BeNeLux Mathematical Congress

Booklet of the Conference Talks

Antwerp (Belgium)

April 7-8, 2026

Speakers list

Session	Speakers
Keynote	Jessica Fintzen Kathlén Kohn Christoph Thiele Nathalie Wahl
A1	**Finite Geometries, Graphs and Codes** *Aida Abiad, Jan De Beule, Jozefien D'haeseleer, Leo Storme* Matteo Bertuzzo, Linda Cook, Sam Mattheus
A2	**Geometric Analysis** *Bruno Premoselli, David Tewodrose* Lucas Lavoyer, Andoni Royo Abrego, Artemis Vogiatzi
A3	**Microlocal Analysis and PDEs** *Andreas Debrouwere, Michal Wrochna* Leonard Busch, Lorenzo Carletti, Marcello Seri
A4	**Mathematics of AI** *Christoph Brune, Leo van Iersel, Tristan van Leeuwen, Tim van Erven* Kerstin Bunte, Jannis Kurtz, Felix Lucka
A5	**Reliable Simulation of Complex Systems** *Victorita Dolean, Iuliu Sorin Pop* Stéphane Bordas, Giovanni Samaey, Laura Scarabosio
A6	**Directional Statistics** *Christophe Ley, Thomas Verdebout* Sophia Loizidou, Davy Paindaveine, Chiara Passamonti
B1	**Mathematical Logic** *Alexi Block Gorman, Andreas Weiermann, Christian Michaux* Juan Aguilera, Elliot Kaplan, Tingxiang Zou
B2	**Dynamics and Geometry of Non-Conservative Systems** *Federico Zadra, Marcello Seri* Mats Vermeeren, David Martin de Diego, Mark Peletier
B3	**Direct and Inverse Problems for PDEs** *Karel Van Bockstal, Michael Ruzhansky* Van Chien Le, Frederick Maes, Bolys Sabitbek
B4	**Quantum Software Consortium** *Quantum Software Consortium, Jonas Helsen* Jop Briët, Dmitry Grinko, Lisa Kohl
B5	**Numerical Methods for Kinetic Plasma Physics** *Julian Koellermeier, Fabio Bacchini, R.-Paul Wilhelm* Julian Koellermeier, R.-Paul Wilhelm, Klaas Willems
B6	**Dependence Modeling** *Alexis Derumigny, Irène Gijbels, Elisa Perrone* Christophe Ley, Anneleen Verhasselt, Phyllis Wan

Session	Speakers
C1	**Categorified Structures** *Kenny De Commer, Geoffrey Janssens, Pedro Vaz* Lucas Hataishi, Hankyung Ko, Léo Schelstraete
C2	**Symplectic Methods in Topology, Analysis and Dynamics** *Gil Cavalcanti, Federica Pasquoto, Thomas Rot* Joel Fine, Jagna Wisniewska, Lauran Toussaint
C3	**Analysis of PDEs** *Koondanibha Mitra, Stefanie Sonner, Peter van Heijster* Anna Geyer, Michael Ruzhansky, Vincent Laheurte
C4	**Evidence-Based University Mathematics Teaching** *4TU+.AMI, Annoesjka Cabo* Stéphanie Bridoux, Tracy Craig, Jos Hageman
C5	**Calculus of Variations Across Borders** *Heiner Olbermann, Jean van Schaftingen, Mark Peletier, Yves van Gennip* Annika Bach, Clément Cancès, Marcello Carioni
C6	**Stochastic Analysis and Probability Theory** *Laurent Loosveldt, Ivan Nourdin* Hélène Halconruy, Céline Lacaux, Francesca Pistolato
D1	**Advances in Algebraic Geometry** *Daniel Bath, Ignacio Barros* Emma Brakkee, Alberto Cobos Rábano, Luca Giovenzana
D2	**EMW-NL: Research Meets Outreach** *Svetlana Dubinkina, Marcello Seri* Relinde Jurrius, Raffaella Mulas, Marcello Seri
D3	**Delay Equations** *Peter De Maesschalck, Bram Lentjes* Otti D'Huys, Bram Lentjes, Evert Provoost
D4	**Random Matrices and Random Graphs** *Arno B.J. Kuijlaars, Alexander Van Werde* Christophe Charlier, Remco van der Hofstad, Alexander Van Werde
D5	**Sequential Decision Making** *4TU+.AMI, Anne Zander, Janusz Meylahn* Joachim Arts, Ann Nowé, Ward Romeijnders
D6	**E-Values and Flexible Inference** *Peter Grunwald, Rianne de Heide, Johan Segers* Rianne de Heide, Nick Koning, Vladimir Vovk
D7	**Mathematics for Renewable Energy Markets** *Karel in 't Hout, Sven Karbach, Michèle Vanmaele* Sven Karbach, Massimiliano Moda, Mustapha Regragui

