Digital Wavefront Sensing with High Speed Optical Coherence Tomography

Rainer A. Leitgeb

Center for Medical Physics and Biomedical Engineering,
Christian Doppler Laboratory for Innovative Optical Imaging and its Translation to Medicine
Medical University Vienna, Waehringer Guertel 18-20, A-1090 Austria
e-mail:rainer.leitgeb@meduniwien.ac.at

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During the last two decades optical coherence tomography has matured to a well-established biomedical imaging technique for high resolution depth resolved structural imaging with high sensitivity and speed. Particularly interesting advantages of OCT come from the availability of phase information, since it is based on short coherence interferometry. Phase information can be used for getting access to the wavefront of the backscattered sample field, and applying digital refocusing techniques in post-processing. Interferometric synthetic aperture microscopy (ISAM) uses complex inverse backscattering calculations to correct for wavefront distortion during propagation of the field through the sample and back to the detector. Other approaches use direct forward propagation models that are simpler to implement and yield the same results. Nevertheless those models rely first on the assumption on isotropic and homogenous refractive index distribution, and second they need specific setup parameters, such as sensor geometry and propagation distances. Digital Adaptive Optics (DAO) as a recent method does not rely on the knowledge of above parameters and allows in addition to refocusing also the correction of higher order aberrations. Its working principle is similar to that of a Hartman Shack sensor, only that it uses a scene-based wavefront reconstruction algorithm based on OCT data alone without the need of additional wavefront sensor hardware. In the presentation we will introduce the method, and demonstrate and discuss its performance in comparison to other refocusing techniques. As all the methods rely on a proper lateral phase definition, they are highly sensitive to motion artifacts. We will show, how parallel OCT modalities achieving more than 2000 tomograms/sec keep sufficient lateral phase stability to allow for DAO in the living human retina.