OPTICALLY-SECTIONED 3D IMAGING BY FOURIER-DOMAIN INTEGRAL MICROSCOPY

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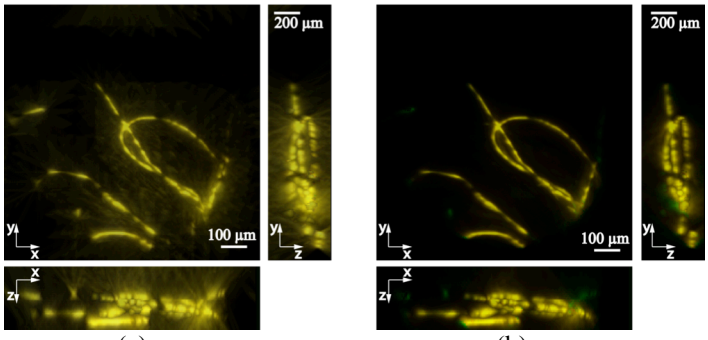
Three-dimensional (3D) imaging of thick samples is only feasible by using some set of optically-sectioned images of the specimen, otherwise the axial crosstalk inside the object volume produce very poor 3D reconstructions. Optical sectioning microscopy is conventionally performed by means of a scanning, multi-shot procedure in combination with non-uniform illumination. However, the scanning process slows down the acquisition, hindering or preventing the proper detection of dynamic biological processes.

To overcome this limitation, in this work we present a new technique that provides optically-sectioned 3D reconstructions from a single-shot capture. The proposed register layout is a non-conventional lightfield microscope, namely, the Fourier-domain Integral Microscope (FiMic) [1,2]. Differently from classical imaging systems, lightfield (a.k.a. integral or plenoptic) setups register the radiance distribution (which contains not only spatial but also angular information of the light rays) on the sensing plane, allowing the 3D reconstruction of the specimen after a single shot [3]. Compared with conventional versions of lightfield microscopes, FiMic provides improved resolution and depth of field.

By digitally postprocessing the integral image obtained by any lightfield imaging system, an equivalent focal stack can be obtained. However, conventional computational algorithms reported for depth-refocusing lack optical sectioning. In this contribution we present an algorithm that is able to produce a stack of optically-sectioned images with a low computational cost and with no resolution worsening [4]. This algorithm was implemented in C++ by using CUDA GPU-parallel programming for real-time performance. We provide the theoretical derivation of the algorithm and demonstrate its utility by applying it to numerical simulations and experimental data obtained with a FiMic setup. In this way, we report here a complete architecture that provides optical sectioning for 3D microscopy imaging after a single-shot capture.

As an example of the performance of the technique, in Fig. 1 we show a comparison of the results obtained after applying the proposed algorithm and a conventional one [3] to a single capture obtained by a FiMic. As a sample we used cotton fibres stained with fluorescent ink. As shown in this figure, the proposed algorithm performs a much better optical sectioning, as a result of the efficient removal of the background noise proceeding from the out-of-focus planes.



(a) (b)

Figure 1: Comparison of the conventional reconstruction technique [3] (a), and the one proposed in this contribution (b), applied to cotton fibres 3D reconstruction.

References

[1] A. Llavador et al., "Resolution improvements in integral microscopy with Fourier plane recording," *Opt. Express* **24**(18), 20792–20798 (2016).

[2] G. Scrofani et al., "FiMic: design for ultimate 3D-integral microscopy of in-vivo biological samples," *Biomed. Opt. Express* **9**(1), 335–346 (2018).

[3] M. Levoy et al., "Light field microscopy," ACM *Transactions on Graphics* **25**(3), 924–934 (2006).

[4] E. Sanchez-Ortiga et al., "Optical sectioning microscopy through single-shot lightfield protocol," IEEE *Access* (accepted, pending publication) (2020). doi: 10.1109/ACCESS.2020.2966323.

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