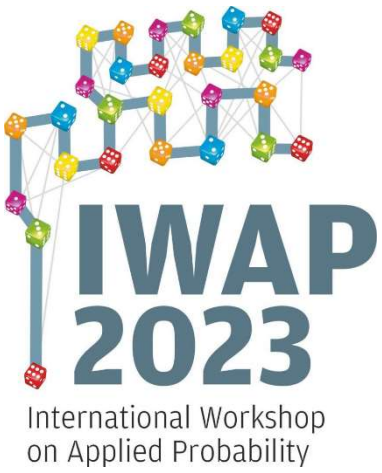
Book of Abstracts

10th International Workshop on Applied Probability

IWAP 2023



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IWAP 2023

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Plenary Talks

Some statistical insights into physics-informed neural networks

G. Biau
Sorbonne Université, France.

Joint work with Claire Boyer (Sorbonne University) and Nathan Doumèche (Sorbonne University)

Physics-informed neural networks (PINNs) are a promising approach that combines the power of neural networks with the interpretability of physical modeling. PINNs have shown good practical performance in solving partial differential equations (PDEs) and in hybrid modeling scenarios, where physical models enhance data-driven approaches. However, it is essential to establish their theoretical properties in order to fully understand their capabilities and limitations. In this talk, I will highlight that classical training of PINNs can suffer from systematic overfitting. This problem can be addressed by adding a ridge regularization to the empirical risk, which ensures that the resulting estimator is risk-consistent for both linear and nonlinear PDE systems. However, the strong convergence of PINNs to a solution satisfying the physical constraints requires a more involved analysis using tools from functional analysis and calculus of variations. In particular,for linear PDE systems, an implementable Sobolev-type regularization allows to reconstruct a solution that not only achieves statistical accuracy but also maintains consistency with the underlying physics.

Opinion dynamics on complex networks: From mean-field limits to sparse approximations

M. Olvera-Cravioto

University of North Carolina at Chapel Hill, USA

In a world of polarized opinions on many cultural issues, we propose a model for the evolution of opinions on a large complex network. Our model is akin to the popular Friedkin-Johnsen model, with the added complexity of vertex-dependent media signals and confirmation bias, both of which help explain some of the most important factors leading to polarization. The analysis of the model is done on a directed random graph, capable of replicating highly inhomogeneous real-world networks with various degrees of assortativity and community structure. Our main results give the stationary distribution of opinions on the network, including explicitly computable formulas for the conditional means and variances for the various communities. Our results span the entire range of inhomogeneous random graphs, from the sparse regime, where the expected degrees are bounded, all the way to the dense regime, where a graph having n vertices has order n^2 edges.

Repeated Significance Tests Based on Multiple Scan Statistics for One- and Two-Dimensional Data

J. Glaz

University of Connecticut, USA

In this lecture multiple scan statistics for one- and two-dimensional data will be reviewed. Repeated Significance Tests (RST) based on multiple scan statistics will be introduced for one- and two dimensional discrete and continuous data. The implementation of these RST's for a specified significance level will be discussed. Numerical results for expected stopping times and power will be presented, for specified null hypotheses and selective alternatives. The simulation algorithms for implementing the RST's will be discussed as well.

Markov Chain Monte Carlo Meets Generative AI

E. Moulines

Ecole Polytechnique, France

Deep generative models parameterize very flexible families of distributions capable of fitting complicated image or text datasets. These models provide independent samples from complex high-dimensional distributions at affordable cost. On the other hand, accurately sampling a target distribution, such as a Bayesian posterior in inverse problems, is typically challenging: either due to dimensionality, multimodality, poor conditioning, or a combination of the aforementioned factors. In this talk, I will discuss recent works that attempt to improve traditional inference and sampling algorithms through learning. I will present flowMC, an adaptive MCMC with normalizing flows, along with initial applications and remaining challenges.

Stationary states and exit times for Lévy processes with partial resetting

Z. Palmowski[1]

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In this talk we consider a d-dimensional stochastic process X_t that arises as a Lévy process Y_t modified by partial resetting at Poisson epochs. This partial reset means that we multiply the position of the process by some $c \in (0,1)$. We mainly focus on the following Y_t: linear drift, Brownian motion and isotropic strictly α-stable processes for $\alpha \in (0,2)$. We discuss various applications of these Lévy processes with partial resetting.

For this class of processes, we prove a non-equilibrium stationary state (NESS) phenomenon that corresponds to the change of the asymptotic behaviour of the transition density of the process X_t with regard to the time-space regime.

We also prove the Fokker-Planck equation and the existence of a unique stationary distribution.

We identify all the moments of this stationary measure.

To prove these results, we use various techniques: martingale methods, the generalised saddle point approximation (in particular, where a saddle point lies outside integration region), and a principle of one big jump.

In the case of $Y_t=t$, our process X_t becomes an additive-increase and multiplicative-decrease (aka growth-collapse) process that grows linearly in time and that experiences downward jumps at Poisson epochs that are (deterministically) proportional to its present position. For this process, and also for its reflected versions, we consider one- and two-sided exit problems that concern the identification of the laws of exit times from fixed intervals and half-lines. All proofs in this part of the talk are based on a unified first-step analysis approach at the first jump epoch, which allows us to give explicit, yet involved, formulas for their Laplace transforms.

The talk is based on the joint works with:

Costantino Di Bello, Tomasz Grzywny, Remco van der Hofstad, Stella Kapodistria, Seva Shneer, Karol Szczypkowski, Bartosz Trojan

Perspectives on Mortality Modelling

G. W. Peters

University of California Santa Barbara, USA

This presentation will discuss and analyse national level demographics that have led to recent developments in new statistical modelling approaches to mortality forecasting and life-table estimation. This is important to actuarial science as such quantities often act as critical components of decision making on pension provision and planning, mortality linked financial securities and life insurance products.

In particular, I will discuss aspects of some recent research papers covering time-series regression modelling that incorporates key population modelling components such as, temporal graduation, period effects, cohort effects and persistence (long memory) in order to enhance national level, age and gender stratified mortality forecasting. These may be considered as important extensions to the classical GLM regression structures and Lee-Carter stochastic mortality models often used by actuaries in practice to undertake mortality projection.

The improvements introduced are demonstrated to help to tackle a key concern raised by the IMF and some national demographic and national statistics agencies that in recent years the classical actuarial mortality projections using standard Lee-Carter or GLM frameworks are beginning to produce under estimation of mortality projections. This can have profound ramifications for governments and private pension providers and life-insurance providers.

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Weak Ergodicity in General Non-Homogeneous Markov Systems

P.-C.G. VASSILIOU
University College London, Department of Statistical Sciences.

We start with the definition of the new concept of the General NonHomogeneous Markov System (G-NHMS) and give the expected population structure of a NHMS in the various states given the transition probability matrices of the memberships. We proceed by establishing the set of all possible expected relative distributions of the initial number of $\mathbf{q}(0)$ memberships at time t and all possible expected relative distributions of the $T(t)$-$T(0)$ memberships at time t. We call this set the *general expected relative population structure* in the states of a G-NHMS. We then continue by providing the new definitions of weak ergodicity in a G-NHMS and weak ergodicity with a geometrical rate of convergence. We then prove the Theorem 5.1 which is a new building block in the theory of G-NHMS.
In Theorem 5.2 we prove a similar theorem under the assumption that $\{\mathbf{\Delta}T(t)/T(t)\}_{t=0}^{\infty}$ which has an interesting apparent physical meaning. We then provide a generalization of the Theorem 4.1 for a NHMS *r*st presented in Vassiliou 1981. In that theorem actually strong ergodicity is assumed of the sequence $\{\mathbf{Q}(t)\}_{t=0}^{\infty}$ and that the limiting matrix is a regular stochastic matrix. In the present we only assume that the sequence $\{\mathbf{\Delta}T(t)\}_{t=0}^{\infty}$ is common for the two populations and that the set W of the cummulative points of $\{\mathbf{Q}(t)\}_{t=0}^{\infty}$ has at least one scrambling matrix. Then we prove that the general relative expected population structures are asymptotically identical if the initial populations are equal. Hence, we actually establish a general Coupling theorem for a G-NHMS. How the terminology Coupling theorems has dominated the literature and their importance could be found in Vassiliou 2014, 2020 and the references in there.

Invited and Contributed Talks

Boundary crossing problems and functional transformations for Ornstein-Uhlenbeck processes

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We are interested in the law of the first passage time of driftless Ornstein-Uhlenbeck processes to time varying thresholds. We show that this problem is connected to the law of the first passage time of the process to some two-parameter family of functional transformations which, for specific values of the parameters, appears in a realisation of a standard Ornstein-Uhlenbeck bridge. We provide three different proofs of this connection. The first proof is based on a similar result to the case of the Brownian motion, the second uses a generalisation of the so-called Gauss-Markov processes and the third relies on the Lie group symmetry method applied to the Fokker-Planck equation of the Ornstein-Uhlenbeck process. We investigate the properties of this transformation and study the algebraic and analytical properties of an involution operator which is used in constructing it. We also show that this transformation maps the space of solutions of Sturm-Liouville equations into the space of solutions of the associated nonlinear ordinary differential equations.

Acknowledgements

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Exploiting Real-time Degradation Data in a Proactive Inventory Policy

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Managing spare parts inventory to achieve service excellence while keeping inventory costs at a minimum is a challenging task. This subject is receiving increasing attention due to the enormous costs associated with managing and owning spare parts [1]. In the scientific communities, this subject is approached either by developing spare parts forecasting methods, that forecast future spare parts demand, or by developing decision methods that prescribe when to order spare parts. Both these techniques use historical data to find an optimal solution to this challenge.

Condition Based Maintenance (CBM) is a proactive maintenance process that exploits real-time information on the system's health to predict functional failures and prescribe appropriate actions. A common practice is implementing a threshold policy where part replacement is triggered when degradation reaches or crosses a threshold [2, 3]. Due to its cost savings potential, CBM has been an active research domain, and major commercial corporations are putting enormous efforts into developing software to benefit from condition information [4]. However, few researchers have considered exploiting condition information in spare parts decision-making despite the obvious cost-saving potential.

Therefore, we consider the problem of exploiting real-time information in spare parts decision-making for multiple machines, with general degradation models, and stochastic lead times. We propose a proactive inventory policy that exploits real-time information in spare parts decision-making. The Proactive Base Stock Policy anticipates the need for spare parts required to perform maintenance actions. Proactiveness is achieved by leveraging degradation data to order a spare part every time a machine crosses an order threshold. An initial level of spare parts may be required to fulfill spare parts requirements.

To compute the optimal parameters of the proposed policy, we develop a simulation-based optimization method. First, a Discrete Event Simulation method is implemented to evaluate the performance of the policy for a given parameter value. Then we exploit the structural properties of the policy to develop an intelligent optimization algorithm to find the optimal policy parameters. Finally, we inspect the potential savings that are achieved compared to an inventory running under a Base Stock policy.

An extensive numerical experiment is done to assess the saving potential of implementing the proposed policy. Potential savings from implementing the proposed policy ranged between 0% and 99% with an average of 68.5%. A thorough investigation of the dispersion of results identifies the influence of the model parameters on the potential savings. Additionally, exploiting real-time data gives the policy flexibility with a varying number of machines. Once optimal parameters are computed, minor changes in the number of machines (±15%) have a negligible effect on the performance of the policy.

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Gamma processes for prognosis: theory, applications and perspectives

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Gamma processes are widely used to model the evolution of the cumulative deterioration of a system over time. Extended gamma processes have been seen as a flexible extension of standard gamma processes in the recent reliability literature, for the purpose of cumulative deterioration modeling. The probabilistic properties of the standard gamma process have been well explored since the 1970s, whereas those of its extension remain largely unexplored. This presentation aims firstly to review the probabilistic properties of standard and extended gamma processes and to present similar ageing properties of both models as well as the extended ones [1, 2, 3]. Secondly, an investigation on the capacity of gamma processes to handle uncertainties for prognosis is provided. Finally, an illustration of some applications of gamma processes [5] is given by highlighting the advantages and disadvantages of such models and by providing some new perspectives [4, 6].

Acknowledgements

I would like to acknowledge and thank all my collaborators cited in [1-5].

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On a Penalty Function in the Erlang Renewal Dual Risk Model Under Independent Randomised Observations

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We consider the dual risk model with insurance and financial application, where the random gains (or claims, using the primal insurance risk model) occur under a renewal process. Due to the mathematical robustness of the model we do not need to impose the usual income condition, as shown by Alcoforado *et al.* (2022), despite resulting in ruin certain if the condition is not respected. We introduce a Gerber-Shiu type of penalty function applied to the dual model and consider that randomised observations are set in place as Albrecher *et al.* 2013) do for the primal or classical compound Poisson insurance risk model.

We go further by studying a renewal risk process, mention in particular the Erlang(n) renewal model with an independent observational Poisson process. Under the model ruin can only arise if it is indeed observed, we mean, the risk process may cross downwards the zero level and recover without being observed.

Targeting ruin probabilities, we develop integral and differential equations, from which we study solutions for some cases, and particularly solve numerically for some examples in full. We show some figures and graphs from some chosen numerical examples. We compare them, where possible, with those of Albrecher *et al.* (2013) although worked for the primal compound Poisson risk model.

Acknowledgements

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A stochastic multiscale modelling framework for the evolution of phenotype-structured cell populations

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In this talk, a stochastic multiscale modelling framework for the evolution of phenotype-structured cell populations is presented. Here, cells are seen as individual agents subject to cell transitions and cell to cell interactions, whose phenotype is controlled by a stochastic intracellular biochemical reaction network. A suitable deterministic continuum limit of this framework is provided, which comprises a Fokker-Planck equation for the cell population density function (i.e. the cell distribution over the space of phenotypic states), whereby the terms capturing the effect of phenotypic changes at the cellular level mirror the structural properties and the dynamics of the underlying molecular networks. The main results of a systematic comparative study between this stochastic multiscale modelling framework and its deterministic continuum counterpart are summarised, and possible specific biological applications are discussed.

Partial synchronization within and across layers in chimera state networks

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We study across-layer synchronization in multiplex networks in chimera states. Each layer consists of a conventional ring network of non-locally coupled phase oscillators. While oscillators within each layer are identical, the layers are made non-identical by introducing mismatches in their oscillators' mean frequencies and phase lag parameters. We find a broad variety of across-layer synchronization types in dependence on these parameter mismatches and the coupling strength between layers. For example, one can achieve phase locking of the two layers' mean fields, while all individual oscillators remain unsynchronized across layers. Furthermore, only a variable fraction of individual oscillators can phase-lock across layers. One can get phase synchronization and generalized synchronization either separately or jointly. Finally, we demonstrate that weak across-layer couplings often destabilize the chimera states in individual layers resulting in almost fully synchronized or almost fully desynchronized dynamics..

Time-consistent Pension Fund Management in Stochastically Changing Markets and Evolving Horizons

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We introduce and study a novel class of Collective Defined Contributions (CDC) pension funds, incorporating stochastic wages and contributions, imperfect correlation with the market, and arbitrarily rolling horizons. How to build time-consistent investment strategies thus becomes a difficult problem, for the traditional approaches under a single, a priori chosen investment horizons fail. We address this by introducing and developing a new class of stochastic risk preferences, suitable for pension fund management, which considerably extend the existing forward performance processes for continuous processes. This class yields time-consistent strategies across horizons (e.g., multi-generational fund management) and also accommodates flexible market models. Defining and constructing these performance criteria is of independent interest. We construct the optimal investment strategies and, among others, compare them with their classical counterparts. This exposes the limitations of the classical approach and the flexibility of forward preferences in modeling and studying CDC pension funds. This is joint work with T. Zariphopoulou (UT-Austin) and E. Blontzou (U. Piraeus).

Strongest aftershock forecasting in Greece

*E. A. Anyfadi[1,2], **S. Gentili[3]**, P. Brondi[3] and F. Vallianatos[1,2]*

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After a major earthquake, aftershocks can exacerbate the damage already caused, especially to weaker structures, and destroy much urban infrastructure. In this paper, we apply the NESTOREv1.0 machine learning algorithm [1] to Greek seismicity to forecast whether the main earthquake will be followed by a large earthquake. NESTOREv1.0 classifies clusters into two types, type A or type B, depending on the difference in magnitude between the main quake and the subsequent strongest earthquake (equal or less than 1 for the most dangerous type A clusters and greater for type B clusters). Some features of seismicity are extracted in the first hours or days after the main shock and used for classification.

To analyze a significant number of clusters, we used the AUTH earthquake database [2] from 1995 to 2022 over a large part of Greece; we obtained 75 clusters, which we divided into two datasets for training and testing the algorithm. We considered different duration for the two datasets and we obtained the best performance with 19-21 years of seismicity for training and 7-9 years for testing, for a time interval of 0.25 days (6 hours) after the main shock. Tests show that 100% of type A clusters was forecasted correctly, the percentage of type B clusters misclassified as cluster A was less than 10%, and the accuracy was between 75% and 80%.

The successful overall implementation of NESTOREv1.0 in Greece, 6 hours after the main quake, shows that this approach is particularly attractive for use in seismic risk mitigation applications.

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Coupling Plateaux and Jumps: the Undershooting of Subordinators and the Corresponding Semi-Markov Processes

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In recent years, there has been a growing attention on general semi-Markov processes and their governing equations. Among them, on can consider semi-Markov processes obtained by applying a time-change to Feller processes by means of an inverse subordinator independent of it. Such processes have been widely studied and their link with time-nonlocal equations (for instance, time-fractional ones) has been exploited (see, for instance, [1]). On the other hand, the composition of a Feller process with an independent subordinator leads to a new Feller process whose generator is obtained by means of Bochner subordination, and thus is a nonlocal operator (see, for instance, [2]). Here we construct another class of time-changed processes. Precisely, we consider the composition of a Feller process with the undershooting process of an independent subordinator, i.e. the left limits of the composition of the subordinator with its inverse. We first show that such processes are semi-Markov and then we proceed with the study of their Kolmogorov equations. However, since there is a form of coupling between plateaux and jumps of the undershooting process, such equations involve an integro-differential operator which couples the nonlocality in both space and time. We determine a class of functions on which such an operator can be applied and then we use this class to prove that the process provides a stochastic representation of solutions of an integro-differential equation. Furthermore, we exploit an application of this theory to subdiffusive Black and Scholes models, as introduced, for instance, in [3]. This is an ongoing joint work with Enrico Scalas from University of Sussex, Bruno Toaldo from University of Turin and Lorenzo Torricelli from University of Bologna.

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Non-parametric Observation Driven HMM

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The hidden Markov models (HMM, [1]) are widely used in different fields, to study the dynamics of a process that cannot be directly observed. However, in some cases, the structure of dependencies of a HMM is too simple to describe the dynamics of the hidden process. In particular, applications such as finance or ecology, the transition probabilities of the hidden Markov chain also depends on the current observation.

In this work we were interested in extending the classical HMM to fit such situations. We thus defined a new model, referred to as the Observation Driven - Hidden Markov Model (OD-HMM), where the following hidden state depends not only on the current hidden state but also on the current observation, as illustrated in Figure 1. Theoretical results obtained for HMM are not applicable as such for the OD-HMM. Similarly the EM algorithm [1] computing the maximum likelihood estimator of a HMM no longer works and has to be adapted.

We present a complete study of the general non-parametric OD-HMM with discrete and finite state spaces (hidden and observed variables). We studied its identifiability [2] and the consistency [3] of the maximum likelihood estimators. We derived the associated forward-backward equations for the E-step of the EM algorithm. The quality of the procedure has been tested on simulated data sets. Finally, we illustrated the use of the model by modeling the dynamics of annual plants in ecology.

This works sets theoretical and practical foundations for a new framework that could be further extended, on one hand to the non-parametric context to simplify estimation, and on the other hand to the hidden semi-Markov models [4] for more realism.

Figure 1: Graphical representation of conditional dependencies in the chain (Z_t, Y_t).

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Preservation of Log Concavity by Bernstein Operator Based on Probabilistic Tools with Applications to the Ageing Properties of a Coherent System

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Preservation of log concavity by Bernstein operator is a well-known shape preserving property. Two novel proofs recently appeared in the literature motivate the current work, providing a new approach based on the bivariate characterization of the likelihood ratio stochastic order. In addition, we come up with applications of the shape preserving property to a coherent system with independent and identically distributed components which are obtained by means of the system's signature representation.

Continuous time Polya urns and applications in random trees

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We investigate applications of Polya processes to spider trees, a particular class of random trees, that grow in continuous time. We will first recall the Polya process that underlies an urn of white and blue balls growing in real time. It can be shown that a partial differential equation governs the evolution of the process. It was shown in an earlier joint work with Hosam Mahmoud, that for urns with (forward or backward) diagonal ball addition matrix, the partial differential equation is amenable to asymptotic solution. As applications, we consider spider trees growing in continuous time under both uniform and preferential attachments. The corresponding ball addition matrices simplify the partial differential equations, thereby giving the expectations of the number of white balls and the asymptotic distributions of the number of white balls scaled by appropriate functions of time.

Unified Formulations of Entropy and Extropy

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The measures of uncertainty are a topic of considerable and growing interest. In this talk a general formulation of entropy is proposed and studied. It depends on two parameters and includes Shannon, Tsallis and fractional entropy, all as special cases. Recently, the introduction of the extropy as a measure of uncertainty, dual of Shannon entropy, opened up interest in many aspects of the subject. For this reason we give a unified formulation also for extropy. Finally, the corresponding entropy and extropy in the context of Dempster-Shafer theory of evidence are analized.

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Testing for the bias in the estimation of business structure indexes from different data sources

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A key question that concerns Statistical Authorities using data collected from surveys and administrative sources for the compilation of specific statistical indexes is whether the data source (survey, administrative files) affects the indexes. In this paper, aggregated data from the Greek Structural Business Statistics of the reference years 2014-2018 for 8 statistical indexes of 140 business branches, originated from two sources, survey and administrative files, have been analyzed to assess whether the computed statistical indexes from the two data sources differ. The same analysis is repeated for each of the eight statistical indexes. The structure of the data is that of repeated measures (5 years) with random effects, where the within-subjects factors of the experimental design are the data source (of prime interest) and the reference year, and the random effects regards the business branches, as the level of a statistical index differs distinctly across the 140 business branches. The statistical testing was performed using two parametric statistical tests, the two-way repeated measures ANOVA and the linear mixed models, as well as the respective bootstrap tests (using wild bootstrap for the linear mixed models). The consistency of the parametric and bootstrap tests was first assessed on simulated data, using the data setting of the real data but determining different scenarios for the dependence of the statistical index on each factor. The simulation study concluded that even for strong deviations of the data from normality the parametric and bootstrap tests agreed to the correct test decisions. The results of the real data analysis confirmed the overall agreement of the parametric and bootstrap tests, and for two statistical indexes statistically significant effect of the data source was found. The results of the study suggest that the data source may have an impact on the derived statistical indexes.

A Multi-factor Model for Commodity Prices

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We introduce a new five-factor affine model for commodity pricing that builds on previous approaches ([1], [2], [3]) by incorporating a higher number of risk factors. Our proposed model allows for both the volatility and long-run mean of commodity prices, as well as the convenience yield and interest rate, to be stochastic. To estimate the model parameters, we utilize an extended Kalman filter in conjunction with quasimaximum likelihood estimation.

We conduct an empirical analysis that focuses on commodity futures to evaluate the performance of our novel specification. We compare our model's results to existing approaches. Our approach can help enhance risk management strategies and improve decision-making in commodity markets.

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A new combinatorial approach for edge universality of Wigner matrices

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In this talk we shall consider a well-known problem in random matrix theory, the edge universality. We shall introduce a new combinatorial approach to analyze the higher power of a trace of a matrix by introducing a new encoding of the contributing words. This type of arguments were introduced by Sinai and Soshnikov. However, they are unable to handle general nonsymmetrically distributed entries which we can handle. Due course of the proof we are able to give an alternative combinatorial description of the GOE Tracy Widom law which was not present in the literature in our understanding. We believe the arguments in this paper will be useful and applicable to other similar models where exact computations are not available, but some combinatorial structures are present.

Maximum Precision Estimation for a Step-Stress Model Using Two-Stage Methodologies

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A two-stage sequential procedure to estimate the parameters of a cumulative exposure model under an accelerated testing scenario is discussed. We focus on a step-stress model where the stress level is updated after a pre-specified number of failures occur, which is also random. This is termed as the 'random stress change time' in the literature. To obtain maximum precision, a certain variance optimality criterion is applied. A pseudo real data example from reliability studies is also analysed to outline the performance of the proposed methodology.

Goodness of fit for the generalized Poisson distribution based on the probability generating function

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The family of generalized Poisson (GP) distributions, which contain among many others as special cases the Compound Poisson and Katz distributions, is a flexible family of distributions for modelling count data. The probability generating function (PGF) of the GP is the unique PGF satisfying certain differential equation. Based on this property, a goodness-of-fit test for the family of GP distributions is proposed and studied. The test is proved to be consistent against fixed alternatives and its null distribution can be consistently approximated by a parametric bootstrap. The goodness of the bootstrap estimator and the power for finite sample sizes are numerically assessed.

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Gaussian and Non-Gaussian Processes Linked to Convolution-type Fractional Operators

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The standard theory of white-noise measures in infinite-dimensional spaces has been extended by the so-called non-Gaussian analysis. In particular, the grey noise has been defined, for the first time, by Schneider in 1990 ([5]), exploiting the complete monotonicity property of the Mittag-Leffler function. Consequently, the grey Brownian motion was introduced in the same paper, allowing to model anomalous diffusions by mimicking the classical procedures.

A further generalization (generalized grey Brownian motion) was obtained by introducing a fractional operator, in the Riemann-Liouville sense, in the definition of the process ([3]); its marginal density function was proved in [4] to coincide with the fundamental solution of a stretched time-fractional master equation. These models represent a family of stochastic processes, with stationary increments, which includes, as special cases, both standard and fractional Brownian motions.

In [1] we construct and study a new non-Gaussian measure, linked to the incomplete-gamma function, and define the so-called Gamma-grey noise; we prove, for it, the existence of Appell system. The related generalized processes are then defined, in the infinite dimensional setting, through the use of the Riemann-Liouville fractional operators.

Our aim in [2] is to extend the previous analyses, both in the Gaussian and non-Gaussian cases, by using more general fractional operators, defined as convolutions of tail Lévy measures, under appropriate conditions on the latter. The well-known Mandelbrot Van Ness representation of the fractional Brownian motion (of Hurst parameter H) is then recovered, as special case, when the convolution kernel is chosen as a power of fractional order H.

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Statistics of grain and orientation characteristics of polycrystalline materials microstructure modelled by a Laguerre tessellation.

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This talk presents a general statistical methodology for the analysis of crystallographic orientations of grains in a 3D Laguerre tessellation dataset which represents the microstructure of a polycrystalline material. We introduce complex stochastic models which may substitute expensive laboratory experiments: conditional on the Laguerre tessellation, we suggest interaction models for the distribution of cubic crystal lattice orientations, where the interaction is between pairs of orientations for neighbouring grains in the tessellation. We discuss parameter estimation and model comparison methods based on maximum pseudolikelihood as well as graphical procedures for model checking using simulations. Our methodology is applied for analysing a dataset representing a nickel-titanium shape memory alloy.

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Price and Capacity Competition between a Make-to-Order and a Make-to-Stock Firm with Strategic Customers

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We consider the problem of competition between two firms, which sell a similar service or product in a market of strategic customers who are price and delay-sensitive. The first firm operates in a make-to-order under first-come-first-served discipline. The second firm is a make-to-stock supplier with a fixed order cost, negligible replenishment lead time, and immediate delivery. The products sold by the two firms are substitutes but not identical, and customers choose which product to buy based on their valuations, selling prices, and estimated waiting time at the make-to-order producer.

We consider the competition between the two firms in a stylized model of queueing and inventory control policies under strategic customer behavior. The two firms determine their selling prices and the production capacity and ordering policies, respectively. We analyze Nash equilibrium strategies between the two firms and the customers under several competition frameworks, explore the social welfare under equilibrium, and discuss coordination possibilities.

A practical application is a market of custom-made and ready-made products or new and second-hand products, where the high price and delay in acquiring the custom-made product may drive some customers to buy the less expensive ready-made product.

A Non-Parametric Monitoring Procedure for Monitoring Multivariate Processes Based on Convex Hulls

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Multivariate Statistical Process Monitoring (MSPM) is one of the most rapidly developing areas of statistical process control in the last decade due to the enormous number of practical problems involving multiple dependent variables. Hotelling's T2 control chart (CC) is the most well-known tool used to monitor a multivariate process. However, the Hotelling's T2 CC demands strict assumptions about the distribution of the random vector representing the stability of the process, i.e. assumes multivariate normality. Furthermore, today, in the big data era where multiple data streams sources should be monitored such a strict assumption is unrealistic. Thus, robust non-parametric monitoring procedures are of great importance. In this work, we introduce a non-parametric control scheme based on convex hulls. The proposed non-parametric control chart is using bootstrap for estimating the kernel of the multivariate distribution and then appropriate statistics based on convex hull are monitored. The performance of the proposed control chart is very promising.

On the preservation of some positive aging properties regarding random maxima

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Order statistics such as the minimum and the maximum observation of a random sample play an important role in Statistics, with applications, for instance, in reliability theory, in survival analysis, in actuarial science, etc. There are various applications where the sample size may depend on the occurrence of some events, making the sample size N random, and thus giving rise to the study of random minima and maxima. The examination of the preservation of aging properties regarding the latter quantities has been of substantial interest in the literature. The positive aging classes such as increasing failure rate (IFR), increasing failure rate average (IFRA), new better than used (NBU) are not generally, among others too, closed under random minima and maxima, see Hazra et al. (2014). On the other hand, Shaked (1975) proved the preservation of the IFR property for the distribution of random maxima by assuming that the probability generating function of N, P_N, satisfies the functional equation

$$1 - P_N\left(1 - P_N\left(z\right)\right) = z, \text{ for } 0 \leq z \leq 1.$$

In this work we show that the closure property of IFR, IFRA and NBU classes under random maxima is guaranteed by a less stringent than the above property of N, that is when N is (discrete) IFR.

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On the time and aggregate claim amount until ruin in a jump diffusion risk model in the presence of an upper safety level

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We consider a two-barrier renewal risk model assuming that insurer's income is modelled via a Brownian motion and the surplus is inspected only at claim arrival times. We are interested in the joint distribution of the time, number of claims and the total claim amount until the surplus process falls below zero (ruin) or reaches a safety level. We obtain a general formula for the respective joint generating function which is expressed via the distributions of the undershoot (deficit at ruin) and the overshoot (surplus exceeding safety level). We offer explicit results in the classical Poisson model and we also study a more general renewal model assuming mixed Erlang distributed claim amounts and inter-arrival times. Our methodology is based on tilted measures and Wald's likelihood ratio identity. We finally illustrate the applicability of our theoretical results by presenting appropriate numerical examples in which we derive the distributions of interest and compare them with the ones estimated using Monte Carlo simulation.

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Modeling and parameter estimation of a multi-hidden chain model of typhoid fever in Mayotte

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The primary aim of this study is to develop and evaluate a new epidemiological model that effectively captures the transmission dynamics of typhoid fever in Mayotte, a French administrative department situated in the Indian Ocean. This model uses medical information on the disease and a dataset of hospital admissions provided by the Regional Health Agency. To achieve our goal, we

propose a parametric approach that employs a two-dimensional pure jump continuous-time Markov process to count the persons exposed and infected by the disease, and estimate critical model parameters, such as person-to-person and environmental contamination rates, incubation, and recovery rates. Our estimation methodology is highly innovative, addressing two key challenges associated with the available data. Firstly, observations are available only at fixed dates (daily hospitalizations), and secondly, on these dates, the total number of infected persons is not observed, only newly reported cases are counted, making parameter estimation more complex. To overcome the dataspecific challenges, we derive explicit expressions for the parameter estimators using the moments of the exposed-infected process. Subsequently, we adapt the Baum-Welch algorithm to estimate the transition matrix for the hidden multi-chain Markov model, and employ Monte Carlo simulation to estimate these parameters.

The proposed model and estimation methodology have significant implications for understanding and controlling the transmission of typhoid fever in Mayotte, and potentially in other regions with similar epidemiological characteristics. The findings from this study could be instrumental in guiding public health policies aimed at mitigating the spread of typhoid fever in Mayotte.

Semi-Parametric Non-Smooth Optimal Dynamic Pricing

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We apply statistical techniques of censored data to a dynamic pricing problem. Recent literature on dynamic pricing focuses on models where the market value of a product is linear in its observed features plus some market noise with known distribution F. Products are sold one at a time, and only a binary response indicating the success or failure of the sale is observed. The goal is to post future prices in order to minimize the seller's regret. The most realistic case occurs when F is not known, and only smoothing kernels have been used to estimate it. These techniques require the choice of some parameters, such as the bandwidth and the kernel, and various regularity assumptions on F are made. To overcome these problems, we estimate F more naturally via non-parametric MLE (NPMLE) under the only assumption that F and 1-F are log-concave, common hypotheses in the dynamic pricing literature. Moreover, we implement a policy that achieves a better regret upper bound than the one using smoothing kernels [1] (see Figure 1). As a modern result, germane to statistical literature, we determine the uniform convergence rate of the NPMLE under log-concavity of F and 1-F.

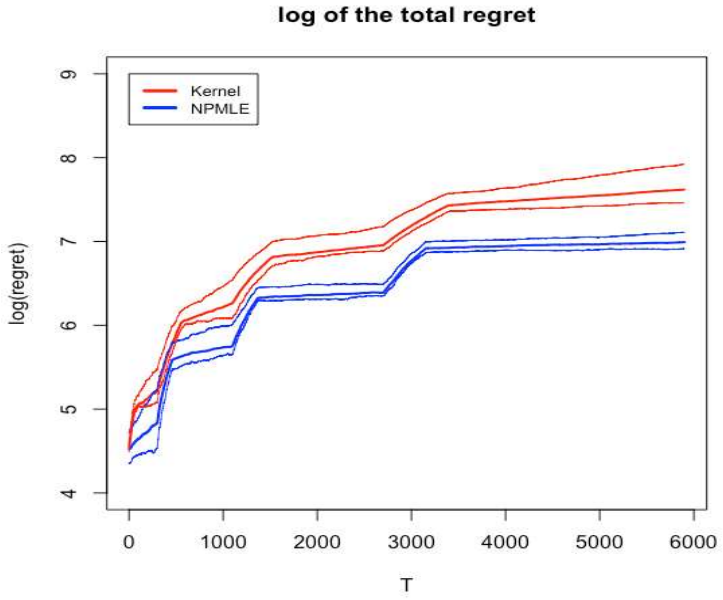

Figure 1: log of the total regret for Kernel approach (red lines) and NPMLE (blue lines). For each color, the upper and lower lines are the 95% CI, the line in the middle is the mean.

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Tail Risk Interference from Theory-Infused Models

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Semi-structural models, inspired by theory incorporating real-life identities, but still relying on empirical identification of behavioural equations, take a central position in many policy institutions. Their headline application remains the forecasting of inflation and economic activity. However, as argued in the presentation, such models can as well inform about the tails of the variable distribution. Moreover, their semi-structural design can help to understand the underlying mechanism of future changes in tails.

