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Book of abstracts

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S1. State Inference Wednesday, June 4, 11:00-12:30

ON ADAPTIVE FILTERING OF LOW NOISE LINEAR SYSTEM

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Parameter estimation; Kalman filter; Asymptotic properties; One-step MLE-process, adaptive filtering:

We consider the problem of constructing an adaptive filter for a partially observed system

$$
\begin{aligned}
\mathrm{d}X_t &= f(\vartheta,t)\,Y_t\,\mathrm{d}t + \varepsilon\,\sigma(t)\,\mathrm{d}W_t, \qquad X_0=0, \quad 0\le t\le T,\\
\mathrm{d}Y_t &= a(\vartheta,t)\,Y_t\,\mathrm{d}t + \psi_\varepsilon\,b(\vartheta,t)\,\mathrm{d}V_t, \qquad Y_0=y_0,
\end{aligned}
$$

where $W_t, V_t, 0\le t\le T$ are independent Wiener processes, $f(\vartheta,t), \sigma(t), a(\vartheta,t), b(\vartheta,t)$ are known smooth functions, $\vartheta\in\Theta\subset\mathcal{R}^d$ is an unknown parameter and $\psi_\varepsilon=\varepsilon^\delta, \delta\in[0,1]$. The main problem is the construction of an asymptotically efficient estimator $m_{t,\varepsilon}^\star$ of the conditional expectation $m(\vartheta_0,t)=\mathbf{E}_{\vartheta_0}(Y_t|X_s, 0\le s\le t)$. We describe the asymptotic ($\varepsilon\to 0$) properties of some estimators of the parameter ϑ and of the error $m_{t,\varepsilon}^\star - m(\vartheta_0,t)$. It is shown that, depending on the value of δ, there are four distinct problems. The point of the *phase transition* is $\delta=1/3$. The proposed construction follows the program: preliminary estimator $\to$ One-step MLE-process $\to$ adaptive filter.

References

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[2] Kutoyants, Y.A. (2025) *Hidden Markov Processes and Adaptive Filtering*. Springer Series in Statistics, Cham.

ASYMPTOTIC ANALYSIS OF THE FINITE PREDICTOR FOR THE FRACTIONAL GAUSSIAN NOISE

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fractional Gaussian noise; long range dependence; asymptotic analysis; prediction.

In this talk I will present a new approach to asymptotic analysis of the finite predictor for stationary sequences. It produces the exact asymptotics of the relative prediction error and the partial correlation coefficients. The assumptions are analytic in nature and applicable to processes with long-range dependence. The ARIMA type sequence driven by the fractional Gaussian noise (fGn), a process that previously remained elusive, serves as our study case.

References

[1] Ibragimov, I. A., Solev, V. N. (1968) *Asymptotic behavoir of the prediction error of a stationary sequence with a spectral density of special form*, Teor. Verojatnost. i Primenen., 13:746–751.

[2] Inoue, A. (2002) *Asymptotic behavior for partial autocorrelation functions of fractional ARIMA processes*, Ann. Appl. Probab. 12(4):1471–1491.

[3] Babayan, N. M. and Ginovyan, M. S. (2023) *Asymptotic behavior of the prediction error for stationary sequences*, Probab. Surv. 20:664–721.

[4] Chigansky, P., Kleptsyna, M. (2025) *Asymptotic analysis of the finite predictor for the fractional Gaussian noise*, arXiv preprint 2504.01562

DEEP LEARNING FOR THE NONLINEAR FILTERING PROBLEM

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Nonlinear filtering; Backward stochastic differential equations; the Fokker–Planck equation; Deep learning:

The problem of estimating the probability density of a continuous state given noisy measurements is called the filtering problem. In the case when the system of states and observations is nonlinear the problem cannot be solved analytically (except in a few special cases). Classical methods, namely particle filters, suffer under the curse of dimensionality in the underlying dimension of the state space. Deep learning is a powerful tool in creating scalable approximations for similar problems. In the last few years we have examined methods that exploits the Fokker–Planck equation that is related to state equations governed by Stochastic Differential Equations (SDE). This work concerns using the Deep Backward SDE [3] approach to solve the Fokker–Planck equation. The obtained approximation, after training, is a fast online filter, similar to that of [1, 2] with deep splitting but more robust. We examine the convergence of the method and show numerical examples compared to the bootstrap particle filter.

References

[1] Bågmark, K., Andersson, A., & Larsson, S. (2023). An energy-based deep splitting method for the nonlinear filtering problem. *Partial Differ. Equ. Appl.* 4, 14 (2023).

[2] Bågmark, K., Andersson, A., Larsson, S., & Rydin, F. (2024). A convergent scheme for the Bayesian filtering problem based on the Fokker–Planck equation and deep splitting. arXiv:2409.14585.

