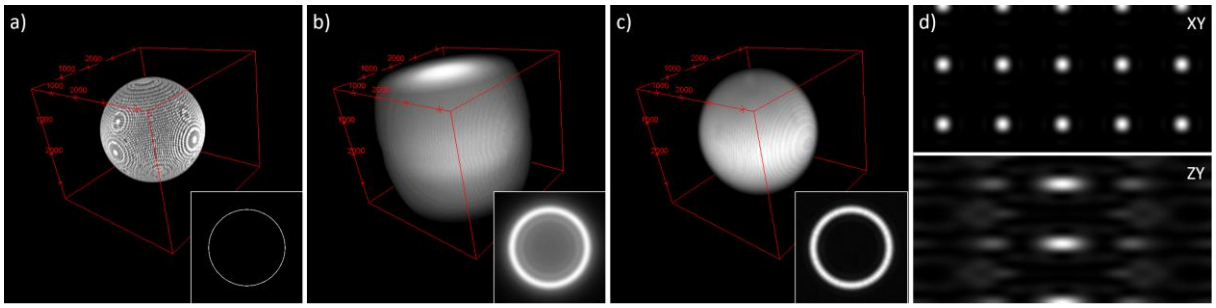

Figure 1: Simulation of a 3 μm spherical shell showing ground truth and images reconstructed under a multipoint illumination confocal (excitation pattern (d)) and epifluorescence modes, and 2D sections (insets). (a) Ground truth, (b) Epifluorescence, (c) Confocal.

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