Speakers list (alphabetical)

Name	First name	Session	University
Aguilera	Juan	B1	TU Wien
Arts	Joachim	D5	University of Luxembourg
Bach	Annika	C5	TU/e
Bertuzzo	Matteo	A1	Eindhoven University of Technology
Bordas	Stéphane	A5	University of Luxembourg
Brakkee	Emma	D1	Leiden University
Bridoux	Stéphanie	C4	UMONS
Briët	Jop	B4	CWI
Bunte	Kerstin	A4	RUG
Busch	Leonard	A3	University of Amsterdam (UvA)
Cancès	Clément	C5	Inria
Carioni	Marcello	C5	UT
Carletti	Lorenzo	A3	ULB
Charlier	Christophe	D4	UCLouvain
Cobos Rábano	Alberto	D1	KU Leuven
Cook	Linda	A1	Utrecht University
Craig	Tracy	C4	University of Twente
D'Huys	Otti	D3	Maastricht University
de Heide	Rianne	D6	University of Twente and CWI Amsterdam
Fine	Joel	C2	ULB
Fintzen	Jessica	Keynote	Bonn
Geyer	Anna	C3	TU Delft
Ruzhansky	Michael	C3	Ghent University
Giovenzana	Luca	D1	UAntwerpen
Grinko	Dmitry	B4	University of Amsterdam, QuSoft
Hageman	Jos	C4	Wageningen University & Research (WUR)
Halconruy	Hélène	C6	Telecom SudParis
Hataishi	Lucas	C1	University of Oxford
Jurrius	Relinde	D2	Netherlands Defence Academy (NLDA)
Kaplan	Elliot	B1	UMONS
Karbach	Sven	D7	University of Amsterdam
Koellermeier	Julian	B5	UGent
Ko	Hankyung	C1	Uppsala university
Kohl	Lisa	B4	CWI Amsterdam
Kohn	Kathlén	Keynote	KTH Royal Institute of Technology
Koning	Nick	D6	EUR
Kurtz	Jannis	A4	University of Amsterdam
Lacaux	Céline	C6	Avignon University, LMA UPR 2151
Laheurte	Vincent	C3	University of Luxembourg
Lavoyer	Lucas	A2	University of Münster
Le	Van Chien	B3	UGent
Lentjes	Bram	D3	Hasselt University
Ley	Christophe	B6	University of Luxembourg
Loizidou	Sophia	A6	uni.lu
Lucka	Felix	A4	CWI
Maes	Frederick	B3	Ghent University
Martin de Diego	David	B2	ICMAT-CSIC

Continued on next page

Name	First name	Session	University
Mattheus	Sam	A1	VUB
Moda	Massimiliano	D7	University of Antwerp
Mulas	Raffaella	D2	VU Amsterdam
Nowé	Ann	D5	Vrije Universiteit Brussel
Paindaveine	Davy	A6	ULB
Passamonti	Chiara	A6	University of Luxembourg
Peletier	Mark	B2	TU/e
Pistolato	Francesca	C6	Université du Luxembourg (UniLu)
Provoost	Evert	D3	KU Leuven
Regragui	Mustapha	D7	Ghent University
Romeijnders	Ward	D5	University of Groningen
Royo Abrego	Andoni	A2	University of Tübingen
Sabitbek	Bolys	B3	Ghent University
Samaey	Giovanni	A5	KU Leuven
Scarabosio	Laura	A5	Radboud University (RU)
Schelstraete	Léo	C1	MPIM
Seri	Marcello	A3, D2	University of Groningen
Thiele	Christoph	Keynote	University of Bonn
Toussaint	Lauran	C2	VU Amsterdam
van der Hofstad	Remco	D4	TU/e
Van Werde	Alexander	D4	University of Münster
Verhasselt	Anneleen	B6	Hasselt University
Vermeeren	Mats	B2	Loughborough University
Vogiatzi	Artemis	A2	University of Copenhagen
Vovk	Vladimir	D6	Royal Holloway, University of London
Wahl	Nathalie	Keynote	University of Copenhagen
Wisniewska	Jagna	C2	University of Augsburg
Willems	Klaas	B5	KU Leuven
Wilhelm	R.-Paul	B5	KU Leuven
Wan	Phyllis	B6	Erasmus University Rotterdam
Zou	Tingxiang	B1	University of Bonn