[3] Han, J., Jentzen, A., & E, W. (2018). Solving high-dimensional partial differential equations using deep learning. *Proceedings of the National Academy of Sciences*, 115(34), 8505-8510.

S2. Stochastic Modeling
Wednesday, June 4, 14:00-15:30

POLYNOMIAL APPROXIMATION OF DISCOUNTED MOMENTS

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Markov processes; Credit models; Generator; Resolvent:

We introduce an approximation strategy for the discounted moments of a stochastic process that can, for a large class of problems, approximate the true moments. These moments appear in pricing formulas of financial products such as bonds and credit derivatives. The approximation relies on high-order power series expansion of the infinitesimal generator, and draws parallels with the theory of polynomial processes. We demonstrate applications to bond pricing and credit derivatives. In the special cases that allow for an analytical solution the approximation error decreases to around 10 to 100 times machine precision for higher orders. When no analytical solution exists we tie out the approximation with existing numerical techniques.

References

[1] Zhao, C., van Beek, M., Spreij, P., Ba, M. (2025) *Polynomial approximation of discounted moments*, Finance and Stochastics 29, 63–95.

ANALYZING RAINFALL RADAR DATA USING MULTIVARIATE MOTION PATTERNS

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Time series; ordinal pattern; limit theorem; environmental data:

The classification of movement in space is one of the key tasks in environmental science. Various geospatial data such as rainfall or other weather data, data on animal movement or landslide data require a quantitative analysis of the probable movement in space to obtain information on potential risks, ecological developments or changes in future. Usually, machine-learning tools are applied for this task. Yet, machine-learning approaches also have some drawbacks, e.g. the often required large training sets and the fact that the algorithms are often hard to interpret. We propose a classification approach for spatial data based on ordinal patterns. Ordinal patterns have the advantage that they are easily applicable, even to small data sets, are robust in the presence of certain changes in the time series and deliver interpretative results. They, therefore, do not only offer an alternative to machine-learning in the case of small data sets but might also be used in pre-processing for a meaningful feature selection. In this talk, we introduce the basic concept of multivariate ordinal patterns, classify them and provide the corresponding limit theorem. The approach is applied to rainfall radar data.

References

[1] Fischer, S., Oesting, M. and Schnurr, A. (2023) *Multivariate Motion Patterns and Applications to Rainfall Radar Data*, SERRA'23.

PARAMETER ESTIMATION OF AN SDE MODELLING THE SLOW DRIFT OF AN OFFSHORE STRUCTURE: A SIMULATION STUDY

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Hypoelliptic SDE; Parameter estimation; Partially observed systems:

We address the problem of estimating a vector of coefficients in the drift of a nonlinear hypoelliptic diffusion which is partially observed in discrete time. The system under consideration is described by the following 2-dimensional SDE, also called the TLP model [4]:

$$d\begin{bmatrix} x_t \\ v_t \end{bmatrix} = \begin{bmatrix} v_t \\ -k_1 x_t - k_2 x_t^3 - c_1 v_t - c_2 |v_t| x_t \end{bmatrix} dt + \begin{bmatrix} 0 \\ \sigma \end{bmatrix} dW_t, \qquad (1)$$

representing the time evolution of the state of the system in the times interval $[0, T]$, with k_1, k_2, σ known and the equation

$$Y_i = \begin{bmatrix} h & 0 \end{bmatrix} \begin{bmatrix} x_t \\ v_t \end{bmatrix} + \gamma w_i,$$

representing the observation process. The time interval $[0, T]$ is discretised with time step Δt, the observations being collected at times $t_i = i\Delta t$, for $i = 0, 1, ..., N$, and $N = T/\Delta t$. The parameter $\gamma > 0$ is a known small number and $h \neq 0$. Here, W_t is a standard Wiener process and w_i is a standard Gaussian white noise. The vector of unknown parameters is $\theta = (c_1, c_2)$. Our goal is to estimate θ based on the observations Y_i at the time instants $t_0, t_1, t_2, ..., t_N$.

In the present study, we propose an estimator for the parameters of the TLP model (1) and we investigate its convergence under conditions of small observation error, that is when $\gamma \to 0$. Our investigation is based on a simulation study. The simulations are performed using both the Milshtein and strong order 1.5 schemes. Regarding the estimation approach, we implement approximation algorithms based on the Stochastic Gradient algorithm [3], combined with fil- tering techniques such as the Extended Kalman Filter (EKF) and the Unscented Kalman Filter (UKF). We show how well the estimator captures the true value in the simulated paths.

References

[1] Ditlevsen, S., Samson, A. (2019) *Hypoelliptic diffusions: filtering and inference from complete and partial observations*, Journal of the Royal Statistical Society. Series B (Statistical Methodology), 81(2), 361–384.

