

M2 Internship offer

Multifractal analysis for multivariate images:

Texture characterization. Anomaly detection. Multifractals and deep networks.

<i>Duration :</i>	6 months	<i>Place :</i>	Ecole Normale Supérieure de Lyon
<i>Requirements :</i>	Solid background in Math & Statistics ; MATLAB	<i>Perspectives:</i>	Ph.D follow-up possible

Research team and supervision.

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Scientific context.

Texture characterization and anomaly detection are ubiquitous and challenging issues in image processing and have been envisaged through many different concepts. Over the decades following the seminal works of Benoît Mandelbrot, an overwhelming number of signals and images have been shown to be well-characterized by *fractal* and *scale invariance* properties. This implies a major change in paradigm: the characterization can no longer rely on one specific analysis scale since all scales play an equivalent role, and the classical signal/image processing tools must thus be replaced with tools that evidence and quantify the mechanisms relating scales one to the other.

Multifractal analysis has recently matured to become one of the most powerful tools for this purpose. It benefits from a well-grounded theoretical framework and a robust practical and has been extremely successful in a large panel of applications of very different natures. Yet, these successes assumed that

- i) data are univariate (independent analysis of one image at a time)
- ii) data are isotropic (all directions in an image are equivalent)
- iii) data are homogeneous (multifractal properties are the same everywhere in the image)

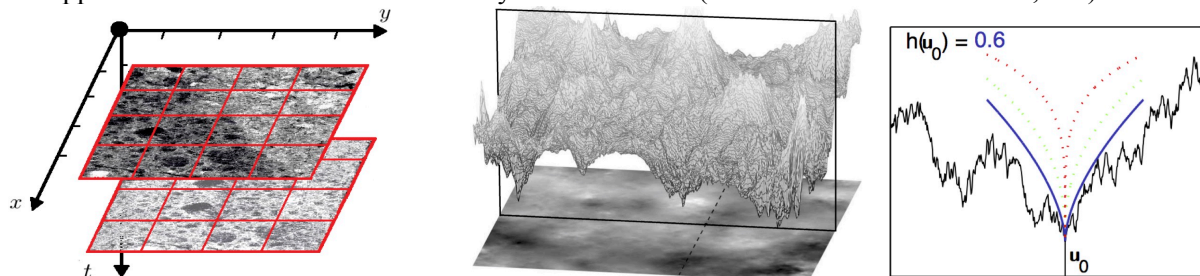
while these requirements are no longer met in many modern real-world applications. Indeed, data are often naturally multivariate (dependent measurements, captured by different imaging sensors, jointly convey the information of interest), anisotropic (certain directions in the image have privileged roles) and often consist of zones, to be detected, whose properties differ from that of the rest of the data.

This internship has the overall objective of studying theoretical and practical solutions to the multifractal analysis of multivariate, anisotropic, heterogeneous images, starting from preliminary results by the advisors. One specific aspect will be the exploration of theoretical connections and potential combinations of *multifractals and learning*, as pioneered for deep scattering networks. The tools will be put to test on real-world data from two major fields of applications - remote sensing and biomedical imaging.

Further details and references are available upon request.

Application.

All applications must be sent electronically to the advisors (minimum: motivation letter, CV).



Left: a multivariate image consisting of a spatial (x,y) and temporal (t) collection of patches (in red).

Multifractal analysis characterizes scale invariance of the image intensities (schematized in the center) via the fluctuation of their pointwise regularity, measured by the Hölder exponent $h(u)$ (right).