Postdoctoral research position (12 months)
with CRAN/SiMul in Nancy, France

Geometric Bayesian inference for bivariate signals

Supervision.

Julien Flamant, CNRS researcher, CRAN

Contact. julien.flamant@cnrs.fr
CRAN website CRAN-SiMul research group

Funding The position is funded by the French National Research Agency (ANR) grant RICOCHET "Bivariate signal processing: a geometric approach to decipher polarization" (2022-2026).
ANR official website RICOCHET webpage

Collaborations This postdoctoral research project will involve strong collaborations with colleagues at CRIStAL, Lille, in particular Pierre-Antoine Thouvenin (Associate Professor, Centrale Lille), Jérémie Boulanger (Associate Professor, Université de Lille) and Pierre Chainais (Full professor, Centrale Lille).

Employment terms. The position is for 12 months, starting anytime from January 2023. The postdoctoral researcher will be located at CRAN, Nancy, France. Gross salary will be about 2900 € /month. He/She will benefit from the scientific environment of RICOCHET, as well as funding for travel and participation in national and international conferences.

Scientific summary.

Bivariate signals are ubiquitous in many areas whenever there is the need to represent and evidence the interrelation between coupled observables. Bivariate signals describe trajectories in a 2D plane whose geometric properties (e.g. directionality) have a natural interpretation in terms of the physical notion of polarization usually used for waves. More generally, polarization encodes the evolution of geometric properties with respect to other variables, such as time, frequency, or spatial coordinates. Fig. 1 depicts an example of a bivariate AM-FM signal, whose polarization properties evolve slowly with time, resulting in complex interrelations between amplitude and phase of each bivariate component. Being able to properly model and reconstruct polarization-based observables is crucial to many applications: for instance, in gravitational wave (GW) astronomy, inference of the instantaneous polarization of GW signals provides unique insights on the orbital motion of the GW source [1]. The ANR grant RICOCHET aims to unlock these essential physical insights by the development of a complete set of theoretical and methodological tools to fully exploit the polarization information of bivariate signals.

This postdoc project focuses on the development of new statistical inference tools for bivariate signals. We will consider a Bayesian framework, as it allows for natural modelling of prior information and the computation of credible intervals. The expected contributions are twofold:

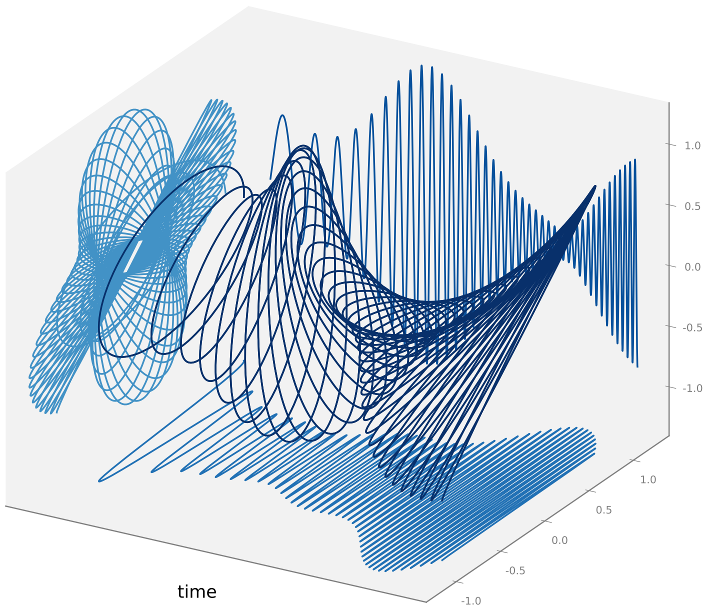

Figure 1: Example of a bivariate AM-FM signal.

(i) the formulation of dedicated priors for bivariate signals that take into account the geometry of polarization information; *(ii)* the development of an efficient and scalable methodology to solve inverse problems using the newly introduced priors.

More precisely, this project will exploit the different geometric representations of polarization, e.g. using the Poincaré sphere of polarization states or the space of 2-by-2 complex covariance matrices [2]. We will exploit the intrinsic geometry of these representations to develop new priors for polarization, using e.g directional distributions [3] or Gaussian densities on covariance matrices [4]. The physical relevance of the solution will also be considered : for instance, gravitational waves are expected to behave as *polarized AM-FM signals* [5], a class of non-stationary bivariate signals with peculiar dynamical constraints. It is likely that constructed Bayesian models will involve high-dimensional complex distributions (e.g. non-differentiable log-distributions). We will take advantage of recent advances in stochastic simulation that marry Markov Chain Monte Carlo (MCMC) methods with convex optimization methods [6]–[8] (such as divide-and-conquer methods [8]) that make Bayesian inference computationally efficient and scalable.

It is recommended, yet not limiting, that the candidate has expertise in one or more of the following fields: multivariate signal processing, Bayesian inference, Riemannian / geometric approaches in signal processing, optimization. A taste for applications in gravitational wave astrophysics will be appreciated.

References

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[2] M. Born and E. Wolf, *Principles of optics: electromagnetic theory of propagation, interference and diffraction of light*. Elsevier, 2013.

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[6] P. J. Green, K. Łatuszyński, M. Pereyra, *et al.*, "Bayesian computation: A summary of the current state, and samples backwards and forwards," *Statistics and Computing*, vol. 25, no. 4, pp. 835–862, 2015. DOI: `10.1007/s11222-015-9574-5`. [Online]. Available: `https://doi.org/10.1007/s11222-015-9574-5`.

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[8] M. Vono, N. Dobigeon, and P. Chainais, "Asymptotically exact data augmentation: Models, properties, and algorithms," *Journal of Computational and Graphical Statistics*, 2020.