Predicting Future Failure Times By Using Quantile Regression

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The problem of predicting the future failure times in a sample from early failures (type II censoring data) is a task of great interest [1, 3]. Here, we present a study on both the case of independent and dependent lifetimes [2]. In both cases we assume identically distributed random variables. To predict the future failures, the quantile regression techniques are used and confidence regions for them are also provided. Some illustrative examples show how to apply the theoretical results to simulated and real data sets.

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Generative Modeling with Optimal Transport Maps

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With the discovery of Wasserstein GANs, Optimal Transport (OT) has become a powerful tool for large-scale generative modeling tasks. In these tasks, OT cost is typically used as the loss for training GANs. In contrast to this approach, we show that the OT map itself can be used as a generative model, providing comparable performance. Previous analogous approaches consider OT maps as generative models only in the latent spaces due to their poor performance in the original high-dimensional ambient space. In contrast, we apply OT maps directly in the ambient space, e.g., a space of high-dimensional images.

First, we derive a min-max optimization algorithm to efficiently compute OT maps for the quadratic cost (Wasserstein-2 distance). Next, we extend the approach to the case when the input and output distributions are located in the spaces of different dimensions and derive error bounds for the computed OT map. We evaluate the algorithm on image generation and unpaired image restoration tasks. In particular, we consider denoising, colorization, and inpainting, where the optimality of the restoration map is a desired attribute, since the output (restored) image is expected to be close to the input (degraded) one. Resulting OT map represents a model for data multidimensional distribution and so it can be used for anomaly detection.

Acknowledgements

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Mittag-Leffler Single Server Queues

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We will present three non-equivalent queueing models in continuous time that each generalise the classical M/M/1 queue in a different way. Inter-event times in all models are Mittag-Leffler distributed. For each of the models we answer the question of the queue being at zero infinitely often (the `recurrence' or `stable' regime) or not (the transient regime). Aside from this question, the different analytical properties of each models allow us to answer a number of questions such as existence and description of equilibrium distributions, mixing times, asymptotic behaviour of return probabilities and moments and functional limit theorems.

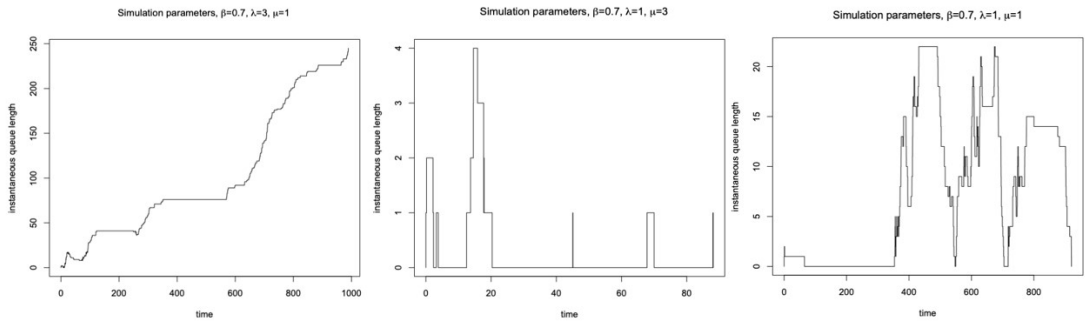

Figure 1: Three simulations for the Mittag-Leffler GI/GI/1 queue. The arrival and departure counting process have the same tail index α = 0.7 but the arrival rates differ.

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Queuing models with Mittag-Leffler inter-event times.

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A model for stochastic dependence implied by failures among deteriorating components

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We consider a system of n components, with component deterioration modeled by non decreasing time-scaled Lévy processes. When a component fails, a sudden change in the time-scaling functions of the surviving components is induced, which makes the components stochastically dependent. We compute the reliability function of coherent systems under this dependence model. We next study the distribution of the ordered failure times, and establish positive dependence properties. We also provide stochastic comparisons in the usual multivariate stochastic order for the failure times of two dependence models with different parameters. Finally, some numerical experimentation illustrates the theoretical results.

Longitudinal Cluster Analysis to the Annual Expenses of the Healthcare System of Selected Countries of the European Union from 2004 to 2018

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Undoubtedly, the organization of a Healthcare System as well as the access of its citizens to all kinds of health services should be a priority of every state. In order to provision healthcare insurance coverage for every employee in any European country wherever they are, the European Union, as an economical union, is forced to observes the workforce movements, due to differences in lawmaking. In this framework, the direction of the state expense of each country by sector of the Healthcare System is interesting, regardless of the healthcare provider. Healthcare expenses of each country constitute longitudinal data which need special methods for a reliable analysis. However, non-parametric statistical methods such as the KmL algorithm are appeared to be useful tools for longitudinal economic analysis. Thus, in the present paper we analyze the expenses of Social Security Funds, as well as the total state healthcare expenses per thousand inhabitants and as percentage of the annual Gross Domestic Product (GDP) of chosen European countries for specific healthcare provisions. In addition, the evolution of the percentage of total state expenses, which is expenses of Social Security Funds of the above countries for each of the above health services is also analyzed. Healthcare expenses, the annual GDP and the population of every country as of Jan. 1st of every year, are published by EUROSTAT. From the longitudinal cluster analysis of countries, observations of economic studies of Eurostat, the World Health Organization (WHO) and the Organization for Economic Cooperation and Development (OECD) about the organization of Health Systems and the evolution of the expenses of the countries, which classified in the same group were also verified.

Scan Statistics in Sequential Trials

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In this talk, we review the approximations and inequalities for scan statistics for both discrete and normal data and for the expected stopping time and its variance associated with a sequential monitoring scheme based on a fixed length moving window. We also present a repeated significance test (RST) for a sequential monitoring scheme, where the designated sample size is predetermined for a specified probability of Type I error associated with the RST. We present algorithms and numerical results for approximating the expected stopping time, p-value and the power of this RST. A quality control example is presented for an application of sequential trials with Bernoulli distribution.

Discrete-time Approximation Rough Volatility Models

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"Rough" volatility models (RVM) have been introduced to describe the anti-persistent behavior of the volatility of financial assets. These are models in which the stock follows a geometric Brownian motion, with volatility described by a fractional Ornstein-Uhlenbeck process with Hurst parameter less than 1/2. In the first part of this talk, we will introduce a new framework for the estimation of the volatility process of an asset using low frequency daily option trading entries. We will apply this method to S&P 500 data and obtain estimates of the Hurst parameter that motivate the need for RVM. In the second part of the talk, we will establish the weak convergence of a novel Donsker-type scheme for RVM, which leads naturally to a Binomial tree for option pricing.

On Spectral Distribution of Sample Covariance Matrices from Large Dimensional and Large k-fold Tensor Products

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We study the eigenvalue distributions for sums of independent rank-one k-fold tensor products of large n-dimensional vectors. Previous results in the literature assume that $k=o(n)$ and show that the eigenvalue distributions converge to the celebrated Marchenko-Pastur law under appropriate moment conditions on the base vectors. In this paper, motivated by quantum information theory, we study the regime where k grows faster, namely $k = O(n)$. We show that the moment sequences of the eigenvalue distributions have a limit, which is different from the Marchenko-Pastur law, and the Marchenko-Pastur law limit holds if and only if $k = o(n)$ for this tensor model. The approach is based on the method of moments.

This is a joint work with Benoit Collins and Jianfeng Yao.

From simulated earthquakes a key to modelling the occurrence of a strong event

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The application of a physics-based earthquake simulation algorithm to the Nankai megathrust fault system allowed the compilation of a synthetic seismic catalog lasting 5,000 years, and containing more than 130,000 Mw ≥ 5.0 events, without limitations in terms of completeness, homogeneity and time duration. This simulator is based on an algorithm constrained by several physical faulting and source parameters, and including some heuristic rules controlling the nucleation, growth and stopping of the rupture of a seismic source. The seismogenic model upon which we applied the simulator code includes the faults that were recognized as the sources of the major historical earthquakes occurred in the study region. The application of our simulation algorithm provides typical statistical features in time, space and magnitude behavior of the seismicity, which are comparable with the observations. These features include long-term periodicity and a realistic earthquake magnitude distribution. We also found in our synthetic catalog a clear trend of long-term acceleration of seismic activity preceding M ≥ 6.0 earthquakes and quiescence following those earthquakes.

Subsidizing Inclusive Insurance to Reduce Impoverishment

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We consider inclusive insurance, namely insurance for financially vulnerable populations. We show that, although insurance alone may not be sufficient to reduce the likelihood of impoverishment for specific groups of households, since premium payments constrain their capital growth, government subsidies can provide maximum social benefits while reducing governmental costs. This is joint work with Severine Arnold, Jose Contro, Kira Henshaw and Sooie Hoe Loke.

Parameter Estimation Issues on the Generalised Gamma Model for Complete and Interval Censored Observations

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The generalized gamma model (GG) was introduced by Stacy (1962) [2] and includes as sub-models the exponential, Weibull, and gamma among others. By a suitable reparameterization, Prentice (1974) [1] also included the lognormal model and gave a central role to the latter distribution. Maximum Likelihood Estimation (MLE) cannot be performed in closed form and Newton-Raphson iterates are necessary to approach the MLE. Additionally, in many applications, data are interval-censored, thus not directly allowing the use of the continuous model, and numerical integration is needed to compute the likelihood function. In many other cases, a priori information should also be incorporated into the model and a Bayesian estimation procedure is more relevant. Devising efficient estimation strategies is challenging both for fully observed and interval-censored observations.

In this talk, we revisit parameter estimation issues with both a frequentist and a Bayesian perspective, either in situations where fully observed data are available or in the case where observations are interval censored. In this study, the censoring mechanism is due to a specific experimental protocol and all the intervals are of equal length, except for the last one which corresponds to a right censoring at a large value (maximum observation time). Efficient estimation strategies are investigated in both scenarios, an asymptotically efficient estimator is proposed as a surrogate to the MLE and an application is given with real data related to the first division time of Hematopoietic Stem Cells (HSC) which are of primary importance when studying blood formation.

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PageRank On Directed Preferential Attachment Graphs

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We study a family of evolving directed random graphs that includes the directed preferential model and the directed uniform attachment model. The directed preferential model is of particular interest since it is known to produce scale-free graphs with regularly varying in-degree distribution. We start by describing the local weak limits for our family of random graphs in terms of randomly stopped continuous-time branching processes, and then use these limits to establish the asymptotic behavior of the corresponding PageRank distribution. We show that the limiting PageRank distribution decays as a power-law in both models, which is surprising for the uniform attachment model where the in-degree distribution has exponential tails. And even for the preferential attachment model, where the power-law hypothesis suggests that PageRank should follow a power-law, our result shows that the two tail indexes are different, with the PageRank distribution having a heavier tail than the in-degree distribution.

System Reliability Modelling via Virtual Ages

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Systems operate commonly in varying environments which are harmful in most situations for system reliability. The usage of virtual ages in reliability increases gradually, which is a powerful tool for analyzing system reliability. In the paper, by employing the virtual ages, a system reliability model is developed for a single-unit system operating in cyclic environments. The system reliability formula is given in an expectation form of random survival function whose variables includes a virtual age, and the asymptotic estimates of system reliability are derived in terms of the law of large number and central limit theorem. Meanwhile, some special cases are discussed, and the simulation algorithm is established. We believe this work may shed light on the related researches in future not only in reliability area but also in maintenance subject.

A non-local Jacobi operator for neuronal modeling

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To overcome some limits of classical neuronal models, we introduce downward jumps in a class of Jacobi processes to model the activity of a single neuron [1-3]. The mathematical study of the model requests the development of general results for the first-passage time, T, of the proposed Jacobi process with jumps through a constant boundary. We characterize the Laplace transform of T in terms of generalized hypergeometric functions that we introduce, getting a new closed-form expression of the expectation of T. We follow an original approach based on intertwining relations, which have been recently established [4], between the semigroup of classical Jacobi processes with the one of their generalized versions.

A numerical investigation of these results is considered in the case of neuronal modeling for some choices of the involved parameters and of the jumps distributions. In particular we address the problem of the first passage time using a discretization scheme for simulating the trajectories of jump-diffusion processes with state-dependent jumps, both in frequency and amplitude [5]. We obtain numerical approximations on the probability density function of T and results on the qualitative behaviour of other statistics of this random variable.

Based on joint works with **Pierre Patie** (Cornell University), **Laura Sacerdote** (Università di Torino) and **Alessandro Lanteri** (Università degli Studi di Milano).

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Seismic sequences identification in Italy by local test of random labelling

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In this work, we present a study on a seismic spatial point pattern with functional marks provided by seismic waveforms.

Indeed, earthquakes can be characterized both by the spatio-temporal hypocentre locations and by the waveform associated with each event and the integration of these two sources of information is crucial to understand the nature of the generating seismic event.

However, despite the relatively long history of point process theory, few approaches to analyzing spatial or spatio-temporal point patterns where the features of interest are functions (i.e. curves) rather than qualitative or quantitative variables have been developed.

With this aims in mind, we present a family of local inhomogeneous mark-weighted summary statistics for general marked point processes, to capture various types of local dependence structures depending on the specified involved weight function.

We use such summary statistics to propose a local random labelling test. This procedure enables us to identify points and thus regions where the random labelling assumption does not hold, for example, when the functional marks (waveforms) are spatially dependent.

In particular, we analyse Italian earthquake data coming from the ISTANCE dataset, that is a sample dataset provided at http://www.pi.ingv.it/instance/, containing 10000 records of 300 events, together with the associated metadata.

The observed point pattern consists of 300 seismic events which occurred in a period ranging from 21st July 2012 to the 9th December 2016. The observation area is [6.729,18.002] x[36.64,46.46], including also seismic events occurring around Italy.

They tend to gather into two main clusters. The northernmost originated in May 2012, when two major earthquakes struck Northern Italy, causing 27 deaths and widespread damage. The events are known in Italy as the 2012 Emilia earthquakes, because they mainly affected the Emilia region. Then, Central Italy seismic sequence began in August 2016, and it is now defined by the INGV as the Amatrice-Norcia-Visso seismic sequence.

As a result of the application of our proposed local test, we are able to correctly identify seismic events belonging to important well known Italian seismic sequences. On the other hand, we find that the shocks related to these sequences are likely generated by different underlying processes, corresponding to different seismic sources. The significant events coincide with the aftershocks, triggered by some mainshocks previously occurred.

Founding

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Comparing Random Variables is Not as Obvious as 1, 2, 3

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Decision making inevitably involves the comparison and ordering of real variables. In the presence of uncertainty, this entails the comparison of real-valued random variables. We briefly review three approaches to such comparison:

1. *Stochastic dominance:* an approach based on a pointwise comparison of cumulative distribution functions;
2. *Statistical preference:* an approach based on a pairwise comparison in terms of winning probabilities;
3. *Probabilistic preference:* an approach based on multivariate winning probabilities.

Whereas the first and third approaches are intrinsically transitive, the second approach requires considerable mathematical effort to unveil the underlying transitivity properties. Moreover, the first approach ignores the possible dependence between the random variables and is based on univariate distribution functions, the second approach is by definition built on bivariate joint distribution functions, while the third approach is based on the overall joint distribution function.

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Spatio-temporal Markov decision theory

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We propose a new framework to support sequential decision-making for spatially interacting Markov processes. Inspired by principles from Markov decision theory and statistical mechanics, we introduce the spatio-temporal Markov decision process (ST-MDP). The purpose of the ST-MDP framework is to control Markovian processes consisting of multiple components, which are governed by local interaction structures and to steer such processes towards a certain desirable behaviour. We formulate and analyse an ST-MDP based on the renowned Ising model and provide insights in the shape of optimal policies and value functions. In particular, we unveil relations between policies and value functions on the one hand and the energy function and temperature parameter of the Ising model on the other hand. Furthermore, we discuss the role of metastability and critical behaviour in the context of our spatio-temporal Markov decision theory. Finally, we touch upon the potential application of the ST-MDP framework to the development of cancer treatment methodologies, which is the motivating force behind this research.

The Ant random walk with superlinear reinforcement

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The Ant random walk is a variation of the standard edge-reinforced random walk. It is well known that the edge-reinforced random walk with superlinear reinforcement traverses a random attracting edge at all large times (see Cotar, Thacker). In contrast, the Ant random walk with superlinear reinforcement traverses a random attracting *circuit* at all large times (see Erhard, Reis). In this talk we will discuss these different phenomena.

A General Procedure for Localising Strictly Proper Scoring Rules

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Forecasters are typically not equally interested in all possible realisations of a random variable under scrutiny. Financial risk managers, for instance, usually put relatively more weight on regions of extreme losses. In density forecast comparison, it is common practice to use strictly proper scoring rules to rank a collection of candidate predictive distributions. When focusing on a region of interest, however, weighted scoring rules obtained via conditioning are no longer strictly proper. We develop a general procedure for focusing, i.e., localising, scoring rules in a way that preserves their strict propriety. Our procedure provides a myriad of strictly locally proper scoring rules beyond the censored likelihood score. In particular, the focusing procedure we develop is general enough to handle both univariate and multivariate scoring rules, including the rich class of kernel scores. The one-to-one correspondence between the censored distribution and the original distribution on the region of interest preserves not only strict propriety but also the optimal power properties of the Logarithmic scoring rule. More specifically, our paper generalises the Neyman Pearson lemma, showing that the uniformly most powerful test for a localised version of this lemma's original hypotheses boils down to a censored likelihood ratio test. Based on a collection of popular scoring rules, including the Logarithmic, Spherical, Quadratic and Continuously Ranked Probability Score (CRPS), Monte Carlo simulations align with the intuition that censoring bears, also in general, more desirable power properties than conditioning, especially if the number of expected tail observations is small.

Stochastic models in the construction of paradoxes in probability, game and voting theory

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In the first part of the talk, we address the question of constructing stochastic models that realize an assigned majority graph. We show that this goal can be achieved in terms of hitting times of special Markov chains. More precisely, we consider a generic oriented graph without self-loops and 2-cycles, $G = ([n],\vec{E})$. For any such oriented graph $G = ([n],\vec{E})$ we construct a Markov chain and n identically distributed hitting times $\{T_1,...,T_n\}$ such that the probability of the event $\{T_i > T_j\}$, for any $i,j = 1,...,n$, is larger than $\frac{1}{2}$ if and only if $(i,j) \in \vec{E}$. We apply this result to construct a class of games which manifest a paradoxical and unexpected behavior and can be seen as a generalization of the Penney games, see [1].
In the second part of the talk we consider the concept of *ranking pattern*. Such concept can be seen as a multivariate version of the one of majority graph. We show how, for any given ranking pattern σ, one can explicitly construct a *load-sharing* model which leads to σ, see [2]. Such a result can be useful in different contexts. In particular, we show that the application of it to the context of voting leads us to an interesting expansion of the theory, see [3] and also [4].

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Markov-Switching State-Space Models with Applications to Neuroimaging

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State-space models (SSM) with Markov switching offer a powerful framework for detecting multiple regimes in time series, analyzing mutual dependence and dynamics within regimes, and assessing transitions between regimes. These models however present considerable computational challenges due to the exponential number of possible regime sequences to account for. In addition, high dimensionality of time series can hinder likelihood-based inference. To address these challenges, novel statistical methods for Markov-switching SSMs are proposed using maximum likelihood estimation, Expectation- Maximization (EM), and parametric bootstrap. Solutions are developed for initializing the EM algorithm, accelerating convergence, and conducting inference. These methods, which are ideally suited to massive spatio-temporal data such as brain signals, are evaluated in simulations and applications to EEG studies of epilepsy and of motor imagery are presented.

Large Deviation results for Controlled Branching Processes

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The topic of large deviation (LD) plays an important role on many results in statistics. In particular, in the field of branching processes the study of large deviations for the standard Bienaymé-Galton-Watson branching processes (BGWP) was initiated in [1] and [4] and investigated in detail in [1] and [3]. Among others results, the LD behavior of the statistic $R_n = \frac{Z_{n+1}}{Z_n}$ has been studied. This statistic has been used in the estimation of the amplification rate in a quantitative polymerase chain reaction (PCR) experiment where only Z_n and Z_{n+1} are observed. In this talk we will focus on LD results in the framework of controlled branching processes (CBP). These are a generalization of BGWPs where at each generation the number of progenitors is randomly chosen through a random control function. The aim of this work is to develop LD results for CBPs under an assumption on the exponential moments or polynomial moments of the offspring distribution and also based on the asymptotic behaviour of the harmonic moments of the generation sizes.

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Distributions induced by probability density functions and applications to differential entropy and varentropy

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The 'pdf-related distributions' are constructed by means of transformations of absolutely continuous random variables through their own probability density functions. Given an absolutely continuous random variable X having pdf f(x), the interest on transformations of the form Y = f(X) stems in various contexts of probability and statistics, such as in the analysis of (i) the Wilcoxon test, (ii) the Rényi entropy and the differential entropy, (iii) the confidence level for applications in Functional Data, and so on.

We investigate the main characteristics of pdf-related distributions, with reference to the general form of the distribution, the quantiles, and some related notions of reliability theory. We also focus on a characterization of the pdf-related distribution being uniform for distributions of exponential and Laplace type as well. Then, we face the problem of stochastic comparing the pdf-related distributions by resorting to suitable stochastic orders. Finally, the given results are used to analyze properties and to compare some useful information measures, such as the differential entropy and the varentropy.

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On approximating the first passage time density from data using generalized Laguerre polynomials

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The first-passage-time (FPT) problem arises in many applications in which a stochastic process evolves in the presence of a threshold. The mathematical study of the FPT problem consists in finding its probability density function (pdf). There are several strategies to approach this problem, whose effectiveness depends on the formulation of a suitable model for the stochastic process and on its properties. But when a random sample of FPTs is analyzed without any prior information on the stochastic dynamics generating the data, the identification of a model could be difficult to implement. In many applications the only available data consist in the direct observation of the FPT variable. In general, classical tools as histograms or kernel density estimators are the first choice aiming to postulate a shape of the FPT pdf and then a model.

This contribution introduces a general method which fits into the broad framework of strategies for the approximation of FPT density on a random sample of FPTs through a constant boundary and, of course, is intended for the cases in which the closed form expression of the pdf is not available. The proposed approximation is of Laguerre-Gamma polynomial type. This proposal have been successfully applied to Feller processes and Inhomogeneous Geometric Brownian Motion for which no closed form expressions of the FPT pdf are available. Moreover, to check the feasibility of the method both in fitting the density and in estimating the parameters, the GBM FPT has been considered (see [1] and references therein).

As the approximating function integrates to unity whatever order of approximation is reached, the proposed method iteratively looks for the best degree of the approximating polynomial such that the normalization condition is preserved. Numerical investigations have confirmed that this stopping criterion is accurate, robust and independent on the shape of the pdf. Moreover, the implemented algorithm relies on simple and new recursion formulae involving FPT moments or cumulants, depending on the treatability of their expressions. Note that it is possible to recover cumulants up to a fixed order from moments up to the same order (and viceversa). In particular, k-statistics might be used as free-distribution estimators of cumulants as they are symmetric functions of the random sample with minimum variance when compared to all other unbiased estimators [2].

In the end, this approximation has a twofold advantage. If the FPT moments/cumulants are not known, the special feature of this approach is the chance to recover an approximation of the FPT pdf starting from a sample of FPT data like the classical density estimators. If the FPT moments/ cumulants are known or can be recovered from the Laplace transform of the FPT random variable, the method is essentially a way to find an approximated analytical expression of its pdf. The method turns to be useful also if the model is known but the knowledge of the FPT moments is limited, as usually happens. In such a case, the approximation might be carried out by simulating the trajectories of the process through a suitable Monte Carlo method.

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Noise reduction for functional time series data

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Curve time series are present in many parts of society and disciplines. Some of them are segments of a single time series (e.g. annual weather record charts, daily stock price charts), while others are not (e.g. term structure of interest rates, intraday asset return patterns). Observed high-dimensional time series are often found to consist of a dynamical part, with serial dependence structure, and an additive noise part. These parts are not separately observable, challenging the identification and modelling of the dynamical part of high-dimensional time series, which currently is an active area of research (Cubadda 2022; Dong, 2022). In this paper we propose a novel pre-processing methodology that filters out the noise in a curve times series, thereby giving access to the dynamics.

Our starting point is the framework of ``dynamic functional principal component analysis", laid out by Bathia *et al.* (2010). This framework uses a functional PCA representation to consider the dynamical part of a curve time series as the time series of a finite-dimensional vector of random variables. By assuming a vector autoregressive model for this time series, we are able to reconstruct the autocovariance of the noise curves. Subsequently, by identifying the subspace of the noise component, we construct an optimal projection of the observed curve time series along the noise subspace, resulting in an estimate of the underlying noise-free curves. We show that this projection is consistent, in the sense that it is asymptotically optimal as the time series length increases.

We apply this method to both simulated data and real-world datasets. If the dynamic and noise spaces differ, we observe near-optimal denoising, even for relatively short curve time series. This result can be seen as a ``blessing of dimensionality" (Gorban, 2018), since we can exploit the high-dimensionality of the observed data to disentangle the dynamics from the noise in the curve time series. We also study the limitations of our approach, in particular the special situation when the dynamical space and the noise space are nearly collinear.

By considering the proposed method as a pre-processing step, we study some of its potential applications. We employ the reconstructed noise autocovariance to estimate the ``dynamics-to-noise" ratio. We also show that using the denoised curve time series leads to improved parameter estimation of an underlying autoregressive model as well as improved forecasts.

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The Impact of Customer Heterogeneity on Equilibrium Strategies in a System of Unobservable M/M/1 Queues in Series

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We consider a system of two unobservable M/M/1 queues in series with heterogeneous delay-sensitive strategic customers who make joining decisions at the entrance of each queue. Specifically, each customer may decide either to balk upon arrival or leave the system permanently after completing service at the first queue or receive service at both queues. After each service completion, customers collect the corresponding service reward. The customers' objective is to maximize their expected net benefit from the total service value minus the delay cost incurred from their passage through the system until they balk. In this model, customers' decisions must take into account not only the trade-off between the acquired service value and the waiting cost in the current queue but also the possibility that this loss may be compensated by joining the subsequent queue.

For this model, we characterize customers' equilibrium behavior which is threshold-based in delay sensitivity, and we derive explicitly the equilibrium for the whole range of the economic and operational parameters. Furthermore, we study numerically the impact of delay-sensitive customer heterogeneity on equilibrium behavior comparing it with the case where the customer population is (almost) homogeneous, considering the equilibrium throughput and the equilibrium customers' social welfare.

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The Disorder Problem. An Approach Based on Partially Observable Markov Decision Processes.

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The discrete time disorder problem has been stated by Shiryev[1] as follows. On some probability space are given a non-observable random variable θ and a sequence of observable random variables ξ_n, $n=1,2,...$The distribution of θ is: $P(\theta=0)=\pi$, $P(\theta=n)=(1-\pi)p(1-p)^{n-1}$, $n=1,2,...$, $0<p,\pi<1$. The distribution of ξ_n has a density $p_1(x)$ if $n> \theta$ and a density $p_0(x)$ otherwise. Let $(\aleph_n)$ be a filtration generated by the observations (ξ_n). The problem is to find a $(\aleph_n)$-stopping time τ which minimizes the risk

$$\rho^{\tau}(\pi)=P^{\pi}(\theta>\tau)+cE^{\pi}(\tau-\theta)^{+},\ c>0. \qquad (1)$$

In (1) P^{π} is a measure that corresponds to the initial distribution π.
A solution to this problem in terms of optimal stopping rules can be found in [1].
Instead of (1), we consider the criterion

$$R^{\tau}(\pi)= E^{\pi}(\theta\wedge\tau-c(\tau-\theta)^{+}). \qquad (2)$$

The problem is to find τ which maximizes (2) over all stopping times. We include this problem into the framework of the Partially Observable Markov Decision Processes which improves the quality of detection, and allows, in some cases, to find solutions to Bellman's equation.

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The Multivariate Fractional Ornstein-Uhlenbeck Process

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In this work, we define a multivariate version of the fractional Ornstein-Uhlenbeck process (fOU), i.e. the solution to a stochastic differential equation with affine drift and constant volatility, driven by a fractional Brownian motion (fBm). This is motivated by several modelling applications, e.g. the rough volatility model introduced in [2]. We allow for different Hurst exponents in each component, defining the process starting from the multivariate fBm (mfBm) introduced in [1]. The resulting multivariate fOU (mfOU) is a multivariate stationary and ergodic process, with smoothness/regularity degree that can be different in any component. Such process has a richer correlation structure than that of the classical diffusive case, in the sense that the correlation between *i-th* and *j-th* components depends on $\rho(i,j)$, analogous to the correlation coefficient of the diffusive situation, and also on a parameter $\eta(i,j)$ that rules the time-reversibility of the process (this is also inherited from the mfBm).

We propose a generalized moment estimator for these correlation parameters ρ and η, based on discrete observations, for which we show consistency and asymptotic normality as the number of equally spaced observations of the process goes to infinity. This estimator presupposes previous knowledge of the parameters of the marginal one-dimensional fOU processes. Even if not ideal, this seems a reasonable assumption since the problem of estimating a one-dimensional fOU has already been widely considered in the literature both in theory and practice. A potential problem with this is the estimation of the mean reversion parameter, in particular when the mean reversion is weak, because of a possible upward bias when estimating such parameter. For this reason we also propose a modified estimator for ρ and η that does not depend on the mean reversion parameters of the one dimensional marginals. We discuss the asymptotic behaviour of such estimators from a theoretical standpoint and provide numerical experiments.

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Monitoring Defects in Manufacturing Procedures Using Scan Statistics

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Monitoring the number of defects in constant-size units, for example the surface of tiles, is an important task in manufacturing procedures to ensure the quality of the product. A useful tool to accomplish this task is the *c* control chart which is often adopted to monitor the total number of defects in a product or a sample of products under the assumption that this number can be described, at least approximately, by a Poisson distribution. Apart from the number of defects on a product, another crucial characteristic of its quality is their special distribution since areas with high concentrations of defects can have a significant impact on the quality of the product even if the total number of defects remains relatively small. In this talk, a monitoring procedure, which combines control charts to monitor not only the evolvement of the number of defects (in general, events) through time but also their spatial distribution using scan statistics, is proposed. Simulation results showed that the new procedure presents an excellent performance under different scenarios.

On NA-consistent Finite Dimensional Manifolds of Forward Rates Where the Diffusion Coefficient is Free

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Abstract:
The classical framework to model the term structure of interest rates, i.e. all infinitesimal forward rates, has been introduced by Heath Jarrow and Morton (HJM). The framework has the undesired tendency to produce infinite dimensional model. Since finite dimensional models are required for practical purposes, one chooses finite dimensional vector spaces (or manifolds) V
that are consistent with the HJM-framework. In a next step, one would infer the nature of the process on V from data. If we assume that it is a diffusion, then its drift is governed by the HJM-drift condition (at least in the risk neutral view) and the diffusion coefficient is left for statistical analysis. However, it is not a priori clear that a (tangential) diffusion coefficient motivated by data allows the process to stay on V because the HJM-drift condition for this diffusion coefficient might point out of V. For this reason, we find those finite dimensional manifolds where any tangential bounded diffusion coefficient process is possible on that manifold. It turns out, that essentially no vector space has this property.

Kyle's model with stochastic liquidity

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We construct an equilibrium for the continuous time Kyle's model with stochastic liquidity, a general distribution of the fundamental price, and correlated stock and volatility dynamics. For distributions with positive support, our equilibrium allows us to study the impact of the stochastic volatility of noise trading on the volatility of the asset. In particular, when the fundamental price is log-normally distributed, informed trading forces the log-return up to maturity to be Gaussian for any choice of noise-trading volatility even though the price process itself comes with stochastic volatility. Surprisingly, we find that in equilibrium both Kyle's Lambda and its inverse (the market depth) are submartingales.

Shannon Entropy in Deep Learning: Applications and Benefits

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Shannon entropy is a measure of the diversity or uncertainty of a probability distribution. It has been widely used in information theory and statistics to quantify the amount of information contained in data or signals. Recently, it has been successfully applied in the field of deep learning in three types of learning: supervised, unsupervised, and semi-supervised. In this talk, we provide an overview of the most important applications of Shannon entropy in these areas. We begin by discussing how entropy is used to regularize deep learning models to prevent overfitting in supervised learning. We also show how entropy can be used to measure the diversity of data and representations in unsupervised learning to identify similar data clusters and generate more diverse and representative data. Finally, we present how entropy can be used in semi-supervised learning to select the most relevant training data and improve learning efficiency by reducing the cost of data labeling. Our results show that Shannon entropy is a versatile and useful measure for deep learning that can improve the quality and efficiency of deep learning models in a variety of application domains.

Probabilistic modelling and assessment of a renewable hybrid energy system

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The two important sources of renewable energy systems are wind speed and solar radiation. Such systems have a stochastic nature due to random fluctuations in wind speed and solar radiation. Therefore, the use of probabilistic methods is inevitable for the performance evaluation and optimization of renewable energy systems based on wind and solar power. In this talk, a renewable hybrid energy system that combines wind and solar generators with a fuel cell system is evaluated from reliability point of view. The computation of some important reliability based characteristics and their use in optimal system design are discussed.

Bayesian Nonparametric Hypothesis Testing with Applications.

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Pólya trees (PT) are a class of random probability distributions that are commonly used as prior distributions in the Bayesian Nonparametrics (BNP) study of infinite-dimensional statistical models.

We will see in this talk how PT is a suitable object for a hypothesis testing problem in a BNP framework. This choice is motivated by a medical application for the study of the brain in stroke patients.

Keywords: Pólya trees, hypothesis testing, Bayesian Nonparametrics, medical imaging.

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Reliability Modeling for Balanced Systems Considering Mission Abort Policies

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This paper studies the optimal mission abort policy for a balanced system performing a specific mission continually for a period of time. The system consists of two subsystems with multi-state by considering mission abort policies and two subsystems operate independently before one of them goes into an absorbing state. In this paper, balance is proposed on the state distance of two subsystems and the system fails if one of them goes into an absorbing state. Two probability indexes, mission success probability and system survivability, are derived by employing the theory of aggregated stochastic processes. Moreover, a case study of the unmanned aerial vehicle performing a mission is given to demonstrate the results under study.

The Warm-starting Sequential Selection Problem and its Extension to a Multi-round Setting

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In the *sequential selection problem* (SSP), immediate and irrevocable decisions are made while candidates arrive randomly for a job interview. Standard variants, such as the *secretary problem*, begin with an empty selection set (cold-start) and perform the selection process once over a single candidate set (single-round). This talk concerns these two limitations. First, we introduce the *warm-starting SSP* (WSSP) setting that starts with a selection set containing previously selected items (i.e. individuals). The objective is to fill up and improve the selection by (re-)assigning each job at most once, while examining the sequence of candidate items. Second, we propose a cutoff-based approach to optimize a rank-based objective function over the final job-to-item assignment. Figure 1 gives an overview of the process. Then, we are going to give a summary of the results presented in a series of recent works (see references):

- some analytical results for the WSSP setting;
- the cutoff-based cost minimization (CCM) algorithm that adapts to the warm-start;
- an empirical comparison of CCM and other algorithms from the literature in a new multi-round selection framework;
- an application of the proposed selection framework for dynamic resource allocation, particularly interesting for epidemic control or health facilities management.