Titles and Abstracts of the Keynote talks

Representing number theoretic symmetries with linear algebra

Jessica Fintzen[1]

[1]Bonn

Abstract. A common theme studied in number theory are congruences between integers modulo prime numbers or modulo powers of prime numbers. A way to encode all those congruences at once is provided by a field that is called “the field of p-adic numbers”. Out of this field one can build interesting groups, called p-adic groups, which are number theoretic analogues of Lie groups, have a similar rich structure, and which play a central role in the Langlands program, for example. A key question that mathematicians ask is how one can represent these complicated-looking p-adic groups using more common complex matrix groups, in other words, using more traditional linear algebra.

In this talk, I will introduce p-adic numbers and p-adic groups and then provide an overview of what we know about the representations of these groups including recent developments. This means I will explain how close we are to answering the key question above. I might also sketch applications to other problems in mathematics.

Algebraic Neural Network Theory

Kathlén Kohn[1,2]

[1]KTH Royal Institute of Technology
[2]Digital Futures, Stockholm

Abstract. The space of functions parametrized by a fixed neural network architecture is known as its 'neuromanifold', a term coined by Amari. Training the network means to solve an optimization problem over the neuromanifold. Thus, a complete understanding of its intricate geometry would shed light on the mysteries of deep learning. This talk explores the approach to approximate neural networks by algebraic ones that have semialgebraic neuromanifolds. Such approximation is possible for any continuous network on a compact data domain. By the universal approximation theorem, algebraic neural networks are essentially the only ones whose neuromanifolds span finite-dimensional ambient spaces. In this setting, we can interpret training the network as finding a 'closest' point on the neuromanifold to some data point in the ambient space. This perspective enables us to understand the loss landscape better, which is the graph of the loss function over the neuromanifold. In particular, the singularities (and boundary points) of the neuromanifold can cause a tradeoff between efficient optimization and good generalization: On the one hand, singularities can yield numerical instability and slow the learning process (which was already observed by Amari). On the other hand, we will observe how the same singularities cause implicit bias to stable and sparse solutions. Computing the singularities is often a technical endeavor, and requires us to determine both the hidden parameter symmetries of the network and the critical points of the network's parametrization map. In this talk, we will carefully compare 3 popular architectures: multilayer perceptrons, convolutional networks, and self-attention networks. The results presented in this talk are based on several joint works with Paul Breiding, Erin Connelly, Nathan Henry, Giovanni Marchetti, Stefano Mereta, Vahid Shahverdi, and Matthew Trager.

Nonlinear Fourier analysis and applications

Christoph Thiele[1]

[1]University of Bonn

Abstract. Motivated by recent applications in quantum signal processing, we will revisit the old subject of nonlinear Fourier analysis. We will discuss new momentum in the subject as well as some classical motivation including formal solutions to integrable PDE, of which the Korteweg de Vries equation is an example, and the theory of orthogonal polynomials.The talk will be accessible to a broad mathematical audience

Bigger is sometimes better

Nathalie Wahl[1]

[1]University of Copenhagen

Abstract. Many objects come in an infinite family: matrices can have as many rows and column as we like, free groups can have as many generators as we want, surfaces exist for any given genus, configuration spaces of points can have any number of points, etc. The principle of homological stability is that letting this size parameter go to infinity can make certain computations easier.

The talk will explain this principle through examples, pictures, paper garlands, introducing some of the main ideas and success stories.

Titles and Abstracts of the Parallel Session Talks

Structural properties of graphs from the injection metric

Matteo Bertuzzo[1], **Aida Abiad**[1,2], **Alberto Ravagnani**[1]

[1] Eindhoven University of Technology
[2] Vrije Universiteit Brussel

Abstract. The injection metric is closely related to, but distinct from, the subspace metric, and induces a notion of distance between subspaces over a finite field. In this talk, we consider graphs arising from the injection metric and investigate its fundamental properties, exploring how the metric influences the combinatorial and geometric structure of the resulting graph.

200,000 colors suffice for t-perfect graphs.

