Workshop
«SDEs/SPDEs: Theory, Numerics and their interplay with Data Science»
June 26-30, 2019
Heraklion, Crete

POSTER SESSION

1. **Presenter:** Waleed Alhaddad, KAUST.

Title: Uncertainty Quantification in Wind Power Forecasting.

Abstract: Reliable wind power generation forecasting is crucial to meet energy demand, to trade and invest. We propose a model to simulate and quantify uncertainties in such forecasts. This model is based on Stochastic Differential Equations whose time-dependent parameters are inferred using continuous optimization of an approximate Likelihood function. The result is a skew stochastic process that simulates the uncertainty of wind power forecasts accounting for maximum power production limit and other temporal effects. We apply the model to historical Uruguayan data and forecasts.

2. **Presenter:** Renzo Caballero, KAUST.

Title: Stochastic Optimal Control of Renewable Energy.

Abstract: Uruguay has always been a pioneer in the use of renewable sources of energy. Nowadays, it can usually satisfy its total demand from renewable sources, but half of the installed power, due to wind and solar sources, is non-controllable and has high uncertainty and variability. We deal with non-Markovian dynamics through a Lagrangian relaxation, solving then a sequence of HJB PDEs associated with the system to find time-continuous optimal control and cost function. We introduce a monotone scheme to avoid spurious oscillations. Finally, we study the usefulness of extra system storage capacity.

3. **Presenter:** Nikolaos Englezos, University of Piraeus.

Title: Stochastic Differential Games in Water Management: Model and Application in Africa

Abstract: We develop and apply a stochastic multistage dynamic cooperative game for managing transboundary water resources, within the water-food-energy nexus framework, under climate uncertainty. The mathematical model is solved for the non-cooperative and cooperative (Stackelberg "leader–follower") cases and is applied to the Omo-Turkana River Basin in Africa between the upstream Ethiopia and the downstream Kenya. The empirical application of the model calls for sector-specific production function estimations, in which we employ a stochastic frontier model for nonparametric treatment of the production functions

where we allow for technical inefficiency in production and autocorrelated total factor productivity (TFP). Bayesian analysis is performed using a Sequential Monte Carlo / Particle-Filtering approach. We find that the cooperative solution is the optimal pathway not only for both riparian countries, but for the sustainable use of the basin as well, whereas it remains the welfare maximizing option even in extreme Climate Change circumstances. This is joint work with X. I. Kartala, P. Koundouri and M. Tsionas. This work has been partly supported by the University of Piraeus Research Center.

4. **Presenter:** Dimitris Farazakis, University of Crete.

Title: Malliavin calculus for the stochastic Cahn-Hilliard/Allen-Cahn equation with unbounded noise diffusion.

Abstract: The stochastic partial differential equation Cahn-Hilliard/Allen-Cahn is a modified model of Cahn-Hilliard and Allen-Cahn equations. It belongs to the general category of the dynamical systems, and specifically represents an evolutionary equation of the form reaction-diffusion. It is experimentally applied to the dynamics of matter, when two chemical elements interact each other (heterogeneous mixture) 'interfacially' and form structures in combination with the changes of time, i.e., during the cooling of the system. These two chemical species are struggling each other in order to dominate (because of their non-uniform composition), and as a consequence of this 'supremacy' process is the production of the free energy from the system to the environment (chemical potential of the experiment). More precisely, the Cahn-Hilliard/Allen-Cahn equation expresses both the energy interactions between the particles of a surface, of the form particle/particle, and simultaneously, the dynamics of the adsorption-desorption phenomenon of these particles, to (adsorption) and from (desorption) the aforementioned surface, respectively. This is joint work with Dimitra Antonopoulou and Georgia Karali.

5. **Presenter:** Andreas Grammenos, The Alan Turing Institute and University of Cambridge.

Title: On Federated PCA.

Abstract: In many online machine learning and data science tasks such as data summarisation and feature compression, d-dimensional vectors need to be collected in a streaming fashion. This is specially true in the limited memory setting since, if d is large, devices cannot store all of the data samples, nor compute algorithms with $\Omega(d^2)$ storage requirements such as Principal Component Analysis, Subspace Tracking, or general Feature Correlation. In this work, we present a streaming memory-limited algorithm for distributed estimation of the r-leading principal components requiring $O(dr)$ memory and is fit for differential privacy. Our algorithm is adaptive since, contrary to the state of art, r does not have to be supplied as a fixed hyper-parameter. This is advantageous when no prior knowledge of the

underlying data distribution is available. Further, large datasets can quickly exceed the processing capabilities provided by singular nodes, so a distributed scheme is highly desirable. Finally, numerical simulations validate that our method exhibits state-of-the-art performance that closely matches or outperforms existing algorithms, and in the absence of communication latency, exhibits attractive horizontal scalability. This is joint work with Rodrigo Mendoza-Smith.