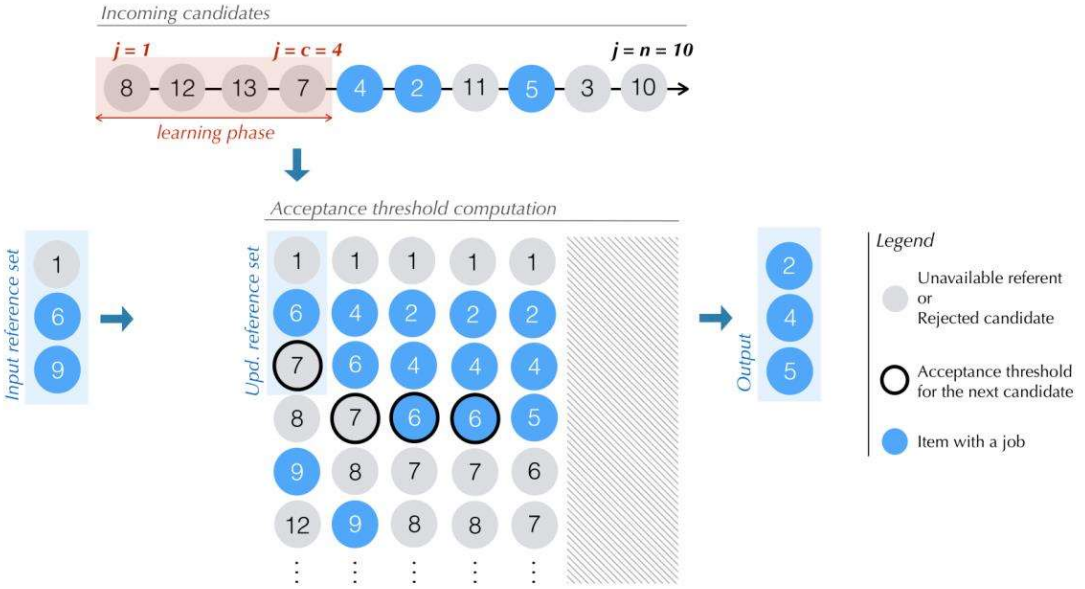

Figure 1: **A step-by-step deployment of the CCM policy for WSSP.** Here, $b = 3$ job positions and $r = 1$ of those initially empty. Items (i.e. individuals) with job positions appear as blue circles, while both available referents and rejected candidates appear as gray circles. Every item's absolute rank is indicated in its associated circle (considering all the $n + b = 13$ items, referents and candidates). The scheme reads from left ($j = 0$) to right ($j = n = 10$), i.e. each column lists the items seen so far ordered by absolute ranks (rank 1 is the best). Starting from the input reference set, CCM builds the updated reference set at step up to $j = c = 4$ (the cutoff threshold), which is then used to take hiring decisions in the selection phase.

Acknowledgements

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Branching Random Walks in Non-homogeneous Branching Media with an Infinite Number of Sources.

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We consider branching random walks (BRW) on a multidimensional integer lattice in non-homogeneous branching media with an infinite number of sources. The main attention is paid to the process with one particle generation center and an infinite number of absorbing sources. The solution of this problem can be reduced to the problem with one particle generation center and the absence of other sources, which was studied, for example, in [1], which significantly simplified the study. It turns out that the spectrum of the new evolutionary operator of mean numbers of particles is a spectrum of the same type as arising in [1], but shifted to the left by the constant, corresponding to the intensity of particle death. Due to this, an isolated eigenvalue that occurs under a certain condition is not always positive, which significantly affects the behavior of the process. It turns out that despite the possible absorption at every point in such BRW, an exponential increase in the numbers of particles can be observed, this occurs with a sufficiently high intensity of particles generation and a constant intensity of absorption, which is supposed to be equal at every point of the lattice. In this case, there is a regular increase in the moments and the weak convergence of the particle numbers to a certain random value is proved. It was also obtained that in this process an exponential decrease of the moments can be observed, which distinguishes it from the previously considered models of BRW and brings it closer to the Markov branching process with continuous time. The research results are presented in [2]. The results for BRW in the supercritical case are generalized for the process with a finite number of particle generation sources and an infinite number of absorbing sources.

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Poisson Network Autoregression

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We consider network autoregressive models for count data with a non-random neighborhood structure. The main methodological contribution is the development of conditions that guarantee stability and valid statistical inference for such models. We consider both cases of fixed and increasing network dimension and we show that quasi-likelihood inference provides consistent and asymptotically normally distributed estimators. The work is complemented by simulation results and a data example.

Target-based Approach with Dependent Targets and Paradoxes in Decision Theory

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We concentrate attention on single-attribute decision problems where consequences can be quantified by monetary amounts, and the prospects or lotteries X_α, $\alpha \in A$, are real-valued random variables on a given probability space. In this framework, we will first review briefly the Target-Based approach ([1]; see also [6]). We will in particular recall its substantial equivalence with the standard setting of decisions under uncertainty, when the existence of a bounded and right-continuous utility function u is guaranteed. In such cases, a target is a random variable T, stochastically independent of each prospect X_α, and with distribution function corresponding to an affine transformation of the function u.

A more general setting is obtained by allowing some form of stochastic dependence for the pairs (T, X_α). This extension gives rise to a framework where maximization of expected utility can be replaced by the maximization over α of $\boldsymbol{P}(T \leq X_\alpha)$. In this talk we highlight some points connecting dependence, ageing properties, and aspects of risk theory, by expressing preferences with respect to the target in terms of the copulas between the target and each prospect. Furthermore, we analyse the issue of risk aversion, and show how the dependence structure of a couple (T, X_α) can lead a risk-averse individual to an apparently risk-seeking choice.

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Applications of information-based causality networks in finance

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Causality networks are powerful tools for analysing complex financial systems, revealing cause-and-effect relationships among variables and investigating information propagation. The Granger causality is a fundamental concept of statistical interdependence in multivariate time series analysis. Among various measures, the parameter-free partial mutual information from mixed embedding (PMIME) has shown strong performance in estimating nonlinear, direct causality effects. PMIME has been applied to study the British stock market during Brexit [1] and detect structural breaks during events like the global financial crisis, commodity crises, Brexit referendum, and COVID-19 outbreak [2]. However, PMIME can exhibit inefficiencies in strongly stochastic systems, leading to false relationships. To address this, two novel modifications have been proposed and evaluated using government bonds and stock market indices during the COVID-19 pandemic. These modifications aim to improve the performance of PMIME in extracting causality networks from multivariate time series systems.

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Objective Shrinkage Priors Via Imaginary Data

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In this work, focus is given in the Bayesian variable selection problem for high-dimensional linear regression problems. The use of shrinkage priors, when the number n of available observations is less than the number p of explanatory variables, is a well-established method, which shares great theoretical and empirical properties. By using imaginary data and shrinkage priors as baseline priors, under the Power-Expected-Posterior (PEP) prior methodology, objective shrinkage priors are being created. In addition, we explore the idea of augmenting the imaginary design matrix in order to make it orthogonal and thus to produce independent PEP-shrinkage priors, based on default baseline priors. Under this setup, properly chosen hyperpriors are placed on the power parameters of the PEP methodology, in order to produced mixtures of independent priors suitable for the variable selection problem when n << p. This second approach provides us with algorithmically flexibility and less time-consuming procedures. We check the theoretical properties of our proposed methods and we explore their behavior via simulated studies.

Stochastic multi-scale modeling of cathode particle geometry in lithium-ion batteries supported by methods from machine learning

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Accurately capturing both the shape and intergranular architecture of single lithium-ion electrode particles in 3D is essential for quantifying their influence on material properties, like, e.g., degradation mechanisms. Microscopy techniques like X-ray nano-computed tomography (CT) and focused ion beam (FIB)-electron backscatter diffraction (EBSD) can provide representative 3D image data of the particles' shape (outer shells) and their grain architecture, respectively. However, it can be quite time-consuming and costly to rely solely on imaging techniques for generating a sufficient amount of data for the analysis of structure-property relationships. In this talk, we present an alternative approach using stochastic geometry models, see Figure 1 [1]. More precisely, using parametric stochastic geometry modeling, we leverage data from both nano-CT and FIB-EBSD to generate artificial but representative single particle architectures completed with grain morphological details. Therefore, a random Laguerre tessellation model is fitted to the grains depicted in FIB-EBSD data from which we can generate virtual, but statistically representative grain architectures. Analogously, we utilize nano-CT data depicting the outer shells of numerous particles to derive a random outer shell model, using mixtures of Gaussian random fields on the sphere. By combining both models, we can generate a large number of virtual particles with statistically representative shapes and grain morphologies. Moreover, by systematic variation of model parameters, even further virtual particles covering a broad range of structural scenarios can be generated. Then, such virtual particles can be used as input for numerical simulations, i.e., for virtual materials testing to study the influence of a material's geometry on its physical properties in the search for improved particle architectures of high energy- or power-density cells [2].

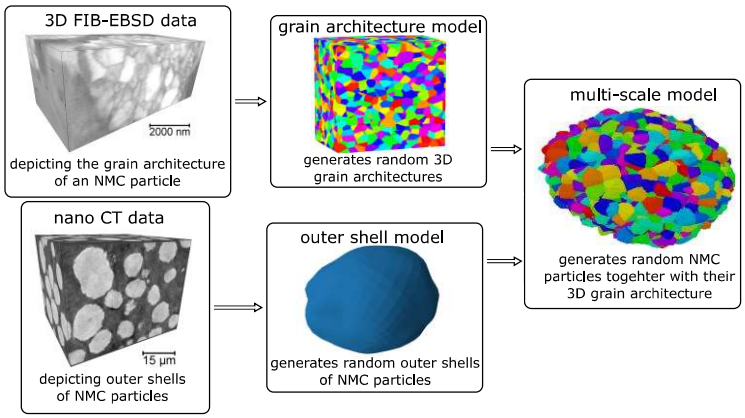

Figure 1: Modeling approach: FIB-EBSD data is used to calibrate a grain architecture model (top). From nano-CT data an outer shell model is fitted (bottom). By combining both models, we can generate representative particle architectures (right) [1].

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Optimal stopping zero-sum games in continuous hidden Markov models

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We study a two-dimensional discounted optimal stopping zero-sum game related to the perpetual game options in a model of financial markets in which the behaviour of a firm value follows a generalised geometric Brownian motion. It is assumed that the dynamics of the economic state of the firm are described by an unobservable continuous-time Markov chain with two states. It is shown that the optimal exercise times forming a Nash equilibrium are the first times at which the firm value hits either lower or upper stochastic boundaries being monotone functions of the running value of the filtering estimate of the state of the chain. We rigorously prove that the optimal stopping boundaries are regular for the stopping region relative to the resulting two-dimensional diffusion process and the price value function is continuously differentiable with respect to the both variables. It is verified by means of a change-of-variable formula with local time on surfaces that the price value function and the boundaries are determined as a unique solution to the associated parabolic-type free-boundary problem. We also give a closed-form solution to an auxiliary optimal stopping game in the model with an observable Markov chain.

Some optimal stopping pre-emption games in two-dimensional continuous Markov models

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We consider several optimal stopping problems related to the real option pricing in two-dimensional continuous Markov models with the leaders and followers. These models are based on either running maximum or minimum of the underlying one-dimensional geometric Brownian motions or two-dimensional geometric Brownian motions with constantly correlated driving standard Brownian motions. We consider the optimal stopping problems as the associated pre-emption games for the leader and follower as well as specify and analyse the appropriate continuation regions. We derive explicit solutions of the problems in the cases of floating costs rates depending on the current values of the underlying asset prices by means of change-of-measure arguments.

Quickest change-point detection problems for multidimensional Wiener processes

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We study the quickest change-point detection problems for the correlated components of a multidimensional Wiener process changing their drift rates at certain random times. These problems seek to determine the times of alarm which are as close as possible to the unknown change-point (disorder) times at which some of the components have changed their drift rates. The optimal times of alarm are shown to be the first times at which the appropriate posterior probability processes exit certain regions restricted by the stopping boundaries. We characterise the value functions and optimal boundaries as unique solutions of the associated free boundary problems for partial differential equations. We also provide estimates for the value functions and boundaries which are solutions to the appropriately constructed ordinary differential free boundary problems.

Multivariate Fay-Herriot Models for Small Area Estimation in Forest Inventory

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Forest inventories are crucial for sustainable forest management as they provide estimates of various forest variables. Small area estimation models are necessary when sample sizes are insufficient to provide reliable direct estimates for specific forest stands or management units. In this study, we propose a multivariate Fay-Herriot (MFH) model for estimating three forest variables, namely the wood volume, basal area, and mean height of forest inventories. The MFH model extends the methodology of the widely used univariate Fay-Herriot (UFH) by leveraging the correlation between the response variables of interest. To run these mixed effect models, good covariates of census and remote sensing data were used. Our comparative results demonstrated that the MFH model provided more reliable estimates for the three forest variables than the UFH model or the direct estimates. Additionally, the MFH model outperformed the UFH model in terms of model fit and mean square error estimations. Our study highlights the importance of using MFH models for reliable small area estimates, particularly in cases where target variables are strongly correlated.

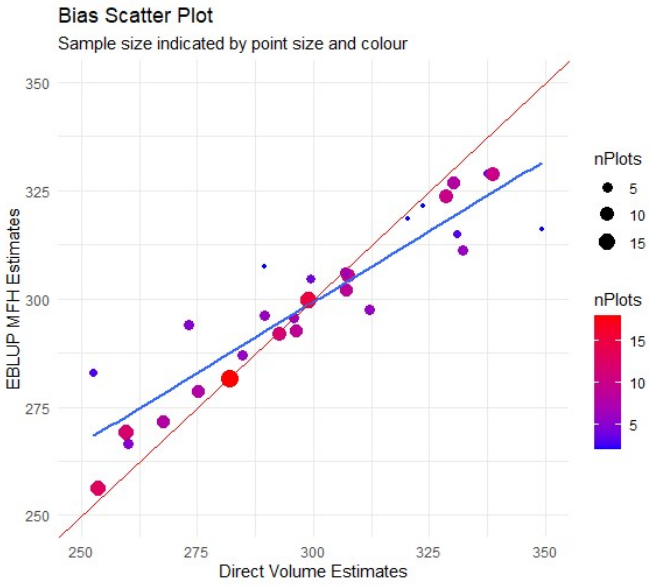

Figure 1: Scatter plot of multivariate Fay-Herriot volume and direct estimates, with point size and colour indicating the sample size of small areas.

Acknowledgements

We sincerely thank Demetrios Gatziolis from USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA for providing the digital surface model data that was crucial to this research.

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Current profiles for TASEP on a Galton-Watson tree

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We will present a generalisation of the totally asymmetric simple exclusion process (TASEP) evolving on a rooted Galton Watson tree, where each particle attempts to jump away from the root, subject to the exclusion rule. We study the large time behaviour of the current of particles across some generation and across a ray of the tree. The current depends heavily on the offspring distribution of the tree as well as the choice of jump rates as these affect the speed in which particle trajectories decouple.

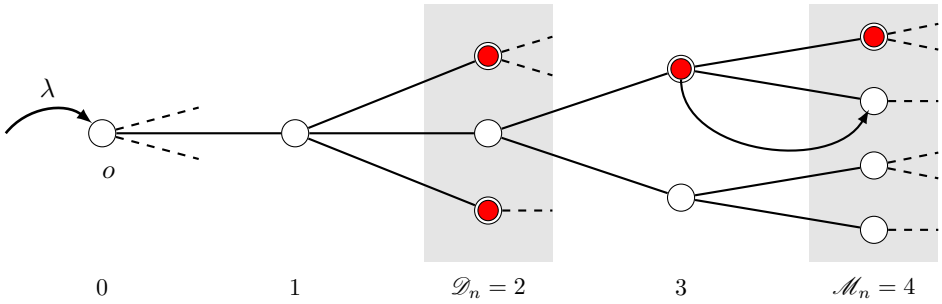

Figure 1: Visualization of the TASEP on trees

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The TASEP on Galton–Watson trees

Electron. J. Probab. 26: 1-38 (2021). DOI: 10.1214/21-EJP725.

Markovian Models in Data Envelopment Analysis Single and Multiple Stage Structures

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This presentation is related to manpower planning, healthcare, and wellbeing in the sense that it investigates the progression of a cohort in its various states through time (such as employees at hierarchical levels or persons with mild, moderate or severe health states). Typically the goal is to drive the system towards a target state, or even towards some desirable set of probable targets using control variables like recruitment floes or transition probabilities. The presentation is based on a recent published work and some work in progress in an effort to blend Data Envelopment Analysis with Markov Chains in various hybrid models. The Markov process offers the tools that can be used to describe the movement of the entities in a hierarchical system and facilitates the investigation of possible amendments that might guide the system towards some desired future structure in a single or multiple stages in time. In this respect we are provided with a set of possible policies which are treated in the DEA context as DMUs and the models provide a framework that can evaluate the relative efficiency of each policy in our effort to reach the target.

Acknowledgements

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Consistency of option prices under bid–ask spreads

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Given a finite set of European call option prices on a single underlying, we want to know when there is a market model that is consistent with these prices. In contrast to previous studies, we allow models where the underlying trades at a bid-ask spread. The main question then is how large (in terms of a deterministic bound) this spread must be to explain the given prices. We fully solve this problem in the case of a single maturity, and give several partial results for multiple maturities. For the latter, our main mathematical tool is a recent result on approximation by peacocks. Joint work with I. Cetin Gülüm.

Asymptotic results for sums and extremes

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The term moderate deviations is often used in the literature to mean a class of large deviation principles that, in some sense, fills the gap between a convergence in probability of some random variables to a constant, and a weak convergence to a centered Gaussian distribution (when such random variables are properly centered and rescaled). We talk about non-central moderate deviations when the weak convergence is towards some non-Gaussian weak limit. In this paper we prove a non-central moderate deviation result for the bivariate sequence of sums and maxima of i.i.d. random variables. Moreover, we prove a moderate deviation result for sums of partial minima of i.i.d. exponential random variables.

The Last-Success Optimal Stopping Problem with Random Observation Times

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We consider a version of the familiar best choice problem. A series of independent Bernoulli trials is observed at times of a mixed binomial process. The task is to stop at the last success using a nonanticipating stopping strategy. Under the optimal strategy the decisions typically depend in complex way on the time and the index of success trial. We derive a general formula for winning probability under strategies with nondecreasing cutoffs, very much in spirit of known formulas due to Gilbert and Mosteller (1966) and Porosinski (1987) for other versions of the problem.

We then specialise to arrivals by a Polya-Lundberg birth process and the profile of success probabilities corresponding to a biased record model, such that the number of records from fixed number of observations follows the Karamata-Stirling law. In essence, the model has two parameters: one responsible for the probabilities of records and the other for the total number of arrivals. Fragments of this setting for classic records were studied by Browne (1993), Kurushima and Ano (2003) Bruss and Rogers (2022) and Gnedin and Derbazi (2022). We show that for some parameters the monotone case of optimal stopping holds, and for some does not. This phenomenon is reduced to apparently new monotonicity properties of the Gaussian hypergeometric function viewed as a function of parameters.

In the monotone case, the optimal strategy is myopic, with nondecreasing cutoffs determined as roots of certain transcendental equations. For the nonmonotone case we construct explicitly strategies that outperform the myopic.

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On optimal stopping of a random sequence with unknown distribution

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We discuss the problem of optimal stopping of a sequence of independent and identically distributed random variables with unknown distribution. We propose a stopping rule that is based on relative ranks and study its performance as measured by the maximal relative regret over suitable nonparametric classes of distributions. It is shown that the proposed rule is first-order asymptotically optimal and nearly rate optimal in terms of the rate at which the relative regret converges to zero. Some numerical experiments illustrate performance of the proposed stopping rule.

Statistical sequential analysis for Controlled Branching Processes

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Controlled branching processes (CBPs) are stochastic growth population models in which the number of individuals with reproductive capacity in each generation is determined by random control functions. This kind of processes is flexible enough to model the evolution of different kind of populations including logistic growth populations or epidemic outbreaks (at least in its exponential growth phase). The recent monograph [1] provides an extensive description of the probabilistic theory and some inferential issues of CBPs.

In this work we go on with the study of the estimation of main parameters of CBPs from a Bayesian perspective. We consider different sampling schemes, including partially observed CBPs. In all situations we use sequential methodologies. We show the accuracy of the proposed methodology via simulated examples making use of the statistical software R.

Acknowledgements

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Modeling the Health Impact of COVID-19 using Mixed Interaction Models and Chain Graph Models

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The COVID-19 pandemic has been a global concern since 2019-2020, having a significant impact on public health. In this study, we used mixed interaction models and chain graph models to analyze post-COVID data from a longitudinal study following patients who were hospitalized for COVID-19 in Santa Maria University Hospital in Terni, Italy. The goal was to understand the long-term predictors of functional and structural damage from the disease.

The survey included functional status questionnaires (e.g., fatigue, sleep disturbances, dyspnea), anthropometric and clinical parameters, medical history data (including treatments), as well as data on the acute phase of the virus (e.g., duration of hospitalization, respiratory support). In addition, laboratory parameters, respiratory function parameters at rest and heart function parameters at rest (echocardiogram) were recorded during the post-acute phase. Furthermore, the survey included a cardiopulmonary test (heart and lungs performance during exercise) and a HRCT (high-resolution computed tomography) at the follow-up visit.

Mixed interaction models, as well as chain graph models, can handle both continuous and categorical variables and can be used to model the relationships among variables. One interesting difference between the two is their approach to grouping variables. Mixed interaction models consider all variables on the same footing, treating them as interconnected and modeling each variable as a function of other variables. In contrast, chain graph models group variables into distinct blocks, resulting in a network of variables that captures the direct dependencies among the different blocks. Thus, both techniques provide valuable outcomes. The mixed interaction models capture the linear and nonlinear relationships between variables, and the chain graph models capture the causal relationships among variables, thus assessing the impact of COVID-19 on health.

According to our findings, COVID-19 was associated with increased risk of various health problems, such as respiratory issues. The relationship between objective measurements of physical impairment and subjective assessment through questionnaires is also investigated. Additionally, we observed that the impact of COVID-19 on health outcomes varied based on factors such as age and gender.

Our study demonstrates the utility of mixed interaction models and chain graph models for studying the complex relationships among health variables in post-COVID data. These techniques can identify the critical factors that predict health outcomes and can provide valuable insights for developing targeted interventions to mitigate the consequences of the disease.

Stochastic Microstructure Modeling and Predictive Simulation of Nanoporous Glass Based on X-Ray Tomography.

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Excursion sets of Gaussian random fields are used to model the 3D morphology of differently manufactured porous glasses, which vary with respect to their mean pore widths measured by mercury intrusion porosimetry. The model is calibrated based on volume fractions and two-point coverage probability functions estimated from tomographic image data. Model validation is performed by comparing model realizations and image data in terms of morphological descriptors which are not used for model fitting. For this purpose, we consider mean geodesic tortuosity and constrictivity of the pore space, quantifying the length of shortest transportation paths and the strength of bottleneck effects, respectively. Additionally, a stereological approach for parameter estimation is presented, i.e., the model is calibrated using merely 2D cross sections of the 3D image data. Doing so, on average, a comparable goodness-of-fit is achieved as well. The variance of the calibrated model parameters, which are estimated on the basis of randomly chosen, individual 2D cross sections is discussed. Moreover, interpolating between the model parameters calibrated to differently manufactured glasses enables for the predictive simulation of virtual, but realistic porous glasses with mean pore widths that have not yet been manufactured. The predictive power is demonstrated by means of cross-validation. Using the presented approach, relationships between the manufacturing process and the resulting morphology of porous glasses are quantified, which opens possibilities for an efficient optimization of the underlying manufacturing process.

Acceptability Model of Risk in Italian Tunnels

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There are numbers of risks associated with road tunnels, including traffic accidents and fires which could result in harm to either an individual user or a group of users. Risk indicators are important forerunners of undesirable or unexpected tunnel events that may have a detrimental impact on Users, Governments and Duty-Holders. Risk indicators including Risk Quantum, Individual Risk, Societal Risk, and Expected Number of Fatalities allow to access to risk exposure level and enable Rights-Holders/Duty-Holders to report hazards, avert disasters, and take prompt remedial action. One of the most important indicators, the concept of the Quantum of Risk indicator, is derived from the forensic evaluation of responsibility in a mortal tunnel accident since 1949 in the UK. The major of the Quantum of Risk can be determined probabilistically for each Scenario (among the reasonable, rational and practicable number of possibilities), it is shown through the mathematics of probability and risk is represented in accordance with the criterion by the judgment. The scenarios are identified, described, and probabilized properly before proceeding to analyse quantitatively the Risk. The above risk indicators are then involved in the process of risk assessment. This article aims to provide a basic understanding of these indicators for road tunnels in Italy. *Environmental Applications, Las Palmas de Gran Canaria*, Spain, 2006, 10.

Some new ordering results for parallel and series systems with dependent heterogeneous exponentiated Weibull components

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In this work, ordering results are presented for parallel and series systems arising from dependent heterogeneous exponentiated Weibull components that share a common or different Archimedean copula(s). Particularly, sufficient conditions are provided under which the sample extremes are stochastically compared with respect to the usual stochastic order, the dispersive and the star-shaped order.

Exact Simulation of the First Time a Stochastic Process Overcomes a Given Threshold

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The aim of our study is to propose a new exact simulation method for the first passage time (FPT) of a diffusion process $(X_t; t \geq 0)$. We shall consider either a continuous diffusion process (in collaboration with Cristina Zucca, University of Turino) either a jump diffusion (in collaboration with Nicolas Massin, UPHF). We define τ_L the first passage time through the level L. To exactly simulate τ_L, we cannot use an explicit expression of its density. The classical way to overcome this difficulty is to use efficient algorithms for the simulation of sample paths, like discretization schemes. Such methods permit to obtain approximations of the first-passage times as a by-product.

For efficiency reasons, it is particularly challenging to simulate directly this hitting time by avoiding to construct the whole paths. The authors introduce a new rejection sampling algorithm which permits to perform an exact simulation of the first-passage time for general one-dimensional diffusion processes. The main ideas are based both on a previous algorithm pointed out by A. Beskos et G. O. Roberts which uses Girsanov's transformation and on properties of Bessel paths. The efficiency of the method is described through theoretical results and numerical examples.

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On the topology of higher-order age-dependent random connection models

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Preferential attachment is a popular mechanism for generating scale-free networks. While it offers a compelling narrative, the underlying reinforced processes make it difficult to rigorously establish subtle properties. Recently, age-dependent random connection models were proposed as an alternative that is capable of generating similar networks with a mechanism that is amenable to a more refined analysis. In this talk, we analyze the asymptotic behavior of higher-order topological characteristics such as higher-order degree distributions and Betti numbers in large domains.

Interval Bayesian method to sequential sampling problem

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We consider the problem of sampling a batch of items. The proportion p of defective items in the batch is unknown, so that we estimate $p \in (0,1)$ from the observation of N items $\{x_1, x_2, \dots, x_N\}$ and initial prior distribution $G_0(p)$ for p. Let c be sampling cost per item. If $\{x_1, x_2, \dots, x_N\}$ contains m defective items and $n = N - m$ non-defective items, then we have a posterior distribution $G_{m,n}(p)$ for p as follows:

$$dG_{m,n}(p) = \frac{p^m(1-p)^n dG_0(p)}{\int_0^1 p^m(1-p)^n dG_0(p)}$$

Let $a(p), r(p)$ respectively be the loss function of accepting and rejecting a batch of proportion defective p. If $p \simeq 0$ we set $a(p) = 0$ and if $p \simeq 1$, $r(p) = 0$. Let $v(m,n)$ be the expected loss when we had m defective items and n non-defective items from sampling, posterior distribution $G_{m,n}(p)$ and we are using an optimal sampling policy from now on. Then, we have the following functional equation:

$$v(m,n) = \min \begin{cases} \text{Stop(Accept)}: \int_0^1 a(p) dG_{m,n}(p), \text{Stop(Reject)}: \int_0^1 r(p) dG_{m,n}(p), \\ \text{Continue(Accept)}: c + \int_0^1 \big(pv(m+1,n) + (1-p)v(m,n+1)\big) dG_{m,n}(p) \end{cases}$$

$$= \{\psi(m,n), c + b_{m,n} v(m+1,n) + (1 - b_{m,n}) v(m,n+1)\},$$

where $\psi(m,n) = \min\left\{\int_0^1 a(p)\, dG_{m,n}(p), \int_0^1 r(p) dG_{m,n}(p)\right\}$, $b_{m,n} = \int_0^1 p\, dG_{m,n}(p)$.

By using a prior interval of measures $I(L,U) = [L,U]$ (cf. DeRobertis&Hartigan (1981)), we derive lower and upper bounds of minimum expectation of loss function with respect to posterior interval of measures under the optimal stopping rule. This problem is related to multi-armed bandit problem with dependent arms (cf. Presman and Sonin (1978)). Therefore, we consider the derived optimistic and pessimistic optimal decision rules as a problem of testing the hypothesis with dependent arms.

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Genetically modified mode jumping MCMC approach for Bayesian multivariate fractional polynomials

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We propose a framework for fitting fractional polynomials models as special cases of Bayesian Generalized Nonlinear Models [1], using an adapted version of the Genetically Modified Mode Jumping Markov Chain Monte Carlo algorithm [2] to fit them. The broad generality of the Bayesian Generalized Nonlinear Models allows us to extend the use of a Bayesian version of the fractional polynomials [4] models to any supervised learning task, including regression, classification and time-to-event data analysis. We show through a simulation study that our novel approach outper- forms the original version of Bayesian fractional polynomials [4] and performs similarly to the clas- sical frequentist fractional polynomials [3] approach in terms of variable selection, identification of the correct functional forms and prediction ability, while providing, in contrast to its frequentist version, a coherent inference framework. Real data examples provide further evidence in favour of our approach and show its flexibility.

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Implicit multi-type branching processes with immigration and periodic integer-valued autoregressive models

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Nowadays, there is a growing interest in non-Gaussian time series, particularly in series comprised of nonnegative integers or counts, see the latest survey [1]. Count series arise in fields, such as agriculture, economics, epidemiology, finance, geology, meteorology, and sports. However, many natural or human phenomena exhibit periodic behavior. A potentially promising model to describe these is the periodic integer autoregressive (PINAR) model based on thinning operation. A particular periodic and seasonal example for PINAR model is considered in [2].

In this talk, for the study of PINAR models, the concept of implicit multi-type branching process with immigration is introduced, and we examine the equivalence between these two classes of processes. A simple spectral criterion based on the model parameters is given for the existence and uniqueness of a solution to these models. We provide a complete description of the probabilistic structure, among others, the mean and the covariance function of unique solutions to these models. Two infinite series representations, moving average and immigrant generation, are also derived. A successive approximation procedure, which is based on immigrant generation representation, is proposed for constructing the unique solution to the models, which is used to simulate the process in an efficient way, see [4]. The Yule-Walker method is applied to estimate the parameters of these models. To investigate the asymptotic behavior of Yule-Walker estimators, we prove limit theorems extending some known results of periodic multi-type Galton-Watson branching process without immigration, see [3].

Finally, we illustrate the theoretical results by analyzing some real integer-valued time series.

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Training neural networks with Langevin based algorithms and key applications.

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In this talk we discuss a new interacting particle system used for implementing an expectation maximization (EM) procedure (or more generally, to optimize over the parameters of a latent variable model). This continuous-time interacting particle system has the property that it can be seen as a Langevin diffusion over an extended state space, where the number of particles acts almost like an inverse parameter in classical settings for optimization. This then allow for use of the well-developed theory Langevin diffusions to prove nonasymptotic concentration bounds for the optimization error of the maximum marginal likelihood estimator. In this talk we shall place this new algorithm in the context of existing approaches, and also discuss the structure of our proof and how it naturally lends itself to generalisation.

New Probabilistic Method for Transient Analysis of M/G/1 systems with Server Vacations

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Semi-Markov models constitute the important part of classical Queuing Theory (QT) and Mathematical Theory of Reliability (MTR) and M/G/1 queuing system is perhaps the most popular Semi-Markov system in the QT on the whole. It is well known and most thoroughly researched in scientific publications. This is due to the importance of the theoretical aspects of the statement and its practical application in industry, transport, communication systems, etc.

In this paper MG1 systems, with single and multiply vacations of server is investigated using the well-established method of supplementary variable in conjunction with purely probabilistic reasoning. This new approach allows us to withhold of solving partial differential equations (Kolmogorov forward equations) of the non-classical boundary value problem of mathematical physics with non-local boundary conditions and directly derive the system's solution in terms of operational calculus.

The starting point of the method is the consideration of the investigated system simultaneously at two time moments: the current time moment t and the previous moment $t - x$, where x is one of possible values of a supplementary variable. The study of the system within the $(t - x, t)$ time-span leads to a transient solution of the systems under consideration.

We believe that our approach shows the intrinsic probabilistic nature of the semi-Markov process, and we are confident that, with an appropriate modification of the method, it will be possible to investigate other semi-Markov systems in a similar way. These results significantly simplify the reliability analysis of the stochastic systems

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Reliability evaluation of discrete time consecutive-k systems

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The lifetimes of many real life systems can be measured in terms of the number of cycles. In such cases, the lifetime of the system/component is modeled by discrete distributions. A linear consecutive-k-out-of-n:F system consists of n linearly ordered components and fails iff at least k consecutive components fail. The linear consecutive-k-out-of-n system and its generalization have been widely studied in the literature from different perspectives. However, it is usually assumed that the system consists of components with continuously distributed lifetimes. In this work, some important reliability characteristics of consecutive-k-out-of-n and related systems are evaluated in the case when the system has components having discretely distributed lifetimes.

On the growth rate of superadditive processes and the stability of functional GARCH models

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We extend the result of Kesten [1] on the growth rate of random walks with stationary increments to super-additive processes. We show that supe-radditive processes which remain positive after a certain time diverge at least linearly to infinity. Our proof relies on new techniques based on concepts from ergodic theory. Different versions of this result are also given, generalizing Lemma 3.4 of Bougerol and Picard [2] on the contraction property of products of random matrices. We use our results to provide necessary and sufficient conditions for the stability of a class of Stochastic Recurrent Equations (SRE) with positive coefficients in the space of continuous functions with compact support, including continuous functional GARCH models.

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Investigation of the Climate Impact on WNV Vectors Abundance

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The purpose of this thesis is the study of the effect of the meteorological conditions, which prevailed during the cold season, on the overwintering of mosquitoes and their abundance during the period they are active (late spring to September), in the context of early prevention of the West Nile Virus (WNV). The study was conducted at three levels, at the level of the Region of Central Macedonia, the Province of Thessaloniki and the Municipality of Halkidona (Thessaloniki). To achieve the purpose of this thesis we used meteorological data from the Copernicus program and entomological measurements of the abundance of mosquitoes for the above areas. Processing the above data, we calculated new meteorological indicators, which proved useful in our study, and the meteorological conditions for the period 2010-2020 are presented in the form of timeseries. A series of statistical tests were also performed to calculate the correlation and the effect of the meteorological conditions of the cold season with the season peak of the abundance of mosquitoes, but also with the abundance of mosquitoes in June (knowing and not the abundance of the previous September) and July. In addition, through machine learning methods, algorithmic models were developed that through the processing of data make, using specific indicators, predictions of the bundance, while their validation was performed through the comparison of predictions with observations. Finally, the conclusions of our research are presented, commenting on our statistically significant results and comparing them based on the three levels of research.