Linda Cook

Utrecht University

Abstract. A stable set in a graph is a set of pairwise non-adjacent vertices.The stable set polytope of a graph on n vertices is the convex hull in $\mathbb{R}^n$ of the incidence vectors of each of its stable sets. Since computing the stable set is NP-Hard, it is not expected that the stable set polytope of a general graph admits a (roughly-speaking) “nice” “easily verifiable” set of defining inequalities. However, certain well-known graph classes such as perfect graphs have this property. In this talk we examine one such graph class called “t-perfect graphs” and show that graphs in this class are 200,000 colorable, answering a question of B. Shephard from 1995. The proof relies largely on techniques from structural graph theory.

Perfect graphs can be described as the graphs whose stable set polytopes are defined by their non-negativity and clique inequalities. In 1975, V. Chvátal defined an analogous class called t-perfect graphs, which are the graphs whose stable set polytopes are defined by their non-negativity, edge inequalities, and odd circuit inequalities. We show that t-perfect graphs are 200,000-colourable. This is the first finite bound on the chromatic number of t-perfect graphs. This bound is probably not tight; M. Laurent and P. Seymour gave an example of a t-perfect graph requiring four colors in the 1990's and it is open whether all t-perfect graphs are 4-colorable.

Joint work with: Maria Chudnovsky (Princeton), James Davies (Leipzig), Sang-il Oum (IBS DIMAG), Jane Tan (Oxford)

Limitations of inertia-type bounds

Aida Abiad[1], Nils van de Berg[1], Sam Mattheus[2]

[1]Technische Universiteit Eindhoven
[2]Vrije Universiteit Brussel

Abstract. The inertia bound is a classical tool from spectral graph theory to upper bound the independence number of graphs. However, up until 7 years ago [1], we did not have a single example where the ratio bound was provably *not* tight. Since then, several researchers have investigated the tightness of the inertia bound. Most notably, a recent result of Kwan and Wigderson [2] shows that in locally sparse graphs (i.e. C_4-free or girth 5) the inertia bound is always linear in the number of vertices, while examples of such are known, for example from finite geometry, with much smaller independence number.

We investigate the tightness of inertia-type bounds related to graph powers. This class of graphs appears in several contexts, such as the theory of distance-regular graphs and coding theory. An important property is that these graphs are never locally sparse, and hence require a different approach. Nevertheless, we are able to show that also for graph powers there can be a large gap between inertia-type bounds and the actual independence number. Our methods draw from several areas in discrete mathematics, ranging from additive combinatorics over probabilistic methods, to character sums over finite fields.

References

[1] J. Sinkovic, *A graph for which the inertia bound is not tight*, J. Algebraic Combin. 47(1): 39–50, 2018.

[2] M. Kwan, Y. Wigderson, *The inertia bound is far from tight* Bull. London Math. Soc. 56(10): 3196-3208, 2024.

The behaviour of Kähler-Ricci flow through conical singularities

Lucas Lavoyer[1]

[1]University of Münster

Abstract. Developing a theory of Kähler-Ricci flow through singularities is a longstanding problem in geometric analysis, with direct applications to different areas, such as Mori's minimal model program in algebraic geometry. Despite the progress in proving existence of the such a flow through singularities in many cases, how the solution behaves near a singular point is still unclear in general. Utilising a glueing procedure, we will construct a solution to the Kähler-Ricci flow starting from a Kähler metric with isolated conical singularities, under very general assumptions on the cone model. Our construction allows us to pin down the short-time behaviour of the flow near the singularity at small scales. Time permitting, we will briefly discuss applications to instances where the flow is already known to exist, such as flowing out of certain metric flips.

Regularity of conformal structures and applications in geometry

Andoni Royo Abrego[1]

[1]University of Tübingen

Abstract. Given a Riemannian manifold (M^n, g) with a metric of rough regularity, is it possible to deform it into a smooth Riemannian manifold via a conformal diffeomorphism? The aim of the talk is to give a precise answer to this question and to show some applications in conformal geometry and general relativity. In particular, we establish global regularity results for constant scalar curvature metrics, Bach-flat metrics, and static spacetimes. This is based on joint work with Rodrigo Avalos and Albachiara Cogo [1, 2].

References

[1] A. Avalos, A. Cogo, A. Royo Abrego, *Conformal Green functions and Yamabe metrics of Sobolev regularity*, Preprint, arXiv:2507.01674, 2025.

[2] A. Avalos, A. Cogo, A. Royo Abrego, *Regularity of conformal structures on closed 3-manifolds*, Preprint, arXiv:2511.00178, 2025.

