Journées Statsitiques du Sud: Book of abstracts

Mini-courses

Statistics for Hawkes processes

Charlotte Dion-Blanc

Sorbonne Université

In this short course, I will present several statistical methods for consistently estimating the shape of the intensity function driving an underlying Hawkes process. Particular attention will be paid to strategies designed for high-dimensional settings. I will then discuss statistical testing procedures. Finally, I will present recent developments on Hawkes processes with covariates, as well as methods for change-point detection.

Spectral Operator Learning of Dynamical Systems

Vladimir R. Kostić

University of Novi Sad, Serbia, and Italian Institute of Technology in Genova, Italy

Many phenomena in science and engineering are governed by dynamical systems whose long-term behavior is encoded in the spectral properties of associated linear evolution operators. Examples range from molecular dynamics and climate systems to neuroscience and machine learning models. Recent years have witnessed the emergence of statistical approaches that aim to recover these spectral objects directly from data, bypassing the need for explicit knowledge of the underlying equations.

This mini-course presents two complementary perspectives on statistical spectral learning. The first lecture introduces Toeplitz-based estimators for transfer and Koopman operators, showing how ideas from harmonic analysis, Toeplitz matrices, and statistical learning theory can be combined to estimate eigenvalues, eigenfunctions, and spectral measures from equilibrium trajectories. The second lecture focuses on overdamped Langevin dynamics and shows how one can learn the spectral structure of the infinitesimal generato even from biased samples, hence recovering slow dynamics, transition timescales, and projected drift fields using only black-box feedback on the potential energy discrepancy.

Throughout the course, emphasis will be placed on the interplay between spectral perturbation theory and statistical learning, as well as on practical applications ranging from chaotic systems and molecular dynamics to modern machine learning models.

Talks

Minimax Independence Testing Based on HSIC and permutation

Mélisande Albert

INSA Toulouse

Dependence measures based on reproducing kernel Hilbert spaces, also known as the Hilbert–Schmidt Independence Criterion (HSIC), are widely used to assess statistical dependence between two random vectors. While earlier nonparametric HSIC-based independence tests have been proposed, they rely on the prior selection of a kernel, which remains a challenging issue. To address this limitation while preserving strong theoretical guarantees, we introduced in 2022 an aggregated HSIC-based testing procedure that combines multiple Gaussian kernels with varying bandwidths. The resulting aggregated test are shown to control the type I error probability and to achieve adaptivity. However, this testing procedure relies on the marginal distributions which are usually unknown. In practice, the critical value of each single test is approximated by permutation. To establish the minimax optimality of this permutation-based procedure, we derive a new concentration inequality for permuted U-statistics, and show that it yields minimax optimal rates. Joint work in progress with Beatrice Laurent.

Box Confidence Depth: simulation based inference with hyper rectangles

Elena Bortolato

Universitat Pompeu Fabra and the Barcelona School of Economics

This work presents a novel simulation-based approach for constructing confidence regions in parametric models, which is particularly suited for generative models and situations where limited data and conventional asymptotic approximations fail to provide accurate results.

The method leverages the concept of data depth and depends on creating random hyperrectangles, i.e. boxes, in the sample space generated through simulations from the model, varying the input parameters. A probabilistic acceptance rule allows retrieving a Depth- Confidence Distribution for the model parameters from which point estimators as well as calibrated confidence sets can be read-off. The method is designed to address cases where both the parameters and test statistics are multivariate.

Federated Learning in Healthcare: From Theory to Practice

Marco Lorenzi

Inria Sophia Antipolis and Université Côte d'Azur

This talk will illustrate current advances in adapting and translating the research on distributed modeling and federated learning (FL) to the analysis of sensitive data in real-world biomedical applications.

I will first discuss the robustness and variability of federated learning to heterogeneous conditions, and I will illustrate novel federated optimization schemes to maximise the representativity and minimize the variability of clients contributions across federated optimization rounds. I will also introduce a novel perspective to Federated Unlearning (FU), a recent development in the FL literature aiming at providing theoretical guarantees on the removal of the contribution of a given client from a federated training procedure. Finally, from a translational perspective, I will introduce Fed-BioMed (`fedbiomed.org`), a large-scale open-source initiative aimed at integrating federated learning into real-world healthcare applications. Fed-BioMed tackles the challenges required to meet real-world translation, concerning FL security, scalability and interoperability. I will give an illustration of the interplay between methodological development and translational effort in neuroimaging that characterise the development of the Fed-BioMed FL platform, and discuss our current effort in delivering FL in hospitals networks.