The Static Duel Discounted Stochastic Game

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A static duel involves two stationary players who shoot at each other until at least one of them dies; a static truel is similar but involves three players. In the past, the static duel has been studied mainly as a component of the static truel, which has received considerably more attention. However we believe that the static duel is interesting in itself. In this paper we formulate the static duel (with either simultaneous or sequential shooting) as a discounted stochastic game. We show that this game has a unique Nash equilibrium in stationary strategies; however, it also possesses cooperation-promoting Nash equilibria in nonstationary strategies}. We argue that the nature of the game and its equilibria is similar to that of the repeated Prisoner's Dilemma. On the one hand, if both players "cooperated", i.e., did not shoot, they would receive a higher payoff; on the other hand, given that one player does not shoot, the other player always has a motive to "defect", i.e., to shoot; hence mutual nonshooting is not a Nash equilibrium and in fact, as we have already mentioned, the only Nash equilibrium in stationary strategies is mutual shooting). However, in analogy to well known results regarding the repeated Prisoner's Dilemma, we show that, for the discounting factor γ sufficiently close to one, nonshooting and nonstationary Nash equilibria also exist. To prove this we borrow an idea from the Prisoner's Dilemma literature and introduce the "grim strategy" σ_g, which can be described in words as follows: ``As long as the other player has not shot at me, I do not shoot at him; if at some round he shoots at me, then I keep shooting at him in all subsequent rounds". Obviously σ_g is not a stationary strategy (since its output depends on the previous history of the game). We prove that (σ_g, σ_g) is a Nash equilibrium.

On fluctuation-theoretic decompositions via Lindley-type recursions

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We study the joint distribution of the running maximum $\bar{Y}(T\beta)$ and the time epoch $G(T\beta)$ at which this maximum last occurs. Our main result is a fluctuation-theoretic distributional equality: the vector $(\bar{Y}(T_\beta), G(T_\beta))$ can be written as a sum of two independent vectors, the first one being $(\bar{Y}(T_{\beta+\omega}), G(T_{\beta+\omega}))$ and the second one being the running maximum and corresponding time epoch under the restriction that the Lévy process is only observed at $\text{Poisson}(\omega)$ inspection epochs (until T_β). We first provide an analytic proof for this remarkable decomposition, and then a more elementary proof that gives insight into the occurrence of the decomposition and into the fact that ω only appears in the right hand side of the decomposition. The proof technique underlying the more elementary derivation also leads to further generalizations of the decomposition, and to some fundamental insights into a generalization of the well known Lindley recursion.

Joint work with Onno Boxma and Michal Mandjes.

State Space Decomposition of Term Structure Shapes in the Two-Factor Vasicek Model

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Using envelopes and winding numbers, we divide the state space of the two-factor Vasicek model into regions of identical term-structure shape and determine the shape. We give lower and upper bounds on the number of attainable shapes for a fixed short rate.

Empirical Likelihood with Censored Data

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We consider semiparametric models defined by moment constraints, with unknown parameter, for right censored data. We derive estimates, confidence regions and tests for the parameter of interest, by means of minimizing empirical divergences between the considered models and the Kaplan-Meier empirical measure. This approach leads to a new natural adaptation of the empirical likelihood method to the present context of right censored data. The asymptotic properties of the proposed estimates and tests are studied, including consistency and asymptotic distributions. Simulation results are given, illustrating the performance of the proposed estimates and confidence regions.

Stochastic Comparisons of Mixtures Models: Review and Discussion

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Let χ be a subset of the m-dimensional Euclidean space $\mathbb{R}^m$ for some m; and let $\boldsymbol{\Theta}$ be a random vector that takes on values in χ with distribution function $H(.)$. Now, for each $\boldsymbol{\theta} \in \chi$, let $\boldsymbol{X}(\boldsymbol{\theta}) \equiv \big(X_1(\boldsymbol{\theta}), X_2(\boldsymbol{\theta}), \dots, X_n(\boldsymbol{\theta})\big)$, denote a random vector with distribution function $F_{\boldsymbol{\vartheta}}$. Then $\boldsymbol{X}(\boldsymbol{\Theta}) \equiv \big(X_1(\boldsymbol{\Theta}), X_2(\boldsymbol{\Theta}), \dots, X_n(\boldsymbol{\Theta})\big)$ denotes a random mapping whose distribution function is a mixture of distribution functions in $\{F_{\boldsymbol{\vartheta}}, \boldsymbol{\vartheta} \in \chi\}$. That is the distribution function G of $\boldsymbol{X}(\boldsymbol{\Theta})$ can be expressed as

$$G(\boldsymbol{x}) = \int_{\chi} F_{\boldsymbol{\theta}}(\boldsymbol{x})\, dH(\boldsymbol{\theta}) \quad , \boldsymbol{x} \equiv (x_1, x_2, \dots, x_n) \in \mathbb{R}^m. \tag{1}$$

In this presentation we review and discuss various stochastic comparisons results established in the literature by several researchers. The results in the literature are often of the following form:

Let $\boldsymbol{\Theta}_1$ and $\boldsymbol{\Theta}_2$ be two χ-valued random vectors. If

$$\boldsymbol{X}(\boldsymbol{\Theta}) \text{has some stochastic monotonicity and/or convexity properties,} \tag{2}$$

and if

$$\boldsymbol{\Theta}_1 \leq_{\text{stochastic order 1}} \boldsymbol{\Theta}_2, \tag{3}$$

then

$$\boldsymbol{X}(\boldsymbol{\Theta}_1) \leq_{\text{stochastic order 2}} \boldsymbol{X}(\boldsymbol{\Theta}_2), \tag{4}$$

where the comparisons in (3) and (4) are with respect to some well know stochastic orders such as usual stochastic order, hazard rate order and likelihood ratio order. Also, the stochastic monotonicity and convexity conditions in (2) vary from one result to another.

Offline Deep Reinforcement Learning for Dynamic Pricing of Consumer Credit

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We introduce a method for pricing consumer credit using recent advances in offline deep reinforcement learning. This approach relies on a static dataset and requires no assumptions on the functional form of demand. Using both real and synthetic data on consumer credit applications, we demonstrate that our approach using the conservative Q-Learning algorithm is capable of learning an effective personalized pricing policy without any online interaction. Our experimental analysis indicates a significant increase in the expected profit using this approach.

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Alternative Transient Solutions for Semi-Markov Systems in Queuing and Reliability

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The main aim of our research is the construction and investigation of new stochastic models for structural control of modern, complex technical systems. These are non-classical Markov and semi-Markov (SM) models of Mathematical Theory of Reliability (MTR) and Queuing Theory (QT). The controlled object is any large-scale, territorially distributed redundant technical system made up of unreliable (both main and redundant) renewable units (computer and telecommunication networks, power, and transportation systems, for example) and its structural control subsystem.

Traditionally, at different stages of the life cycle of complex technical systems, control decisions are made using the methods of classical MTR and classical QT.

However, in the context of widespread modern large-scale systems (including territorially and spatially distributed ones), these methods have proven to be less effective, and in some cases completely useless, over the last three to four decades.

The reasons for that are new influencing factors that are characteristic of the above systems. This is unlike machines considered in classical MTR and in classical QT when it is used for the analysis of reliability and efficiency of complex systems (Machine Interference (Repairman) Problem—MIP).

These factors are: 1) a large number of units (hundreds, thousands, and so on); 2) a remote location of storage for redundant units and spares from main units (tens, hundreds, and more); 3) the necessity to consider replacement of a failed main unit by a redundant one as a separate maintenance operation; as a result, the bifurcation of arrivals arises; 4) Failed main units are frequently temporarily replaced by redundant ones until the main unit is repaired; and 5) maintenance is outsourced.

In the framework of the proposed research, we will discuss completely novel stochastic models in which the above new influencing factors are taken into account (one, several, or all of them). The construction and investigation of such models are much more complex (than classical ones). The implementation of the research means a many-sided generalization of the classical MIP in the framework of structural control. That also means the significant generalization of many other models of MTR and QT.

In addition, structural control topics also include ensuring the survivability, technical security, and cybersecurity of modern systems. Cybersecurity over the past 20–30 years has become especially topical.

Namely, the cybersecurity of critical infrastructure is one of the biggest challenges of modernity.

Particularly, telecommunication and computer systems in the military, banking, etc., where highly confidential information is transmitted, stored, or processed, require the use of high standards for information protection against cyberattacks.

On the other hand, the processes of conducting cyberattacks, stopping them, neutralizing them, and eliminating damages are usually stochastic and are akin to the failure and repair processes of technical systems. That is why solving the problems of analysis, design, and operation of information protection systems is most effectively possible using our Markov and semi-marking models (of course, with their proper modifications) that either already exists or the ones, which will be developed in the near future.

That will be the further development of the results of our previous research and the next stage in the formation of the Mathematical Theory of Structural Control (and Managment). Moreover, it will have a large practical value.

Estimation of the Hirst Parameter from Continuous Noisy Data

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The talk presents a contribution to the problem of asymptotic minimax estimation of the Hurst parameter of the fractional Brownian motion (fBm). We consider the setting in which the fBm trajectory is observed continuously in time with noise modeled by an independent Brownian motion. The two relevant asymptotic regimes are either when the length of the observation interval increases to infinity or intensity of the noise decreases to zero. The main result is a proof of local asymptotic normality in both of these asymptotic regimes, which reveals the optimal minimax rates.

The Inverse First-passage Time Problem as Hydrodynamic Limit of a Particle System

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Given a probability distribution on the positive real numbers, the so-called inverse first-passage time problem for reflected Brownian motion consists of finding a time-varying boundary such that the first-passage time over that boundary by a reflected Brownian motion has the given distribution. In this talk we see that this problem can be rediscovered in the macroscopic behavior of a particle system which undergoes selection according to a given probability distribution on the positive real numbers. With the help of stochastic order methods, which were used for proving uniqueness, and ideas from the analysis of the so-called N-branching Brownian motion, the hydrodynamic limit of the particle system is identified as the distribution of a reflected Brownian motion conditioned to not having passed the solution of the inverse first-passage time problem.

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Horseshoe Prior for Bayesian Quantile Regression

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This paper extends the horseshoe prior of Carvalho et al. (2010) to Bayesian quantile regression. The performance of the proposed method is evaluated on Monte Carlo simulations and a high dimensional Growth-at-Risk (GaR) forecasting application for the U.S. Compared to alternative shrinkage priors, the proposed method yields better (or at worst similar) performance in coefficient bias. In the GaR application, we forecast tail risks as well as complete forecast densities using the McCracken and Ng (2020) database. Quantile specific and density calibration score functions show that the proposed method provides the best performance, especially at short and medium run horizons. The ability to produce well calibrated density forecasts and accurate downside risk measures in large data contexts makes this a promising tool for policymakers.

On the properties of inverted repeats and word frequencies in DNA sequences via semi Markov modeling

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Semi-Markov processes generalize the Markov chains framework by utilizing abstract sojourn time distributions. They are widely known for offering enhanced accuracy in modeling stochastic phenomena. The dynamic characteristics of such models influence first passage to a state as well as the number of times the chain occupies a state. Therefore, in order to accompany the basic parameters of the semi-Markov chain and to enhance the modeling framework, additional attributes of critical interest are the occupancy and the first passage time which are described by the corresponding probabilities as follows: (a) Occupancy probabilities, which describe the distribution of the number of times the chain has visited a specific state during an arbitrary time interval (b) First passage time probabilities which describe the transition from a state to a different state for the first time. In literature the properties of the first passage time probabilities have been investigated for Markov processes and some specific types of semi-Markov processes. Details for the first passage time probabilities have been also presented for various stochastic processes. DNA sequences are usually studied using probabilistic models, as nucleotide appearances are inter-correlated and attempts to use Markov models to model them have been reported. We provide analytic forms on the actual behavior of the recursive relations of the aforementioned probabilities. The analytical results are accompanied with two illustrations on human genome DNA strands which are often studied using probabilistic modeling and, specifically, Markovian models. Although, in the relevant literature, there exist several algorithmic approaches analyzing the occupancy and appearance of words in DNA sequences, the results of the illustration section strongly suggest that the proposed modeling framework could also be used for the investigation of the structure of genome sequences.

Expected Discounted Penalty Function of Gerber-Shiu for a Renewal Risk Model with Positive Jumps Perturbed by Diffusion

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We study the expected discounted penalty function of Gerber-Shiu for a class of renewal risk models with positive jumps with rational distribution, perturbed by Brownian motion. We assume that the times between jumps have generalized Erlang distribution and that the gain process is a homogeneous Poisson process. We obtain the Laplace transform of the Gerber-Shiu functional, as well as an explicit expression for this functional in terms of functions depending only on the parameters of the risk process. We also provide an approximation for the probability of ruin and illustrate our results in some special cases.

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Joint Distribution Of Increasing And Decreasing Successions Of Multisets

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The distributions of the number of patterns and successions in a random sequence have been used in various areas of statistics and applied probability. Traditionally these distributions were studied by combinatorial analysis. When the systems under study are complicated these ingenious but ad hoc methods become tedious and cumbersome due to the combinatorial complexity involved.

We have developed a systematic approach inspired by methods in statistical physics that solve many patterns and runs related problems in a unified way [1,2,3,4]. This approach decouples the study of distributions of runs into two easy independent steps. In the first step, elements of each object are considered in isolation without regard to elements of the other objects. By considering only one kind of object each time, the complexity arising from the simultaneous interactions of elements from multiple objects is avoided. In the second step, formulas in matrix or explicit forms combine the results from the first step into a whole multi-object system with potential nearest neighbor interactions.

In this paper we apply this method to solve a problem that has remained unsolved for many years in the field, i.e., the joint distributions of increasing and decreasing successions of arbitrary multisets. A related but simpler problem, i.e., the distributions of increasing successions of arbitrary multisets, was solved by the method previously [5]. For a sequence $\sigma=(a_1, a_2, \ldots, a_n)$, where $a_i \in \{1, 2, \ldots, k\}$, we call (a_i , a_{i+1}) an increasing succession if $a_{i+1} - a_i = 1$, and a decreasing succession if $a_{i+1} - a_i = -1$. For example, for the particular sequence 3231212, there are three increasing successions (2, 3), (1, 2) and (1, 2), and two decreasing successions (3, 2) and (2, 1). The problem is to find the joint distribution of increasing and decreasing successions of sequences of any length, of any arbitrary multisets.

By using the systematic two-step decoupling approach we developed, recurrence and explicit formulas for the generating functions of increasing and decreasing successions of multisets are derived. From these generating functions explicit formulas for mean and covariance of the joint distribution of increasing and decreasing successions of multisets are obtained.

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Multiscale Scanning With Nuiscance Parameters

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In this talk, we consider the problem to scan a multivariate field of random variables

$$Y_i \sim F_{\theta_i,\xi_0} \qquad \text{for} \qquad i \in I_n^d := \{1,\dots,n\}^d$$

for anomalies. Here, F_{θ_i,ξ_0} denotes a parametric family of distributions with $\theta_i \in \Theta$ being the parameter of interest, and $\xi_0 \in \Xi$ a (collection of) nuiscance parameter(s). A natural approach is to use a calibrated scan statistic based on (local) log-likelihood ratio tests, where the unknown baseline parameter $\theta_0 \in \Theta$ and the nuiscance $\xi_0 \in \Xi$ are pre-estimated from the data. Even though this method has been proposed and applied in the literature, obtaining valid critical values for the corresponding local tests is a difficult issue and has not been addressed in the literature so far. If both $\theta_0 \in \Theta$ and $\xi_0 \in \Xi$ are known and F_{θ_i,ξ_0} forms a natural exponential family, then it has been shown in [1] that the quantiles of the calibrated multiscale scan statistic can be approximated by a Gaussian version, which is distribution free.

We extend this result to the present case with estimated $\theta_0 \in \Theta$ and $\xi_0 \in \Xi$ under mild assumptions on the differentiability structure of F_{θ_i,ξ_0}, provided that the considered local regions are not too small and not too large. We prove a general invariance principle, which allows to compute valid scale-dependent quantiles for the local tests and hence yields an asymptotically FWER-controlled selection of anomalies.

Our results are illustrated in simulations and on real data examples from super-resolution microscopy.

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Background risk model in presence of heavy tails under dependence

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In this paper we study the asymptotics of the tail distorted risk measures in systemic risk models under various forms of dependence, with regularly varying risk distributions in each portfolio. Further we extend Breiman's theorem under Asimit-Jones dependence structure. Next we introduce a new risk measure and we study it under strong asymptotic independence. Finally, we investigate the asymptotic behavior of two weighted random sums, but in this case a generalization is provided to dependence among the components of each random vector, under a new dependence structure.

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A wide family of continuous univariate distributions and applications

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In this work we introduce a wide family of continuous univariate distributions with support $(-\infty,\infty)$. We study its properties, including aging properties, unimodality and probability bounds. We also illustrate simple to apply techniques for the generation of new members of the family by combining two or more members of the family. We finally highlight its applicability in real data and discuss statistical inference issues arising in the fitting process.

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Information measures for balancing redundancy and relevance in data analysis

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Redundancy and relevance are the prominent properties when studying the association, correlation and dependence among variables. These two properties constitute the typical selection criteria for dimension reduction in data of observed variables. For regression tasks, where the response variable is continuous-valued, the dimension reduction is commonly called variable selection and in classification tasks, where the response is discrete-valued, it is called feature selection. For bivariate and multivariate time series, the same approach is used to estimate dependencies of the response variable at a future time on present and past states of another driving variable, commonly referred to as Granger causality or simply causality. To address the redundancy and relevance in any of the above settings, information theory has been an attractive framework, as it accounts for any form of correlation or dependence, not only linear.

In this presentation, the work of our research group using information theory (particularly the conditional mutual information) to address redundancy and relevance for dimension reduction will be reviewed. The contribution in the following settings will be discussed: a) bivariate and multivariate causality analysis on continuous-valued time series, b) multivariate causality analysis on phases of continuous-valued time series, c) multivariate causality analysis on discrete-valued time series, d) feature selection in classification tasks, and e) variable selection in regression tasks (only some first results as the work is in progress).

Inflation Dynamics in Greece and Asymmetric Causal Effects

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The contribution of supply shocks to the inflation dynamics changed substantially over time. Besides the configuration of the forces affecting inflation, understanding the linkages over time between inflation and shocks is crucial for maintaining price stability. In this paper, possible interdependencies between Greek inflation and its volatile components are taken into account by employing the asymmetric Partial Transfer Entropy causality measure introduced by Kyrtsou et al., (2019). We proxy supply shocks by the food and energy components of the Greek CPI. The empirical findings in rolling windows indicate the persistent contribution of the energy component to the overall inflation dynamics. However, food inflation seems to have a dominant role during the last subsample.

δ -records in Models with Trend

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The study of records under different models is an area of active research due to its applications in several fields. In this work, we focus on δ-records, which generalize the concept of records. A δ-record is defined as an observation being greater than all previous entries plus a fixed real quantity δ, positive or negative.

In this framework, we extensively study the occurrence of δ-records under the Linear Drift Model (LDM), introduced by Ballerini and Resnick[1]. That is, we consider a sequence of observations Y_n, n: 1, 2…, such that

$$Y_n = X_n + c \cdot n, \qquad n \geq 1,$$

where c is a positive constant standing for the linear trend of the model, and X_n is a sequence of continuous i.i.d.r.v.

We show analytical properties of the δ-record probability under the LDM, such as the positivity and continuity, and we analyze how the right-tail behavior of the underlying distributions affects the δ-record probability. As a consequence of our results, we solve a conjecture posed in the Physics literature[2] regarding the finiteness of the total number of records in a LDM with negative drift.

We further investigate the asymptotic behavior of the number δ-records among the first n observations. We prove a Law of Large Numbers and provide conditions for weak convergence to the Gaussian distribution. We also consider two generalizations of the LDM: one relaxing independence to stationarity and the other incorporating an underlying random trend with a linear-growing expectation.

Finally, we explore statistical properties of δ-records in the LDM. We propose two estimators for the variance of the number of δ-records, proving their consistency. We also develop a framework for Maximum Likelihood Estimation and provide analytical solutions for a family of distributions. We assess the performance of these estimators based on δ-records via Montecarlo simulation and compare the results with those using only records. Additionally, we illustrate the application of our results to a real dataset of summer temperatures in Spain, where the LDM is consistent with the global-warming phenomenon.

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Distribution of the number of carrier genotypes in Mendelian models

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Mendelian models are founded on Bayesian networks for them to be particularly suited for analyzing a family history of disease. They allow indeed for modeling the structure dependency between genotypes (usually latent) and phenotypes (usually observed) of family members. That structure dependency can be used to reduce the computational complexity of an inference via the sum-product algorithm [1, 2, 3].

Given a genetic model (allele frequencies of a major gene, mode of inheritance, disease-specific penetrance per genotype, etc.), genetic counselors are usually interested in computing the marginal posterior probability of carrying a deleterious allele for an individual of interest and his/her resulting probability of developing the disease in the future. Along with these marginal posterior probabilities, one may also be interested in familial risks, in particular the distribution of the number N of carriers within a family.

In this work, we address this question following the idea of introducing probabilistic relationships between variables through polynomials for computing generating functions in probabilistic graphical models [4,5]. In particular we introduce specific polynomials for computing the probability generating function (pgf) of N. From the pgf of N, one can derive marginal posterior carrier probabilities for an individual or a group of individuals conditional on the family history and N=k carriers.

We illustrate the method over various simulated family histories using different genetic models estimated in the framework of the breast/ovarian and the Lynch syndrome. We show the interest of considering the distribution of the number of carriers in posterior risks inference for highlighting at-risk individuals and helping clinicians in prioritizing genetic investigations.

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Online Change Point Detection in High-Dimensional Data

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We propose some new procedures to detect change points in high-dimensional online data. Theoretical properties of the proposed procedures are explored in the high dimensional setting. More precisely, we derive their average run lengths (ARLs) when there is no change point, and expected detection delays (EDDs) when there is a change point. Accuracy of the theoretical results is confirmed by simulation studies. The practical use of the proposed procedures is demonstrated by real data.

Mean Hitting Time Approximation for Rare Events

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The probability of an a process which describe the temporal behaviour of a multi-state system, to reach a "bad" state (death, failure, negative performance, etc.) is of importance. The time to reach such a state for the first time is the so called the *hitting time*.

For a process, $Z^{\in}(t), t \geq 0$, indexed by the small parameter $\in > 0$, with general state space E, and D a measurable subset of E, the bad states for which transition probabilities, from E \ D, are small and depend on the parameter $\in$. Define now hitting time $\tau^{\in}$ of D, by the process $Z^{\in}(t)$, i.e., $\tau^{\in}$:= inf{t ≥ 0 : $Z^{\in}(t) \in$ D}.

We can consider D as a single merged state since we are interested just by the hitting time to D. The problem we are considering now is the asymptotic behaviour of mean hitting time in regards of the asymptotic merging of states E \ D. For a large family of stochastic processes, as Markov chains, Markov processes, semi-Markov processes, semi-Markov chains, diffusion processes, etc., the expectation function of $\tau^{\in}$, $\eta^{\in}(x) \coloneqq E_x\tau^{\in}$(x), $x \in E$, satisfies the operator equation $\epsilon^{-1}\mathbf{L}_0^{\epsilon}\eta^{\epsilon} = -1$, where $L_0^{\in}$is a partial operator on E \ D which is specialized for each particular family of processes. This is a singular perturbation problem that we solve by V.S. Koroliuk's method in order to obtain limit results.

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Finding the Number of Clusters, based on the Susceptibility of the Similarity Matrix: An Application to Earthquake Declustering

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Determining the optimal number of clusters is a critical step in cluster analysis. Few automatic techniques exist for estimating the number of clusters, K^*, which are often based on validity indexes and are computationally expensive. In this study, we present a new algorithm for estimating K^* which unlike existing methods, does not require partitioning the data into clusters, making it more efficient in terms of both time and space complexity. The algorithm, indeed, highlights the block structure which is implicitly present in the similarity matrix, and associates K^* to the number of blocks in the matrix. We validate our algorithm on synthetic data sets with and without hierarchical organization and compare it to existing methods based on internal validity indices. Our results show that our algorithm outperforms existing methods in terms of accuracy and computational efficiency. Furthermore, we demonstrate the effectiveness of our algorithm to the declustering of instrumental earthquake catalogs, providing valuable insights into the level of background seismic activity for seismic hazard assessment.

Testing of the Seismic Gap Hypothesis in a model with realistic earthquake statistics

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The seismic gap hypothesis states that fault regions where no large earthquake has recently occurred, are more prone than others to host the next large earthquake. It can lead to the idea of immunity after local disaster which, notwithstanding it sounds reasonable, it has been frequently rejected by objective testing. More generally, the estimate of the occurrence probability of the next big shock on the basis of the time delay from the last earthquake still represents a big challenge. The problem is that this issue cannot be addressed only on the basis of historical catalogs which contain too few well documented big shocks, and decades of future observations appear necessary. On the other hand, recent results have shown that important insights can be obtained from the spatial organization of aftershocks and its relationship to the mainshock slip profile.

Here we address this issue by monitoring the stress evolution together with the occurrence of big shocks and their aftershocks in a model where the fault is described as an elastic interface embedded in a ductile medium. The model reproduces all relevant statistical features of earthquake occurrence and allows us to perform accurate testing of the seismic gap hypothesis and its consequences, particularly on the side of aftershock spatial patterns. We show that large earthquakes do not regularly repeat in time, but it is possible to achieve insights on the time until the next big shock from the percentage of aftershocks occurring inside the mainshock slip contour.

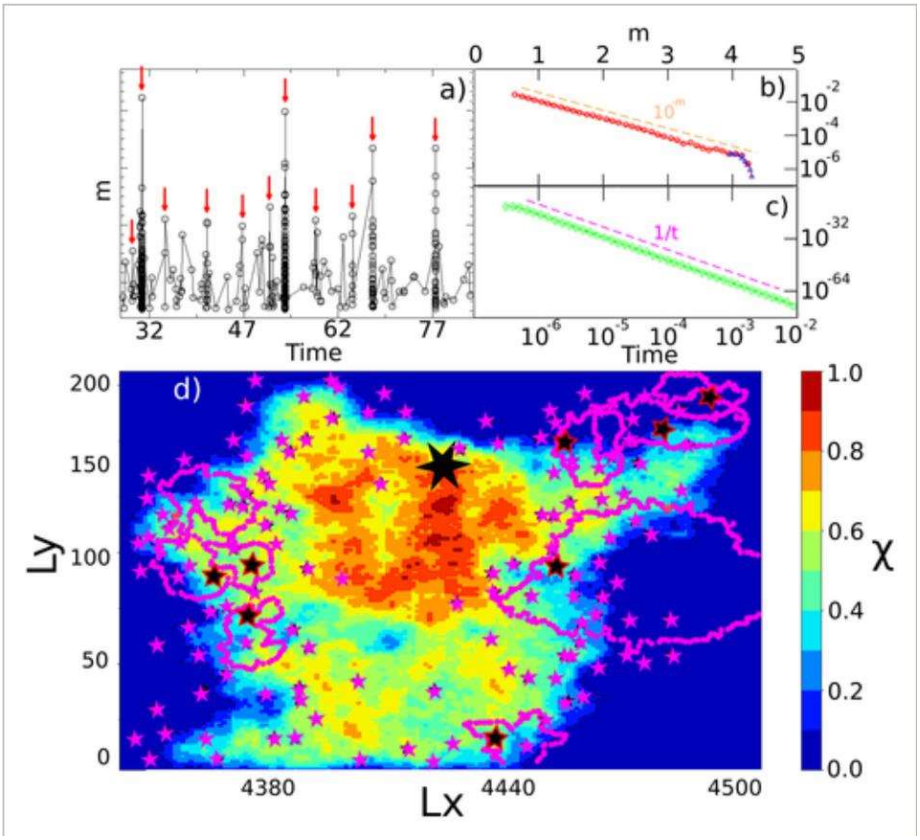

Figure 1: (a) A subset of the numerical catalog containing 11 sequences. We plot the magnitude of each event m versus its occurrence time. Different arrows identify the temporal position of the mainshock in each sequence. (b) The magnitude distribution P(m) of the whole catalog (red circles) and of mainshocks (blue triangles). The orange dashed line is the GR law with b=1. (c) The number of aftershocks as function of time since the mainshock. The magenta dashed line is the hyperbolic Omori decay. (d) The stress drop configuration after a mainshock. Different colors correspond to different level of the stress drop as indicated in the color code. Pink circle dots represent the contour of M1.8+aftershocks whose hypocenters are identified by black stars with red contour. Smaller magenta stars represent the hypocenters of all M1+ aftershocks.

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Sparsification of Phylogenetic Covariance Matrices via Wavelets

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Phylogenetic covariance matrices have a rich structure that is not immediately apparent. While these matrices are commonly used in applications, they can be challenging to work with due to their large and dense nature. This talk presents a novel approach for sparsifying phylogenetic covariance matrices based on a Haar-like wavelets similarity transformation, which leverages their underlying tree structure. We demonstrate that the vast majority of the off-diagonal entries in random but large phylogenetic covariance matrices become asymptotically negligible after the transformation and provide a fast algorithm to compress such matrices directly from their tree representation. Finally, we identify a subset of matrices that can be diagonalized by the wavelets and establish a sufficient condition for approximating the spectrum of phylogenetic covariance matrices outside this subset. Our results offer a promising solution for efficiently handling large and dense phylogenetic covariance matrices in practical applications.

Acknowledgements

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Evolution of a Deterministic SIS Epidemic Model with Infection Characteristics Environmentally Dependent

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A large number of authors have developed computational and qualitative results concerning the basic deterministic SIS model and variants that take into account special characteristics, such as the inclusion of demography, latent periods, population heterogeneities, etc. The stochastic counterpart of the SIS model has also received considerable attention. Its crucial difference from the deterministic one, is that extinction of the epidemic occurs with probability one in the stochastic model, when there is no external source of infection. Thus, the interest of the investigators lies in the behaviour of the epidemic till its extinction, which is usually quantified with the so-called quasi-stationary distribution.

One drawback of many studies dealing with SIS models is that they do not account for seasonality effects and environmental changes that may influence the infection and/or the recovery rates.

Our research considers the classical deterministic SIS epidemic model, where the infection and recovery rates depend on a background environmental process that is modelled by a continuous time Markov chain, capturing several important characteristics appearing in the evolution of real epidemics in large populations, such as seasonality effects and environmental influences. We propose computational approaches for the determination of various distributions that quantify the evolution of the number of infective individuals in the population.

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Analysis of the elapsed time before first recovery in a SIVS stochastic model with an imperfect vaccine

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In this talk we present a Markovian model to describe the transmission of a contagious disease in a finite population of constant size N, and we perform an analysis on the time until the first recovery T_R.

We consider an infective disease which spreads homogeneously among the susceptible individuals. We assume that after recovery, any previously infected individual acquires temporary immunity to the disease, and that any susceptible individual can receive the vaccine to prevent the illness. However, it loses effectiveness over time and can fail to protect against infection.

We introduce a compartmental model in which the population is divided into four epidemiological groups: susceptible (S), vaccinated (V), infected (I) and recovered (R) individuals, who progress through compartments in time. The obtained set of states in each time instant is represented by a three-dimensional continuous-time Markov chain, whose transitional rate block matrix Q is studied. In this framework, we perform an analysis on T_R, which constitutes a suitable first-passage time. Moreover, it is of particular interest when the illness cannot be diagnosed until it causes the death of the first individual.

The aim is to study the probabilistic behavior of T_R and to derive theoretical results for its probability mass function and factorial moments. Moreover, we perform a global and local sensitivity analysis with some fixed parameters to evaluate the influence of parameter variations on it.

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Estimates for Exponential Functionals of Real-Valued Continuous Gaussian Processes

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In this talk, an exponential functional of a real-valued stochastic process $\big(X(t)\big)$ is a random variable of the prototype

$$I(T) = \int_0^T \exp[\,X(t)]\,dt, \qquad T \geq 0.$$

Exponential functionals of stochastic processes are useful in various fields of application, such as Finance, Actuarial Mathematics and SPDEs. Despite this, the laws of $I(T)$ and $I(\infty)$ are known in only a very few interesting cases, see [1], [2] and [3]. Therefore, useful computable estimates for the laws of such functionals are in order. In this talk we give general upper bounds for the cumulative distribution functions of exponential functionals of continuous Gaussian processes, with emphasis in the case of fractional Brownian motion. We also find estimates for the *p*-th order moment and the moment generating functions of such functionals.

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Conditional Gambler's Ruin Problem with Arbitrary Winning and Losing Probabilities with Applications

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In this paper we provide formulas for the expectation of a conditional game duration in a finite state-space one-dimensional gambler's ruin problem with arbitrary winning *p(n)* and losing *q(n)* probabilities (i.e., they depend on the current fortune). The formulas are stated in terms of the parameters of the system. Beyer and Waterman [1] showed that for the classical gambler's ruin problem the distribution of a conditional absorption time is symmetric in *p* and *q*. Our formulas imply that for non-constant winning/losing probabilities the expectation of a conditional game duration is symmetric in these probabilities (i.e., it is the same if we exchange *p(n)* with *q(n)*) as long as a ratio *q(n)/p(n)* is constant.

Most of the formulas are applied to a non-symmetric random walk on a circle/polygon. Moreover, for a symmetric random walk on a circle we construct an optimal strong stationary dual chain -- which turns out to be an absorbing, non-symmetric, birth and death chain. We apply our results and provide a formula for its expected absorption time, which is the fastest strong stationary time for the aforementioned symmetric random walk on a circle. This way we improve upon a result of Diaconis and Fill [2], where strong stationary time -- however not the fastest -- was constructed. Expectations of the fastest strong stationary time and the one constructed by Diaconis and Fill differ by 3/4, independently of a circle's size.

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On the Asymptotic Distribution of the Least Singular Value of Random Matrices with alpha-Stable Entries.

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In the past few years, there has been an increasing interest in results from Random Matrix Theory (RMT). In general, RMT investigates the asymptotic behavior of several elements of the spectrum of random matrices as the matrix-dimension tends to infinity.

This talk is based on the recent work [1] and investigates the asymptotic spectral property of a heavy tailed random matrix model. We determine the asymptotic distribution of the least singular value of random matrices with α-stable entries. Specifically, if $\lambda_1(X_N X^T_N)$ denotes the least eigenvalue of the matrix $X_N X^T_N$, where X_N is a matrix of dimension N with identically distributed and independent α-stable entries, appropriately normalized, then

$$\lim_{N\to\infty} P(N^2\lambda_1(X_N X^T_N) < r) = 1 - exp(-r^2/2 - r) \text{ for all } r > 0 \qquad (1)$$

The basic difference of this model with other classical models from RMT (Wigner Matrices, Wishart Matrices, Sparse Matrices etc) is that the entries of the matrix have heavy tails and very few finite moments (infinite variance, possibly infinite mean). The methods that are used are based on the modern techniques, whose heart is the three step strategy, an important strategy developed in the last decade in the RMT literature. So before presenting the proof of (1) , a short overview of the three step strategy will be sketched.

