Space-Variant Hyperparameter Estimation in Image Microscopy Inverse Problems by Deep Learning

M2 internship proposal for spring 2021 (Duration: 5/6 months)

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

Context

Over the last years, numerous advances in the modelling and in the numerical solution of several image microscopy inverse problems (deconvolution, super-resolution...) and in image classification and segmentation problems have been made, both in statistical and in variational contexts. For both cases, the resulting model is typically composed by a data attachment term and by another term encoding *a priori* assumption on the solution where one or more hyperparameters appear. The estimation of these parameters is crucial for obtaining good reconstruction quality. Several approaches (heuristic or sophisticated) allow to estimate these parameters iteratively (see, e.g., [2, 1] for maximum likelihood approaches). However, in many cases, such estimation is performed globally, without taking into consideration the spatial variability of image contents. On the other hand, recent deep-learning-based approaches have been shown to be very effective for several image reconstruction and image analysis problems such as the estimation of classification classes or representative features associated to a set of data [5].

Internship objectives

The objective of this internship project is the development of a deep-learning-based approach for the estimation of locally varying hyperparameters following, for instance, by means of U-NET [4] or the unrolling strategy considered, e.g., in [3]. For this task, the training set will be constituted by patches of reduced size associated to optimal values of the parameters which will be created either by a simulation of the model considered to which perturbations will be added or from samples extracted from real images on which the parameters will be empirically adjusted. For the numerical tests, hyperparameter maps will be estimated by the networks considered by considering different patches centred at each image pixels. We will compare the results obtained with the ones computed by a direct deep-learning approach where no modelling is encoded.

Different case studies on several simulated and (possibly) real microscopy images will be tested in order to validate the approach proposed.

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 (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 and a motivation letter to Xavier Descombes (xavier.descombes@inria.fr), Luca Calatroni (calatroni@i3s.unice.fr).

References

[1] L. Calatroni, A. Lanza, M. Pragliola, F. Sgallari, *A Flexible Space-Variant Anisotropic Regularization for Image Restoration with Automated Parameter Selection*, SIAM Journal on Imaging Sciences, 12(2), 2019.

[2] X. Descombes, R.D. Morris, J. Zerubia, M. Berthod, *Estimation of Markov Random Field Prior Parameters Using Markov Chain Monte Carlo Maximum Likelihood*, IEEE Trans. on Image Processing, 8(7), 1999.

[3] G. Dardikman-Yoffe, Y. C. Eldar, *Learned SPARCOM: unfolded deep super-resolution microscopy*, Optics Express, 28 (19), 2020.

[4] O. Ronneberger, P. Fischer, T. Brox, *U-Net: Convolutional Networks for Biomedical Image Segmentation*, In: Navab N., Hornegger J., Wells W., Frangi A. (eds) Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015. MICCAI 2015. Lecture Notes in Computer Science, vol 9351. Springer, Cham, 2015.

[5] F. Xing, Y. Xie, H. Su, F. Liu, L. Yang, *Deep Learning in Microscopy Image Analysis: A Survey*, IEEE Transactions on Neural Networks and Learning Systems, 29(10), 2017.