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[4] Varghese,V.A., Saha,N.(2021) *Effect of Uncertainty on Slow Drift Motion of TLP*, Proceedings of the Fifth International Conference in Ocean Engineering (ICOE2019), Springer, pp. 53–64.

S3. Stochastic Equations I
Wednesday, June 4, 16:00-17:30

ON A COMPUTABLE SKOROKHOD'S INTEGRAL BASED ESTIMATOR OF THE DRIFT PARAMETER IN FRACTIONAL SDE

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Least squares estimation; Fractional diffusions; Skorokhod's integral.

After a brief overview on copies-based estimation in stochastic differential equations (SDEs), the talk will focus on the following topic: the least squares (LS) estimation of the drift function of a SDE driven by the fractional Brownian motion of Hurst parameter $H > 1/2$. A parametric estimator, and a projection LS nonparametric estimator, will be presented. However, when $H \neq 1/2$, the solution of the SDE is not a semi-martingale, and the natural extension of the Itô integral involved in the definition of the estimators - the Skorokhod integral - is not computable. So, for the parametric estimator, some statistical properties of a computable approximation defined as the fixed point of a map constructed from the well-known relationship between the pathwise integral and the Skorokhod integral will be presented (see Marie [1]).

References

[1] Marie, N. (2025). On a Computable Skorokhod's Integral Based Estimator of the Drift Parameter in Fractional SDE. *Scandinavian Journal of Statistics* 52(1), 1-37.

THE LEVEL OF SELF-ORGANIZED CRITICALITY IN OSCILLATING BROWNIAN MOTION: n-CONSISTENCY AND STABLE POISSON-TYPE CONVERGENCE OF THE MLE

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Stable Poisson convergence; infill asymptotic; n-consistency; maximum likelihood estimation:

For some discretely observed path of oscillating Brownian motion with level of self-organized criticality ρ_0, we prove in the infill asymptotics that the MLE is n-consistent, where n denotes the sample size, and derive its limit distribution with respect to stable convergence. As the transition density of this homogeneous Markov process is not even continuous in ρ_0, the analysis is highly non-standard. Therefore, interesting and somewhat unexpected phenomena occur: The likelihood function splits into several components, each of them contributing very differently depending on how close the argument ρ is to ρ_0. Correspondingly, the MLE is successively excluded to lay outside a compact set, a $1/\sqrt{n}$-neighborhood and finally a $1/n$-neigborhood of ρ_0 asymptotically. The crucial argument to derive the stable convergence is to exploit the semimartingale structure of the sequential suitably rescaled local log-likelihood function (as a process in time). Both sequentially and as a process in ρ, it exhibits a bivariate Poissonian behavior in the stable limit with its intensity being a multiple of the local time at ρ_0.

References

[1] Brutsche, J., Rohde, A. (2025) *The level of self-organized criticality in oscillating Brownian motion: n-consistency and stable Poisson-type convergence of the MLE*, Preprint.

THE DOUBLE HESTON MODEL

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Stochastic volatility, Affine diffusion, Classification, Stationarity, Ergodicity, Continuous-time observations, Maximum liklelihood estimation, Conditional least squares estimation, Asymptotic behavior:

The double Heston model is one of the most popular option pricing models in financial theory. It is applied to several issues such that risk management and volatility surface calibration. This talk deals with the problem of global parameter estimations in this model. Our main stochastic results are about the stationarity and the ergodicity of the double Heston process. The statistical part of the talk is about the maximum likelihood and the conditional least squares estimations based on continuous-time observations; then for each estimation method, we study the asymptotic properties of the resulted estimators in the ergodic case.

References

[1] Ben Alaya M., Dahbi H., and Fathallah H. (2023) Asymptotic properties of AD(1, n) model and its maximum likelihood estimator. arXiv preprint arXiv:2303.08467.

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[5] Peng Q. and Schellhorn H. (2018) On the distribution of extended cir model. Statistics & Probability Letters, 142:23–29.

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S4. Particle Systems Thursday, June 5, 9:00-10:30

ON NONPARAMETRIC ESTIMATION OF THE INTERACTION FUNCTION IN PARTICLE SYSTEM MODELS

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Zhou, Shi-Yuan *University of Luxembourg, Luxembourg*

drift estimation; McKean-Vlasov diffusions; non-linear SDEs; nonparametric statistics; particle systems:

This talk delves into the challenging problem of nonparametric estimation for the interaction function within diffusion-type particle system models. We introduce two estimation methods based on empirical risk minimization. Our study encompasses an analysis of the stochastic and approximation errors associated with both procedures, along with an examination of certain minimax lower bounds. In particular, for the first method we show that there is a natural metric under which the corresponding estimation error of the interaction function converges to zero with a parametric rate that is minimax optimal. This result is rather surprising given the complexity of the underlying estimation problem and a rather large class of interaction functions for which the above parametric rate holds.