Specifically the main influence for this work were the papers [2],[3] and [4].

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Functional Central Limit Theorem for Certain Markov Chains in Random Environment with Applications in Machine Learning

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The Functional Central Limit Theorem (FCLT) is a useful tool for understanding the behavior of ergodic sums and analyzing various stochastic processes. Recently, there has been a focus on extending the FCLT to Markov chains in random environments (MCREs), which are Markov processes that are influenced by an external random environment. Such processes have been studied by several authors in the past few years. Truquet has investigated the ergodic properties of MCREs when the random Markov kernels satisfy drift and small set conditions with random coefficients [4]. The recent paper [1] is a continuation of [2] where under a bit stronger assumptions on the environment, the existence of limiting distributions with explicit sub-geometric rates of convergence has been proved for MCREs, and also it was established that a law of large numbers holds for bounded functionals of the process. This theory provides a framework for studying stochastic optimization algorithms used in machine learning applications.

In this study, we examine the mixing properties of a specific machine learning optimization algorithm, the stochastic gradient Langevin dynamics (SGLD), with a fixed step size. We prove the FCLT for SGLD when the data stream is only stationary and satisfies some mixing conditions. Our proof relies on the transition of mixing to the chain, and FCLT follows from the general results of Herrndorf [3]. A similar argument appears in the related work [5], but the setting does not cover ours since the strong minorization property A2 does not hold for our processes. This research contributes to the statistical analysis of machine learning algorithms and provides a better understanding of the behavior of MCREs in random environments.

Acknowledgements

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Filtering a Hidden Open Homogeneous Markov System

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A hidden open discrete-time homogeneous Markov System (HMS) is studied. In the basic hidden HMS, a population of a finite number of members is distributed to a finite state space, while the population members move from one state to another at discrete time steps, according to a homogeneous transition probability matrix. In this study, the system is open, that is, at every time step, existing members may leave the system while new members may enter it. The members that enter the system are distributed to the states according to a multinomial distribution of a varying in time number of trials. Moreover, the population structure is considered hidden, as noisy observations of it are received at every time step. Within this approach, the model is handled by use of hidden Markov modelling techniques for the estimation of the hidden population structure: A linear state-space representation of the model is configured. For big populations, an appropriate Kalman-type filter is constructed as the distribution of the system noise is approximated with the Gaussian distribution.

Keywords: Open Homogeneous Markov System; Hidden closed discrete-time Homogeneous Markov System; Statistical filtering

New Tamed Langevin MCMC algorithms and their applications

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Recently, Langevin-based algorithms have grown in popularity, because of their importance in the fields of sampling and optimization. The majority of works in the current literature deals with problems which involve objective functions with linearly-growing gradients (drift coefficients in the respective Langevin SDE). Inspired by the taming technology developed in Hutzenthaler et al. (2012) and Sabanis (2013), Sabanis (2016), we propose new Langevin-type MCMC algorithms to deal with cases where the gradient of the objective functions grows superlinearly. We provide non-asymptotic analysis of the new algorithms' convergence properties and their application in optimization.

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Power-weight trees

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We study the insertion depth in a class of nonuniform random recursive trees grown with an attachment preference for a power of the node index. The strength of index preference is controlled by a real-valued power parameter α; the model accommodates both young-age and old-age preference as specific cases. We find the exact probability law in terms of the Poisson-Binomial distribution, and consequently, the exact and asymptotic mean and variance. Under appropriate normalization, we derive concentration laws and limiting distributions.

For $\alpha > -1$, with logarithmic normalization of the depth, we have a normal limit. The case $\alpha = -1$ is a critical point at which we retain a normal limit but under an iterated logarithm normalization. For these normal cases, Chen-Stein approximation gives a slow rate of convergence in the Wasserstein distance.

The case $\alpha < -1$ is a phase that has a different behavior.

Monitoring Long-Term Relationship Between Cointegrated Time Series

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Most real-world time series exhibit a certain nonstationary behavior, but if they are studied jointly, there might exist a linear combination of them that could be considered as a stationary process; those time series are said to be cointegrated. If two or more time series are cointegrated, there is a correlation between them in the long term, sharing a long run relationship. Since, fast detection of any change in the cointegration relationship is very important in several scientific fields, such as economics, finance, epidemiology, medicine, environmental engineering, and many others, the current work focuses on the monitoring of two cointegrated time series to detect as early as possible any changes in the long-run equilibrium relationship between them. The proposed monitoring process is based on rolling window regression and the use of suitable control charts for the Ordinal Least Squares estimates of the coefficients of the linear combination. If the estimates over the rolling window do not differ significantly, the parameters can be considered constant over time, and this is also the case for the cointegration relation. On the other hand, if the parameters change at some point, the time series are not cointegrated anymore or their cointegrated relation is altered. Our main aim is to detect any change point in the cointegrated time series relationship. The effect of the rolling window's size was also examined via simulations. Simulated data confirm the validity of the proposed method. The proposed method is also applied to a real dataset.

On Round-Robin Tournaments with a Unique Maximum Score and Some Related Results

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Richard Arnold Epstein (1927-2016) published the first edition of "The Theory of Gambling and Statistical Logic" in 1967. He introduced some material on roundrobin tournaments (complete oriented graphs) with n labeled vertices in Chapter 9; in particular, he stated, without proof, that the probability that there is a unique vertex with the maximum score tends to one as n tends to infinity. Our object here is to give a proof of this result along with some remarks and comments. We also give related results on pairs of equal scores and degrees in tournaments and graphs. Time permits, I will discuss a method to obtain the distribution of winners' scores in a round-robin tournament.

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Retrospective forecast testing of short-term earthquake clustering models in Greece: Results from recent (2020-2022) earthquake sequences

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The occurrence of destructive earthquakes worldwide motivates the scientific community to strengthen the research efforts for reliable earthquake forecasting and seismic hazard assessment. Over the years, a wide variety of stochastic forecasting models has been proposed in both long- and short- time scales. Among them, the short-term seismicity based models became the most popular, due to the tendency of earthquake time series to be clustered in both space and time and the continuous improvement of earthquake catalogs. The large number of the proposed short-term clustering models highlights the problem of selecting the optimal earthquake forecasting model. For this purpose, many methodologies and techniques were proposed for testing the performance and the forecasting skills of the candidate stochastic models in a transparent and reproducible way (e.g. those proposed by the Collaboratory for the Study of Earthquake Predictability; CSEP) and in both retrospective and prospective ways.

In this framework, the application of short-term clustering models in Greece, which exhibits high seismic moment rates, with frequent strong (e.g. $M_w \geq 6.0$) earthquake occurrence, is necessary for understanding the clustering features of Greek seismicity. This fact also renders the study area a particularly favorable and interesting case for assessing the performance of those models. During the past years, two average short-term spatiotemporal clustering model were proposed for the broader Aegean area. The parameter estimates of both models were calculated based on the period until 2019, offering the opportunity of assessing their performance for the testing period 2020-2022, in which 40 $M_w \geq 5.0$ earthquakes occurred within the Greek territory.

The main objective of the current study is the examination of the forecast ability of the two candidate models in a retrospective way by means of both stochastic techniques, such as the Numbers and the Spatial tests, and binary approaches, namely the Relative Operating Characteristics (ROC) diagrams, the R-score and the probability gain. The experiment is implemented using a highly accurate earthquake catalog covering the testing period and focusing on selected target mainshocks with various magnitude thresholds ($M_w \geq 5.0$, $M_w \geq 5.5$, $M_w \geq 6.0$). Both models are tested for their skills in short-term aftershock forecasting of $M_w \geq 6.0$ mainshocks, as well, since potential earthquake occurrence of large magnitude earthquakes may cause significant problems to already severely damaged infrastructures.

Conditional Distributions of Statistics and Other Inferential Procedures in States of Hidden Sparse Markov Models

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Whereas the number of parameters in a general higher-order Markov model is exponential in the order of dependence, in a sparse Markov model, conditioning histories are clustered into classes with equal conditional probability distributions within classes, reducing the number of parameters. This paper introduces a model where variables following a sparse Markov structure are latent, and all inference over the latent states is conditioned on observed data. Several tasks are considered in this setting: methodology for efficient computation of distributions of statistics of the hidden states, determining the likelihood of the observations, and obtaining the most likely hidden state at each time point and the most likely state sequence. Also discussed is a very important task for statistical applications: determining the model and estimating model parameters, based on data.

Scaling Limits of Critical Controlled Multi-type Branching Processes

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This paper presents a scaling limit theorem which establishes the asymptotic behavior of some critical controlled multi-type branching processes (CMBPs) and extends the work by González et al. [1] to the multi-type case. CMBPs are stochastic processes used to model the evolution of populations with different types of individuals, where the number of progenitors of each type at a given generation is determined by a random control mechanism and the number of individuals of different types in the previous generation. It is proved that a sequence of appropriately scaled and normalized critical CMBPs converges weakly towards a certain squared Bessel process. Among the applications, the main result from Ispány and Pap [2] and a first Feller-type diffusion approximation of a promiscuous two-sex Galton-Watson branching process with immigration stand out.

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Modeling Rainfall Interarrival Times, Rainfall Depths and their dependence, using the Hurwitz Lerch Zeta family of distributions and Discrete Copulas

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The Poisson-stopped sum of the Hurwitz-Lerch zeta distribution (PSHLZD) is proposed for the univariate modeling of rainfall interarrival times IT and rainfall depths h since this discrete distribution presents excess zeroes and a long tail, which are statistical properties commonly found in IT and h data.

Theoretical properties and characterizations will be presented [1]. Indeed many properties can be carried out using the combinatorics of exponential Bell polynomials such as closed form expressions for the probability mass functions (pmf) and their convolutions, as well as moments and cumulants. Comparisons are presented with other two models implemented to perform the same task: the Hurwitz-Lerch zeta distribution (HLZD) and the one inflated Hurwitz-Lerch zeta distribution (OIHLZD). In particular the results of fitting all these models to rainfall data are discussed, proving that the PSHLZD provides a very general framework for rainfall modelling.

Indeed the PSHLZD replicates the fitting features of the OIHLZD and outperforms the fitted HLZD in some cases. The PSHLZD has a limited number of parameters and at the same time can adapt very well to data collected in very different climates, from England to Sicily.

Let us underline that the analyzed dataset has never been considered in the literature and consists of measures sampled along 70 years at 5 different stations. These stations were chosen in order to represent different climates from the rainfall characteristics point of view. Indeed they present different patterns of both IT and h.

The fitting was remarkable independently from the station characteristics, assessing the flexibility of the proposed distributions.

Future works will be addressed on modeling the dependence (inter-correlation) between IT and h by exploiting possibly new methodological advances in the subject of Discrete Copulas [2].

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Some results on a non-homogeneous telegraph process

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The (integrated) telegraph process X(t) describes a random motion with finite velocity on the real line. It describes a motion characterized by constant velocity, the direction being reversed at the random epochs of a homogeneous Poisson process. The telegraph process possesses a probability law governed by a hyperbolic partial differential equation (the telegraph equation) widely used in mathematical physics. Moreover, such process deserves interest in many other applied fields, such as finance and mathematical biology. Among the first authors that studied the solution of the telegraph equation we recall Goldstein (1951) and Kac (1974). Several aspects and generalization of the telegraph process have been provided in a quite large body of literature (see, for instance, Kolesnik and Ratanov (2013)).

Some recent studies have been devoted to a non-homogeneous version of the telegraph process, in which the changes of the particle direction are governed by a non-homogeneous Poisson process with time-dependent intensity function $\lambda(t)$. An interesting case for $\lambda(t)$ was considered by Iacus (2001), and, recently, a special case related to the Euler–Poisson–Darboux equation has been considered by Garra and Orsingher (2016).

In this talk we analyze some properties of a non-homogeneous integrated telegraph process with time-dependent intensity function. To this aim, we follow the approach proposed by Foong and Van Kolck (1992) based on the ordinary differential equation satisfied by the characteristic function of X(t).

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Using Markov and Related Models for Characterising and Monitoring Patients in Smart Homes

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There have been considerable research efforts towards using sensor-based smart homes for patient activity and monitoring over recent years. In particular, older people often experience difficulties in performing activities of daily living (ADLs), such as grooming, showering, or taking medication, leading to associated difficulties with such residents continuing to live independently in their own homes. Smart homes that use sensors or imagery are therefore being increasingly used to provide a home environment that offers assisted living and patient activity monitoring, through the use of probability models to describe the home environment, its inhabitant behaviours and the potential impact of proposed interventions if such behaviours become unhealthy, unsafe, or dangerous.

Markov, or related, models such as semi-Markov or nth-order Markov models are frequently employed in healthcare for a wide range of applications, including patient monitoring in smart homes. With sensors, smart homes can collect a vast amount of information about a patient's activities, such as their movements, sleep patterns, and medication adherence. Markov models can help process this data to provide insights into the health status of a patient and predict future events. They can also be used to monitor patients in smart homes by processing the data collected by sensors. For example, a sensor that detects a patient's movement can be used to determine if the patient is active or inactive. By collecting data over time, a Markov model can be used to predict the patient's future activity levels and detect any changes in their health status. In addition, we can use such models to detect anomalies which may be indicative of deterioration or danger for the patient.

In such contexts, the specific patient ADLs may not be observed but instead can be “viewed” by low-level sensor data. If explicit knowledge of activities is available we can use models from the Markov family, by regarding the activities as states of the Markov chain; if not hidden Markov models may be employed. Such models can then be used to recognise and understand future ADL activities, thus assisting completion of an activity if necessary, or executing an intervention, if a problem is detected. However, fitting such models may be complex and might, for example, require the use of semi-Markov models (if ADL execution times do not follow the exponential distribution), nth-order Markov models (if some sequences of activities do not possess the Markov property), or be non-homogeneous (if there is drift in the ADL execution behaviour distributions through time). In addition there may be statistical problems due to missing or incomplete data which complicates model fitting and validation.

We will describe the use of such models for patients living in sensorised smart homes, using open source public domain data for different such scenarios.

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The joint distribution of value and local time of simple random walk and reflected simple random walk. Pandemic-motivated queueing analysis

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The joint distribution of value and local time for Brownian Motion has been reported. So has its asymptotic behavior for recurrent random walk. Motivated by the need for queue size control during a pandemic, the current study presents closed form formulas for random walk and reflected random walk with unit increments, not necessarily fair.

In a M/M/c/n service facility, waiting room n is designed to restrict the number of - and total time spent with - other customers while waiting for service. These are pandemic-motivated novel criterions, where the usual waiting loss due to earlier arrivals is complemented with the exposure loss due also to later arrivals. Threshold balking strategies are identified as Nash equilibria. "Local time" enters as the times when the queue is full to capacity, and its distribution identifies pertinent queuing statistics.

This is joint research with Yael Perlman, Bar Ilan University

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Sequential Analysis: Stopping Rules to Detect Changes in a Markov Chain

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We propose in this presentation stopping rules to detect changes in a Markov chain. We introduce stopping times based on the distribution of some processes, one of which corresponds to the maximum of the Lindley, or CUSUM, process associated to the sequence. This maximum is called the local score and has been defined by Karlin et Altschul in 1990. The panel of the theoretical results on the distribution of the local score will be rapidly presented. We will then focus on the case of a sequence modeled by a Markov chain and we will present both exact and asymptotic methods to establish the distribution of the local score, a joint work with Simona Grusea. Simulations highlight that this proposed sequential detector allows a large average run length to a false alarm, with a competitive average detection time. It is then well adapted for high frequency data as in health monitoring, microelectronics among many other examples.

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Assessing the Performance of Bootstrapping in Network Data Envelopment Analysis: Monte Carlo Evidence

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Data Envelopment Analysis (DEA) provides an empirical estimation of the production frontier based on an observed sample of decision making units (DMUs). If the observed set of DMUs is considered a random sample drawn independently and uniformly from an underlying population, then the true efficient frontier is unknown. Except for the single input-single output case, the asymptotic distribution of the DEA estimator can only be approximated through bootstrapping approaches, which have been widely implemented for the case of the production process with a single-stage structure. However, in many cases, the transformation of inputs into outputs involves more than one stage. This study examines the applicability and performance of subsampling bootstrap when the production process has a network structure, and the relation between the different stages is considered. Evidence on the performance of subsampling bootstrap is obtained through Monte Carlo experiments for the case of two-stage series structures, where the overall and stage efficiency estimates are calculated using the additive decomposition approach. Results indicate great sensitivity both to the sample and subsample size, as well as to the data generating process -higher than in one-stage structures. A practical approach is suggested to overcome some result inconsistencies that are due to the peculiarities of the additive decomposition algorithm. The method is then illustrated in real-world data about European railways, where the railway noise pollution problem is considered an undesirable output.

Stochastic simulation, analysis and inference for reaction networks

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The continuous biotechnological advances, particularly over the last two decades, continue to provide larger and more informative datasets. They promise a more insightful understanding of biological processes and biomedical advances. Analogous mathematical and statistical advances are required to support these technological advances. A critical challenge to overcome is that biological data are often highly variable due to multiple sources of non-trivial variability affecting them. Stochastic models for reaction networks can describe biological processes incorporating their stochasticity. They can also describe epidemiological, ecological, and sociological processes. In this talk, I will introduce the main approaches for developing stochastic models of reaction networks. I will then describe a new approach for stochastic modelling that achieves a suitable balance between model accuracy, computational speed, and scalability to large systems. I will discuss methods for long-time stochastic simulation, analysis of parameter sensitivities, and statistical inference using time-series data. The method will be applied to large biological systems with oscillatory dynamics.

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On the absorption and limiting behaviour of defective branching processes in a varying environment

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The simplest branching process (known as the Bienaymé-Galton-Watson process) describes populations where the reproduction of each individual occurs independently of the others and the distribution of its number of offspring, $p = \{p_k\}_{k\in\mathbb{N}_0}$ (where p_k is the probability that an individual produces k offspring), is the same for every individual in the population at any generation.

In this work, we study on a twofold modification of this classical branching process. First, we consider defective branching processes (DBPs) with defective offspring distributions (that is, satisfying that $\sum_{k=0}^{\infty} p_k = 1 - \varepsilon$, for some $\varepsilon \in (0,1)$). These modified processes were studied in [2]. In [1], we introduced a second additional modification that results from allowing the defective offspring distribution to change over the time. These processes are called *defective branching processes in a varying environmen*t (DBPVE) $v = \{f_1, f_2, \dots\}$, where f_n denotes the probability generating function of the possibly defective offspring distribution in the generation n of the process. The defect of the distribution f_n, $1 - f_n(1)$, can be seen as the probability that at any generation n, an individual sends the process to a graveyard state Δ at generation $n+1$, where the process stays forever. Therefore, the process has an enhanced state space $\mathbb{N}_\Delta = \mathbb{N}_0 \cup \{\Delta\}$ with two absorbing states: 0 and Δ.

We focus our attention on the asymptotic behaviour of DBPVEs. We show the almost sure convergence of the process to a random variable with values in $\mathbb{N}_\Delta \cup \{\infty\}$ and two characterisations of the duality extinction - absorption at Δ which holds for the DBPs. We also discuss some limiting results on the moments of the process, the absorption time and on the expectation of the process conditioning upon non-absorption.

Acknowledgements

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Intermittency and Percolation in the Population Dynamics

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The phenomenon of intermittency was discovered in the theory of the magnetic fields of the hot stars (dynamo problem). Mathematically, it is manifested by the progressive growth of the statistical moments of the physical fields. In the particular case of the population dynamics, the intermittency is related to the random fluctuations of the environment. The corresponding equations have the form of the parabolic Anderson models with the random potential which can be either time independent (stationary environment) or time dependent with the fast and short oscillations in time. The talk will contain the review of the recent results in this area including the description of the percolation transition from intermittency to homogenization.

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√2-Estimation for Smooth Eigenvectors of Matrix-Valued Functions

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Joint with Wei Biao Wu (University of Chicago) and Mohsen Pourahmadi (Texas A& M University)

Modern statistical methods for multivariate time series rely on the eigendecomposition of matrix-valued functions such as time-varying covariance and spectral density matrices. The curse of indeterminacy or misidentification of smooth eigenvector functions has not received much attention. We resolve this important problem and recover smooth trajectories by examining the distance between the eigenvectors of the same matrix-valued function evaluated at two consecutive points. We change the sign of the next eigenvector if its distance with the current one is larger than the square root of 2. In the case of distinct eigenvalues, this simple method delivers smooth eigenvectors. For coalescing eigenvalues, we match the corresponding eigenvectors and apply an additional signing around the coalescing points. We establish consistency and rates of convergence for the proposed smooth eigenvector estimators. Simulation results and applications to real data confirm that our approach is needed to obtain smooth eigenvectors.

Data-Driven Markovian Optimal Stopping

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Classical Markovian Optimal Stopping theory requires knowledge of the underlying transition (conditional) probability densities. Modern dataset unfortunately cannot be adequately modeled by the usual statistical models (as Gaussian) which suggests that applying the optimal stopping theory is no longer straightforward. The goal of this presentation is to offer a method which is purely data-driven and capable of approximating the optimal solution. More specifically, assuming that a sequence of consecutives samples of the Markov process is available (training set) we develop a means for efficiently approximating the solution of a general form of the optimal stopping problem without the need of knowing the corresponding probability densities. We must emphasize that our method does not utilize some density estimation idea. Instead, we employ a neural network based scheme which efficiently approximates conditional expectations under a purely data-driven setup. This capability is then employed to recursively solve the equation, offered by optimal stopping theory, that defines the optimal solution. We present interesting examples that demonstrate the efficiency of our computational methodology.

Optimal Stopping Methodology for the Secretary Problem with Random Queries

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Candidates arrive sequentially for an interview process which results in them being ranked relative to their predecessors. Based on the ranks available at each time, one must develop a decision mechanism that selects or dismisses the current candidate in an effort to maximize the chance to select the best. This classical version of the ``Secretary problem'' has been studied in depth using mostly combinatorial approaches, along with numerous other variants. In this work we consider a particular new version where during reviewing one is allowed to query an external expert to improve the probability of making the correct decision. Unlike existing formulations, we consider experts that are not necessarily infallible and may provide suggestions that can be faulty. For the solution of our problem we adopt a probabilistic methodology and view the querying times as consecutive stopping times which we optimize with the help of optimal stopping theory. For each querying time we must also design a mechanism to decide whether we should terminate the search at the querying time or not. This decision is straightforward under the usual assumption of infallible experts but, when experts are faulty, it has a far more intricate structure.

Acknowledgements

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A local online matching algorithm on the configuration model

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We present a class of local Markov algorithms for the online construction of maximal matchings on large random graphs. For this, we present a hydrodynamic limit result for a measure-valued Markov process representing the construction of the graph by the configuration model, joint with an exploration algorithm constructing a matching on the latter graph, edge by edge. The dynamics of the matching algorithm can then be approximated by a set of ordinary differential equations. Then, we show how this result can be used to approximate the matching coverage, to the large graph limit. We compare the performance of various such local online algorithms, among which, greedy and degree-greedy.

Sequential Architecture-Agnostic Black-Box Attack Design and Analysis

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Although adversarial machine learning attacks on images have been heavily investigated, the rising popularity of vision transformers revitalized the research in this topic. Due to the fundamental architectural differences between the CNNs, which still dominate the image recognition applications, and transformers, the state-of-the-art attacks designed for CNNs are not effective against transformers, and vice versa. Such lack of transferability in attacks and the growing architectural heterogeneity in practice make the black-box attack design increasingly challenging. However, skillful attackers can handle the increasing uncertainty in target model architecture by identifying the target architecture for attack selection. We present a novel approach driven by both prior information and data, sequential attack strategy selection (SASS), which can effectively deal with the architectural uncertainty of target model (i.e., CNN-based, or transformer-based) using a practical number of queries (tens or hundreds of queries). SASS strikes a practical balance between the transfer learning and query-based approaches (Figure 1). We analyze the performance of the proposed method and provide guidance on how its parameters can be set. We benchmark our method with extensive experiments and analyze its effectiveness compared to the current state-of-the-art attacks. Experimental results show that SASS achieves consistently high attack success rates against both CNN-based and transformer-based target models by sending a feasible number of queries.

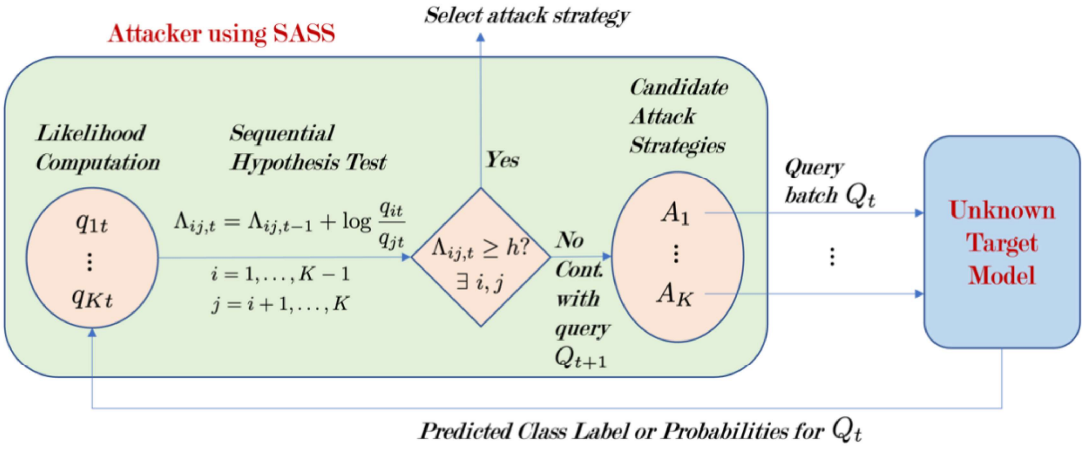

Figure 1: Diagram of the proposed SASS method.

Performance Analysis for a Two-Server Queue with Disasters and Vacations

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In this paper we present an M/M/2 queue performing with heterogeneous servers. The first server is reliable and may leave for a vacation when the system becomes empty under the MAV policy. The other sever is unreliable and may break down while serving customers causing disaster. When a disaster occurs, 2nd server a repair process commerce where server after repair period considered as new. We modelling the problem using a quasi birth-and-death (QBD) process, using the matrix geometric method to compute the stationary distribution of system size. We also develop several measures to evaluate the performance of the system.

Moments Computation for Markov-Modulated Fluid Models with Upward Jumps and Phase Transitions

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The study of Markov-modulated fluid models with upward jumps and phases transitions shows that the joint distribution is governed by a non-homogeneous linear differential system with specific boundary conditions. Spectral analysis technique was used to solve this system in which the unique solution is expressed by components that are calculated through the resolution of a linear system. The purpose of this work is to propose an algorithm for the computation of moments for these models. Our approach is recursive: the nth moment is obtained from the preceding moment via a linear system which in turn is expressed via the components derived for the joint distribution of the fluid level and the modulating process. Numerical illustrations will be presented and analyzed.

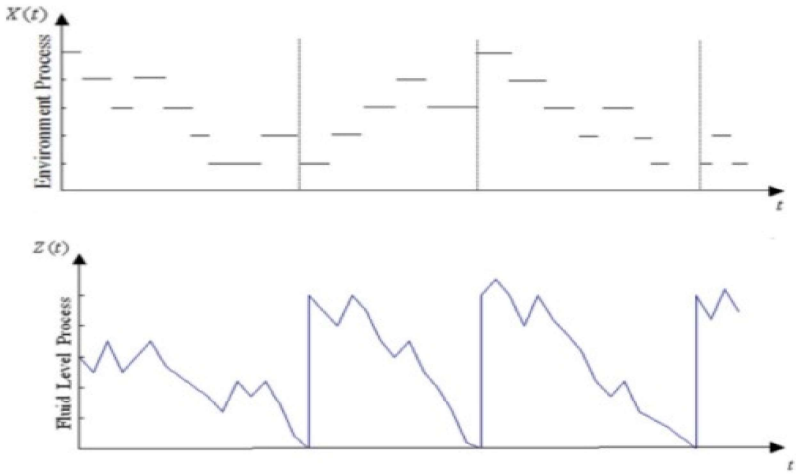

Figure 1: *Sample trajectory of the fluid flow and its controlling Markov process.*

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Large deviations for super-heavy tailed random walks

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This talk is based on [4]. We study large deviations for sums of independent and identically distributed random variables (random walks) with nonnegative "super-heavy tailed" distributions, which roughly mean that the tail probabilities are heavier than those of the Pareto type (see Falk et al. [1, Section 2.7]).

While Hu and Nyrhinen [2] gave results for heavy tailed distributions, our result is an improvement of one of theirs for super-heavy tailed ones. Moreover, we apply it to the "log-Pareto distribution" and the distribution for the "super-Petersburg game" (see [3, Section 4]).

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Second-order smoothness prior over the Delaunay Tessellation in Bayesian geophysical inversion

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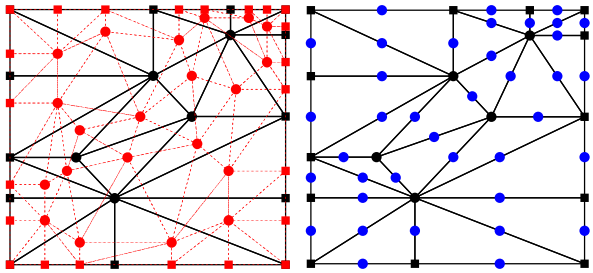
Prior information is always used to form up additional restrictions in geophsical inversions to solve the non-uniqueness problem of the solution. A commonly used restriction is on the smoothness (the second-order derivative) of the inverted model. The smoothness is usually calculated through interpolation over regular grids for easy implementation in numerical calculations. When observed data are irregularly distributed, such as in geodetic inversions, interpolation based on a Delaunay Tessellation (DT) over the observation locations is popularly used to avoid additional interpolations and to maintain the flexibility in the resolution of the model solution. However, the numerical calculation of the second-order derivatives (smoothness) of a function based on the DT interpolation is more difficult than differentiating over regular grids. We compare two methods for calculating the smoothness with DT based interpolation, named as the double linear and the quadratic interpolators. Fig. 1 (a) illustrates the DT used in the double linear method, and Fig. 1 (b) illustrates the DT used in the quadratic interpolation method. The efficiency of those two methods is verified through numerical experiments in the framework of Bayesian inversion and applied to a gravity inversion problem.



(a) (b)

Figure 1: DTs over 5 irregularly distributed points: (a) the 2nd-layer DT on 5 randomly distributed points; (b) the 1st-layer DT with mid-points. Black dots are 5 irregularly distributed observed points, black squares are auxiliary points on boundaries of the original DT, red dots in (a) are vertices of the triangles in the 2nd-layer DT, red squares in (a) are auxiliary points on boundaries of the 2nd-layer DT.

Acknowledgements

Emeritus Prof. Yosihiko Ogata kindly provided the 2D Delaunay Tessellation FORTRAN program, originally coded by Emeritus Prof. Masaharu Tanemura.

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Modeling RNA Sequences with Secondary Structures: Markov Models, Bayesian Networks, and Motif Distributions

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In molecular biology, ribonucleic acids (RNA) are polymeric molecules playing a key role in many biological processes including gene regulation and expression. The functional form of single-stranded RNA frequently requires a specific tertiary (3D) folding whose scaffold is the secondary structure (2D) formed by stem-loops patterns. From a mathematical point of view, single-stranded RNA can be seen as sequences of four possible bases: adenine (A), cytosine (C), guanine (G), and uracil (U). These four bases can form two kinds of hydrogen bonds between them: either A-U or C-G bonds. The secondary structure of a RNA molecule can therefore be described by a sequence of bases with additional bonding information. Databases such as STRAND (http://www.rnasoft.ca/strand/) make available this information in various formats including the Bpseq one. Here is for example some entries from Entry ASE_00199

[…]

115 A 0

116 U 0

117 A 127

118 U 126

119 U 125

120 U 0

121 U 0

[…]

For each position in the sequence (first entry), we get the base identification (second entry), and finally a bonding position (third entry) which is 0 by convention for unbounded position (loops). The objective of the present work is to suggest a model of structured RNA where a homogeneous Markov model is assumed along the sequence with the constraint that connected positions are likely to respect the A-U or C-G bonds (exceptions are still possible using a i.i.d. error model).

The resulting model is a Bayesian network whose dependence structure is given by the secondary structure of the RNA. In addition to the classical Markov dependencies along the sequence, any two bound positions Xi and Xj will be connected through an additional variable Cij such that $P(Cij=1 \mid Xi \sim Xj)=P(Cij=0 \mid \text{not } Xi \sim Xj)=1-e$ where e is a (small) error rate and where ~ denotes the complementary relationship (e.g. A~U and C~G). Using sum-product algorithms [1], we provide the means of computing the likelihood of the model given a set of secondary structure, perform exact inference, and derive a Expectation-Maximization algorithm [2]. Once the model parameters calibrated, we also explain how we can sample from this model, and how we can derive the distribution of regular expressions or simpler motifs by combining Markov chain embedding techniques [3] with moments/probability generating

functions. All theses methods and algorithms are illustrated with real secondary structures taken from the STRAND database.

For example, the Entry PDB_01199 has a sequence length of 66, a total of 48 bound positions, and 5 loops. The corresponding Bayesian network has a total of 66+48/2=90 variables. We can build a junction tree associated to this model with a total of 87 cliques each with at most three variables, and the sum-product algorithm has a total complexity of 25*4^2+62*4^3=4368.

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A Remote Sensing Application of Generalized Linear Mixed-Effects Models in Crop Phenology Prediction

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Crop development is a continuous process that can be witnessed in the form of changes in plant phenology. To study crop development, its life cycle is partitioned into discrete phenological stages, which the crop occupies sequentially. In large areas, the overall cultivation progress is expressed as the percentage of plants that occupy each stage. Crop progress percentages (CPP) are hard to acquire, demanding frequent in-situ measurements. This talk presents a remote-sensing approach to CPP estimation, in which satellite data allow real-time predictions of low computational cost. Specifically, two Generalized Linear Models are developed, based on the Binomial and Multinomial distribution, respectively. The consistency, asymptotic normality, and misspecification robustness properties of the methodology are highlighted. Random effects are incorporated to capture the inherent inter-annual variability. An ecosystem of R packages capable of downloading and processing crop and remote-sensing data, as well as implementing the proposed methodology is developed to reinforce research reproducibility. The subject is illustrated by an application in 8 crops (alfalfa, corn, millet, dry beans, oats, sorghum, soybeans, and winter wheat) over 20 years in Nebraska. The predictive features employed include growing degree days, day length, precipitation, water vapor pressure, and the normalized difference vegetation index.

Analyzing the Number of Failed Components in a series-parallel System

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The number of components that fail in the event of a system failure is a critical factor to track, as it indicates how many spares are required to replace all the failed components when the system fails. This study considers the number of failed components in a series-parallel system with N subsystems. In particular, it is assumed that each subsystem consists of dependent components. Copulas have been used to model the dependencies between the components. Once the results have been obtained, they are used to find out how to reduce the average cost per unit time in the event of a system failure by selecting the optimum number of components for each subsystem.

