Information-optimized adaptive optics for biomedical microscopy

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Wavefront aberrations are a prominent issue in microscope imaging. System imperfections and inhomogeneous sample structures introduce phase distortion (or aberration) compromising image quality. Adaptive optics (AO) are reconfigurable devices that modulate the phase of light to correct aberrations, restoring focusing quality and allowing non-invasive deep penetration through inhomogeneous tissue samples to facilitate challenging in-vivo imaging for biomedical studies. Particularly useful are indirect – or "sensorless" – AO methods, which do not require a wavefront sensor. They infer wavefront correction via iterative processes, but this can lead to prolonged and repeated sample exposures. We developed a sensorless AO method using embedded machine-learning (ML) based control that considerably improved the efficiency of aberration estimation. We took steps further advancing information and ML-powered AO methods. In particular, we used Fisher information to guide AO method design, including multi-foci for wavefront sensing. We studied optimised wavefront representations to benefit deep multiphoton microscopy. We showed how alternative modal decompositions can assist the wavefront correction process.

Short Bio:

Prof Martin Booth is chair in Optical and Photonic Engineering at the University of Oxford. His research involves the development and application of adaptive optical methods in microscopy, laser-based materials processing and biomedical imaging. In particular, his group have developed numerous implementations of adaptive optics for aberration correction in high resolution microscopes and

precision laser fabrication systems. He has held Royal Academy of Engineering and EPSRC Research Fellowships and in 2016 received an Advanced Grant from the European Research Council. In 2014 he was awarded the International Commission for Optics Prize. He was appointed Professor of Engineering Science in 2014 and Chair in Optics and Photonics in 2023. He is a fellow of SPIE, Optica, and the Institute of Physics and serves on the board of Optica. He has over 180 publications in peer-reviewed journals, over thirty patents, and has co-founded two spin-off companies, Aurox Ltd and Opsydia Ltd.