SINGLE-SHOT FULL-FIELD VOLUMETRIC IMAGING USING OPTICAL PROJECTION TOMOGRAPHY

Connor Darling, Samuel P. X. Davis, Sunil Kumar, Paul M. W. French, James McGinty
Physics Department, Imperial College London, London SW7 2AZ, UK
E-mail: cjd12@ic.ac.uk

KEY WORDS: 3D imaging, single-shot, optical tomography

We present a single-shot volumetric imaging method, capable of imaging mm-sized samples at up to 70 volumes/second utilising optical projection tomography (OPT) implemented with compressive sensing and machine learning. The technique can utilise absorption and/or fluorescence contrast in weakly scattering samples.

Conventional OPT [1] entails acquiring a series of wide-field projection images through a sample that are recorded as it rotates. The 3D volumetric structure of the sample can then be reconstructed, e.g. using filtered back projection. The use of non-ionising radiation makes OPT applicable to (longitudinal) *in vivo* 3D imaging of mm–cm biological samples [2,3] but the sequential recording of projection images to acquire the OPT data set constrains the imaging of dynamic samples. We present a method to simultaneously acquire 8 projection images, enabling single shot volumetric imaging by utilising compressed sensing [2] and convolutional neural network [3] based methods to reconstruct the 3D image data.

We acquire 8 projection images simultaneously on 4 CMOS cameras, utilising angular multiplexing on each camera that is implemented by placing two off-axis apertures in the back focal plane of each of 4 imaging objective lenses to select pairs of viewing angles separated by 3.4°. A pair of tube lenses is matched to each pair of apertures to image the projections to separate halves of the camera sensor. The cameras are angularly spaced by 45°, to provide even angular sampling and the objective lens depth of field extends throughout the sample. The total component cost (excluding computer) is less than £5000.

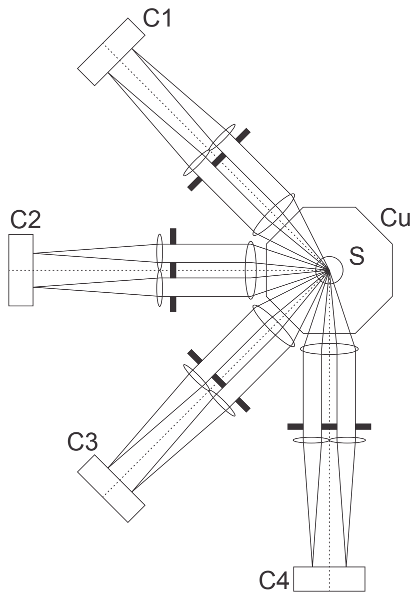

Figure 1: System diagram. Cameras (C1-4) simultaneously record 8 projections through sample (S), situated in a cuvette (Cu) filled with index matching fluid.

This rapid, single-shot volumetric imaging extends OPT to dynamic samples, including live organisms, fluid dynamics and 3D object tracking. The approach can be adapted for a wide range of samples, including by using additional image channels, or changing of magnification to trade resolution vs sample size.

[1] J. Sharpe *et al.*, "Optical Projection Tomography as a Tool for 3D Microscopy and Gene Expression Studies," *Science (80-.).*, vol. 296, pp. 541–542, 2002.
[2] T. Correia *et al.*, "Accelerated Optical Projection Tomography Applied to In Vivo Imaging of Zebrafish," *PLoS One*, vol. 10, no. 8, p. e0136213, Aug. 2015.
[3] S. P. X. Davis *et al.*, "Convolutional neural networks for reconstruction of undersampled optical projection tomography data applied to in vivo imaging of zebrafish," *J. Biophotonics*, vol. 12, no. 12, pp. 1–10, 2019.