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Time-Fractional Diffusion from Two Markovian Hopping-Trap Mechanisms

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We show that the paradigmatic features of anomalous diffusion are also the main features of a (continuous-time) random walk driven by two Markovian hopping-trap mechanisms [1]. In particular, an intermediate regime emerges and it is described by the laws of time-fractional diffusion. If $p \in (0, 1/2)$ and $1 - p$ are the probabilities of occurrence of each Markovian mechanism, then this intermediate regime is characterized by slow-diffusion with parameter $\beta \in (0, 1)$ determined by $\beta \simeq 1 - 1/\{1 + \log[(1 - p)/p]\}$ and the walker distribution follows the corresponding stretched exponential law that is proper of time-fractional diffusion. Moreover, ensemble and single-particle observables of this model have been studied and they match the main characteristics of anomalous diffusion as they are typically measured in living systems. The celebrated transition of the walker's distribution from exponential to stretched-exponential and finally to Gaussian distribution is also displayed together with the Brownian yet non-Gaussian interval. These results provide a physical argument for supporting modelling through time-fractional diffusion in living systems and – on the other hand – they also allow for an interpretation of the tools of fractional calculus. In particular, they highlight the bridging modelling-role of fractional operators supporting Zaslavsky interpretation [2]. Zaslavsky argued that, since chaotic dynamics is a physical phenomenon whose evolution bridges between a completely regular integrable system and a completely random process, fractional kinetic equations and statistical tools arise as modelling methods. In the present approach, fractional diffusion emerges as a mathematical method for bridging two co-existing equilibrium states in a disordered medium.

Acknowledgements

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Spacings-Based Goodness-of-Fit Testing

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One of the important steps before performing any parametric statistical analysis is to conduct a formal goodness-of-fit (GOF) testing. In this talk, we introduce somehow less known GOF testing procedure based on spacings which has been shown to have larger power in some cases in compare to the conventional Empirical Distribution Function (EDF)-based GOF methods. Indeed, GOF testing based on spacings cover a large class of tests including the Greenwood's statistic, the Moran's statistic and the Quesenberry and Miller's statistic.

GOF tests based on higher order spacings and some suggestions for new testing methodologies for the case of censored data will also be discussed.

Key words: Censored data, Empirical distribution function, Goodness-of-fit, Parametric inference, Spacings.

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Development of methodology for automated crop mapping in Greece using Neural Networks and Sentinel-2 satellite imagery

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Reliable and accurate cropland mapping at national, regional and global level is essential within the framework of Sustainable Development, food security and sustainable environmental management. Earth Observation data, collected by satellite sensors of European Union's Copernicus Earth observation programme, provide the opportunity for the development of automated high accurate methods for information extraction at regular temporal intervals. Within the framework of the current study, computational approaches for cropland mapping in Greece using deep learning methods and high spatial resolution Sentinel-2 satellite images of the Copernicus programme were developed and evaluated. The study area was selected within the Regional Unit of Serres where reliable reference data from OPEKEPE (Greek Payment Authority of Common Agricultural Policy (C.A.P.) Aid Schemes) were collected for a complex classification scheme consisting of 20 classes. Furthermore, the effect of different methods of training sample extraction was examined and evaluated, not only in terms of classification accuracy metrics, but also considering classification uncertainty. The experimental design included five supervised machine learning classification algorithms, including a Temporal Convolutional Neural Network (Temporal CNN), a bidirectional Gated Recurrent Unit Neural Network (Bi-GRU), a bidirectional Long Short-Term Memory Neural Network (Bi-LSTM), a combination of a Recurrent and a 2-D Convolutional Neural Network (R-CNN) and finally a Random Forest. The normalized Shannon entropy of the test instances and a variant of the metric Root Mean Square Error (RMSE) were calculated in order to capture the spatial distribution of the classification error. In all these methods, two stratified sampling strategies for the acquisition of the training dataset – pixel-based and object-based – were developed and evaluated. Splitting the data based on the distribution of pixels among classes, the architectures of Temporal CNN and Bi-LSTM had almost equivalent performance in the classification metrics of Overall Accuracy, Cohen's Kappa, Macro Average Precision, Macro Average Recall and Macro Average F1-Score, with the first being effective in classifying both classes of limited size and frequent classes. On the contrary, the neural network R-CNN doesn't manage to reach the average levels of efficiency of the rest four architectures, performing the worst results in rarer classes. When the object-based splitting method was applied, the results were different, with the Bi-LSTM architecture having the highest value of Macro Average F1-Score and subsequently being assessed as the best model. In both splitting approaches, Random Forests failed to keep the values of entropy low in the classification of test instances and had the highest percentage values of the variant RMSE. Thus, the tree-based algorithm, being the only one among the models which ignored the temporal dimension of data, offered more uncertain predictions in comparison with the neural networks. In this study, not only the traditional classification algorithm of Random Forest, but also four deep learning models, whose architectures belong to Temporal Convolutional Neural Networks, bidirectional Gated Recurrent Unit Neural Networks, bidirectional Long Short-Term Memory Neural Networks and combined Recurrent and 2-D Convolutional Neural Networks, were implemented for the classification of multi-spectral satellite images. In this task, the number of classes (crops etc) was relatively high (more than 10). Some of them were specialized types of crops while others were more general, a fact whose effect was investigated in the results. After exploring the influence of restructuring the training set, we suggest that the splitting should be on the basis of the objects' distribution among the classes, despite the higher values of classification metrics when applying the other splitting method. The main reason is the existence of similar spectral values of the pixels being included in the same objects.

The imbalance among the number of instances per class leads us to pay attention to Macro Average F1-Score, with the proposed architecture of Bi-LSTM being this one which achieves the highest value in the case of object-based splitting approach. At the same time, the study proves and justifies why Random Forests in combination with the available data and methods are unable to provide reliable classification results from both perspectives of classification, accuracy and uncertainty. Moreover, the results made it clear that the number of instances belonging to the same class together with their spectral variability can have a significant impact to the values of uncertainty. The whole code of the thesis was created and developed in Python 3.8.5 and R Studio, with the concurrent support of the software packages called Quantum Geographic Information System (QGIS) and diagrams.net.

All the above conclusions can support the transfer of the approach nationwide, for the operational inventory of spatial explicit information over agricultural areas.

A stochastic SIHRD model for the optimization of hospital operation during epidemic outbreaks

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In this paper, we focus on modelling a novel stochastic epidemiological SIHRD (susceptible-infected-hospitalized-recovered-deceased) model for optimizing hospital operations based on a continuous-time Markov process adapted to the characteristics of the epidemic scheme. Several novel stochastic properties are examined, such as the maximum number of simultaneous hospital admissions, the cumulative number of hospitalizations and the joint distribution of total infections and hospitalizations until the extinction of the disease. Theorems and recursive formulas are provided for the efficient computation of the distributions and moments of interest, leading to additional information beyond the mean and standard deviation of the stochastic characteristics. A detailed sensitivity analysis sheds light on the influence of the system's parameters on the tendencies of the studied characteristics.

A Stochastic Particle Extended SEIRS Model with Repeated Vaccination. Application to Real-Data of COVID-19 in Italy

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In this paper, an extended epidemiological particle filter with time-varying parameters is proposed, with the aim of describing the evolution of pandemics. The validity of the model is examined on daily records of COVID-19 in Italy over the extensive period of 525 days, showing remarkable ability in revealing the hidden dynamics of the pandemic. Key findings include estimating rates of asymptomatic carriers, a well-known feature of COVID-19. Unlike other models that use additional states for the asymptomatic carriers, forcing the estimation of this ratio and increasing the complexity of the model, the proposed approach leads to the emergence of the hidden dynamics of COVID-19 without extra computational burden. Additional findings that confirm the appropriateness of the model are the evolution of the time-varying parameters, as well as the resulting variation in the incidence of ICU admissions compared to official records, during the most prevalent infection wave in January 2022. Finally, as the majority of datasets contain observations of the total numbers of recovered and vaccinated cases, a stochastic algorithm is presented for the estimation of the currently recovered and protected by vaccination individuals. Finally, we not only present a novel stochastic epidemiological model and test its efficiency, but also investigate its mathematical properties such as the existence and stability of epidemic equilibria, providing new elements to the existing literature.

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A corrected mutual information estimator for the improvement of mRMR feature selection filter.

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mRMR is a widely used feature selection method that is applied in a wide range of applications in various fields. mRMR adds to the optimal subset the features that have high relevance to the target variable while having minimum redundancy with each other. Mutual information is a key component of mRMR as it measures the degree of dependence between two variables. However, the real value of mutual information isn't known and needs to be estimated. The aim of this study is to examine whether the choice of mutual information estimator affects the performance of mRMR. For this reason, two different variations of mRMR are compared. The first one uses an estimator of mutual information which is based on equidistant partitioning with the cells method, in order to assess the joint probability distribution of two variables. The second one uses a correction of the same mutual information estimator that in a previous study appeared to reduce the bias. The study is performed on time series, generated by linear and non-linear systems. The study carried out showed that the choice of mutual information estimator can affect the performance of mRMR and it must be carefully selected depending on the dataset and the parameters of the examined problem. The application of the corrected mutual information estimator improves the performance of mRMR in the examined setup.

Nonlinear Connectivity as a Driver of Time-Horizon Heterogeneity

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The effect of sample size on the performance of causality measures constitutes an appealing issue when researchers look for causal inference in simulated and real time series. The intensity and the nature of the relationship among variables significantly affects the informational content in small and large data samples. Real high-dimensional systems hide strong interdependences that can arise not only because of direct causal effects but also because of autocorrelation effects within each time series, indirect effects, or common drivers. In a recent joint paper, we highlight the tight linkage between the degree of nonlinearity and the detection of false positive causal couplings in various multivariate systems. We further elucidate this behavior by using financial data in which time horizon seems to crucially determine causal directionality due to the activation of heterogenous trading activity. In the present study, we provide additional evidence that complex connectivity in longer samples helps direct causality measures to identify true positive couplings but at the same time it contributes to the appearance of many false positive cases as the coupling strength intensifies. In the simulation experiment we use both linear and nonlinear multivariate systems, as well as fully and partially conditioned causality measures.

Stochastic Models of Microstructure, Crystallographic Texture and Internal Stress in Polycrystals

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Our contribution is motivated by the analysis of internal stresses arising from the elastic deformation of a polycrystalline metal alloy. The internal stresses determine the mechanical response of the material. Their distribution is driven by the microstructure and the crystallographic texture. Random tessellations are natural mathematical models for three-dimensional polycrystalline microstructures. The grains of the tessellation correspond to the crystals composing the polycrystal. Texture describes the lattice orientation distribution of the crystals. A single lattice orientation could be regarded as a random element with values in the space of all rotations subject to symmetry. The crystal lattice orientations vary from grain to grain and may be stochastically modelled by a joint distribution involving correlations among neighbouring grains. The internal stresses are modelled by a random field whose values are tensors of the second order. We deal with grain-wise averaged stresses to characterize inter-granular stress fluctuations. On the other hand, the standard deviations of stresses within individual grains express behaviour of intra-granular stresses. We propose a statistical method that enables assessing the relationship between stress field and microstructure characteristics. Both spatial and non-spatial dependencies are investigated. The procedure is examined on the considered models and datasets resulting from the polycrystalline materials subjected to external loading.

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Coverage and connectivity in stochastic geometry

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Consider a random uniform sample of size n over a compact d-dimensional region A with smooth boundary and unit volume (or more generally a compact d-dimensional manifold with boundary), with $m \geq d \geq 2$. The coverage threshold T_n is the smallest r such that the union Z of balls of radius r centred on the sample points covers A. The connectivity threshold K_n is twice the smallest r required for Z to be connected. The two-sample coverage threshold $S_{n,m}$ is the smallest r such that Z covers all the points of a second independent sample of size m. These thresholds are random variables determined by the sample, and are of interest, for example, in wireless communications, set estimation, and topological data analysis.

In [1] the first author determined the large-n limiting distribution of T_n, namely (with v denoting the volume of the unit ball in R^d and $|dA|$ the perimiter of A) weak convergence of $nvT_n^d - (2-2/d)\log n - a_d \log(\log n)$ to a Gumbel-type random variable with cumulative distribution function

$$F(x) = \exp(-b_d e^{-x} + c_d |dA| e^{-x/2}),$$

for suitable constants a_d, c_d with $b_2 = 1$, $b_d = 0$ for $d > 2$.

We discuss further recent results on the limiting distributions of K_n and $S_{n,m(n)}$ where $m(n)/n$ tends to a poisitive finite limit for large n. These results take the same form as above with different constants a_d, c_d.

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The Hidden Segmentation Model: an Hidden Markov Model for Segmentation Leveraged on a Prior on the Total Number of Segments

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Given a sequence of real-valued observations, the segmentation problem consists in searching for a set of non-overlapping consecutive intervals where the observations are homogeneous. Segmentation and its dual problem, change point detection, have many applications in fields such as signal analysis, econometrics, neuroscience and bioinformatics.

Hidden Markov Models (HMMs) provide a unifying framework for standard tools in segmentation analysis [1]. These include standard HMMs where hidden states pertain to levels in a fixed set (level-based HMMs), and constrained HMMs where hidden states refer to segment indexes and the total number of segments is fixed (segment-based HMMs) [2]. In this work we provide an extension of the latter, dubbed the Hidden Segmentation Model, which makes it possible to dispense with the Markovian hypothesis.

The standard segment-based model is a HMM where hidden states are positive integers representing the unobserved segments with the only admissible transitions being 0 (no change) or 1 (segment change). In such a model, it is straightforward to incorporate variables counting the total number of segments up to a given position; the resulting probabilistic graphical model can be used to study the posterior distribution of the total number of segments N given the observations [3]. The prior distribution of N crucially depends on the Markov component of the model, and in particular on the geometric sojourn times given by the transition probabilities.

In order to get rid of this constraint, we introduce the hidden segmentation model (HSM), a variant of the segment-based HMM where the prior distribution of N is arbitrarily fixed (for example using a uniform distribution) rather than induced by the Markov component of the model. This model is particularly promising for applications where neither sojourn time nor transitions are consistent with a Markov model.

Inference is based on modified forward/backward recursions with probability generating function (for the number of segments) that can be calculated using efficient polynomial algebra. We validate our HSM by means of simulation studies and compare its performance to the standard approach based on constrained HMMs.

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Covariance Identity for q-Distributions

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In a series of papers, Cacoullos with his students and collaborators established an extended Stein-type identity for the covariance, cov(X,g(X)), and derived several characterization results. In this presentation, within a stochastic q-calculus consideration, a covariance identity for q-Distributions is obtained and a q-type covariance kernel is defined. Some illustrative examples are also discussed in detail.

Acknowledgements

This presentation is dedicated to the memory of Professor T. Cacoullos and his student Associate Professor V. Papathanasiou.

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Some recent results on time-changed stochastic processes and applications

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We present some recent results about stochastic processes with the time changed by means of the inverse of a stable subordinator. We consider the cases of discrete and continuous processes, providing the mean features of such time-changed processes. Moreover, we show the use of such kind of processes in the framework of the applications such as that of queueing theory and of risk theory.

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The Monte Carlo method for the fractional calculus

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The use of the Monte Carlo method for evaluation of fractional-order integrals and fractional-order derivatives is discussed. While fractional-order integration using the Monte Carlo method is straightforward and similar to evaluation of classical integrals, the case of fractional differentiation is more interesting and has been elaborated only recently in [1] and [2]. The main idea is using the Grunwald–Letnikov approximation and interpreting its coefficients as probabilities. Those probabilities turned to be signed probabilities: some are positive, some other are negative. Although this might look unusual, negative probabilities were used in quantum mechanics by such great physicists as E. Wigner, P. Dirac, and R. Feynman, and the mathematical formalism for them goes back to M. Bartlett. We first present the Monte Carlo methods for fractional differentiation of orders between 0 and 1, an in this case all necessary probabilities are of the same sign. For orders above one, some probabilities become negative, and some are necessarily greater than one, and we demonstrate how to deal with them. A MATLAB toolbox [3] implementing the presented Monte Carlo method for fractional differentiation is developed. The presented method allows various further extensions (including, first of all, parallel computations) and applications in various fields, such as fractional-order modeling of material structures and their properties.

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Functional Limit Theorems for Random Walks

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We consider continuous-time critical symmetric branching random walks on a multidimensional lattice $\mathbb{Z}^d$, $d \geq 1$, with the source of particle generation at the origin. We assume that the underlying random walk is symmetric, homogenous by space and irreducible and the birth and death of particles at the source is described by a Markov branching process. One of the main problems is to study the exact form of limit distribution of the particle population at the source. Such problem has been solved for only for some relations between the parameters specifying walking and branching of particles. Based on limit theorems about the distribution of the sojourn time of the underlying recurrent random walk at the origin (see, Aparin, Popov, and Yarovaya, 2021 [1]) we obtain limit theorems distribution of the particle population at the source with finite variance of random walk jumps. At present, random walks with infinite variance of jumps have been much less studied than those with finite variance. In this regard, the theorems for such random walks deserves special attention. For $d = 1$ the limit distribution of the particle population at the source under normalization on the Green function of transition probabilities depends on parameters of system and may have the form of the Mittag-Leffler or the exponential distribution for a recurrent random walk. The talk is based on the joint article by A. Aparin, G. Popov, and E.Yarovaya.

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Mixture models based on a probabilistic analogue of the mean value theorem

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The mean value theorem (MVT) is very popular in calculus. A probabilistic analogue of the mean value theorem (PMVT) for nonnegative continuous/discrete random variables was introduced and studied by Di Crescenzo (1999), providing also applications to various contexts of reliability theory. In this talk, a family of unimodal real valued continuous distributions is introduced, by applying the PMVT and using Stein-type covariance identities. Several mixture models are members of the proposed family, as well as the normal distribution. Applying the PMVT for two normally distributed random variables with the same variance, a new symmetric unimodal distribution is obtained, for which some statistical properties are given. Mixture models for nonnegative discrete random variables are also studied, focusing on Poisson distribution.

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Market maker's optimal limit order book imbalance

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Volume imbalance in a limit order book is often considered as a reliable indicator for predicting future price movements. We confirm this statement by analyzing an optimal control problem in which a market maker controls volumes in the limit order book of a large-tick stock and quotes prices at a half-tick distance from the mid-price. We model the mid-price, which is not a controlled variable, using uncertainty zones. The market maker has information about the underlying efficient price and consequently of the probability of a price jump in the future. By using this information, it is optimal for the market maker to create imbalances which are predictive of price movements. The value function of the market maker's control problem can be understood as a family of functions, indexed by the level of the market maker's inventory, solving a coupled system of PDEs. We show the existence and uniqueness of smooth solutions for this coupled system of equations. In the case of a continuous inventory, we also prove the uniqueness of the market maker's optimal control policy.

Multitype Branching Process with Nonhomogeneous Poisson and Contagious Poisson Immigration.

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In a multitype branching process, immigrants are assumed to arrive according to a nonhomogeneous Poisson or contagious Poisson process (both processes are formulated as a nonhomogeneous birth process with appropriate choice of intensities). We show that the normalized numbers of particles of the various types alive at each instant for supercritical, critical and subcritical cases jointly converge in distribution under those two different arrival processes. Furthermore, some transient expectation results when there are only two types of particles are provided. This is joint work with J.K.Woo (University of New South Wales).

A Two-Sided Control Chart for Monitoring General Inflated Processes

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In this work, a two-sided control chart with runs rules is proposed and studied in the case of monitoring general inflated processes. Usually, the standard attributes control charts (e.g. *c*-chart) for inflated process such as for the zero-inflated Poisson or the zero-one inflated Poisson do not have a lower control limit. Thus, it is not possible to detect a decrease in the process mean level. To overcome this difficulty, we suggest a Shewhart-type chart, supplemented with two runs rules. One of these rules is of type "*k-out-of-k consecutive points*" below a lower warning limit and it is used for detecting decreases in process mean level. In addition, a rule of type "*r-out-of-m consecutive points*" above an upper warning limit is used for improving chart's sensitivity in the detection of small and moderate shifts in the process mean level. The performance of various schemes is examined for several inflated Poisson processes, in terms of *ARL* and *EARL*. Finally, an illustrative example for the use of the proposed schemes in practice is also discussed.

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A Busy Period Analysis of a 2-Queue Polling System with a Threshold-Based Switching Policy

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We study a 2-queue Markovian service system attended by a single server that alternates between the queues following a threshold-based switching policy. Each of the two non-identical and separate queues, denoted Q1 and Q2, is an M/M/1-type queue. When the server attends Q1 (Q2), and the number of jobs in Q2 (Q1) reaches its threshold, a zero-time switchover to the latter queue is exercised. In the case where a served queue becomes empty while the other queue is not, the server Immediately switches to the latter queue. We first derive the Laplace-Stieltjes transform of the length of a busy period and then analyze the steady state probabilities of the 2-dimensional state space. A discrete time Markov chain is embedded at server's switching instants and the steady state distribution follows from the semi Markov renewal theory.

Large deviations for a non-markovian particle system

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In this talk we discuss the stochastic Kuramoto model with delays. The model, a system of stochastic ODE's, is inspired by the interaction between neurons, which has the feature that one neuron interacts with the past of other neurons. The goal is to prove the law of large numbers and large deviations as the number of particles increases. The limit object is described by a path-dependent McKean-Vlasov PDE. Based on joint work with Rangel Baldasso (PUC Rio) and Alan Pereira (UFAL).

A Stochastic Control Problem With Linearly Bounded Control Rates In A Brownian Model.

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We will discuss the result of [1] in which we optimize the expected value of discounted dividends up tuo ruin. This work applies fluctuation theory on a problem in the realm of de Finetti's optimal dividends problem [2].

In our work, the dividend rate is bounded by a linear function of the controlled process and the optimal dividend strategy leads to a controlled process which is a refracted process. Alternating between an arithmetic Brownian motion and a mean-reverting Ornstein-Uhlenbeck process. We will see how the solution of our problem bridges the gap between de Finetti's classical problem and the study of [3] about suboptimal dividend strategies deemed more realistic. An exogeneous parameter can be selected so that the optimal strategy is either closer to the more realistic strategy studied in [3] or provides a higher expected value for the dividends.

We will also discuss advances on a similar problem including capital injection and a more general family of controls.

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Eliminating Sharp Minima from SGD with Truncated Heavy-Tailed Noise

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The empirical success of deep learning is often attributed to the stochastic gradient descent (SGD) algorithm's mysterious ability to avoid sharp local minima in the loss landscape, as sharp minima are known to lead to poor generalization. Recently, evidence of heavy-tailed gradient noise was reported in many deep learning tasks, and [1] Simsekli et al. (2019) argued that SGDs are capable of escaping sharp local minima under the presence of such heavy-tailed gradient noise. This shed an exciting new light on the mystery, but when heavy-tailed gradient noises are present, the pure form of SGD analyzed in [1] often fails to train DNNs, and one needs to employ a variant of SGD, where gradients are truncated above a fixed threshold. In this talk, we analyze the global dynamics of such a variation (often called gradient clipping) and show that they are fundamentally different from those of the pure form of SGD. In particular, this variant avoids sharp minima in a stronger sense: it effectively eliminates sharp local minima entirely from SGD's training trajectory. We prove this by rigorously establishing sample-path large deviations and Eyring-Kramers-type first exit time analysis for heavy-tailed SGDs. Further, we prove that under some structural conditions, the dynamics of heavy-tailed truncated SGD with small learning rates closely resemble those of a continuous-time Markov chain that never visits any sharp minima. Real data experiments on deep neural networks confirm our theoretical prediction that SGD with truncated heavy-tailed gradient noise finds flatter local minima and achieves better generalization.

This talk is based on the joint work [2] with Xingyu Wang and Sewoong Oh.

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Negative dependence notions and tournament scores

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Negative dependence of sequences of random variables is an interesting characteristic of their distribution and a useful tool for studying various asymptotic results, including central limit theorems, Poisson approximations, the rate of increase of the maximum, and more. In the study of probability models of tournaments, negative dependence of participants' outcomes arises naturally, with application to various asymptotic results. In particular, the property of negative orthant dependence was proved in several articles for different tournament models, with a special proof for each model. We unify and simplify these results by proving a stronger property: negative association. We also present a natural example of a knockout tournament where the scores are negatively orthant dependent but not negatively associated. The proof requires a new result on a preservation property of negative orthant dependence that is of independent interest.

From single cells to microbial consortia and back: stochastic chemical kinetics coupled to population dynamics

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At the single-cell level, biochemical processes are inherently stochastic. Such processes are typically studied using continuous-time Markov chain models governed by a so-called chemical master equation (CME). The CME describes the time evolution of the probability distribution over system states and has been a tremendously helpful tool in shedding light on the functioning of cellular processes. However, both in nature and the majority of lab experiments, single cells are not living in isolation but are part of a growing population or community. In such contexts, stochasticity at the single-cell scale leads to population heterogeneity and cells may be subject to population processes, such as selection, that drive the population distribution away from the probability distribution of the single-cell process. Here, I will present our work on augmenting the CME to construct multi-scale models that capture coupled dynamics of stochastic single-cell and population processes [1]. I will then present an engineered optogenetic recombination system for yeast cells that allows one to partition isogenic yeast populations into different cell types via external application of blue light the population [2]. Finally, I will show how multi-scale models based on an augmentation of the CME can be used to predict emerging yeast population dynamics from a single cell model of the recombination system [3].

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Training neural networks with Langevin based algorithms and key applications.

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We present a new class of Langevin based algorithms, which overcomes many of the known shortcomings of popular adaptive optimizers that are currently used for the fine tuning of deep learning models. Its underpinning theory relies on recent advances of Euler's polygonal approximations for stochastic differential equations (SDEs) with monotone coefficients. As a result, it inherits the stability properties of tamed algorithms, while it addresses other known issues, e.g. vanishing gradients in neural networks. Key applications of this new approach will be discussed.

Public Health Monitoring Using Control Charts Based on Convex Hull

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In the last three years, the coronavirus pandemic showed up, even more, the significance of continual systematic collection, analysis, interpretation, and dissemination of health data for early detection of disease outbreaks. For the timely and efficient detection of infectious or non-infectious disease outbreaks, we should consider both spatial and temporal dimensions. Of interest are global changes in the number of new disease events on time in a specific broader area and/or hotspots of disease events in smaller areas which may evolve into outbreaks or even into pandemics, such as the coronavirus pandemic. In this talk, we propose a monitoring procedure through which we simultaneously monitor the number and the spatial distribution of disease events. The proposed method exploits a flexible and efficient mathematical tool, the convex hull, in conjunction with control charting procedures. The numerical illustration showed, that the proposed method has excellent performance under different outbreak scenarios.

Urn Processes with Graph-based Interactions

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We consider a general two-color urn process with graph-based interactions such that the reinforcement in each urn depends on the compositions of balls in the urns at the neighbouring vertices of the graph. We will discuss the asymptotic properties of the fraction of balls of either colour and classify the limiting behaviour based on the underlying graph and the type of reinforcement. We will also discuss the extension to vertex-dependent reinforcement. This is based on joint work with Dr. Gursharn Kaur.

Stochastic Maximum Principle For A Constraint Nonzero-Sum Game Application: Bancassurance

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We develop an approach for two player constraint nonzero-sum stochastic differential games, which are modeled by Markov regime-switching jump-diffusion processes. We provide the relations between a usual stochastic optimal control setting and a Lagrangian method. In this context, we prove corresponding theorems for two different type of constraints, which lead us to find real valued and stochastic Lagrange multipliers, respectively. Then, we illustrate our results to formulate the Nash Equilibrium of a cooperation between a bank and an insurance company, which is a popular, well-known business agreement type, called Bancassurance. In this work, we apply stochastic maximum principle to derive the indicated relation and the mathematical set-up.

Acknowledgements

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Scaling Limits and Universality: Critical Percolation on Weighted Graphs Converging to an L^3 Graphon

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Consider critical bond percolation on a sequence of edge-weighted graphs converging to an L^3 graphon. We use a general universality principle to establish the scaling limit of these random graphs viewed as metric measure spaces. This gives the first such result where no assumptions on the particular functional form of the graphon is required. As a corollary, we obtain the critical metric scaling limit of the RGIV model (random graphs with immigrating vertices) studied by Aldous and Pittel.

Acknowledgements

Based on joint work with Jnaneshwar Baslingker, Shankar Bhamidi, Nicolas Broutin, and Xuan Wang.

Reliability Modelling for Systems Degrading in Markovian Environments with Protective Auxiliary Components

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Studies of reliability modeling for systems operating in dynamic environments are receiving increasing research attention, but most of the existing studies focus on single-unit systems. More challenging is for multi-component systems, as the existing of dependence between different components. In this paper, we study a special multi-component system with both main and auxiliary components operating in dynamic environments. For such systems, main components perform the essential function of the system under the protection of auxiliary components. Environmental changes influence the failure rate of auxiliary components. If the auxiliary components fail, the degradation process of the main components which lose protection would be also affected by environmental changes. A reliability model is developed for this system, the distribution of system reliability is first derived based on this model. Next, we determine the maintenance policy in which opportunistic inspections of auxiliary components are considered, and the system availability and long-run average cost are then derived for the scenario where evolution of the environments only occurs when the system is working. Finally, we conduct a numerical example and sensitivity analysis for some parameters to illustrate the results.

Information-based causality in high-dimensional discrete-valued time series

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Granger causality or simple causality analysis aims at estimating the interactions of the observed variables and subsequently the connectivity structure of the observed dynamical system or stochastic process. Whether the observations are in the form of discrete-valued or continuous-valued time series, information theory offers a model-free framework for nonlinear causality analysis. The main focus is on direct causality from driving to response variable or subsystem conditioning on the other observed variables or subsystems. However, the estimation of the conditional mutual information (CMI) deteriorates as the dimension of the conditioning term increases, i.e., the number of observed variables increases. For continuous-valued high-dimensional time series, dimension reduction in the CMI by appropriate selection of the most relevant lag variables of all the observed variables to the response is implemented as a progressive scheme giving the so-called mixed embedding vector of the most relevant lag variables under a termination criterion. The presence of lag components of the driving variable in this vector implies direct causal (driving-response) effect and this causality measure is called partial mutual information from mixed embedding (PMIME). In this work, the PMIME is appropriately adapted to discrete-valued multivariate time series (symbol sequences), called discrete PMIME (DPMIME) [1]. Appropriate estimation of discrete probability distributions and CMI for discrete variables is implemented in DPMIME. Further, asymptotic distribution of the estimated CMI is derived allowing for a parametric significance test for CMI in DPMIME, whereas for PMIME there is no parametric test for CMI and the test is done using resampling. The parametric significance test for CMI in the progressive algorithm of DPMIME is compared favorably to the corresponding resampling significance test. The performance of DPMIME is demonstrated in a simulation study, where the discrete-valued time series are (a) formed by discretizing time series from continuous-valued chaotic dynamical systems, (b) generated from a multivariate Markov chain with transition probabilities estimated on discretized time series in (a). Further, high-dimensional continuous-valued time series are generated from coupled dynamical systems with random, small-world and scale-free coupling structure, which are then discretized to compare directly DPMIME to PMIME. The results of the simulations suggest the accuracy of DPMIME in the estimation of direct causality converges with the time series length to the accuracy of PMIME. Moreover, the DPMIME is found to perform well even in high dimensional systems of 25 subsystems provided the sparsity of the connectivity network. An application to connectivity networks of financial world market is finally presented.

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SIR EPIDEMICS PERTURBED BY FELLER PROCESSES

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SIR epidemic models describe the spread of an infectious disease in a closed homogeneously mixing population subdivided into three classes: the susceptibles, the infected individuals and the removed cases. The class of susceptibles contains the healthy individuals who can become infected. When contaminated, a susceptible is contagious for a random duration, called the infectious period. During this period, he can transmit the disease to the susceptibles, independently of the other infected individuals. Then he becomes a removed case and plays no further role in the spread of the epidemic.

The SIR process which received the most attention in the literature is called the general epidemic model. It assumes that the infectious periods and the intervals between two successive contaminations are exponentially distributed. In this talk, we consider an extension of the general epidemic in which the contamination and removal rates are no longer constant. Instead, they are represented by a Feller process. When an individual gets infected, a version of this process starts to govern his period: the contamination and removal rates are functions of the state occupied by his infection process.

We use a martingale approach to determine the exact final epidemic outcome, that is, the state of the population when there are no more infected individuals. We derive the distribution of two statistics: the ultimate number of susceptibles and the final severity, a measure of the total cumulative cost due to all infected individuals that emerged during the course of the epidemic. To conclude, we present some particular cases in more details.

A Dual Hidden Markov-Change Point Analysis Approach for Link Quality Detection in Wireless Networks

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Smart-cities environments are characterised by challenging and dynamic network conditions, such as time-varying, or even, intermittent connectivity performance among the network devices. Consequently, it is of paramount importance to rapidly detect and respond to changes on link connectivity in order to ensure reliable and stable communication performance, and, identify potential security vulnerabilities. The existing literature considers the problem of link quality detection, although not without shortcomings: there is a research gap on resource constraints and joint detection of different levels of connectivity dynamics.

This paper targets these limitations by introducing a lightweight and online link detection scheme, based on non-parametric change point (CP) analysis and hidden Markov modeling (HMM), that monitors quality of service metrics affected by connectivity performance (e.g., delay or packet loss ratio). The proposed detector enables the identification of both long-scale and short-scale connectivity changes, by employing CP and HMM, respectively. More precisely, first an off-line cumulative sum (CUSUM) procedure is employed to define an initial (stationary) training period. During the training phase, the model parameters of the HMM are estimated and the statistical characteristics of the time-series are extracted. Next, a sequential CUSUM detector is applied in parallel with an HMM to distinguish between reliable and unreliable time instances over the specific stationary time period, until an on-line CP is detected. If a CP is estimated, the procedure collapses and a new training phase has to be determined. The procedure is iterated. In other words, the sequential CP detects the major connectivity transitions, and, within each transition, HMM monitors the short-term evolution of the link (which is infeasible through the CP detector).

The proposed integrated algorithm is assessed over real delay measurements provided through the indoor w-iLab.t Fed4FIRE+ testbed.

Multi-type Sevastyanov Branching Processes and Application in Cancer Research

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We define the novel continuous-time branching process model that is the Multi-type Sevastyanov Branching Process through probabilities of Mutation between types (MSBPM). The MSBPM can be considered as a relative of the classical multi-type Sevastyanov branching process. The novel characteristic of the MSBPM, with respect to the classical formulation in is the use of probabilities of mutation (a particle is called a "mutant", if it is of type that is different from the type of its mother particle) between types. More speciffically, through the use of probabilities of mutation, effectively, we decompose the classical probabilities for a particle of type i of age u to transform into a certain number of particles at the end of its lifespan into two components.

The use of probabilities of mutation opens the way for applications of the MSBPM into many biological contexts. Most notably, the MSBPM is well suited for modeling biological populations under stress that face certain extinction unless a "beneficial" mutation occurs (or a combination of mutations occur), leading to supercritical behavior. Such situations are of interest in the areas of cancer modeling and treatment, spread of viruses, vaccination campaigns, control over agricultural pests and others.

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Testing for determinism in symbolic sequences: Is Bach's brain a Markov chain?

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Joint work with Jack Moore and Debora Correa.