High Codimension Curve Shortening Flow with Free Boundary

Artemis Vogiatzi

[1]University of Copenhagen

Abstract. We study curve shortening flow in high codimension for arcs with free boundary meeting a fixed smooth barrier orthogonally. We prove dilation-invariant curvature and higher-derivative estimates up to the boundary using a Stahl-type localised maximum principle and an adapted cut-off. Using a reflected Gaussian entropy and blow-up analysis, Type I boundary singularities yield a shrinking semicircle model after reflection. Type II blow-ups give a Grim Reaper translator, which is ruled out under a free-boundary entropy bound < 2. Hence in the low-entropy regime the flow either converges to the orthogonal chord or has only semicircle boundary singularities.

Analytic Microlocal Analysis and Inverse Problems

Leonard Busch[1], Tony Liimatainen[2], Mikko Salo[2], Leo Tzou[3]

[1]University of Amsterdam
[2]University of Jyväskylä
[3]University of Melbourne

Abstract. Does knowledge of the volumes of embedded minimal hypersurfaces in a compact Riemannian manifold (M, g) with boundary uniquely determine the metric g? By measuring at the surface of the earth the response of an induced seismic wave, can one uniquely recover the speed of sound below ground? What bridges these otherwise unrelated inverse problems is that both naturally give rise to transforms that are Fourier integral operators (FIOs).

Thereby motivated, upon presenting basic tools of analytic microlocal analysis relating support and analytic wavefront set, we develop a recipe that reduces uniqueness questions to the following analytic microlocal statement proven in [1]: one can recover the analytic wavefront set of a distribution from its image under a general class of elliptic analytic FIO.

Exploiting this framework, we show that the conformal perturbation of an analytic metric can be recovered in a Hölder stable way from minimal hypersurface volume data, provided a sufficiently rich family of minimal hypersurfaces exists. For the seismic inversion problem we show that perturbations of an analytic sound speed are uniquely determined by boundary measurements under some geometric conditions. This talk is based on [1, 2], the latter being joint work with Tony Liimatainen, Mikko Salo and Leo Tzou.

References

[1] Busch, L. Analytic Fourier Integral Operators and a Problem from Seismic Inversion. (2025), https://arxiv.org/abs/2505.08472

[2] Busch, L., Liimatainen, T., Salo, M. & Tzou, L. Generalized boundary rigidity and minimal surface transform. (2025), https://arxiv.org/abs/2510.23366

Compactness of the set of solutions to critical polyharmonic equations

Lorenzo Carletti[1]

[1]Université Libre de Bruxelles (ULB)

Abstract. Let $\Omega \subset \mathbb{R}^n$, $n \geq 3$, be a smooth bounded domain, and $k \geq 1$ an integer such that $n > 2k$. We consider critical equations of the form $Lu = |u|^{2^\sharp - 2}u$ in Ω, with Dirichlet boundary conditions, where $2^\sharp := \frac{2n}{n-2k}$ is the critical Sobolev exponent, and L is a linear elliptic operator whose leading order term is $(-\Delta)^k$. We show that, in high dimensions, the set of energy-bounded solutions is compact under perturbations of the lower-order terms of L. We bypass the difficulties brought by the higher-order setting by deriving a pointwise multi-bubble decomposition of sequences of solutions that present an asymptotic blow-up behavior. This is based on a joint work with Bruno Premoselli (ULB).

Scientific Machine Learning for partially observed dynamical systems

Kerstin Bunte[1], Peter Tino[2], Janis Norden[1], Michael Chappell[3], Dave Smith[2]

[1]University of Groningen
[2]University of Birmingham
[3]Coventry University

Abstract. Nowadays, most successful machine learning (ML) techniques for the analysis of complex interdisciplinary data use significant amounts of measurements as input to a statistical system. The domain expert knowledge is often only used in data preprocessing. The subsequently trained technique appears as a “black box”, which is difficult to interpret and rarely allows insight into the underlying natural process. Especially in critical domains such as medicine and engineering, the analysis of dynamic data in the form of sequences and time series is often difficult. Due to natural or cost limitations and ethical considerations data is often irregularly and sparsely sampled and the underlying dynamic system is complex. Therefore, domain experts currently enter a time-consuming and laborious cycle of mechanistic model construction and simulation, often without direct use of the experimental data or the task at hand. We now combine the predictive power of ML and the explanatory power of mechanistic models. Therefore we perform learning in the space of dynamic models that represent the complex underlying natural processes, with potentially very few and limited measurements. We use principles of dimensionality reduction, such as subspace learning, to determine relevant areas in the parameter space of the underlying model as a first step to achieve task-driven model reduction. We furthermore incorporate identifiability analysis for informed posterior construction to improve learning with ill-posed systems caused by data limitations. Findings indicate the possibility of an alternative handling of epistemic uncertainties for scientific machine learning techniques.