References

[1] Belomestny, D., Podolskij, M., Zhoud, S.-Y. (2024) *On nonparametric estimation of the interaction function in particle system models* , available at https://arxiv.org/html/2402.14419v1.

SUPERVISED CLASSIFICATION FOR INTERACTING PARTICLE SYSTEMS

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Charlotte, Dion-Blanc *Sorbonne University, France*

Drift estimation; Interacting particle systems; McKean-Vlasov equation; Mean-field interactions; Propagation of chaos; Supervised classification:

In this talk, we present a supervised classification method for K distinct interacting particle systems, each characterized by a different drift coefficient function, within the framework of the McKean-Vlasov equation. In these systems, particles are identically distributed but not independent. The central question we address is: given discrete observations of a new particle, how can we determine to which system it belongs? Our approach relies on a plug-in classification rule and requires the estimation of the drift functions. A key aspect of the analysis involves applying the propagation of chaos property. This is joint work with Christophe Denis and Charlotte Dion-Blanc.

References

[1] Denis, C., Dion-Blanc, C., Liu, Y. (2025) *Supervised classification for interacting particle systems*, in progress.

LOCAL ASYMPTOTIC NORMALITY FOR DISCRETELY OBSERVED MCKEAN-VLASOV DIFFUSIONS

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LAN property; Log-likelihood ratio; Malliavin calculus; McKean-Vlasov diffusions; Parametric estimation:

We study the local asymptotic normality (LAN) property for the likelihood function associated with discretely observed d-dimensional McKean-Vlasov stochastic differential equations over a fixed time interval. The model involves a joint parameter in both the drift and diffusion coefficients, introducing challenges due to its dependence on the process distribution. We derive a stochastic expansion of the log-likelihood ratio using Malliavin calculus techniques and establish the LAN property under appropriate asymptotic conditions. The main technical challenge arises from the implicit nature of the transition densities, which we address through integration by parts and Gaussian-type bounds. This work extends existing LAN results for interacting particle systems to the mean-field regime, contributing to statistical inference in non-linear stochastic models.

References

[1] Heidari, A., Podolskij, M. (2025) *Local asymptotic normality for discretely observed McKean-Vlasov diffusions*, The paper is a work in progress.

S5. High-Dimensional Statistics
Thursday, June 5, 11:00-12:30

NETWORK STOCHASTIC DIFFERENTIAL EQUATIONS: ERROR BOUNDS AND GRAPH RECOVERY

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parametric inference; lasso estimation; non-asymptotic bounds; high-dimensional diffusion:

We propose a novel framework for Network Stochastic Differential Equations (N-SDE), where each node in a network is governed by an SDE influenced by interactions with its neighbors. The evolution of each node is driven by the interplay of three key components: the node's intrinsic dynamics (momentum effect), feedback from neighboring nodes (network effect), and a stochastic volatility term modeled by Brownian motion. Our objectives are parameter estimation of the N-SDE system, for which we provide non-asymptotic error bounds, as well as graph recovery.

The motivation behind this model lies in its ability to analyze very high-dimensional time series by leveraging the inherent sparsity of the underlying network graph. We consider two distinct scenarios: *i) known network structure*: the graph is fully specified, and we establish conditions under which the parameters can be identified, considering the linear growth of the parameter space with the number of edges. *ii) unknown network structure*: the graph must be inferred from the data. For this, we develop an iterative procedure using adaptive Lasso, tailored to a specific subclass of N-SDE models.

We assume the network graph is oriented, paving the way for novel applications of SDEs in causal inference, enabling the study of cause-effect relationships in dynamic systems. Through extensive simulation studies, we demonstrate the performance of our estimators across various graph topologies in high-dimensional settings. We also showcase the framework's applicability to real-world datasets, highlighting its potential for advancing the analysis of complex networked systems.

We consider both the frameworks of high frequency observations for an ergodic diffusion ([1]) as well as the case of continuous observations in a small-diffusion non-ergodic setting ([2]).

References

[1] Iafrate, F., Iacus, S. M. (2024) *Ergodic network stochastic differential equations*, arXiv preprint arXiv:2412.17779.

[2] Iafrate, F., Iacus, S. M. (2025) *Small diffusion network stochastic differential equations*, working paper.

CONSISTENT SUPPORT RECOVERY FOR HIGH-DIMENSIONAL DIFFUSIONS

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Adaptive Lasso; support recovery; diffusion models; high-dimensional statistics:

Inference in high-dimensional settings introduces novel challenges, especially when the parameters of the model themselves exhibit asymptotic behavior unlike classical frameworks where only time or sample size tends to infinity. Under this extended scenario, this talk focuses on adaptive Lasso estimation in ergodic diffusion processes, examining the conditions under which consistent support recovery and asymptotic normality are achievable. We discuss the role of the tuning parameter, structural assumptions on the model, and the impact of pre-estimator choice, along with numerical results that illustrate the method's effectiveness in high-dimensional regimes.

