M2 Internship offer

Multivariate selfsimilarity analysis using Complex wavelets.

Duration :	**6 months**, from April 2020	*Place :*	Ecole Normale Supérieure de Lyon
Requirements :	Solid background in Math & Statistics ; MATLAB	*Perspectives:*	Ph.D follow-up possible

Research team and supervision.

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Scientific context: multivariate selfsimilarity.

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 ones to the others. Scale invariance is well modeled by stochastic processes gathered under the generic concept of selfsimilarity.

However, so far, selfsimilarity analysis remains univariate: one signal is analyzed at a time even when several time series are collected jointly. In most modern applications, several, often many (the data deluge) time series are collected to monitor one same system. The goal of the proposed internship is to contribute to multivariate selfsimilarity analysis.

Proposed work: Phase and complex wavelet.

So far, the analysis of has been conducted using mostly real wavelets. However, multivariate analysis puts phases and delays at the heart of the analysis. This internship is intended to explore the potential benefits of using complex wavelets to analyze phases in multivariate selfsimilarity. Notably, in neurosciences, notably, Functional Connectivity, an important concept for understanding brain activity, assess the dependencies between different regions of the brain. However, delays in brain signals received on sensors due to propagation through the brain may preclude an accurate measure of Functional Connectivity. A first goal will hence be to explore if and how the use of complex wavelets can permit to detect delays and to more robustly assess dependencies amongst time series. After benchmarking with synthetic data, the devised tools will be applied to real MEG data collected at NeuroSpin. Beyond functional connectivity, the statistics of phases in complex wavelet coefficients will be studied on several stochastic models commonly used to model scale invariance: selfsimilarity and multifractality. The goal here is understand what structural information is encoded in phase.

Possible follow-up: Multivariate self-similarity in large dimension.

A PhD continuation of this internship is possible. It would be centered around the analysis of selfsimilarity in very large dimension (the number of components or collected time series becomes large compared to the number of samples in time). This raises difficult question related to the mathematical formulation of the estimation problem, to the theoretical study of estimation performance and to development of corresponding practical codes. This is relevant for multivariate images as well as for multivariate signals.

Application. All applications must be sent via email (minimum: motivation letter, CV, M2 marks). Due to the funding, EU citizenship is mandatory.

References.

Neurosciences context: **http://perso.ens-lyon.fr/patrice.abry/18EUSIPCO.pdf**
Methodology**: http://perso.ens-lyon.fr/patrice.abry/18SSPTestH.pdf**

Further details and references are available upon request.