Mixed-Integer Optimization and (Explainable) Artificial Intelligence

Jannis Kurtz[1]

[1]University of Amsterdam

Abstract. Mixed-integer optimization is a powerful framework for modeling and solving a wide range of optimization problems involving discrete decision variables. Such problems typically arise in industries as logistics, healthcare, energy systems, and disaster management. In recent years, mixed-integer optimization has gained increasing attention in the context of machine learning, particularly for modeling trained classifiers such as decision trees and neural networks. These mixed-integer representations enable the integration of predictive models into classical optimization frameworks. Moreover, they can be used in explainable artificial intelligence (XAI), for example in the computation of counterfactual explanations. Conversely, concepts developed in XAI can be leveraged to explain classical optimization models.

Learning for X-ray Computed Tomography

Felix Lucka[1]

[1]Centrum Wiskunde & Informatica, Computational Imaging Group, Amsterdam, The Netherlands

Abstract.

Due to its remarkable success for a variety of complex image processing problems, Artificial intelligence (AI), in particular Deep Learning (DL), is nowadays also more commonly used in the field of X-ray Computed Tomography (CT). In this talk, we will highlight some of the challenges and potential solutions of integrating Deep Learning into tomographic work-flows found in scientific, clinical or industrial applications. In particular, we will cover the acquisition of large-scale experimental data collections suitable for DL, the development of benchmarking frameworks for image reconstruction methods, and advanced topics such as online learning for real-time X-ray CT, adaptive projection angle selection using reinforcement learning and the use of diffusion models for tomographic image reconstruction.

TBA

Stephane Bordas

University of Luxembourg

Abstract. TBA

Multilevel computational methods for Bayesian inference of space-dependent parameter is parabolic partial differential equations

Giovanni Samaey

[1]KU Leuven

Abstract. This talk presents computational strategies for Bayesian inversion based on multilevel methods. We study Multilevel Markov Chain Monte Carlo (MLMCMC) for high-resolution observations and reduce the cost of evaluating large data sets through level-dependent data resolution and likelihood scaling using weighted subsets of observations at coarser levels. We compare parameter representations for spatially varying random fields using Karhunen–Loève expansions, wavelet expansions, and Local Average Subdivision (LAS), and identify LAS as the most efficient option on very fine grids. We also analyze subsampling in the MLMCMC hierarchy and show that independent coarse-level proposals are not required for valid multilevel acceptance probabilities. We derive an adaptive criterion for selecting subsampling rates that balance sampling error and per-level cost, yielding order-of-magnitude reductions in computational effort. We then consider multilevel interacting particle methods for Bayesian inversion. We focus on a single-ensemble MLMC formulation for Ensemble Kalman methods (EnKF, EKI, EKS), where MLMC is applied at each time step to estimate interaction terms within a globally coupled ensemble. This construction improves asymptotic cost-to-error scaling for computationally expensive forward models. To address non-Gaussian target measures, we introduce localized Consensus-Based Sampling (CBS). This derivative-free, affine-invariant method approximates the potential using a Moreau envelope and its gradient via a proximal operator, leading to dynamics driven by local particle interactions and a correction term that improves performance in multimodal settings.

This talk is based on joint work with Pieter Vanmechelen, Geert Lombaert, Arne Bouillon and Toon Ingelaere

Uncertainty quantification for time-harmonic wave propagation

Laura Scarabosio[1]

[1]IMAPP, Radboud University, The Netherlands

Abstract. Wave propagation and scattering lie at the core of many technologies, from nano-optical devices to medical imaging and seismology. In these systems, the propagation of waves is subject to sources of uncertainty, for instance in material properties or geometric features, and understanding how these affect the scattered field is crucial for reliable design and inference.

In this talk, I will focus on material and geometric uncertainties and their impact on time-harmonic wave scattering, as described by the Helmholtz equation, addressing both the forward problem of propagating uncertainty and the Bayesian inverse problem of recovering material properties or geometrical features from noisy measurements.

