Post-doctoral position:
Multilevel unrolled and plug-and-play methods

Keywords: Inverse problems, deep learning, multilevel algorithms, proximal algorithms.

Supervisors:
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Location: ENS Lyon, France.

Start date and duration: The exact starting date is flexible and will be arranged with the candidate, and it should take place between the end of 2023 and the beginning of 2024. The position is funded for the duration of 12 months.

Research environment: The postdoctoral research associate will be part of the SYSIPHE and OCKHAM teams at ENS Lyon in Lyon, France. ENS Lyon is a small-size research-driven university in France, that is consistently ranked among the best universities in France. The applicant will benefit from a stimulating environment of research scientists in machine learning, signal processing and physics, with weekly seminars given by international experts.

Subject: Inverse problem solving is a challenging question in image processing, leading to a large panel of applications going from geophysics research to societal studies. The common point of these applications is the willingness to have an accurate estimation at a fine scale from high-resolution data.

A natural way to tackle such increasingly large problems is to exploit their underlying structure and represent them at different resolution levels. The use of multi-resolution schemes, such as the wavelet transform, is not new in imagining and is widely used to define regularization strategies. However, such techniques can be used to a wider extent, in order to accelerate the optimization algorithms used to solve inverse problems and to tackle large datasets. Techniques based on such ideas are usually called multilevel optimization methods and are well-known and widely used in the field of smooth optimization, especially in the solution of partial differential equations. Only recently these techniques have been extended to multilevel versions of proximal methods, adapted to solve non-smooth optimization problems arising in image reconstruction [1].

The most recent strategies to solve inverse problems benefit from deep learning techniques going from plug-and-play methods to proximal neural networks [2]. However, multilevel approaches have not been yet explored in the context of plug-and-play restoration with deep denoisers, or in unrolled optimization architecture with learnable parts.

The project will aim to adapt and extend multilevel optimization techniques to the following two settings:

- **Plug-and-play**: In this project, we propose to combine multilevel proximal methods and multi-resolution analysis to plug-and-play techniques as a solution to accelerate such techniques and obtain better estimates.

- **Unrolled**: This project will also investigate the construction of unrolled network architectures based on multilevel optimization techniques. We aim to understand the scale equivariance properties of the resulting network [3] by leveraging some of the recent advances in scale equivariant neural networks, which have been mostly studied in the context of classification [4].

Apply: applicants should send a CV including a list of publications and contact information for two references to Nelly Pustelnik, Julian Tachella, and Elisa Riccietti.

References:

[1] G. Lauga, E. Riccietti, N. Pustelnik, and P. Goncalves, IML FISTA: Inexact MuLtilevel FISTA for Image Restoration, arXiv :2304.13329, 2023.

[2] H.T.V. Le, A. Repetti, N. Pustelnik, PNN: From proximal algorithms to robust unfolded image denoising networks and Plug-and-play methods, arXiv :2308.03139, 2023.

[3] D. Chen, M. Davies, M. J. Ehrhardt, C.-B. Schönlieb, F. Sherry, and J. Tachella, Imaging With Equivariant Deep Learning: From unrolled network design to fully unsupervised learning, in IEEE Signal Processing Magazine, Jan. 2023.

[4] D. Worrall and M. Welling, Deep scale-spaces: Equivariance over scale, Advances in Neural Information Processing Systems, vol. 32, 2019.