References

[1] Marushkevych, D., Pina, F., Podolskij, M. (2025) *Consistent support recovery for high-dimensional diffusions*, arXiv preprint arXiv:2501.16703.

LASSO ESTIMATION OF HIGH-DIMENSIONAL ORNSTEIN–UHLENBECK PROCESSES WITH I.I.D. PATHS

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Lasso; i.i.d. paths; Ornstein–Uhlenbeck processes; sparse estimation:

We consider lasso estimation of the drift coefficient of high-dimensional Ornstein–Uhlenbeck processes with i.i.d. paths. In recent days, sparse estimation of the drift coefficient of high-dimensional Ornstein—Uhlenbeck processes has been of interest [1–3]. However, theoretical guarantees by these studies are based on the ergodicity of the processes and long-term observations, which do not hold sometimes in real data analysis. Our interest is to discuss sparse estimation in the i.i.d. path observation scheme; this scheme is also topical [4–5] and important in longitudinal data analysis.

We study estimation of the drift parameter $\mathbf{A} \in \mathbb{R}^{d\times d}$ of the following d-dimensional stochastic differential equation:

$$\mathrm{d}\boldsymbol{x}_i(t) = \mathbf{A}\boldsymbol{x}_i(t)\mathrm{d}t + \mathrm{d}\boldsymbol{w}_i(t),\ \boldsymbol{x}_i(0) = \boldsymbol{\xi}_i,\ t \in [0,T],\ i \in \{1,...,N\}, \tag{1}$$

where $\mathbf{A} \in \mathbb{R}^{d\times d}$ is the unknown drift parameter, $\boldsymbol{w}_i = \{\boldsymbol{w}_i(t); t \in [0,T], i \in \{1,...,N\}\}$ is a sequence of independent d-dimensional standard Wiener processes, $\{\boldsymbol{\xi}_i\}_{i=1}^N$ is a sequence of d-dimensional deterministic vectors, and $T > 0$ is the terminal. Our lasso estimator is given as follows:

$$\hat{\mathbf{A}}_{\mathrm{L}} \in \arg\min_{\mathbf{A}\in\mathbb{R}^{d\times d}} \left\{ \frac{1}{N}\sum_{i=1}^N \left(-\int_0^T (\mathbf{A}\boldsymbol{x}_i(t))^\top \mathrm{d}\boldsymbol{x}_i(t) + \frac{1}{2}\int_0^T \|\mathbf{A}\boldsymbol{x}_i(t)\|_2^2\,\mathrm{d}t \right) + \lambda\|\mathbf{A}\|_1 \right\}, \tag{2}$$

where $\|\cdot\|_1$ is the entry-wise ℓ^1-norm for matrices.

We obtain an upper bound of the error of $\hat{\mathbf{A}}_{\mathrm{L}}$ against the true value $\mathbf{A}_0$ such that

$$\frac{1}{N}\sum_{i=1}^N \int_0^T \left\| \left(\hat{\mathbf{A}}_{\mathrm{L}} - \mathbf{A}_0 \right) \boldsymbol{x}_i(t) \right\|_2^2 \mathrm{d}t = \mathcal{O}\left(s\lambda^2\right), \tag{3}$$

where s is the number of nonzero elements of $\mathbf{A}_0$ and $\lambda \geq c\sqrt{\log d/N}$ for some $c > 0$. We also show that $\hat{\mathbf{A}}_{\mathrm{L}}$ with $\lambda = \Theta(\sqrt{\log d/N})$ achieves the minimax optimal rate of convergence.

References

[1] Gaïffas, S. and Matulewicz, G. (2019). *Sparse inference of the drift of a high-dimensional Ornstein–Uhlenbeck process.* Journal of Multivariate Analysis, 169, 1–20.

[2] Ciołek, G., Marushkevych, D., and Podolskij, M. (2020) *On Dantzig and Lasso estimators of the drift in a high dimensional Ornstein-Uhlenbeck model.* Electronic Journal of Statistics, 14(2), 4395–4420.