A central theme of the talk will be the role of frequency. Higher frequencies are essential in applications, as they carry more information, but they also introduce significant challenges for uncertainty quantification, affecting both the convergence and stability of numerical methods and the cost of model evaluations. I will therefore discuss the robustness of numerical methods for forward and inverse problems with respect to the frequency, and present a frequency-robust strategy based on recycling preconditioners to accelerate the repeated model evaluations.

Multiple change-point detection on the circle via isolation using permutation testing

Sophia Loizidou[1], **Andreas Anastasiou**[2], **Christophe Ley**[1]

[1]University of Luxembourg
[2]University of Cyprus

Abstract. In this talk we propose a new method for multiple change-point detection for piecewise-constant circular signals, a setting that, despite its importance in many scientific domains, remains comparatively under-explored. The proposed method, Permutation-based Circular Isolate-Detect, denoted PCID, uses an appropriately chosen contrast function and permutation testing to detect change-points in an offline manner, for the data sequence under consideration. Prior to detection, PCID isolates the change-points. The contrast function used is derived under the assumption of von Mises distribution for the noise, but we show that the method is robust and performs well for other distributions as well. Simulations are used to showcase the usability of the method in different signal and noise structures, including serially correlated noise. In order to exhibit the practical relevance of the method in real-world applications, PCID is applied to real-world datasets.

Spherical Oja means

Davy Paindaveine[1], **Thomas Verdebout**[1]

[1]Université libre de Bruxelles

Abstract. We propose a new class of location functionals for probability measures P supported on the unit hypersphere $\mathcal{S}^{d-1}$. The main idea is to minimize with respect to $\mu \in \mathcal{S}^{d-1}$ the expected (squared) ℓ-measure of the simplex with vertices $X_1, \ldots, X_\ell$ and μ, where the X_i's form a random sample from P. Here, $\ell \in \{1, \ldots, d\}$. For $\ell = 1$, it is easy to see that this provides the spherical mean functional, whereas for $\ell = d$, the resulting location functional is somehow related to the Oja median from [2]. Since the construction is based on an L_2 loss rather than an L_1 loss, this is actually closer to some of the location functionals introduced in [1] for Euclidean data. We leverage the methods introduced in [1] and [3] to study the properties of these new location functionals. One of the main issues is that, unlike in these earlier Euclidean works, the objective function to be minimized fails to be convex. Quite fortunately, it is possible to explicitly solve the non-convex optimization problem at hand, which is a key asset not only to study the theoretical properties of these functionals but also to evaluate these in the sample case.

References

[1] A. Dürre, A., D. Paindaveine. *Affine-equivariant inference for multivariate location under L_p loss functions.* Annals of Statistics, 50(5):2616-2640, 2022.

[2] H. Oja. *Descriptive statistics for multivariate distributions.* Statistics and Probability Letters, 1(6):327-332, 1983.

[3] D. Paindaveine. *On the measure of anchored Gaussian simplices, with applications to multivariate medians.* Bernoulli, 28(2):965-996, 2022.

Recovering the true density from rounded circular observations

Di Marzio Marco [1], Fensore Stefania [1], Passamonti Chiara[2], Taylor C. Charles [3],

[1]University of Chieti-Pescara
[2]University of Luxembourg
[3]University of Leeds

Abstract. In several fields, event times are often recorded with varying degrees of precision due to human rounding behavior. As a consequence, these artifacts affect the estimate of the distribution of event times and, if unaddressed, can lead to misleading conclusions.

Our research aims to recover the true event-time distributions when only rounded clock-time data are available. We start estimating rounding probabilities via a regression approach based on "minutes past the hour". The obtained probabilities are then used as an intermediate step for penalized inversion over the 24-hour cycle. Because clock-time data are circular, we take into account the periodic nature of the observations.

The methodology is applied to both simulated and real crime data.

The Reverse Mathematics of Lusin's Theorem

J. P. Aguilera

Abstract. Reverse Mathematics studies the question "given a theorem T, which specific axioms are necessary to establish T?" This talk concerns the reverse mathematics of Lusin's theorem that every analytic set (i.e., every continuous image of a Borel set) is Lebesgue measurable. We prove that, relative to the system of Arithmetical Transfinite Recursion (ATR0), the theorem is equivalent either to Σ^1_1-induction over the natural numbers, or to Π^1_1-comprehension, depending exactly on how it is formalized. This answers a question of Simpson (1999) and yields as a corollary a description of the best possible Turing complexity of measures of analytic sets. This is joint work with T. Kouptchinsky and K. Yokoyama.

