Deblurring with imperfectly known blurring kernels and applications in microscopy

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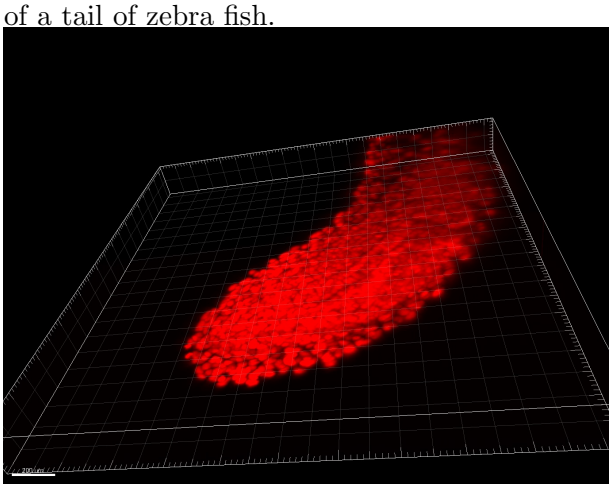
The image obtained by a microscope is typically a convolution of the so-called point-spread function (PSF) of the microscope and the true image of the object of interest. To obtain the original image from the blurred (and typically noisy) measurements, one needs to solve an operator equation

$$Au = f, \quad u \in U,\ f \in F, \tag{1}$$

where U and F are spaces of images and measurements, respectively, and $A\colon U \to F$ is a linear operator that models the convolution with the PSF.

The PSF depends on the physical characteristics of the microscope and is typically estimated during calibration measurements, where images of bright localised objects are recorded. Coming from measurements, the PSF is therefore inevitably prone to errors, which critically influence the reconstruction.

Figure 1: A blurred light-field microscopy image of a tail of zebra fish.



One way to overcome this issue is to estimate the PSF and the image simultaneously, which is referred to as blind deconvolution. This process, however, results in a non-convex optimisation problem that suffers from local minima.

Another way to deal with model imperfections is to account explicitly for errors in the operator and design reconstruction algorithms that remain stable despite the errors in the operator. This approach was taken in [1]. In the proposed framework errors in the operator are modeled using intervals in an appropriate partial order, which allows formulating a convex optimisation problem for the reconstruction of the image of interest.

The goal of this project is to apply this idea to deblurring of microscopy images. It will involve modeling the forward operator in microscopy as well as errors therein and realising the reconstruction scheme in an efficient numerical algorithm.

Experience with MATLAB or Python is required. Knowledge of inverse problems and/or numerical optimisation is an advantage, but not a requirement.

We are looking for a work commitment of 8-10 weeks during the summer.

References

[1] Y. Korolev and J. Lellmann. "Image reconstruction with imperfect forward models and applications in deblurring". In: *SIAM Journal on Imaging Sciences* 11.1 (2018), pp. 197–218.