There are many interesting ways to study time series from continuous deterministic systems, including via the ubiquitous Takens' Embedding Theorem. One recent approach that has gained popularity circumvents embedding by create dynamically relevant symbolic representations of system states which then allow one to represent the dynamics of the system as a network of transitions between states or, almost equivalently, a Markov chain. In such situations an interesting question arises, namely, how does one create a randomised proxy for a symbolic system that allows one to test the Markov hypothesis of given order? Or, what does a random sequence of symbolic states from a time series of a dynamical system look like. With this motivation we will present several possible avenues to achieve this and, along the way, apply these techniques to symbolic time series corresponding to musical score and to financial market movements.

Speed-based Measures of Signal-to-Noise Ratios

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We present an innovative method to measure the signal-to-noise ratio in a Brownian motion model. That is, the ratio of the mean to the standard deviation of the Brownian motion. Our method is based on a method of moments estimation of the drawdown and drawup speeds in a Brownian motion model, where the drawdown process is defined as the current drop of the process from the running maximum and the drawup process is the current rise of the process above the running minimum respectively. The speed of a drawdown of K units (or a drawup of K units) is then the time between the last maximum (or minimum) of the process and the time the drawdown (or drawup) process hits the threshold K. We target the problem of estimating the ratio directly rather than estimating the Uniformly Minimum Variance Unbiased Estimator (UMVUE) of the mean and dividing that by the UMVUE of the standard deviation. Numerical results show that our estimator consistently outperforms the traditional estimator which is the ratio of the UMVUE of the mean to the UMVUE of the standard deviation, especially in the case when the noise (i.e., the standard deviation) is significantly stronger than the signal (i.e., the mean).

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Blotto Game with Testing (The Locks, Bombs and Testing Model)

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We present a Defense/Attack resource allocation model, where the Defender has some number of ``locks" to protect *n* vulnerable boxes (sites), and the Attacker is trying to destroy these boxes, having some number of ``bombs", which can be placed into the boxes. Similar models were studied in game theory - e.g. (Colonel) Blotto games, but our model has a feature that is absent in the previous literature. Here, the Attacker tests the vulnerability of all sites before allocating her resources. However, these tests are not perfect, i.e., a test can give a positive result for a box without a lock and a negative result for a box with a lock. We give a full solution for some important special cases of a general Locks-Bombs-Testing (G-LBT) model, where sites have distinct values. These results complement previously known results for a symmetrical LBT model, where all parameters are the same for each box. We also outline an approach to a solution for the G-LBT model.

The inspiration for this model was the paper by Sonin K., Wright A., 2017-2022. Rebel Capacity and Combat Tactics. Working Paper \# 2018-74.

Information Concepts in Reliability Analysis

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In this talk we present use of information theoretic methods in reliability analysis and discuss how models and inferences are developed and decisions are made in this framework. We present a range of Bayesian information measures for reliability analysis and discuss their use in failure model selection, prior specification, prediction, assessment of reliability importance and optimal design of life tests.

Affine urns and their applications to hyperrecursive trees

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The affine urn model is a structure such that the replacement criteria is based on a linear combination of the balls sampled within a draw. These models prove useful in graph theory, providing the foundation for an extension known as the hypergraph: a generalization of graphs to which we have vertices along with hyperedges consisting of collections of vertices. We take the well-studied structure of the recursive tree and apply its framework within the context of hypergraphs to form hyperrecursive trees, an area that shows promise in network theory and beyond. We investigate the hyperrecursive tree through its local containment profile, which observes the number of hyperedges that contains a given vertex, and its global containment profile, observing the number of vertices found within a particular containment level. We then establish an asymptotically multivariate normal distribution for the number of vertices for the first k containment levels. This is joint work with Hosam Mahmoud and Srinivasan Balaji (The George Washington University).

Load-sharing models in the study of random permutations, minima within subsets of random variables, and related paradoxes

Fabio L. Spizzichino

We start by considering a vector $\mathbf{X}\equiv(X_1,\dots,X_m)$ of, generally interdependent, non-negative random variables satisfying the *no-tie* condition $\mathrm{P}(X_i = X_j) = 0,\ \forall i \neq j$. Denoting by $X_{1:m},\dots,X_{m:m}$ the corresponding order statistics, and letting $[m] \equiv\{1,\dots,m\}$, we consider both the $[m]$-valued random variables $J_1,\dots,J_m$ defined by $J_h = i \Leftrightarrow X_{h:m} = X_i$ and the family

$$\mathcal{A}\equiv \{a_j(A) \mid A \subseteq \{1,\dots,m\}, j \in A\},$$

where $a_j(A) := \mathrm{P}(\min_{i\in A} X_i = X_j)$. The joint probability distribution of $\boldsymbol{J} \equiv (J_1,\dots,J_m)$., denoted by $\boldsymbol{P_J}$, is a probability distribution over the set of permutationsof 1, ..., m and the elements of $\mathcal{A}$ are determined by $\boldsymbol{P_J}$.

In the first part of the talk I will point out different types of paradoxes that may emerge when comparing, for the different subsets A⊆ [m], the probabilities $a_j(A)$. It will be noticed furthermore a complete analogy between such a class of paradoxes and the class of those which emerge within some standard contexts of voting theory.In this respect, it can be argued that such analogy should not come as a surprise. It will shown in fact that a sort of isomorphism exists between the voting situations, considered in those contexts of voting theory, and the probability measures $\boldsymbol{P_J}$ when their probability masses are rational numbers.

Based on these arguments, a second part of the talk will be devoted to discussing the meaning and the role of the system of multivariate conditional hazard rates within a related analysis of the distributions $\boldsymbol{P_J}$, when the joint distribution of $\mathbf{X}$ is absolutely continuous. As well known such a system provides in that case a method, to describe the latter joint distribution, which is alternative to the one based on joint survival function, joint density function, marginal densities, and survival copulas.Such a method can be specially convenient in the analysis of the distribution $\boldsymbol{P_J}$ and of the distribution of minima among interdependent lifetimes (see [1]). Under that description of joint distribution, Load-sharing emerges as a natural condition for defining very simple special cases. As it may be then expected, the condition of Load-sharing leads to a significant simplification to the analysis of the distribution $\boldsymbol{P_J}$ and of the family $\mathcal{A}$. As one main purpose of this talk I aim to highlight the relevance of such a circumstance in obtaining results which have been presented in the recent paper [2].

Acknowledgements

Joint work with Emilio De Santis at Sapienza University, Rome.

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Continuous-time Equilibrium Returns in Markets with Price Impact

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We consider a diffusion financial market where the assets' returns are derived endogenously in a non-competitive equilibrium transaction among strategically behaved traders. Under quadratic preferences and random endowments, we study the equilibrium returns in markets with and without frictions. Traders act strategically by taking into account the impact that their orders have to the equilibrium returns. In the frictionless case, we derive a unique equilibrium at which traders' demand schedules reveal different hedging needs than the true ones, which in turn makes non-competitive equilibrium returns deviate from the competitive ones. When frictions are included, we consider the simplified case of deterministic endowment shocks and derive the unique equilibrium through a system of second order ODEs. While equilibrium returns under frictions differ from the frictionless ones, they coincide at expectation when investors have the same risk aversion and there is no noise traders.

New Criterion for Moment Determinacy of Probability Distributions via Maximum Entropy

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The discussion will be on probability/statistical distributions and their properties expressed in terms of the positive integer order moments. The main, and classical, question is about the uniqueness (M-determinacy) and non-uniqueness (M-indeterminacy) of a distribution based on the knowledge of the whole moment sequence. I will start with a summary of conditions, which are necessary and sufficient. They are expressed in terms of the limit of the minimal eigenvalues of increasing sequences of large Hankel matrices, and it is very difficult to check and deal with them, [1]. This is why a great attention was and is paid to reasonably checkable conditions which are only sufficient or only necessary for either M-determinacy or for M-indeterminacy, [2], [3]. It may happen, however, that none of the conditions can be checked, we have in our disposal the moment sequence, e.g., the sequence of empirical moments, and want to make a conclusion about the distribution as being M-determinate or M-indeterminate. In such a case the idea is to follow the Maximum Entropy approach, [4], [5], [6]. Based on the first n moments, n is a fixed integer, we construct the Maximum Entropy approximant for the unknown density function. Then we calculate the entropy of the approximant, and show that there are exactly two possibilities, the limit is equal to minus infinity, or it is more than minus infinity. This is the key point: these two possibilities exactly correspond to the conclusion that the distribution is either M-determinate or M-indeterminate.

The Maximum Entropy approach is both, interesting from theoretical point of view, and significant for applications in different areas.

Some of the results in this talk are joint work with G.D. Lin and A. Tagliani.

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Comparisons between Systems with Two-Component Subsystems

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We consider systems that have n independent two-component subsystems. The lifetimes of the components from a subsystem are dependent random variables, with the same bivariate distribution for all the subsystems. We suppose that the failure of the system can be provoked only by the components from the first place and in the moment of failure the components from the second place can give important information that can decide what will happen with the system (e.g. to be repaired or discarded). For such systems we determine some information measures and make some comparisons that can assist in making a decision.

Nonstationary Financial Risk Factors and Macroeconomic Vulnerability for the United Kingdom

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Tracking the build-up of financial vulnerabilities is a key component of policy aimed at attaining financial stability. As such, monitoring and quantifying systemic stress is a key exercise of macroprudential policy. Due to the complexity of the financial system, this task is daunting, and there have been several proposals on how to manage this goal. One way to do this is by the creation of indices that act as a signal for the policy maker. A natural candidate to create these indices is factor modelling whereby one compresses available information from a rich set of variables into a few factors.

While factor modelling in finance and economics has a rich history, most of the applications tend to focus on stationary factors. Nevertheless, financial stress (and in particular tail events) exhibit a high degree of inertia. Modelling this with a stationary framework will only allow us to track sudden surges in financial stress, which is equivalent to tracking the start of a financial crisis. Another weakness of stationary factor models is that, due to its stationary nature, such measures tend to revert to the mean very quickly unless one allows for heteroskedasticity. Furthermore, stationary factor models are not capable of tracking gradual build-up of stress. To amend this, this paper advocates moving away from the stationary paradigm and instead proposes nonstationary factor models as measures of financial stress.

Key advantage of a non-stationary factor model is that while some popular measures of financial stress describe the variance-covariance structure of the financial stress indicators, the new index can capture the tails of the distribution. We argue that this is a key advantage of the construction, as turbulent periods are best characterised as tail events.

While the advantages of a nonstationary factor model for tracking financial vulnerabilities is clear, it is not trivial to construct such a measure on account of spurious correlation. It is also clear that a limit theorem is needed to relate them, which may not exist if the variables are nonstationary. In particular, the empirical mean and variance of nonstationary time series need not be constant.

This paper will offer an overview of how to construct nonstationary dynamic factors of financial stress. To showcase the method, the paper will construct a stress index for the United Kingdom.

Best Arm Identification in Stochastic Bandits

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This paper focuses on best arm identification (BAI) in stochastic multi-armed bandits (MABs) in the fixed-confidence, parametric setting. In such pure exploration problems, the accuracy of the sampling strategy critically hinges on the sequential allocation of the sampling resources among the arms. The existing approaches to BAI ad- dress the following question: what is an optimal sampling strategy when we spend a β fraction of the samples on the best arm? These approaches treat β as a tunable parameter and offer efficient algorithms that ensure optimality up to selecting β, hence β−optimality. However, the BAI decisions and performance can be highly sensitive to the choice of β. This paper provides a BAI algorithm that is agnostic to β, dispensing with the need for tuning \beta, and specifies an optimal allocation strategy, including the optimal value of β. This is achieved by (eventually) sampling from the set of under-sampled arms, which is shown to ensure the almost sure convergence of the sampling proportions to the optimal allocation. Furthermore, the existing relevant literature focuses on the family of exponential distributions. This paper considers a more general setting of any arbitrary family of distributions parameterized by their mean values (under mild regularity conditions).

Boundary Crossing of Delayed Brownian Motion and The Non-Local Heat Equation on a Time-Dependent Domain

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We first briefly introduce the theory of semi-Markov processes. In particular we discuss a general theory to construct semi-Markov processes by means of a suitable random time-change. A prototype example of this theory are processes X(t) for X(t):= M(L(t)) where M= M(s) is Feller process and L(t) is the inverse (hitting-time) process of a subordinator. Then we describe, in general, the interplay of these semi-Markov processes with non-local equations.
We will focus, in particular, on a non-local (in time) heat equation on a time-increasing parabolic set whose boundary is determined by a suitable curve. We provide a notion of solution for this equation and we study well posedness under Dirichlet conditions outside the domain. A maximum principle is proved and used to derive uniqueness and continuity with respect to the initial datum of the solutions of the Dirichlet problem. Existence is proved by showing a stochastic representation based on the delayed Brownian motion (a suitable semi-Markov process) killed on the boundary.

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This is a joint work with G. Ascione (University of Naples Federico II) and P. Patie (Cornell University).

From Semi-Markov Evolutions to Scattering Transport and Superdiffusions

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We consider random evolutions driven by a class of semi-Markov processes. The expectation of such evolutions is shown to solve abstract Cauchy problems, which is non-local in time and space. Further, the abstract telegraph (damped waves) equation is generalized to this semiMarkov setting.

Particular attention is devoted to semi-Markov models of scattering transport processes which can be represented through these evolutions. It turns out that the Cauchy problem in this case is a direct (non-local) generalization of the linear Boltzmann equation. In particular, random motions with infinite mean scattering times are considered and their scaling limit is proved to converge to a super-diffusive process.

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On the Effect of Dependence on Random Lifetimes of Systems with Redundancies

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The dependence of random lifetimes of components in a system with redundancies can have a significant impact on the overall reliability of the system. Dependency refers to the extent to which the component lifetimes are correlated with each other. This occurs when multiple components in the system are affected by a common cause, such as a power outage or a natural disaster. To address the issue of dependence in a system, it is important to carefully consider the design of the system and to use appropriate techniques to model the dependencies and analyze the reliability of the system.

On the other hand, redundancy is an important concept in the design of reliable systems. In general, the reliability of a coherent system with redundancies is higher than that of a system without redundancies. Redundancies can be implemented at different levels in a system. In fact, redundancy allocation can be done at both the component level and the module level, depending on the specific system being considered and the goals of the redundancy design.

In this talk, we present a new model to study redundancy mechanisms at multiple levels for systems with dependent components or modules. To account the potential dependencies among the components or modules within a system, we use Sklar's copula representation, which allows us to express the joint distribution of the system variables as a function of their marginal distributions and a copula function that describes the dependence structure among them. This approach allows us to obtain several general results under different assumptions. By considering different scenarios, we can identify the best redundancy options for a given system. The results presented in this talk have been recently published in [1].

Acknowledgements

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On the reliability structures with two common failure criteria and cold standby redundancy

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In the present work we investigate the family of consecutive-type systems with two common failure criteria. The effect of adding cold standby redundancy to the system is evaluated at both system level and components level. For each member of the aforementioned class of reliability structures considered, we determine its survival function, Mean Time to Failure, Conditional and Unconditional Mean Residual Lifetime by the aid of the corresponding signature vector. In addition, some stochastic orderings between the lifetimes of the consecutive-type structures considered are also provided. Based on the numerical investigation carried out, we shed light on the performance of the underlying enhanced systems with cold standby redundancy.

Acknowledgements

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Granger causality among economic indices of industry in Greece

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This study was made with support from and collaboration with the Hellenic Statistical Authority (ELSTAT). The purpose of the study was to identify direct Granger causality among the following Greek industry indices: Producer Price Index in Industry, Import Price Index in Industry, Industrial Production Index and Turnover Index in Industry. Linear and nonlinear correlation and causality measures were used on time series records of these four indices, where the correlation measures were the Cross Correlation (linear) and Cross Mutual Information (nonlinear) and the causality measures were the Grander Causality Index GCI (linear, bivariate), the Conditional Granger Causality Index CGCI (linear, multivariate), the Transfer Entropy TE (nonlinear, bivariate), the Partial Transfer Entropy PTE (nonlinear, multivariate) and the Partial Mutual Information from Mixed Embedding PMIME (nonlinear, multivariate). To consider temporal changes in causal effects among the variables, we also split the record to two and five periods. To assess the significance of the results, the performance of the causality measures was tested on time series of the same lengths as the original data from generating stochastic processes (linear and nonlinear) derived by fitting with constraints on the real time series. The results of the simulation study suggested that the measures CGCI, PTE, and PMIME rarely detected non-existing causal relationships, the measure TE was less effective and the measure GCI effectively identified most causal relationships in linear systems. Guided by the findings of the simulation, the trusted causality estimation on the four industry indices were concluded. Concretely, it was concluded that a) the Producer Price Index affects the Industrial Production Index and the Turnover Index, b) the Import Price Index affects the Producer Price Index, the Turnover Index, and, possibly, the Industrial Production Index, and c) the Turnover Index affects the Industrial Production Index. lication in Financial Markets, Entropy 25(2), 370

Analysis of a multi-level manpower model under different circumstances

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In this work a mathematical model in a multi-level manpower planning setting is presented and analyzed incorporating the divisions of an organization's personnel into several homogeneous groups. The proposed framework builds upon recent research to develop, via discrete and continuous time scale, a departmental model encompassing employees flows within departments (intra-departmental transitions), as well as transfers among departments (inter-departmental transitions). We elaborate on functional forms by studying the system's equilibrium behavior under various conditions and properties. The proposed modelling structure is accompanied by cost and stocks (personnel) objectives which are set and, in the sequel, could be achieved by controlling either the recruitment policy or the allocation policy of employees transferred to other departments (or both).

The Failure Rate for the Convolution of Two Distributions One of Which has Bounded Support

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We study the behavior of the failure rate associated with the distribution of a random variable of the form $X = Y + U$, where Y, U are independent and U has bounded support. First, we obtain monotonicity results and bounds for the

failure rate of X where U has a uniform distribution and, in particular we show that, asymptotically, the failure rates of X and Y tend to the same limit. Some of the results are generalized for the case where the distribution of U is not uniform, but has bounded support. Further, we show that if the failure rate of a nonnegative variable X is constant in some interval (L, ∞), then X can be written as the sum of two independent random variables, one of which is

exponential and the other (which is not necessarily uniform) has support $[0, L]$.

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Windings Of Planar Stochastic Processes And Applications

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During the last few decades, two-dimensional (planar) processes have attracted the interest of many researchers. This happens both because of the richness of the behavior of their trajectories from a theoretical point of view and because their study turns out to be very fruitful in terms of applications (e.g. in Biology, in Finance, but also in other fields).

A reason for that is because planar processes involve the study of exponential functionals e.g. of Brownian motion, which are very common quantities in Mathematical Finance

These exponential functionals are strongly related to the exit time from a cone of planar Brownian motion (through its windings), which finds applications in Biology.

This talk focuses on the fine study of trajectories of planar processes, and in particular on the the way these processes move around the origin, widely known as windings.

We will survey several results concerning windings of two-dimensional processes and the distribution of (random) exit times from a cone.

The processes in discussion will include planar Brownian motion (BM), complex-valued Ornstein-Uhlenbeck (OU) processes and planar stable processes. We will first characterize the distribution of these exponential functionals via Gauss-Laplace transforms and then we will be interested in the asymptotic study of the processes, i.e. for the large and for the small time scale including Spitzer's asymptotic Theorem for each case.

Then, we will turn our interest to applications including the pricing of Asian options and the rotation of a planar polymer.

For obtaining the above mentioned results, our starting point will be the skew-product representation. We will also introduce Bougerol's celebrated identity in law which is very useful. However, this approach cannot be applied to the case of planar stable processes.

For the latter, we will use firstly new methods invoking, firstly, the continuity of the composition function and, secondly, new techniques from the theory of self-similar Markov processes together with the so-called Riesz-Bogdan-Zak transform which gives the law of the stable process when passed through the spatial Kelvin transform and an additional time change.

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Cost-efficient Payoffs under Model Ambiguity

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Dybvig (1988a,b) solves in a complete market setting the problem of finding a payoff that is cheapest possible in reaching a given target distribution ("cost-efficient payoff"). In the presence of ambiguity the distribution of a payoff is however no longer known with certainty. We study the problem of finding the cheapest possible payoff whose worst-case distribution stochastically dominates a given target distribution ("robust cost-efficient payoff") and determine solutions under certain conditions. We study the link between "robust cost-efficiency" and the maxmin expected utility setting of Gilboa and Schmeidler, as well as more generally with robust preferences in a possibly non-expected utility setting.

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Bayesian analysis of temporal changes in the probability distribution of seismic parameters and links with the seismic cycle

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In the frame of nonextensive statistical mechanics, the q-exponential probability distribution arises from the maximization of the Tsallis entropy under appropriate constraints [1]. The Tsallis entropy, unlike the Boltzmann-Gibbs entropy, is non-additive and more suitable to describe complex systems far from equilibrium and with possible long-range interactions. These features have suggested several studies on earthquakes as complex system (e.g. [2] and references therein). In this study we assume the q-exponential probability distribution for the analysis of the temporal variations of some seismic parameters (e.g. magnitude, spatial location of the epicentres) in earthquake sequences of Italy. Bayesian inference is performed by processing data on sliding time windows, such that each window has a fixed number of events (100 in this study) and shifts at each new event [3]. Other distributions (e.g. tapered Pareto, generalized gamma) are also considered and the best fitting distribution in each time window is selected by comparing the estimated values of the posterior marginal likelihood (Fig. 1). We found that the best fitting distribution varies over time and can be a further indicator of the activation state of the systems [4].

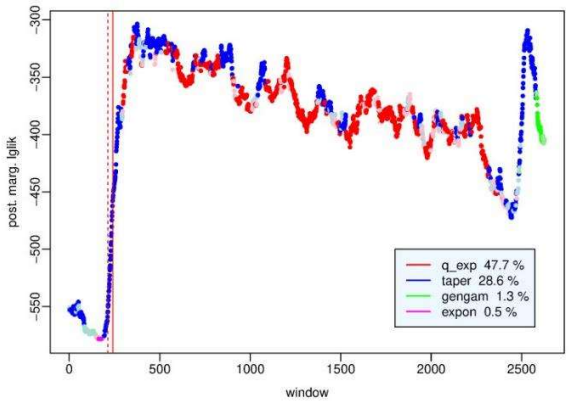

Figure 1: L'Aquila sequence - Posterior marginal log-likelihood of the probability distribution of Voronoi cell area that fits better than the other distributions to the dataset of each time window. The red vertical lines indicate the mainshock of Mw 6.1 occurred on April 6, 2009 (solid line) and the 30 March earthquake of Mw 4 (dashed line) respectively.

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Small Sample Properties of a Linear Programming Estimator in Quantile Regression Models with Time Series Data: An Application to Growth at Risk

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This paper examines the small sample properties of a linear programming estimator in quantile autoregressive models. Under certain regularity conditions, the estimator produces consistent and asymptotically normally distributed estimates of model parameters. However, despite these desirable asymptotic properties, we find that the estimator performs quite poorly in sample sizes usually encountered in applied macroeconomics. We suggest using a subsampling method for correcting a bias and discuss a simple rule of thumb for setting a block size. Our simulation results indicate that the subsampling method substantially reduces the bias at negligible costs of the increased root mean squared error of the estimated quantile regression parameters. An empirical example using the Euro Area data is provided as well.

Quickest Change Detection with Controlled Sensing

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We consider the problem of quickest change detection in the presence of parametric uncertainty in the post-change regime and controlled sensing. That is, the post-change distribution contains an unknown parameter, and the distribution of each observation, before and after the change, is affected by a control action. In this context, in addition to a stopping rule that determines the time at which it is declared that the change has occurred, one also needs to determine a sequential control policy, which chooses the control action at each time based on the already collected observations that is "best" for the unknown post-change parameter. We formulate this problem mathematically using Lorden's minimax criterion, and assuming that there are finitely many possible actions and post-change parameter values. We established a universal lower bound on the worst-case detection delay, as the mean time to false alarm goes to infinity, which needs to be satisfied by any procedure for quickest change detection with controlled sensing. We then developed a specific procedure for this problem, which we call the Windowed Chernoff-CuSum procedure, for which the worst-case detection delay matches the universal lower bound up to a first-order asymptotic approximation as the mean time to false alarm goes to infinity.

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Ancestral Inference for Age-Dependent Branching Process with Immigration

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Age-dependent branching processes are routinely used to model various dynamical phenomena arising in biological and physical systems. In some of these applications, the initial number of ancestors initiating the process is unknown. However, it is of critical importance to estimate the parameters associated with the ancestral distribution for addressing meaningful scientific questions. We describe a new estimated martingale technique to develop an estimator for the parameters of the ancestral distribution. We establish the asymptotic properties of the estimators under both the true model and under model misspecification. Extensions to birth-death processes will also be indicated.

Pricing and hedging of financial claims by entropy segmentation and convex duality.

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It is well known that in incomplete markets, under the no arbitrage hypothesis, the price of a financial claim is no longer unique, and the perfect replication is not attainable, only partial replication is possible at the cost of leaving a remaining risk that can compromise the position of the claim issuer.

Still, there exists an interval of prices compatible with the no arbitrage hypothesis. Its upper and lower extremes are the so-called seller and buyer prices. Fixing a set of benchmark assets, it is possible to calculate their associated benchmark portfolios -the super-replicating and sub-replicating portfolios- by solving two linear programs and their duals. Both the seller's price and its associated super-replicating portfolio are of particular interest to the issuer because they guarantee a null remaining risk closing a sort of perfect hedging position. Yet its cost is so high that it uses to be unachievable from a practical point of view.

In this talk we give a unified frame to value and hedge financial claims in incomplete markets by bringing entropy into play. In the same style as used in the cases of seller and buyer prices, we set up two entropy segmentation convex programs that model the level of efficiency of the market giving as solutions all the interval of no arbitrage prices. We translate these primals to their duals by convex duality, finding the dual feasible set of all the partial replicating portfolios of benchmark assets and expressing the sensitivity of the price with respect to the entropy-efficiency thanks to the multiplier associated to the entropy constraint. Also, the super-replication at the seller's price (resp. sub-replication at the buyer's price) is found as a particular case of our method when the entropy tends to zero, while we find the most efficient price with a partial replication position when the entropy is maximal.

Slicing the dual feasible set by any no arbitrage price we get a feasible set where we can look for a partial replicating portfolio calculated by means of the minimization of some risk measure of the remaining risk. Again, super-replication is obtained when the entropy vanishes and the same minimization program is used for both partial and super-replication.

If we reduce our setting to the case of a finite state market by sampling all the random variables and processes, we can apply the CVaR minimization methodology of Rockafellar and Uryasev (2001), which consists in the resolution of a fast linear program, to find the optimal partial replicating portfolio of benchmark assets.

In our exemplification we consider a Cliquet guarantee implicit in a participating life insurance policy, and we estimate a Heston model for the underlying portfolio.

Failure Rates for (hidden) semi-Markov models and applications

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In the present paper, we aim at providing different explicit formulas to describe reliability indicators for semi-Markov chains such as the mean time to failure and the corresponding moments. The Markov chains are defined in a discrete state space and the indicators are estimated by means of empirical plug-in type estimators. Our objective is to compare the different expressions, study the asymptotic properties of the estimators and finally compare them in terms of asymptotic variance. The strong consistency and the asymptotic normality of the estimators are proved. The asymptotic study is made in the large-sample sense. Second we focus on hidden Markov and hidden semi-Markov chains. The failures are considered to be observed and respective reliability indicators are presented. Concerning the estimation part, bootstrapped estimators, kernel-type estimators and bootstrapped kernel-type estimators are studied. These last estimators are very advantageous in the case of real data studies, since the evaluation of their asymptotic confidence intervals is feasible due to the fact that they do not depend on theoretical quantities. We illustrate our results by means of a simulated study. Different applications are presented based on wind, earthquake and vibration data.

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A hybrid bi-level DEA approach for resource allocation and targeting under stochastic conditions

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Resource allocation of limited resources and output target setting are two critical processes for attaining sustainability and competitiveness of decision-making units (DMUs) with complex structures such as banks, hospitals, large organizations etc. These processes are usually implemented through a central unit that has the authority to distribute the resources to the subordinate DMUs and to decide for the desirable outputs. To maximize organizational efficiency, we propose a bi-level data envelopment analysis (DEA) model that optimizes overall efficiency while imposing lower bounds on the efficiencies of all subordinate DMUs. The bi-level DEA model has an upper level (leader) problem that maximizes total benefits while the lower level (follower) problem maximizes the efficiency of the subordinate DMUs. Moreover, bounds for inputs and outputs along with availability constraints for inputs are considered. Historical data which are needed for our study are often unavailable, as DMUs are unwilling to publish them and erroneous, when calculations and measurements are incorrect. This is not uncommon, since many DMUs protect personal data and sensitive information from becoming known to the public such as the number of clients in banks. To investigate centralized resource allocation and target setting simultaneously for DMUs with network structure, we propose a bi-level network DEA approach in a stochastic framework. Our approach exploits the leader-follower relations between the central unit and the subordinate DMUs that cannot be easily captured otherwise. Moreover, in our bilevel approach, stochasticity takes the form of discrete scenarios associated with a user-defined realization probability. The model, which is stochastically constrained, is transformed to a single-level problem with a known theorem [1]. Then the single-level problem which is non-linear is solved and the obtained results are presented.

Keywords: Bi-level optimization, DEA, stochasticity, resource allocation

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A Forensic Statistical Analysis of the United States Federal Food Stamp Program

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This talk will consider methods to detect anomalous transactions linked with fraud in a welfare program funded by the United States government. A brief history of the United States ``Food Stamp" program is considered. Old paper currency-based methods of program misuse are observed in the current digital transaction-based program. The statistical methods to detect program misuse are based on order statistics methods. The methods detect clusters in the order statistics of the transaction amounts that are historically linked to fraud. Our techniques use scan statistics to determine when an excessive number of transactions occur (cluster) near a given price point. A scoring paradigm is constructed that ranks the degree in which detected clusters and transactions within clusters are anomalous among approximately 250 million total transactions.

Resilience Modeling for multi-component systems based on Markov process

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Multi-component systems are often encountered in engineering practice, such as critical infrastructure systems like transportation systems and power systems. During operation, multi-component systems tend to cripple when facing the threat of disruptive events. This paper develops a resilience evaluation framework for multi-component systems where the state evolution of each component is described by Markov processes. Five types of resilience measures are proposed in order to characterize different resilience attributes. The theory of aggregated stochastic processes is employed to obtain formulas for computing these resilience measures. Finally, a numerical example is given to illustrate the proposed resilience measures and calculation methods. The results show that our framework can comprehensively quantify the resilience of multi-component systems.

Data-driven Quickest Change Detection using Wasserstein Uncertainty Sets

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The problem of quickest detection of a change in the distribution of a sequence of independent observations is considered. It is assumed that the pre-change distribution is known (accurately estimated), while the only information about the post-change distribution is through a (small) set of labeled data. This post-change data is used in a data-driven minimax robust framework, where an uncertainty set for the post-change distribution is constructed using the Wasserstein distance from the empirical distribution of the data. The robust change detection problem is studied in an asymptotic setting where the mean time to false alarm goes to infinity, for which the least favorable post-change distribution within the uncertainty set is the one that minimizes the Kullback-Leibler distance to the pre-change distribution. It is shown that the density corresponding to the least favorable distribution is an exponentially tilted version of the pre-change density and can be calculated efficiently. A Cumulative Sum (CuSum) test based on the least favorable distribution, which is referred to as the distributionally robust (DR) CuSum test, is then shown to be asymptotically robust. The results are extended to the case where the post-change uncertainty set is a union of multiple Wasserstein uncertainty sets, corresponding to multiple post-change scenarios, each with its own labeled data.

Window-limited Adaptive CUSUM for sequential change detection

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We study the parametric online changepoint detection problem, where the underlying distribution of the streaming data changes from a known distribution to an alternative that is of a known parametric form but with unknown parameters. We propose a joint detection/estimation scheme, which we call Window-Limited CUSUM, that combines the cumulative sum (CUSUM) test with a sliding window-based consistent estimate of the post-change parameters. We characterize the optimal choice of window size and show that the Window-Limited CUSUM enjoys first-order asymptotic optimality. Compared to existing schemes with similar asymptotic optimality properties, our test is far simpler in implementation because it can recursively update the CUSUM statistic by employing the estimate of the post-change parameters. Numerical simulations corroborate our theoretical findings.

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Sequential and Asynchronous Identification of Signals

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We will consider the problem of simultaneously testing the marginal distributions of sequentially monitored, independent data streams. A general formulation will be proposed, according to which the decisions for the various testing problems can be made at different times, using data from all data streams, each data stream can be monitored even after the decision for its testing problem has been made, and arbitrary, a priori bounds are assumed on the number of signals, i.e., data streams in which the alternative hypothesis is correct. A novel sequential multiple testing procedure will be proposed that asymptotically minimizes the expected time for decision, simultaneously in every data stream and under every signal configuration, as global error rates of both kinds go to zero. Moreover, it will be compared with two existing schemes, a synchronous one and a decentralized one, in various simulation studies.

New Trends for Studying of Particle Processes with Generation and Walk

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The talk is devoted to continuous-time stochastic processes, which can be described in terms of birth, death and transport of particles. Such processes on multidimensional lattices are called branching random walks, and the points of the lattice at which the birth and death of particles can occur are called branching sources. Particular attention is paid to the analysis of the asymptotic behavior of the particle number at each point of the lattice for a branching random walk, which are based on a symmetric, spatially homogeneous, irreducible random walk on the lattice. The behavior of particle number moments is largely determined by the structure of the spectrum of the evolutionary operator of average particle numbers and requires the use of the spectral theory of operators in Banach spaces to study a number of models [1]. Two ways of proving limit theorems will be considered, one of which is based on the conditions guaranteeing the uniqueness of the limit probability distribution of particle numbers by its moments, see, e.g., [2], and the other is based on the approximation of the normalized number of particles at a lattice point by some non-negative martingale [3], which makes it possible to prove the mean square convergence of these quantities to the limit under some general assumptions on the characteristics of the process.

Acknowledgements

The research was partly supported by the Russian Foundation for the Basic Research (RFBR), project No. 20-01-00487.

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Reliability of Three-dimensional Consecutive *k*-type System

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In this paper, several three-dimensional consecutive k -type systems are studied, namely, linear connected- (k_1,k_2,k_3) -out-of- $(n_1,n_2,n_3):F$ system, linear connected- $(k_1,k_2,k_3)!$ -out-of- $(n_1,n_2,n_3):F$ system and linear l -connected- (k_1,k_2,k_3) -out-of- $(n_1,n_2,n_3):F$ system without/with overlapping. Reliabilities of these systems are studied through finite Markov chain imbedding approach (FMCIA). Some numerical illustrative examples are also provided, and finally, some possible applications and generalizations are also pointed out.

Volterra sandwiched volatility model: Markovian approximation and hedging

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We propose a new market model with stochastic volatility driven by a general Hölder continuous Gaussian Volterra process, i.e. the resulting price is not a Markov process. On the one hand, it is consistent with the empirically observed phenomenon of market memory, but, on the other hand, it brings a vast amount of issues of a technical nature, especially in optimization problems. In the talk, we describe a way to obtain a Markovian approximation to the model as well as exploit it for the numerical computation of the optimal hedge. Two numerical methods are considered: Nested Monte Carlo and Least Squares Monte Carlo. The results are illustrated by simulations.

