Marco Leonetti, Denzel Fusco Ylenia Gigante Lorenza Mautone, Silvia Di Angelantonio, Giorgia Ponsi, Giancarlo Ruocco

Center for Life Nano- & Neuro-Science, Italian Institute of Technology, Rome, Italy & Institute of Nanotechnology, CNR-NANOTEC, Rome Unit, Italy

Stochastic SIM: a scan-less super resolution retinal imaging

Abstract: Super-Resolution Microscopy (SRM) encompasses a set of techniques that surpass the instrumental resolution limit of objective lenses used to collect light emitted or reflected by an imaged object. SRM is particularly useful in scenarios where high-performance objectives cannot be employed, such as when the lens's native instrumental function is inadequate. The human eye's lens system (crystalline lens and cornea) has evolved primarily for flexibility, long-distance vision, and range finding, but it is suboptimal when used in reverse for retinal microscopy. Fundus imaging, for instance, is an area where super-resolution techniques prove highly advantageous. SRM typically involves acquiring multiple images through illumination scanning, which are then combined into a single super-resolution image using algorithms that incorporate experimental prior information, such as the point spread function (PSF). However, in ophthalmic SRM, a significant challenge arises from the eye's saccadic movements—unpredictable and random shifts of the fundus that disrupt the super-resolution process.

Here, we present a novel super-resolution microscopy method called Stochastically Structured Illumination Microscopy (S2IM), which offers two key advantages: it overcomes the challenges posed by saccadic movements and eliminates the need for an expensive, technically complex optical scanning system. S2IM leverages micro-saccadic movements as a natural scanning mechanism, transforming these uncontrolled translations into an asset for image acquisition. Our findings demonstrate that S2IM enables scan-less super-resolution, achieving a resolution enhancement factor of 1.91, with promising potential for applications beyond ophthalmoscopy.

Keywords: Super resolution, Fundus Imaging, Retinal Imaging, Structured Illumination Microscopy.

Biography :

Marco Leonetti is a lead researcher at the Italian National Research Council (CNR-Nanotec), a principal investigator in the Bio-Photonics group at IIT-CLNS in Rome, and collaborates on the optical design for the D-Tails Company. He has authored over 50 peer reviewed papers, patents, and other scholarly work. His research has received funding exceeding 1 million euros. His expertise spans photonics, bio-imaging, microscopy, and super-resolution techniques.

doi.org/10.51219/URForum.2025.Marco-Leonetti

ISBN: 978-1-917892-00-1