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S6. Point Processes, Thursday, June 5, 14:00-15:30

POINT PROCESSES APPLIED TO HIGH FREQUENCY DATA: RATIO MODEL AND DEEP LEARNING

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Marked point process; Deep learning; Limit order book:

This paper's attempt to incorporate deep learning to point processes is motivated by the studies on modeling of limit order book data. Muni Toke and Yoshida [2] took a parametric approach with a Cox-type model (the ratio model) for relative intensities of order flows in the limit order book. The Cox-type model with a nuisance baseline hazard has an advantage to cancelling non-stationary intraday trends in the market data. They showed consistency and asymptotic normality of the quasi-likelihood estimators and validated the model selection criteria applied to the point processes, based on the quasi-likelihood analysis ([4,5]). Their method is applied to real data from the Paris Stock Exchange and achieves accurate prediction of market order signals, outperforming the traditional Hawkes model. It is suggested that the selection of the covariates is crucial for prediction. Succeedingly, Muni Toke and Yoshida [3] extended the ratio model to a marked ratio model to express the hierarchical structure in market orders. Each market order is categorized by Bid/Ask and then further classified as aggressive or non-aggressive depending on whether it causes price movements. The marked ratio model outperforms other intensity-based models like Hawkes-based models in predicting the sign and aggressiveness of market orders on financial markets. However, the trials of model selection in [2,3] suggest a possibility of taking more covariates in the model; the information criteria seem to prefer relatively large models among a large number of models generated by combinations of our proposal covariates. This motivates us to use deep learning to automatically generate more covariates and to enhance the power of expression of the model for more nonlinear dependencies behind the data.

We investigate applications of deep neural networks to a point process having an intensity with mixing covariates processes as input. Our generic model includes Cox-type models and marked point processes as well as multivariate point processes. An oracle inequality giving a rate of convergence of the prediction error is derived in [1]. Simulation study shows that the marked point process can be superior to the simple multivariate model in prediction. We apply the marked ratio model to real data of limit order book.

References

[1] Gyotoku, Y., Muni Toke, I., Yoshida, N. (2025) *Deep learning of point processes for modeling high-frequency data* arXiv:2504.15944
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[3] Muni Toke, I., Yoshida, N. (2022) *Marked point processes and intensity ratios for limit order book modeling* Japanese Journal of Statistics and Data Science **5**(1), 1–39
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[5] Yoshida, N. (2025) *Simplified quasi-likelihood analysis for a locally asymptotically quadratic random field* Annals of the Institute of Statistical Mathematics **77**(1), 1–24

NONPARAMETRIC ESTIMATION OF THE INVARIANT DENSITY FOR HAWKES DIFFUSION SYSTEMS

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Hawkes process; Invariant density estimation; Kernel density estimator; Ergodic theory

In this work, we study the process $(X_t)_{t\geq 0}$ which is a diffusion with jumps driven by a nonlinear Hawkes process of intensity (λ_t), and λ_t is a piecewise deterministic Markov process (PDMP). We first explore the probabilistic properties of the process. Then, we propose estimating the invariant density $\pi(x, y)$ of (X, λ) using kernel density estimation, assuming a continuous record of X is available. This step is crucial due to the potential applications of the model. We measure accuracy by the pointwise L^2 error, requiring pre-estimation of λ's parameters, yielding an estimator $\hat{\lambda}$, whose analysis is crucial for obtaining our main results. Our main contributions include explicitly determining the convergence rates of the proposed estimator, which vary based on the estimation point. These results are compared to those for estimating the invariant density of a Lévy process.

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ON THE ESTIMATION OF CUSP LOCATION IN A MISSPECIFIED POISSONIAN MODEL

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Misspecification; Inhomogeneous Poisson process; Parameter estimation; Cusp-type change-point:

We consider the problem of the estimation of a parameter in the intensity of a Poisson process. After recalling the properties of the maximum likelihood estimator (MLE) in the different cases (the case of a cusp-type singularity, but also the regular and change-point cases), we will focus on the situation where the model is misspecified: the statistician uses a given model, but the observations come from a somewhat different model. We will study how this situation modifies the behavior of the MLE, and we will see, in particular, that the modification of the properties of the MLE in the case of a cusp-type singularity is surprisingly different as well from what happens in the regular case, as from what happens in the change-point case.

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S7. Stochastic Equations II
Friday, June 6, 9:00-10:30

ESTIMATION FOR A LINEAR PARABOLIC SPDE IN TWO SPACE DIMENSIONS WITH A SMALL NOISE USING TRIPLE INCREMENTS

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High-frequency spatio-temporal data; small dispersion asymptotics; stochastic partial differential equation; Q-Wiener process:

We consider parametric estimation for a second-order linear parabolic stochastic partial differential equation (SPDE) in two space dimensions driven by a Q-Wiener process with a small noise based on high-frequency spatio-temporal data. Bibinger and Trabs (2020) and Hildebrandt and Trabs (2021) studied minimum contrast estimators (MCEs) for unknown coefficient parameters of a second-order linear parabolic SPDE in one space dimension driven by a cylindrical Wiener process using high-frequency spatio-temporal data. Kaino and Uchida (2021) derived parametric adaptive estimators of a second-order linear parabolic SPDE in one space dimension with a small noise. Extending the results of Bibinger and Trabs (2020) and Kaino and Uchida (2021) to the SPDE in two space dimensions with a small noise, Tonaki et al. (2024) investigated parametric estimation for the SPDE in two space dimensions based on discrete observations. In this talk, applying the methodology of Hildebrandt and Trabs (2021) and Kaino and Uchida (2021) to the SPDE in two space dimensions with a small noise, we introduce MCEs of the diffusive and advective parameters of the SPDE in two space dimensions based on temporal and spatial increments. Additionally, we obtain an estimator of the reaction parameter in the SPDE utilizing an approximate coordinate process. We also present simulation results to illustrate the performance of the proposed estimators.

