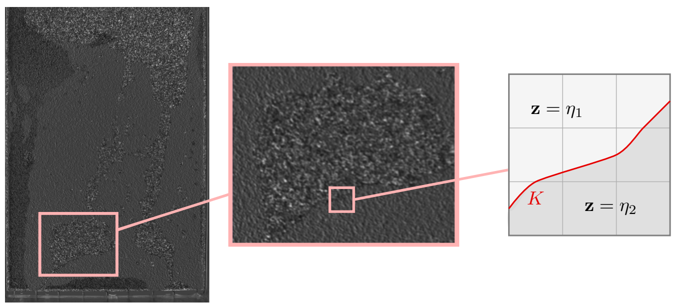
PhD position
Multiscale estimation and Interface detection

Key-words – Proximal algorithms, multiscale analysis, interface detection, large-scale image processing, deep learning

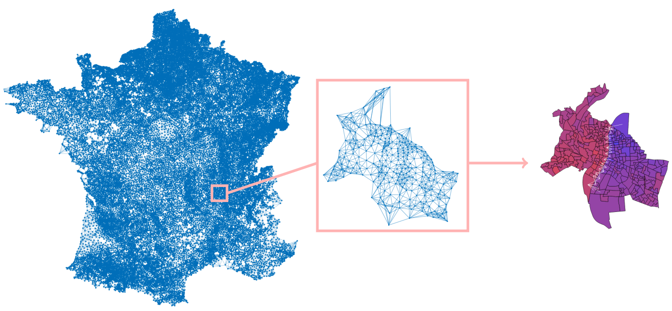
Context – Interface detection is a challenging question in image processing, and more generally in graph processing, leading to a large panel of applications going from geophysics research to societal studies as illustrated in Figure 1. The common point to these applications is the willingness to have an **interface detection at a fine scale**, possibly with subpixel accuracy, in order to extract interpretable parameters (e.g. physical or societal), from **high resolution data**.

Subject – This PhD is devoted to the development of innovative image/graph processing tools relying both on optimization and multiresolution analysis in order to provide a new paradigm for the interface detection on large scale data. This project essentially relies on:

- a deep theoretical study of the discrete Mumford-Shah (MS) model to perform accurate interface detection, and thus measure precise interface length;
- the design of multiscale proximal algorithms to make possible the implementation of the discrete Mumford-Shah model on large scale data;
- the study of alternative solutions relying on deep learning strategies.



(a) Multiphasic flow



(b) Graph analysis

Figure 1: *1st row: left) 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. Image composed with* 2.10^7 *pixels. Analysis to be performed on a sequence of images. (1st row: middle) Zoom at the location of the interface. (1st row: right) The red line models the resolution of the interface we would like to obtain while the grid models the pixels of the image. (2nd row: left) Graph of French vote locations. Goal: estimate the transfer matrice between two elections at each vote location with a special focus on similar electoral behaviour and sharp transitions. Size of the data to estimate* $\sim 10^7$*. (2nd row: middle) Zoom on Lyon city. (2nd row: right) Illustration of the estimate on syntetic data (interfaces are displayed with white lines).*

The interest in dealing with the original (and not a relaxed) MS model is the possibility to handle jointly with a reconstruction task and interface detection rather than performing a two-step procedure. The main limitations of MS formalism are the non-convexity of its discrete formulation and its computational burden. The objective of this PhD subject is to tackle this twofold difficulties by having recurse to recent development in optimization, offering the possibility to handle complex nonsmooth objective functions and even more recently adapted to nonconvex formulation [1,2].

Performance resulting from the theoretical developments explored in this project will be evaluated both on synthetic and on real data. We identified several challenging applications for which data and specialist knowledge are avalaible.

Location : ENS de Lyon (France) and/or UCLouvain (Belgium).

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Funding : This PhD is part of the ANR JCJC Multisc'In (Multiscale estimation and Interface detection) whose consortium is composed with L. Briceño-Arias (Univ. Técnica Federico Santa María, Chili), L. Condat (CNRS and KAUST, Saudi Arabia), M. Foare (CPE Lyon and ENS de Lyon, France).

Skills: The candidate must have a Master degree in computer science, mathematics or physics and should have skills in some of the following areas: Signal and Image Processing, Data science, Optimization, Machine Learning.

Application: The deadline for applications to this post is 15 March 2020. Applicants must send by email a CV and a statement of interest to Nelly Pustelnik (nelly.pustelnik@ens-lyon.fr). For further information, candidate can contact nelly.pustelnik@ens-lyon.fr with questions related to this position.

References:

[1] M. Foare, N Pustelnik, L. Condat, "Semi-linearized proximal alternating minimization for a discrete Mumford-Shah model," IEEE Transactions on Image Processing, 2019. (HAL).

[2] H. Attouch, J. Bolte, P. Redont, and A. Soubeyran, "Proximal alternating minimization and projection methods for non convex problems: An approach based on the Kurdyka-Lojasiewicz inequality," Mathematics of Operations Research, vol. 35, no. 2, pp. 438–457, May 2010. (HAL).