6. **Presenter:** Sebastiano Grazzi, Delft University of Technology.

Title: A piecewise deterministic Monte Carlo method for diffusion bridges

Abstract: The simulation of a diffusion process conditioned to hit a point at a certain time (diffusion bridge) is an essential tool in Bayesian statistic for parameter estimation of diffusion models with low frequency observations. This has been proven to be a challenging problem, as the transition density of the conditioned process is only known in very special cases.

Standard techniques rely on reversible Markov Chain Monte Carlo methods, that propose simpler bridges from which it is possible to sample. These techniques may perform poorly when the diffusion of interest is non-linear. Motivated by this, we explore and apply the Zig-Zag sampler, a rejection-free scheme based on a non-reversible continuous piecewise deterministic Markov process. Inspired by the Levy-Ciesielski construction of a Brownian bridge, we expand the infinite dimensional diffusion path in the Faber-Schauder basis. The Zig-Zag sampler is a flexible scheme able to exploit the conditional independence structure implied by the Faber-Schauder basis functions. By its nonreversible nature, it is promising for improving mixing properties of the process.

In the poster session, I will explain in detail how the Zig-Zag sampler scheme works for diffusion bridge simulation and show its performance for some challenging diffusion processes. This is joint work with Joris Bierkens, Frank van der Meulen and Moritz Schauer.

7. **Presenter:** Anamika Pandey, RWTH University.

Title: Multilevel Markov Chain Monte Carlo Sampler for Seismic Inversion by Bayesian Approach.

Abstract: We propose a multilevel Markov chain Monte Carlo sampling strategy to determine the posterior distribution of earthquake's source parameters, under the uncertainties of Earth's material properties, by Bayesian inversion approach. In Bayesian formulation, we assume that the recorded/observed data are subjected to some noise and can be reproduced by recovering some unknown input parameters to an underlying mathematical model. Bayesian approach naturally exploit any prior information/belief about the unknown parameter.

We consider initial-boundary value problem (IBVP) for the forward seismic wave propagation in an inhomogeneous linear viscoelastic media with random wave speeds and densities, subject to deterministic boundary and initial conditions. The random parameters model the inherent uncertainties of the Earth's material. We then use this forward model together with MCMC algorithm to generate samples from the posterior probability distribution of the earthquake source location. But this needs to simulate the IBVP a large number of times; and the approach becomes prohibitively expensive. This motivates to work on multilevel algorithms to accelerate seismic inversion addressing earthquake source estimation. We use a publicly available code SPECFEM, based on the spectral element method, to approximate solutions of IBVP for seismic wave propagation.

Numerical results show that the large number of simulations of the underlying IBVP are performed at coarser discretizations where the computational cost of the IBVP solver is significantly cheaper. Moreover, samples generated by multilevel approach decorrelate faster compared to those obtained by single level and hence less number of samples are required to generate necessary samples. Therefore, multilevel approach reduces the computational cost of seismic inversion dramatically.

We are interested in inferring parameters, which define seismic events, by a given set of data recorded at a seismic network. In this work, our main focus is to infer the epicenter of an earthquake. This approach can also be applied to general seismic inversion problems such as inferring magnitudes, slip-distributions and moment tensors.

This is joint work with Juan Pablo Madrigal Cianci, Panagiotis Tsilifis, Fabio Nobile and Raul F. Tempone.

8. **Presenter:** Sergey Samsonov, Higher School of Economics.

Title: Variance reduction for dependent sequences via empirical variance minimization.

Abstract: In this work a novel and practical variance reduction approach for additive functionals of Markov Chains is proposed. We combine the use of control functions with minimising estimates of an empirical asymptotic variance. We perform analysis of finite sample properties of the proposed method and derive convergence rates of the excess asymptotic variance to zero. Our methodology is applied to Unadjusted and Metropolis Adjusted Langevin Algorithms and to Stochastic Gradient MCMC methods. Theory is accompanied with various numerical results on different artificial and real-world benchmarks, showing good performance of our algorithm. This is a joint work with D. Belomestny, L. Iosipoi, E. Moulines and A. Naumov.

9. **Presenter:** Junyi Zhang, LSE.

Title: Weak Representation of the Maximum of SDEs by Brownian Bridge.

Abstract: The Euler scheme has been widely used to generate the sample path of stochastic differential equations, and then to estimate the maximum of the SDEs in a time interval. This work provides a Brownian bridge representation that improves the performance of the Euler

scheme in estimating the maximum. For SDEs with a constant diffusion coefficient, we assume that there exists a Brownian bridge connecting each pair of the consecutive sample points generated by the Euler scheme. Then we represent the maximum of the SDE by the maximum of these Brownian bridges. For SDEs with non-constant diffusion coefficient, we apply the Lamperti transform to convert it to the previous case. Numerical examples are provided to compare the performance of the Euler scheme and our method. This is joint work with Angelos Dassios.