References

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ESTIMATING NON-LINEAR FUNCTIONALS OF TRAWL PROCESSES

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Trawl processes; Nonparametric estimation; Functional limit theorems; Infinite divisible processes

Trawl processes is a class of continuous-time infinitely divisible stationary processes whose correlation structure is characterized by their so-called trawl functions. In this talk we investigate the problem of estimating non-linear functionals of a trawl function under both in-fill and long-span sampling schemes. Building on [1], we develop nonparametric estimators for functionals of the form $\int_0^t g(a(s))\mathrm{d}s$, $\int_t^\infty g(a(s))\mathrm{d}s$, where a represents the trawl function of interest and g a non-linear test function. We show that our estimators are consistent and provide of functional central limit theorems. If time allows, we will discuss applications in testing T-dependence of the underlying process.

References

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SPLITTING METHODS FOR ONE-DIMENSIONAL SDEs AND PARAMETER INFERENCE

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Stochastic differential equations, Lie-Trotter splitting, Strang splitting, Parameter inference:

Many real-world biological phenomena, such as population dynamics, neuronal activity, and ecological systems, are modeled using stochastic differential equations (SDEs) with multiplicative noise. Important examples include the Jacobi (Wright-Fisher) processes for genetic drift and neuronal models, as well as the broader Pearson diffusion class, the stochastic Ginzburg-Landau equation, and the stochastic Verhulst equation. However, exact simulation schemes for these models are often unavailable or computationally prohibitive.

In this work, we propose a general numerical splitting method for SDEs with locally Lipschitz drift and Hölder continuous diffusion coefficients. Specifically, we decompose the original equation into tractable subequations and apply Lie-Trotter and Strang compositions [1] to recover the full solution. Our approach outperforms traditional stochastic Taylor expansion methods, such as Euler-Maruyama, in both order of convergence and property preservation. The proposed method ensures boundary preservation for SDEs with constrained state spaces (e.g., Wright-Fisher diffusion) and improves empirical distribution convergence to invariant measures, allowing for more accurate and robust simulations.

Beyond simulation, these splitting schemes admit tractable transition densities, enabling parameter inference via pseudo-maximum likelihood estimation [2] and Bayesian approaches, providing a practical framework for learning parameters of interest in complex biological systems.

References

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S8. Jump Processes I
Friday, June 6, 11:00-12:30

JUMP-RESISTANT VOLATILITY REGRESSION

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Continuous volatility regression; Gaussian quasi-likelihood; Jumps; Robust divergence:

We consider a Gaussian quasi-likelihood (GQLF) based inference for parametric volatility regression models observed at high frequency over a fixed period. As is well-known, the GQLF is quite fragile against jump-type contaminations, with which the original asymptotically efficient behaviour of the Gaussian quasi-maximum-likelihood estimator (GQMLE) is broken. The most popular approach is threshold estimation through a jump-detection filter, the idea of which goes back a long way: the publications [3] and [4], and many subsequent works. The well-recognized practical bottleneck is how to choose the fine-tuning parameter, which can crucially affect the finite-sample property of the associated estimator.

In this talk, we demonstrate how to robustify the conventional GQLF explicitly by perturbing the Kullback-Leibler divergence through a single fine-tuning parameter, say $\lambda \in (0, 1]$. We theoretically show that the modified GQLF is robust against several finite-activity discontinuous contaminations, enabling us to estimate the parametric volatility part while leaving other characteristics as nuisance elements; the fine-tuning parameter λ controls the trade-off between efficiency and robustness (e.g. chapter 9 of [1] the references therein). Some illustrative simulation results will be given to observe the finite-sample performance of the modified GQMLE and the sensitivity of the estimation performance against the fine-tuning. It is worth mentioning that the proposed method works well even when there are no discontinuous contaminations and can be applied analogously to any GQLF-based estimation.

We will also present some related issues: the implementation in `yuima` package in R (see [2]) and how to adapt the proposed estimation strategy to ergodic diffusions with jumps.

