Physics-inspired GANs 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 and it is typically around 200nm in the transverse plane and 400nm in the optical axis. Over the recent years, several super-resolution techniques have been developed to overcome this drawback. Popular techniques, such that, for example, SMLM (Single Molecule Localization Microscopy) are based on the use photoactivable molecules, while others on structured illumination or on the analysis of the stochastic behaviour of molecule intensity fluctuations(such as SOFI [1]) and many more [2]. In the Morpheme group we have developed advanced algorithms for the analysis of SMLM and SOFI-type data based on sparse optimization reconstruction methods, see, e.g. [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. A different and increasingly popular class of methods producing outstanding results in many applied fields is based on the use of generative learning approaches. Among them, Generative Adversarial Networks (GANs) [5] have the ability, upon training, of generating samples from the unknown distribution of given images by adversarial learning. Inspired by [6], we have combined GANs in the framework of super-resolution reconstruction for estimating a super-resolved image from a sequence of fluorescence images generated by a SOFI simulator tool. The FluoGAN method [7] allows to reconstruct a super-resolved image by generating images from the physical model of acquisition such that the reconstructed image follows the distribution of the observed image, thus mixing data-driven and model-based approaches.

Internship objectives

The purpose of this internship consists in generalising the model of molecule fluctuations, since in FluoGAN [7] approximations have been made for simplicity purposes in the optimization procedure. We aim to introduce a Poisson distribution to model molecule fluctuations, in addition to a Poisson-Gauss noise distribution. The development of unsupervised super-resolution approaches is of utmost interest for the biological community as they are harmless for the sample. Furthermore, they do not need any specific microscope and maintain adequate time resolution. The performance of this approach will be compared with the model-driven (e.g., COL0RME [4]) and data-driven (e.g., VAEs [8]) approaches already developed in the Morpheme research group on synthetic and real data. This work is part of a study on fluorescence images of samples of jellyfish muscles with two fluorescent molecules where super-resolution is needed to study the fine properties of the linkages.

Candidate profile

Second year of Master degree in computer science, applied mathematics, data science with background in image processing, imaging inverse problems, deep learning and optimisation. Good coding skills for numerical simulation (Pytorch, 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), Luca Calatroni (calatroni@i3s.unice.fr).

References

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