Splitting methods for stochastic Hodgkin-Huxley type systems and a localized fundamental mean-square convergence theorem

Anna Melnykova

Université Avignon

Existing fundamental theorems for mean-square convergence of numerical methods for stochastic differential equations (SDEs) require globally or one-sided Lipschitz continuous coefficients, while strong convergence results under merely local Lipschitz conditions are largely restricted to Euler-Maruyama type methods. To address these limitations, we introduce a novel localized version of the fundamental mean-square convergence theorem for SDEs with locally Lipschitz coefficients, which naturally arise in a wide range of applications.

The proposed convergence framework is then applied to the splitting schemes approximating the solution of conditionally linear SDEs (a key example of one being stochastic Hodgkin-Huxley model). In addition, we establish key structure-preserving properties of the splitting methods, in particular state-space preservation and geometric ergodicity. Numerical experiments support the theoretical results and demonstrate that the proposed splitting schemes significantly outperform Euler-Maruyama type methods in preserving the qualitative features of the model.

Inference for Hüsler–Reiss block models

Nicolas Meyer

Université Montpellier

Extreme events, though rare, can have substantial environmental, societal, and economic consequences. Their modeling is typically studied within the framework of extreme value theory, where statistical inference is challenging due to the scarcity of observations, particularly in high dimension. This motivates the search for parsimonious and interpretable structures. In this work, we focus on the Hüsler–Reiss distribution, a versatile model in which extremal dependence can be captured through an extremal precision matrix that plays a role analogous to that of the precision matrix in the Gaussian framework. Building on a clustering algorithm proposed for Gaussian dependence, we introduce a convex fusion penalty for the maximum likelihood estimation of the extremal precision matrix, encouraging variables with similar tail dependence patterns to cluster together. This method promotes block structures, thereby inducing a sparse representation that is interpretable in terms of extremal dependence. We study the theoretical properties of the procedure and prove consistency of the estimator under a block-structured assumption. Simulation studies illustrate the performance of the proposed approach.

Efficient Stochastic Zeroth-order Bilevel Optimization

Marco Rando

Université Côte d'Azur

Bilevel optimization problems consist of minimizing a value function whose evaluation depends on the solution of an inner optimization problem. These problems are typically tackled using first-order methods that require computing the gradient of the value function (the hypergradient). In several practical settings, however, first-order information is unavailable, rendering these methods inapplicable. Finite-difference methods provide an alternative by approximating hypergradients using function evaluations along a set of directions. However, such surrogates are notoriously expensive, and most finite-difference bilevel approaches rely on two-loop algorithms that are poorly parallelizable. Recently, several works have proposed single-loop finite-difference methods enabling parallelization. However, to ensure stability, these methods require a large number of function evaluations per iteration, limiting their applicability in high-dimensional settings with limited evaluation budget. To tackle this limitations, we propose ZOBA, an efficient finite-difference single-loop algorithm for bilevel optimization. Our method leverages hypergradient approximations based on delayed information and function values reusage to enable parallelization while limiting the per-iteration cost. We analyze the proposed algorithm and establish convergence rates in the non-convex setting, achieving a complexity of $\mathcal{O}(p(d+p)^2\varepsilon^{-2})$, where p and d denote the dimensions of the inner and outer variables, respectively and $\varepsilon \in (0,1)$ is the accuracy. This improves upon prior approaches based on Hessian approximation. We further introduce and analyze HF-ZOBA, a Hessian-free variant that yields optimal complexity. Finally,

we corroborate our findings with numerical experiments on synthetic functions and a real-world black-box task in adversarial machine learning. Our results show that our methods achieve accuracy comparable to state-of-the-art techniques while requiring significantly less computation time.

Hawkes Processes for Modeling Learning in Neural Networks

Patricia Reynaud-Bouret

Université Côte d'Azur

Thanks to the neurons in our brain, we are capable of learning and memorizing. Unlike artificial neural networks, these biological networks locally adjust their synaptic weights to achieve global learning. We will discuss a toy model based on Hawkes processes, where we can mathematically demonstrate that local rules can lead to global learning. Additionally, these networks can help recover measurable macroscopic quantities, such as the evolution of reaction times during a learning task. This presentation will be based on several studies conducted during Sophie Jaffard's PhD thesis, in collaboration with Samuel Vaiter, Etienne Tanré (LJAD, Nice), and Giulia Mezzadri (Columbia, USA).