Acknowledgements

The present research is carried out within the frame and support of the ToppForsk project nr. 274410 of the Research Council of Norway with title STORM: Stochastics for Time-Space Risk Models.

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Reliability Modeling and Evaluation of Continuous Degradation System under Dynamic Environments

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With the complexity of the system structure and the diversity of the function, the system needs to operate stably and reliably under dynamic environments. The system's natural degradation rate and shock arrival rate vary with the environment. This paper proposes a reliability modeling method for continuous degradation systems under dynamic environments, and the calculation method of the system reliability index is given. Stochastic process theory and the Monte Carlo method are used to describe the environmental changes experienced by the system. Finally, a numerical example is given to illustrate the correctness of the proposed reliability index and the algorithm. The results show that our method can be used to evaluate the system's reliability under dynamic environments.

On extending the ETAS model

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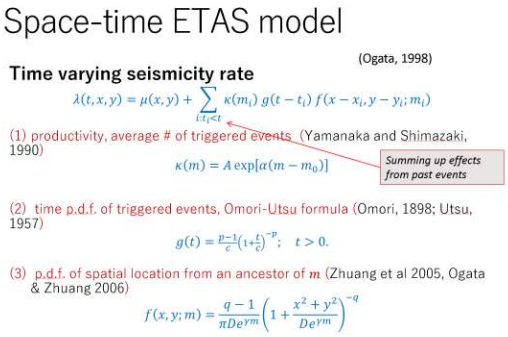
The space-time Epidemic-Type Aftershock Sequence (ETAS) model, which is special type of marked Hawkes process, has been widely used as a standard model to analyze local, regional, or even global seismicity. The assumptions of this model include:

(1) The magnitudes are identically independently distributed according to the Gutenberg-Richter magnitude-frequency relationship and are independent from other components such as occurrence times and locations.
(2) The background seismicity is stationary in time but nonhomogeneous in space of epicenter locations.
(3) Each event, no matter whether it is a background event or is triggered by other shocks, triggers its own offspring independently according to some probability rules: the occurrence times of triggered shocks follows the Omori-Utsu formula, and the epicenter locations of the triggered events follow an inverse power law in space.



Many features of seismicity that are not included in the ETAS model have been revealed by analysis of seismic data from different regions, indicating that the ETAS model should be extended to incorporate more information of seismicity. In this talk, the author summarizes the current developments on the extension of the ETAS model, including: (1) Non-stationary background rate, such as long-term trend and seasonality, (2) Earthquake depth, (3) Geometry of earthquake rupture, and (3) Earthquake focal mechanisms.

In the implementations of the above extensions, the stochastic declustering and stochastic reconstruction have been used as basic tools to estimate the non-parametric parts. In this presentation, I will outline the current achievements in this topic and give a brief perspection of its possible development in the near future.

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Structural reliability assessment of composite columns in steel and concrete

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In the poster is presented the structural reliability assessment of composite columns in steel and concrete under axial compression at the ultimate limit state using stochastic finite element analysis (SFEM). In Eurocode 0 [1], the ultimate limit state is related to the structural failure (collapse) of a part e.g., column, beam, foundation or the entire structure. Mathematically, this can be expressed in terms of limit-state function g(x) = R(x) – S(x), and the probability of failure as $P_f = P\,[g(x)<0]$ where R is the resistance of the structure and S is the loading part. In Eurocode 0 [1], the target reliability index β for reference period of 50 years is β=3.8 which represents the probability of failure of 0.1%. The probability of failure is related to reliability index β as $P_f = \Phi(-\beta)$, where Φ is cumulative distribution function of the standard normal distribution. In finite element analysis (FEM), the input parameters e.g., geometry of the structure, materials, loads, and other structural properties are deterministic, while the stochastic finite element analysis is an extension of FEM, which allows variation of these parameter as random variable. In this study the stochastic finite element analyses for composite columns in steel and concrete were performed using OpenSeesPy [4] and QuoFEM [3]. First the deterministic model was developed in OpenSeesPy and validated with experimental results and ABAQUS then, the model is transformed in probabilistic one using QuoFEM which is an open-source research application software with focus on providing uncertainty qualification methods. To generate sampling of the random variables, The Latin Hypercube Sampling (LHS) and Monte Carlo (MS) were used. The results from parametric SFEM analyses were compared with safety level provided by Eurocode 4 [2] according to general and simplified method for design of composite columns in steel and concrete under compressive axial load.

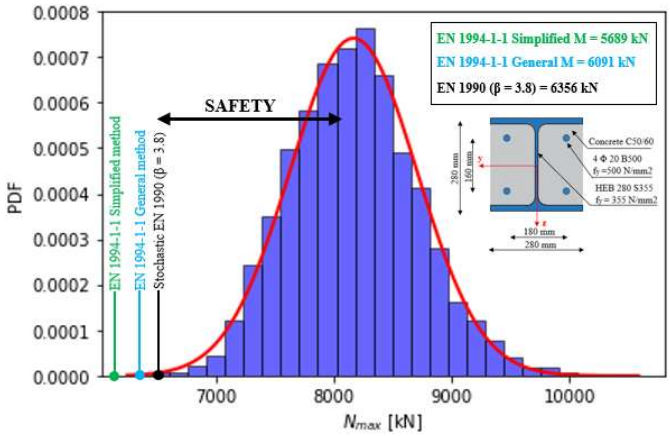

Figure 1: Comparison SFEM analyses with safety level provided by Eurocode 4 [2]

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Title Index

Plenary Talks

Invited and Contributed Talks

Wednesday, 7 June

9.00-10.00	**Reception**					
10.00-11.00	**Plenary talk-Room:Crystal Hall**					
	Markov Chain Monte Carlo Meets Generative AI -Eric Moulines					
	Chair: Gregory Nuel					
11.00-11.30	Coffee Break					
IS: Invited session	Room: Crystal Hall	Room: Timber I	Room: Timber II	Room: Dock Six I	Room: Dock Six II	
	IS: Recent advances in actuarial, credit and financial risk modeling	**IS: Information and modeling in continuous-valued time series - Part I**	**IS: Modelling Tail Risk**	**IS: Issues of Stochastic Dependence and Orderings in Game and Voting Theory**	**IS: New trends in Reliability, Coherent Systems and Measures of Information**	
11:30-13:30	Chair: *Jose-Luis Vilar-Zanon*	Chair: *Dimitris Kugiumtzis*	Chair: *Katalin Varga*	Chair: *Fabio Spizzichino*	Chair: *Maria Longobardi*	
	Pricing and hedging of financial claims by entropy segmentation and convex duality *Jose-Luis Vilar-Zanon*	Partial synchronization within and across layers in chimera state networks *Ralph Andrzejak*	Tail risk interference from theory-infused models *Katarzyna Budnik*	Comparing Random Variables is Not as Obvious as 1, 2, 3 *Bernard De Baets*	Information Concepts in Reliability Analysis *Refik Soyer*	
	Offline Deep Reinforcement Learning for Dynamic Pricing of Consumer Credit *Ramin Okhrati*	Noise reduction for functional time series data *Cees Diks*	Small Sample Properties of a Linear Programming Estimator in Quantile Regression Models with Time Series Data: An Application to Growth at Risk *Marian Varva*	Negative dependence notions and tournament scores *Yoseph Rinott*	Comparisons between Systems with Two-Component Subsystems *Florentina Suter*	
	Subsidizing inclusive insurance to reduce impoverishment *Corina Constantinescu*	A Dual HMM-Change Point Analysis Approach for Link Quality Detection *Sotiris Skaperas*	Horseshoe Prior for Bayesian Quantile Regression *Tibor Szendrei*	Load-sharing models in the study of random permutations, minima within subsets of random variables, and related paradoxe *Fabio Spizzichino*	Predicting Future Failure Times By Using Quantile Regression *Francesco Buono*	
	On a Penalty Function in the Erlang Renewal Dual Risk Model Under Independent Randomised Observations *Alfredo D. Egídio dos Reis*	A General Procedure for Localising Strictly Proper Scoring Rules *Ramon de Punder*	Nonstationary Financial Risk Factors and Macroeconomic Vulnerability for the United Kingdom *Katalin Varga*	Stochastic models in the construction of paradoxes in probability, game and voting theory *Emilio De Santis*	Unified Formulations of Entropy and Extropy *Maria Longobardi*	
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15.00-16.00	**Plenary talk-Room:Crystal Hall**					
	Some statistical insights into physics-informed neural networks- Gerard Biau					
	Chair: Sotirios Sabanis					
CT: Contributed Talks	Room: Crystal Hall	Room: Timber I	Room: Timber II	Room: Dock Six I	Room: Dock Six II	Room: Grand Pietra
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16:00-17:00	Chair: *Evgeny Burnaev*	Chair: Samuel Herrmann	Chair: Alfredo D. Egídio dos Reis	Chair: *Yoseph Rinott*	Chair: *Vittorio Perduca*	Chair: *George Afendras*
	Multiscale Scanning With Nuiscance Parameters *Frank Werner*	Gamma processes for prognosis: theory, applications and perspectives *Zeina Al Masry*	Expected Discounted Penalty Function of Gerber-Shiu for a Renewal Risk Model with Positive Jumps Perturbed by Diffusion *Ekaterina T Kolkovska*	Conditional gambler's ruin problem with arbitrary winning and losing probabilities with applications *Pawel Lorek*	The Disorder Problem. An approach based on Partially Observable Markov Decision Processes *Doncho Donchev*	The Failure Rate for the Convolution of Two Distributions One of Which has Bounded Support *George Tzavelas*
	Spacings-Based Goodness-of-Fit Testing *Reza Pakyari*	On fluctuation-theoretic decompositions via Lindley-type recursions *Offer Kella*	On the time and aggregate claim amount until ruin in a jump diffusion risk model in the presence of an upper safety level *Jacob David Economides*	The Static Duel Discounted Stochastic Game *Athanasios Kehagias*	Non-parametric Observation Driven HMM *Hanna Bacave*	Covariance Identity for q-Distributions *Violetta E Piperigou*
	Goodness of fit for the generalized Poisson distribution based on the probability generating function *Apostolos Batsidis*	δ-records in Models with Trend *Miguel Lafuente Blasco*	Background risk model in presence of heavy tails under dependence *Dimitrios G. Konstantinides*	Some optimal stopping pre-emption games in two-dimensional continuous Markov models *Pavel V. Gapeev*	Distribution of the number of carrier genotypes in Mendelian models *Alexandra Lefebvre*	A wide family of continuous univariate distributions and applications *Markos Koutras*
17.00-17.30	Coffee Break					
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17.30-19.30	Chair: *Laura Lea Sacerdote*	Chair: *Sotirios Sabanis*	Chair: *Olympia Hadjiliadis*	Chairs: *Athanasios Thanopoulos and George Tsaklidis*	Chair: *Donald E. K. Martin*	Chair: *Dimitris Kugiumtzis*
	Exact Simulation of the First Time a Stochastic Process Overcomes a Given Threshold *Samuel Herrmann*	Training neural networks with Langevin based algorithms and key applications *Sotirios Sabanis*	Sequential and Asynchronous Identification of Signals *Georgios Fellouris*	Development of methodology for automated crop mapping in Greece using Neural Networks and Sentinel-2 satellite imagery Eleni Papadopoulou	Inference in states of hidden sparse Markov models *Donald martin*	A corrected mutual information estimator for the improvement of mRMR feature selection filter *Nikolaos Papaioannou*
	Boundary crossing problems and functional transformations for Ornstein-Uhlenbeck processes *Aria Ahari*	Interacting Particle Systems for EM *Tim Johnston*	Generative Modeling with Optimal Transport Maps *Evgeny Burnaev*	Testing for the bias in the estimation of business structure indexes from different data sources Michaela Balkoudi	Hidden segmentation models *Vittorio Perduca*	Information-based Causality in High-Dimensional discrete-valued time series *Elsa Siggiridou*
	The Joint Distribution of Value and Local Time Of Simple Random Walk and Reflected Simple Random Walk. Pandemic-Motivated Queueing Analysis. *Isaac Meilijson*	New Tamed Langevin MCMC algorithms and their applications *Iosif Lytras*	Speed-based Measures of Signal-to-Noise Ratios *Yuang Song*	Longitudinal Cluster Analysis to the Annual Expenses of the Healthcare System of Selected Countries of the European Union from 2004 to 2018 *Christina Chatzimichail*	Patterns in structured RNAseq, mixture of Bayesian networks, deterministic finite automata, and generating functions *Gregory Nuel*	Testing for determinism in symbolic sequences: Is Bach's brain a Markov chain? *Michael Small*
	Boundary Crossing of Delayed Brownian Motion and The Non-Local Heat Equation on a Time-Dependent Domain *Bruno Toaldo*		Sqrt2 estimation for smooth eigenvectors of matrix-valued functions *Giovanni Motta*	Granger causality among economic indices of industry in Greece *Eleni Tsakalidou*	Sparsification of Phylogenetic Covariance Matrices via Wavelets *Manuel Lladser*	Poisson Network Autoregression *Konstantinos Fokianos*
20.00-21.00	Welcome Reception					

Thursday, 8 June

9.00-10.00	**Plenary talk-Room: Crystal Hall** **Perspectives on Mortality Modelling - Gareth Peters** *Chair: Athanasios Kehagias*				
IS: Invited session CT: Contributed Talks	Room: Crystal Hall **CT: Markov Models**	Room: Grand Pietra I **CT: Decision Theory- Part II - Stochastic control**	Room: Grand Pietra II **CT: Probabilistic modeling in applied sciences**	Room: Dock Six I **IS: Stochastic Modeling in Reliability and Resilience**	Room: Dock Six II **CT: Applications of statistics to environmental and related topics**
10.00-11.00	Chair: *Andreas Georgiou*	Chair: *Alexander Gnedin*	Chair: *Serkan Eryılmaz*	Chair: *Bei Wu*	Chair: *Rodi Lykou*
	Analysis of a multi-level manpower model under different circumstances *Nikolas Tsantas*	A Stochastic Control Problem With Linearly Bounded Control Rates In A Brownian Model *Clarence CS Simard*	Structural reliability assessment of composite columns in steel and concrete *Pellumb Zogu*	System Reliability Modelling via Virtual Ages *Lirong Cui*	A Remote Sensing Application of Generalized Linear Mixed-Effects Models in Crop Phenology Prediction *Ioannis Oikonomidis*
	Functional Central Limit Theorem for Certain Markov Chains in Random Environment with Applications in Machine Learning *Attila Lovas*	Stochastic Maximum Principle For A Constraint Nonzero-Sum Game Application: Bancassurance *Emel Savku*	Acceptability Model of Risk in Italian Tunnels *Massimo Guarascio*	Reliability Modeling for Systems Degrading in Markovian Environments with Protective Auxiliary Components *Jingyuan Shen*	Modeling Rainfall Interarrival Times, Rainfall Depths and their dependence, using the Hurwitz Lerch Zeta family of distributions and Discrete Copulas *Tommaso Martini*
	Moments Computation for Markov-Modulated Fluid Models with Upward Jumps and Phase Transitions *Abdallah Itidel*	Optimal stopping zero-sum games in continuous hidden Markov models *Pavel V. Gapeev*	Investigation of the climate impact on WNV vectors abundance *Orfeas Karathanasopoulos*		Multivariate Fay-Herriot Models for Small Area Estimation in Forest Inventory *Aristeidis Georgakis*
11.00-11.30	Coffee Break				
IS: Invited session	Room: Crystal Hall **IS: Branching Processes and Related fields I**	Room: Grand Pietra I **IS: Sequential Selection, Best Choice and Games Problems**	Room: Grand Pietra II **IS: Probabilistic Modeling of Engineering Systems**	Room: Dock Six I **IS: Stochastic Modeling in Reliability and Resilience**	Room: Dock Six II **IS: Fractional long-range dependence processes: theory, applications and simulations**
11:30-13:30	Chair: *Miguel Gonzalez*	Chair: *Yaakov Malinovsky*	Chair: *Serkan Eryılmaz*	Chair: *Bei Wu*	Chair: *Enrica Pirozzi*
	Ancestral inference for age-dependent branching process with immigration *Anand N. Vidyashankar*	The Last-Success Optimal Stopping Problem with Random Observation Times *Alexander Gnedin*	Reliability evaluation of discrete time consecutive-k systems *Cihangir Kan*	Reliability of Three-dimensional Consecutive k-type System *He Yi*	Estimation of the Hirst Parameter from Continuous Noisy Data *Marina Kleptsyna*
	Scaling Limits of Critical Controlled Multi-type Branching Processes *Pedro Martín-Chávez*	On optimal stopping of a random sequence with unknown distribution *Alexander Goldenshluger*	Analyzing the Number of Failed Components in a series-parallel System *Murat Ozkut*	Reliability Modeling for Balanced System Considering Mission Aborted Policies *Chen Fang*	The Monte Carlo method for the fractional calculus *Igor Podlubny*
	Multi-type Sevastyanov Branching Processes and Application in Cancer Research *Maroussia Bojkova*	On Round-Robin Tournaments with a Unique Maximum Score and Some Related Results *Yaakov Malinovsky*	On the reliability structures with two common failure criteria and cold standby redundancy *Ioannis Triantafyllou*	Resilience Modeling for multi-component systems based on Markov process *Bei Wu*	Mittag-Leffler Single Server Queues *Nicos Georgiou*
	Large Deviation results for Controlled Branching Processes *Inés M. del Puerto*	Blotto Game with Testing (The Locks, Bombs and Testing Model) *Isaac Sonin*	Probabilistic modelling and assessment of a renewable hybrid energy system *Serkan Eryılmaz*	Mean Hitting Time Approximation for Rare Events *Nikolaos Limnios*	Coupling Plateaux and Jumps: the Undershooting of Subordinators and the Corresponding Semi-Markov Processes *Giacomo Ascione*
13:30-15:00	Lunch Break				
15.00-16.00	**Plenary talk-Room:Crystal Hall** **Repeated Significance Tests Based on Multiple Scan Statistics for One- and Two-Dimensional Data- Joseph Glaz** *Chair: Markos Koutras*				
CT: Contributed Talks	Room: Crystal Hall **CT: Stochastic Modelling in Epidemiology**	Room: Grand Pietra I **CT: Bayesian methods**	Room: Grand Pietra II **CT: Brownian and Gaussian Processes**	Room: Dock Six I **CT: Stochastic processes- Part II**	Room: Dock Six II **CT: Distribution theory and related topics- Part II**
16:00-17:00	Chair: *Dimitris Kugiumtzis*	Chair: *Apostolos Batsidis*	Chair: *Marina Kleptsyna*	Chair: *George Vasiliadis*	Chair: *George Afendras*
	Modeling and parameter estimation of a multi-hidden chain model of typhoid fever in Mayotte *Ibrahim Bouzalmat*	Parameter Estimation Issues on the Generalised Gamma Model for Complete and Interval Censored Observations *Samis Trevezas*	Estimates for Exponential Functionals of Real-Valued Continuous Gaussian Processes *Jose Alfredo Lopez-Mimbela*	Reliability Modeling and Evaluation of Continuous Degradation System under Dynamic Environments *Yamei Zhang*	Coverage and connectivity in stochastic geometry *Mathew D Penrose*
	SIR epidemics perturbed by Feller processes *Matthieu Simon*	Genetically modified mode jumping MCMC approach for Bayesian multivariate fractional polynomials *Aliaksandr Hubin*	Quickest change-point detection problems for multidimensional Wiener processes *Pavel V. Gapeev*	Windings Of Planar Stochastic Processes And Applications. *Stavros Vakeroudis*	Asymptotic results for sums and extremes *Claudio Macci*
	Modeling the Health Impact of COVID-19 using Mixed Interaction Models and Chain Graph Models *Konstantina Gourgoura*	Interval Bayesian method to sequential sampling problem *Masayuki Horiguchi*	The Inverse First-passage Time Problem as Hydrodynamic Limit of a Particle System *Alexander Klump*	On the growth rate of superadditive processes and the stability of functional GARCH models *Baye Matar Kandji*	Stochastic Comparisons of Mixtures Models: Review and Discussion *Bahaedin Khaledi*
17.00-17.30	Coffee Break				
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17.30-19.30	Chair: *Inés María del Puerto García*	Chair: *Dimitris Kugiumtzis*	Chair: *Salim Bouzebda*	Chairs: *Eleftheria Papadimitriou, Rodolfo Console and Jiancang Zhuang*	Chair: *Giacomo Ascione*
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	On the absorption and limiting behaviour of defective branching processes in a varying environment *Carmen Minuesa*	Nonlinear connectivity as a driver of time-horizon heterogeneity *Angeliki Papana*	Markov-Switching State-Space Models with Applications to Neuroimaging *David Degras*	On extending the ETAS model *Jiancang Zhuang*	From Semi-Markov Evolutions to Scattering Transport and Superdiffusions *Bruno Toaldo*
	Statistical sequential analysis for Controlled Branching Processes *Miguel González*	Applications of an information-based causality networks in finance *Akylas Fotiadis*	Bayesian Nonparametric Hypothesis Testing with Applications *Mame Diarra Fall*	From simulated earthquakes a key to modelling the occurrence of a strong event *Rodolfo Console*	Gaussian and Non-Gaussian Processes Linked to Convolution-type Fractional Operators *Luisa Beghin*
	Multitype Branching Process with Nonhomogeneous Poisson and Contagious Poisson Immigration *Landy Rabehasaina*	Information measures for balancing redundancy and relevance in data analysis *Dimitris Kugiumtzis*	Shannon Entropy in Deep Learning: Applications and Benefits *Issam El Hattab*	Testing of the Seismic Gap Hypothesis in a model with realistic earthquake statistics *Eugenio Lippiello*	Time-Fractional Diffusion from Two Markovian Hopping-Trap Mechanisms *Gianni Pagnini*

Friday, 9 June

9.00-10.00	**Plenary talk-Room: Crystal Hall**					
	Weak Ergodicity in General Non-Homogeneous Markov Systems- Panagiotis G.C. Vasileiou					
	Chair: Alexandra Papadopoulou					
10.00-11.00	**Plenary talk-Room:Crystal Hall**					
	Opinion dynamics on complex networks: From mean-field limits to sparse approximations - Mariana Olvera-Cravioto					
	Chair: Zbigniew Palmowski					
11.00-11.30	Coffee Break					
IS: Invited session CT: Contributed Talks	Room: Crystal Hall	Room: Grand Pietra I	Room: Grand Pietra II	Room: Dock Six I	Room: Dock Six II	
	IS: Stochastic modelling for dynamical biological systems	**IS: Random trees, tools and extensions**	**IS: Financial Mathematics I**	**IS: Hidden Markov models and applications**	**CT: Queueing Processes**	
11.30-13.00	Chair: *Giorgos Minas*	Chair: *Hosam Mahmoud*	Chair: *Michail Anthropelos*	Chair: *George Tsaklidis*	Chair: *George C Mytalas*	
	From single cells to microbial consortia and back: stochastic chemical kinetics coupled to population dynamics *Jacob Ruess*	Affine urns and their applications to hyperrecursive trees *Joshua Sparks*	Kyle's Model with Stochastic Liquidity *Gordan Zitkovic*	Failure Rates for (hidden) semi-Markov models and applications *Eirini Votsi*	Performance Analysis for a Two-Server Queue with Disasters and Vacations *George C Mytalas*	
	A stochastic multiscale modelling framework for the evolution of phenotype-structured cell populations *Konstantinos Alexiou*	Continuous time Polya urns and applications in random trees *Srinivasan Balji*	Discrete-time Approximation of Rough Volatility Models *Alexandra Chronopoulou*	Filtering a Hidden Open Homogeneous Markov System *Rodi Lykou*	A Busy Period Analysis of a 2-Queue Polling System with a Threshold-Based Switching Policy *Rachel Ravid*	
	Stochastic simulation, analysis and inference for reaction networks *Giorgos Minas*	Power-weight trees *Hosam Mahmoud*	Continuous-time Equilibrium Returns in Markets with Price Impact *Constantinos Stefanakis*	A Stochastic Particle Extended SEIRS Model with Repeated Vaccination. Application to Real-Data of COVID-19 in Italy *Vasileios Papageorgiou*	Alternative Transient Solutions for Semi-Markov Systems in Queuing and Reliability *Nino Svanidze*	
				A stochastic SIHRD model for the optimization of hospital operation during epidemic outbreaks *George Vasiliadis*	New Probabilistic Method for Transient Analysis of M/G/1 systems with Server Vacations *Revaz Kakubava*	
13.00-14.30	Lunch Break					
IS: Invited session	Room: Crystal Hall	Room: Grand Pietra I	Room: Grand Pietra II	Room: Dock Six I	Room: Dock Six II	
	IS: Recent Advances and Applications in Statistical Process Monitoring	**IS: Probabilistic Analysis of Complex Stochastic Systems**	**IS: Sequential Methods and Stopping Times I**	**IS: Statistical Seismology**	**IS: Dependence, stochastic orders and ageing properties of random lifetimes**	
14.30-17.00	Chair: *Sotirios Bersimis and Athanasios Rakitzis*	Chair: *Elena Yarovaya*	Chairs: *George V. Moustakides and Venugopal V. Veeravalli*	Chairs: *Eleftheria Papadimitriou, Rodolfo Console and Jiancang Zhuang*	Chairs: *Antonio Di Crescenzo*	
	A Non-Parametric Monitoring Procedure for Monitoring Multivariate Processes Based on Convex Hulls *Sotiris Bersimis*	Intermittency and percolation in population dynamics *Stanislav Molchanov*	The warm-starting sequential selection problem and its extension to a multi-round setting *Argyris Kalogeratos*	Seismic sequences identification in Italy by local test of random labelling *Nicoletta D'Angelo*	On the Effect of Dependence on Random Lifetimes of Systems with Redundancies *Nuria Torrado*	
	Monitoring Defects in Manufacturing Procedures Using Scan Statistics *Polychronis Economou*	Functional limit theorems for random walks *Grigory Popov*	Sequential architecture-agnostic black-box attack, design and analysis *Yasin Yilmaz*	Finding the Number of Clusters, based on the Susceptibility of the Similarity Matrix: An Application to Earthquake Declustering *Polyzois Bountzis*	Some new ordering results for parallel and series systems with dependent heterogeneous exponentiated Weibull components *Milto Hadjikyriakou*	
	A Two-Sided Control Chart for Monitoring General Inflated Processes *Athanasios Rakitzis*	New M-determinacy criterion for probability distributions via MaxEntropy approach *Jordan Stoyanov*	Optimal stopping methodology for the secretary problem with random queries *Olgica Milenkovic*	Retrospective forecast testing of short-term earthquake clustering models in Greece: Results from recent (2020-2022) earthquake sequences *Christos Kourouklas*	Preservation of Log Concavity by Bernstein Operator Based on Probabilistic Tools with Applications to the Ageing Properties of a Coherent System *Francisco German Badia*	
	Public Health Monitoring Using Control Charts Based on Convex Hull *Athanasios Sachlas*	Branching random walks in non-homogeneous media with an infinite number of sources *Elena Filichkina*	Stopping rules to detect changes in a Markov chain *Sabine Mercier*	Second-order smoothness prior over the Delaunay Tessellation in Bayesian geophysical inversion *Yuanyuan Niu*	A model for stochastic dependence implied by failures among deteriorating components *Carmen Sanguesa*	
	Monitoring Long-Term Relationship Between Cointegrated Time Series *Sonia Malefaki*	New trends for studying of particle processes with generation and walk *Elena Yarovaya*	Data-driven Markovian optimal stopping *George Moustakides*	Strongest aftershock forecasting in Greece *Stefania Gentili*		
17.00-17.30	Coffee Break				Room: Dock Six II	
IS: Invited session	Room: Crystal Hall	Room: Timber I	Room: Timber II	Room: Dock Six I	**IS: Stochastic models, processes and applications- Part I**	Room: Grand Pietra
	IS: Stochastic Models in Queueing and Inventory Management	**IS: Recent Advances in Anomaly/Cluster Detection**	**IS: Financial Mathematics II**	**IS: Random Matrix Theory and Its Applications**	Chair: *Antonio Di Crescenzo*	**IS: Applied probability in materials research**
17.30-19.00	Chair: *Ioannis Dimitriou and Apostolos Burnetas*	Chairs: *Tung Lung Wu and Jie Chen*	Chairs: *Michail Anthropelos*	Chairs: *Zhigang Bao*	Evolution of a Deterministic SIS Epidemic Model with Infection Characteristics Environmentally Dependent *María Jesús López Herrero*	Chair: *Viktor Beneš*
	Price and Capacity Competition between a Make-to-Order and a Make-to-Stock Firm with Strategic Customers *Apstolos Burnetas*	A Forensic Statistical Analysis of the United States Federal Food Stamp *Jon Woody*	Time-consistent Pension Fund Management in Stochastically Changing Markets and Evolving Horizons *Michail Antrhropelos*	A new combinatorial approach for edge universality of Wigner matrices *Debapratim Banerjee*	Analysis of the elapsed time before first recovery in a SIVS stochastic model with an imperfect vaccine *Verdiana Mustaro*	Stochastic models of microstructure, crystallographic texture and internal stress in polycrystals *Zbyněk Pawlas*
	The Impact of Customer Heterogeneity on Equilibrium Strategies in a System of Unobservable M/M/1 Queues in Series Yiannis Dimitrakopoulos	Online Change Point Detection in High-Dimensional Data Jun Li	Cost-efficient Payoffs under Model Ambiguity Steve Vanduffel	On spectral distribution of sample covariance matrices from large dimensional and large k-fold tensor products Wangjun Yuan	A non-local Jacobi operator for neuronal modeling Giuseppe D'Onofrio	Stochastic multi-scale modeling of cathode particle geometry in lithium-ion batteries supported by methods from machine learning *Orkun Furat*
	Exploiting Real-time Degradation Data in a Proactive Inventory Policy *Naim AlKhoury*	Scan Statistics in Sequential Trials *Jie Chen*	Market maker's optimal limit order book imbalance *Sergio Pulido*	On the Asymptotic Distribution of the Least Singular Value of Random Matrices with alpha-Stable Entries *Mixalis Louvaris*	Some results on a non-homogeneous telegraph process *Barbara Martinucci*	Stochastic microstructure modeling and predictive simulation of nanoporous glass based on X-ray tomography *Phillip Gräfensteiner*
19.05-19.45	Room: Crystal Hall	Room: Timber I	Room: Timber II	Room: Dock Six I	Room: Dock Six II	Statistics of grain and orientation characteristics of polycrystalline materials microstructure modelled by a Laguerre tessellation. *Viktor Beneš*
CT: Contributed Talks	**CT: Decision Theory- Part III - Stochastic control**	**CT: Stochastic Methods**	**CT: Stochastic Processes in Finance**	**CT: Random Walks**	**CT: Estimation**	
	Chair: *Clarence CS Simard*	Chair: *Zie Chen*	Chair: *Sergio Pulido*	Chair: George Tsaklidis	Chair: *George Afendras*	
	Target-based Approach with Dependent Targets and Paradoxes in Decision Theory *Rachele Foschi*	Joint distribution of increasing and decreasing successions of multisets *Yong Kong*	A Multi-factor Stochastic Model for Commodity Prices *Christian Tezza*	Large deviations for super-heavy tailed random walks *Toshio Nakata*	Maximum Precision Estimation for a Step-Stress Model Using Two-Stage Methodologies *Sudeep R. Bapat*	
	Spatio-temporal Markov decision theory *Maike C. de Jongh*	Objective Shrinkage Priors Via Imaginary Data *Dimitrios Fouskakis*	Semi-Parametric Non-Smooth Optimal Dynamic Pricing *Daniele Bracale*	The Ant random walk with superlinear reinforcement *Guilherme Henrique de Paula Reis*	On the preservation of some positive aging properties regarding random maxima *Panayiotis Bobotas*	
21.00	Conference Dinner					

Saturday, 10 June

	Room: Crystal Hall	Room: Timber I	Room: Timber II	Room: Dock Six I	Room: Dock Six II	Room: Grand Pietra
IS: Invited session	**IS: Mathematical finance**	**IS: Stochastic models, processes and applications- Part II**	**IS: Random graphs and heavy tails**	**IS: Markovian hybrid models and extension with applications in wellbeing and healthcare**	**IS: Self-organised and reinforced processes**	**IS: Sequential Methods and Stopping Times**
9:00-11:00	Chair: *Stefan Gerhold*	Chair: *Antonio Di Crescenzo*	Chair: *Mariana Olvera- Cravioto*	Chair: *Alexandra Papadopoulou and Andreas Georgiou*	Chair: *Debleena Thacker*	Chair: *George V. Moustakides and Venugopal V. Veeravalli*
	Consistency of option prices under bid–ask spreads *Stefan Gerhold*	Mixture models based on a probabilistic analogue of the mean value theorem *Georgios Psarrakos*	A local online matching algorithm on the configuration model *Pascal Moyal*	Using Markov and Related Models for Characterizing and Monitoring Patients in Smart Homes *Sally McClean*	Urn Processes with Graph-based Interactions *Neeraja Sahasrabudhe*	Best arm identification in stochastic bandits *Ali Tajer*
	On NA-consistent Finite Dimensional Manifolds of Forward Rates Where the Diffusion Coefficient is Free *Paul Eisenberg*	On approximating the first passage time density from data using generalized Laguerre polynomials *Elvira Di Nardo*	Eliminating sharp minima from SGD with truncated heavy-tailed gradient noise *Chang-Han Rhee*	On the properties of inverted repeats and word frequencies in DNA sequences via semi Markov modeling *Pavlos Kolias*	Current profiles for TASEP on a Galton-Watson tree *Nicos Georgiou*	Data-driven quickest change detection using Wasserstein uncertainty sets *Liyan Xie*
	The Multivariate Fractional Ornstein-Uhlenbeck Process *Paolo Pigato*	Some recent results on time-changed stochastic processes and applications *Enrica Pirozzi*	Scaling limits and universality: Critical percolation on weighted graphs converging to an L3 graphon *Sanchayan Sen*	Assessing the Performance of Bootstrapping in Network Data Envelopment Analysis: Monte Carlo Evidence *Maria Michali*	Large deviations for a non-markovian particle system *Guilherme Reis*	Window-limited CUSUM for sequential change detection *Yao Xie*
	State Space Decomposition of Term Structure Shapes in the Two-Factor Vasicek Model *Felix Sachse*	Distributions induced by probability density functions and applications to differential entropy and varentropy *Antonio Di Crescenzo*	Local limit theorems for general attachment graphs and their applications *Mariana Olvera-Cravioto*	Markovian models in Data Envelopment Analysis Single and multiple stage structures *Andreas Georgiou* A hybrid bi-level DEA approach for resource allocation and targeting under stochastic conditions *Eleni-Maria Ms Vretta*	On the topology of higher-order age-dependent random connection models *Christian Hirsch*	Quickest change detection with controlled sensing *Venugopal Veeravalli*
11.00-11.30	Coffee Break					
11.30-12.30	**Plenary talk-Room: Crystal Hall** **Stationary states and exit times for Lévy processes with partial resetting - Zbigniew Palmowski** Chair: Nikolaos Limnios					
12.30-13.00	**Closing remarks**					
13.00-14.30	**Lunch**					
15.00-20.00	**Excursion**					