Curves modelling for super-resolution fluorescence microscopy

M2 internship proposal for spring 2023 (Duration: 5/6 months)

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Host institution: MORPHEME research group (INRIA, CNRS, I3S, Sophia-Antipolis, France)

Context

Conventional optical microscopy techniques, as confocal microscopes, are widely used in biology for cellular and sub-cellular structures investigation. However, their spatial resolution is limited by the light diffraction phenomena, typically around 200nm in the lateral plane, orthogonal to the objective axis. Over the recent years, several super-resolution techniques have been developed to bypass this barrier. In the Morpheme group we have developed advanced algorithms for super-resolved image reconstruction based on sparse functional optimization, see, e.g. [1, 2, 3, 4]. The super-resolved image reconstruction problem is formalized in mathematical terms as an ill-posed inverse problem which is regularized by introducing a sparsity-promoting penalization. Recently we have considered off-the grid methods to get higher localisation precision without increasing the amount of the unknown data [5]. As no methods were developed in this area for curve reconstruction, only for points considering Diracs measures or sets by considering the total variation of the gradient, we recently propose a new functional on the space, denoted $\mathcal{V}$, of 2-dimensional Radon measures with finite divergence [6]. Our main contribution lies in the sharp characterisation of the extreme points of the unit ball of the $\mathcal{V}$-norm: there are exactly measures supported on 1-rectifiable oriented simple Lipschitz curves, thus enabling a precise characterisation of our functional minimisers.

Internship objectives

We are currently working on the optimization algorithm for this functionanal, based on the Sliding-Franck-Wolfe algorithm as proposed for points and sets. The purpose of this internship is to understand the functional and the numerical algorithm we are developing, to extend the initial version to super-resolution by fluctuation of molecules based on the correlation and to test this algorithm on geometrical calibrated slide as well as on Ostreopsis alga microtubule reconstruction, useful for biologists to understand the uncontrolled proliferation of this toxic alga.
This work should be continued within a Phd Thesis where the time evolving reconstruction problem will be studied, theoretically as well as numerically to hand up with a 2D+t super-resolution method for fluorescence micrscopy.

Candidate profile

Second year of Master degree in applied mathematics, computer science, data science with background in optimisation, image processing, imaging inverse problems. Good coding skills for numerical simulation (Python, MATLAB, ...). A general interest in health and biology is welcome.

Practical information

MORPHEME research team is a joint research group between INRIA Sophia Antipolis Méditerranée., I3S Lab (Université Côte d'Azur and CNRS).

Remuneration: internship gratification (approximately 550 euros/month) and possible discounts for nearby accommodation facilities (CIV).

Application procedure

Please send your CV, motivation letter, marks of the last two years of study and the name and e-mail address of a contact for recommendation to Laure Blanc-Féraud (blancf@i3s.unice.fr), Gilles Aubert(Gilles.Aubert@unice.fr).

References

[1] S. Gazagnes, E. Soubies, and L. Blanc-Féraud, "High density molecule localization for super-resolution microscopy using CEL0 based sparse approximation," in *2017 IEEE 14th International Symposium on Biomedical Imaging (ISBI 2017)*, pp. 28–31, 2017.

[2] A. Bechensteen, L. Blanc-Féraud, and G. Aubert, "New $\ell_2 - \ell_0$ algorithm for single-molecule localization microscopy," *Biomedical Optics Express*, 2020.

[3] A. Bechensteen, L. Blanc-Féraud, and G. Aubert, "A continuous relaxation of the constrained $\ell_2 - \ell_0$ problem," *Journal of Mathematical Imaging and Vision*, 2021.

[4] V. Stergiopoulou, L. Calatroni, H. de Morais Goulart, S. Schaub, and L. Blanc-Féraud, "COL0RME: Super-resolution microscopy based on sparse blinking/fluctuating fluorophore localization and intensity estimation," *Biological Imaging*, vol. 2, 2022.

[5] B. Laville, L. Blanc-Féraud, and G. Aubert, "Off-the-grid variational sparse spike recovery: methods and algorithms," *Journal of imaging*, 2021.

[6] B. Laville, L. Blanc-Féraud, and G. Aubert, "Off-the-grid curve reconstruction through divergence regularisation: an extreme point result," *submitted*, 2022.