M2 internship + PhD subject
Unfolded proximal algorithms for texture segmentation

Mots-clés : Wavelets, scale-free, multifractal analysis, optimization, proximal algorithms, segmentation, deep learning.

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Contexte : The objective of this Internship (and PhD) is to propose deep learning network architectures designed from proximal optimization schemes [1]. This class of optimization methods was originally dedicated to non-smooth convex minimization by replacing the usual explicit gradient descent step by a proximal operator step that can be interpreted as an implicit subgradient descent.

Nowadays, deep learning methods are the norm for several image processing tasks such as classification or segmentation. The main limitation of these supervised approaches may come from difficult annotation of a large database and extremely high learning costs.

A less expensive alternative in terms of learning time relies on the joint construction of functionals to be minimized and proximal algorithmic schemes. However, the performance of this class of methods can strongly depend on adjustable parameters such as the algorithm step-size, ensuring convergence, and regularization parameters, allowing a good fitting between the data fidelity term and the penalization.

In order to take advantage of both worlds, the construction of deep networks relying on unfolded iterations has emerged. We can refer to LISTA proposed by Gregor and LeCun [2] as pioneering work on this subject in the context of "sparse coding" where each layer is built as the combination of a linear transformation and the application of a proximal operator (assimilated to an activation function). In this design, the number of layers of the network corresponds to a number of iterations of the algorithm and a gradient backpropagation procedure allows to learn the previously adjustable parameters (step-size, regularization parameters) [3]. The stability of this unfolded algorithms are mainly due to the links between the activation functions and the proximal operators.

This analogy makes it possible to guide the deep network architecture by relying on the variational formulation guided by the considered problem (segmentation, inverse problem solving, etc.) and the associated variational formulation developed during the last 20 years to ensure understanding and robustness of the network. This PhD subject focuses on the specific issue of texture segmentation.

Texture segmentation : Automated image segmentation constitutes a crucial task in image processing, for many different purposes ranging from medical imagery to geophysics (cf. Figure 1). For years, texture segmentation was performed via a classical two-step procedure : First, prior knowledge or expert choice driven features are computed (e.g., Gabor, gradients, differencesof oriented Gaussians,...) ; Second, these features are combined via a clustering algorithm. Recently, research focus has been on combining these two steps into a single one to improve interface detection and thus segmentation performance. This has been first envisaged by retaining hand-crafted features but modifying classical frameworks. Recently, deep learning renewed this topic, jointly performing feature estimation as well as segmentation, rapidly followed by texture segmentation.

In SYSIPH team, we recently develop efficient segmentation tools relying both on unsupervised and supervised strategies in order to perform simultaneously feature estimation as well as segmentation. On the one hand, the combinaison of scale-free descriptors (based on wavelets transforms) and nonsmooth optimization (based on proximal algorithms) allowed us to perform unsupervised segmentation on synthetic and real texture data [4,5]. On the other hand, an architecture based on CNNs has been proposed [6] and compared to the unsupervised strategy.

The objective of this PhD subject is to go further to perform simultaneously feature estimation and segmentation by combining unsupervised and supervised strategies using the previously mentioned deep unfolded algorithms. Such an hybrid strategy will benefit from a better understanding of the designed network and is expected to improve the performances on smaller databases.

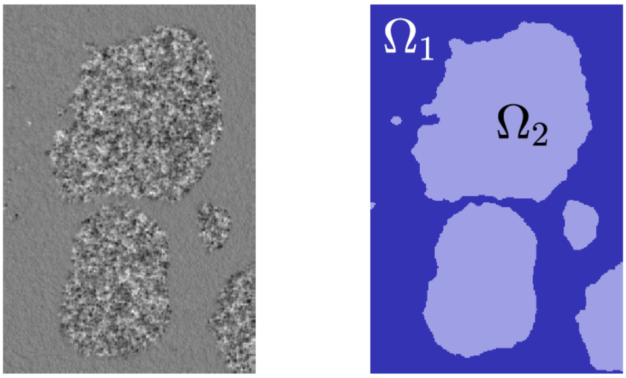

FIGURE 1 – *Multiphasic flow experiment conducted at Laboratoire de Physique de l'ENS de Lyon (LPENSL) modeling gas and liquid in a porous medium. Goal : identifying the interface between gas and liquid.*

Skills : The candidate should have knowledge in signal and image processing as well as optimization and deep learning. He/She will also have to master Python.

Eligibility : EU Citizenship.

Application : CV + motivation letter by email.

Références :

[1] P. L. Combettes and J.-C. Pesquet, Proximal splitting methods in signal processing, in : Fixed-Point Algorithms for Inverse Problems in Science and Engineering, (H. H. Bauschke, R. S. Burachik, P. L. Combettes, V. Elser, D. R. Luke, and H. Wolkowicz, Editors), pp. 185-212. Springer, New York, 2011.

[2] K. Gregor and Y. LeCun, Learning fast approximations of sparsecoding,in International Conference on Machine Learning, 2010, pp.399-406.

[3] M. Jiu, N. Pustelnik, A deep primal-dual proximal network for image restoration, accepted to IEEE JSTSP, 2021. (PDF).

[4] B. Pascal, N. Pustelnik, and P. Abry, How Joint Fractal Features Estimation and Texture Segmentation can be cast into a Strongly Convex Optimization Problem, submitted, 2019. (PDF).

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[6] B. Pascal, V. Mauduit, P. Abry, and N. Pustelnik Scale-free texture segmentation : Expert feature-based versus Deep Learning strategies, European Signal Processing Conference (EUSIPCO), The Netherlands, Amsterdam, January 18 - 22, 2021. (PDF).