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ADAPTIVE MINIMAX ESTIMATION FOR DISCRETELY OBSERVED LEVY PROCESSES

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Lévy processes; Density estimation; Spectral estimator; Minimax rates of convergence:

We study the nonparametric estimation of the density f_Δ of an increment of a Lévy process X based on n observations with a sampling rate Δ. The class of Lévy processes considered is broad, including both processes with a Gaussian component and pure jump processes. A key focus is on processes where f_Δ is smooth for all Δ. We introduce a spectral estimator of f_Δ and derive both upper and lower bounds, showing that the estimator is minimax optimal in both low- and highfrequency regimes. Our results differ from existing work by offering weaker, easily verifiable assumptions and providing non-asymptotic results that explicitly depend on Δ. In low-frequency settings, we recover parametric convergence rates, while in high-frequency settings, we identify two regimes based on whether the Gaussian or jump components dominate. The rates of convergence are closely tied to the jump activity, with continuity between the Gaussian case and more general jump processes. Additionally, we propose a fully data-driven estimator with proven simplicity and rapid implementation, supported by numerical experiments.

References

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A DEPENDENT AND CENSORED FIRST HITTING - TIME MODEL WITH COMPOUND POISSON PROCESSES

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Survival analysis, dependent censoring, compound Poisson process, first hitting-time model :

We use a survival analysis framework with a random censoring time. We consider a bivariate first hitting-time model in which durations are the crossing times of dependent compound Poisson processes with fixed thresholds. The processes are assumed to belong to a certain parametric family of compound Poisson processes. The dependency linking the two processes induces the possibility of both hitting-times occurring at the same instant with non-zero probability. Contrarily to models with independant censoring, model like our or the one from [1] with dependant censoring do not induce the non-parametric identifiability of the density function of the variable of interest. The identifiability of the model is discussed, and likelihood estimators of the model parameters are proposed. We obtain the asymptotic properties of the estimators and underline their finite sample performance with a simulation study on synthetic data. The practical applicability of our approach is demonstrated by an original application using real data of amanita poisoning.

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S9. Jump Processes II
Friday, June 6, 14:00-15:00

VOLATILITY AND JUMP ACTIVITY ESTIMATION IN A STABLE COX-INGERSOLL-ROSS MODEL

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Cox-Ingersoll-Ross model; Parametric inference; Stable process; Stochastic differential equation

We consider the parametric estimation of the volatility and jump activity in a stable Cox-Ingersoll-Ross (α-stable CIR) process defined by the stochastic equation

$$dX_t = (a - bX_t)dt + \sigma X_t^{1/2} dB_t + \delta^{1/\alpha} X_{t-}^{1/\alpha} dL_t^\alpha, \quad X_0 = x_0 > 0,$$

where $(B_t)_{t\geq 0}$ is a standard Brownian Motion and $(L_t^\alpha)_{t\geq 0}$ a spectrally positive α-stable Lévy process with jump activity $\alpha \in (1, 2)$. The main difficulties to obtain rate efficiency in estimating these quantities arise from the superposition of the diffusion component with jumps of infinite variation. Extending the approach proposed in Mies [2], we address the joint estimation of the volatility, scaling and jump activity parameters from high-frequency observations of the process and prove that the proposed estimators are rate optimal up to a logarithmic factor.

We first prove the existence of a consistent and asymptotic (mixed) normal estimator based on a method of moments, in both cases $n\Delta_n$ fixed and $n\Delta_n \to +\infty$, where n is the number of observations and Δ_n the step between two consecutive observations. Moreover, we illustrate the theoretical results by numerical simulations in the case $n\Delta_n$ fixed. Finally, we remark on the optimality of the estimator.

References

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EFFICIENT ESTIMATION FOR STABLE-LÉVY STOCHASTIC DIFFERENTIAL EQUATIONS

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LAMN property; Lévy process; one-step procedure, parametric estimation; stable process, stochastic differential equation :

In this work, the joint parametric estimation of the drift coefficient, the scale coefficient, and the jump activity index in stochastic differential equations driven by a symmetric stable Lévy process is considered based on high-frequency observations. Firstly, the LAMN property for the corresponding Euler-type scheme is proven, and lower bounds for the estimation risk in this setting are deduced. Therefore, when the approximation scheme experiment is asymptotically equivalent to the high-frequency observation of the solution of the considered stochastic differential equation, these bounds can be transferred. Secondly, since the maximum likelihood estimator can be time-consuming for large samples, an alternative Le Cam's one-step procedure is proposed in the general setting. It is based on an initial guess estimator, which is a combination of generalized variations of the trajectory for the scale and the jump activity index parameters, and a maximum likelihood type estimator for the drift parameter. This proposed one-step procedure is shown to be fast, asymptotically normal, and even asymptotically efficient when the scale coefficient is constant. In addition, the performances in terms of asymptotic variance and computation time on samples of finite size are illustrated with simulations. This talk is based on joint work with Alexandre Brouste and Laurent Denis in [1].

References

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