A few inverse problems in High Angular Resolution Imaging for Astronomy and Ophtalmology

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Abstract

High angular resolution imaging refers to a set of techniques to fight blur in optical imaging applications where the propagation medium introduces time-varying aberrations that degrade the resolution of images.

One can distinguish three families of techniques for high angular resolution imaging: instrument design (including adaptive optics when necessary), instrument calibration, and post-processing. In this talk I'll discuss post-processing, in relationship with instrument design, for two applications where we use adaptive-optics (AO) assisted instruments: in vivo retinal imaging and space observation from the ground.

I'll first address the processing of images from an existing AO-corrected retinal imaging. Because the observed object is 3D, whereas the recorded image is 2D, the inversion is fundamentally under-determined. I'll show that a reasonable assumption on the observed object leads to a simplification of the imaging model, which can then be combined with marginalized deconvolution to obtain a satisfactory PSF identification and image deconvolution. I'll illustrate the results on experimental images taken on patients at the XV-XX hospital in Paris.

I'll then turn to the co-design of a retinal imaging instrument that combines hardware to sculpt the object illumination with a tailored reconstruction algorithm in order to obtain both optical sectioning and super resolution. I'll also illustrate the results on experimental images taken on our Structured Illumination Ophtalmoscope at the XV-XX hospital.

Finally, I'll touch upon some challenges and results on space observation from the ground. One major challenge is the fact that the PSF is variable, often partly random and unknown, which can lead to an unstable or under-determined inversion. I'll show that the combination of a physics-based PSF model with the above marginalized approach leads to the consistent PSF identification and a successful deconvolution of images taken with very different imaging systems, i.e., both for astronomy on the European Very Large telescope and for Low Earth Orbit satellite imaging at Observatoire de la Côte d'Azur with an Onera AO bench.

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