References

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Geometric fields and minimality

Elliot Kaplan[1]

[1]University of Mons

Abstract. Many interesting fields and expansions of fields are geometric, meaning that the model-theoretic algebraic closure induces a pregeometry in every model. These include o-minimal expansions of ordered fields, h-minimal expansions of valued fields, and fields in which the model-theoretic and field-theoretic algebraic closure coincide (such as algebraically closed and pseudofinite fields). We show that under various model-theoretic hypotheses (stability, simplicity, rosiness), a theory of fields is geometric if and only if it is in some sense minimal. This is joint work with Antongiulio Fornasiero and Angus Matthews.

Around the Elekes-Szabó Theorem

Tingxiang Zou[1]

[1] University of Bonn

Abstract. The Elekes–Szabó Theorem can be stated informally as follows. Let $R \subseteq C^3$ be an algebraic surface defined over a field K of characteristic 0, where C is an irreducible curve defined over K, such that any two coordinates are interalgebraic with the third (for example, the collinearity relation for three distinct points on a curve). Suppose that there exist arbitrarily large finite subsets $A \subseteq C(K)$ of size n such that the intersection of R with A^3 has size approximately n^2. Then R is essentially the graph of the group operation of a one-dimensional algebraic group G.

In this talk, I will give an overview of several results, joint work with Martin Bays and Jan Dobrowolski, aimed at generalising the Elekes–Szabó Theorem to higher-dimensional settings using tools from model theory.

Geometric integration for double-bracket dissipation and metriplectic systems

David Martín de Diego[1]

[1] ICMAT (CSIC), Madrid, Spain

Abstract. In this talk, we will introduce geometric integration methods for modified Euler–Poincaré equations that include a special type of dissipative force.

The first case concerns mechanical systems with double-bracket dissipation. In particular, we will consider forced Euler–Poincaré and forced Lie–Poisson systems. The case of interest for us is when the coadjoint orbits remain invariant while the energy decreases along the orbit [1].

The second case addresses systems whose equations of motion can be described using a metriplectic formalism. This metriplectic representation of the dynamics allows us to describe the conservation of energy while guaranteeing entropy production. We will discuss different strategies for deriving geometric integrators that preserve the geometric properties of both types of systems [2].

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The discrete Herglotz variational principle

Mats Vermeeren[1]

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Abstract. Mechanical systems with linear dissipation are described by contact Hamiltonian systems. These can be characterised by a variational principle due to Herglotz, which can be used to construct variational integrators. There are a few different ways to formulate the Herglotz variational principle, which are equivalent in the context of continuous mechanics. In this talk, we discuss the analogous versions of the discrete Herglotz principle, as well as the use of geometric integrators for contact Hamiltonian systems in general.

Finding dissipation in a Hamiltonian system

Mark A. Peletier[1]

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Abstract. Hamiltonian systems are conservative. Nonetheless, 'hidden' inside such Hamiltonian systems one can sometimes find dissipative subsystems. This seems counter-intuitive. In this talk we discuss this phenomenon using a simple example, as well as some of its consequences.

In particular, we discuss how when coupled with random initial data this dissipative subsystem becomes an Ornstein-Uhlenbeck process, complete with accompanying fluctuation-dissipation relation. In recent work with Johannes Zimmer and Alex Mielke we show how this feature can give insight into the origins of the so-called GENERIC structure of thermodynamic dynamical systems.

Function spaces and well-posedness of elliptic-parabolic problems with moving subdomains

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Abstract. In this talk, I will present the key ingredients required to formulate the variational formulation for initial boundary-value problems of parabolic-elliptic PDEs posed on a fixed spatial domain containing time-dependent subdomains. The main difficulty arises from a coefficient in front of the time derivative that vanishes in part of the domain and is discontinuous across the moving interface. A class of function spaces that extend standard Sobolev–Bochner spaces will be introduced to capture this degeneracy and interface behavior. I will then establish the density of smooth functions in these spaces, develop the corresponding "embedding" result, and derive an appropriate integration-by-parts formula. Based on these results, the well-posedness of the variational problem in the natural setting is proved using the Banach–Necas–Babuska theorem.

Reconstruction of space-dependent sources in thermoelastic systems

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Abstract. A thermoelastic system describes the interaction between the elastic and thermal behavior of a material through the evolution of the displacement vector $\mathbf{u}$ and the temperature θ. The system of coupled equations governing the evolution of an isotropic thermoelastic system of type-III occupying a bounded domain $\Omega \subset \mathbb{R}^d$ over the time interval $(0, T)$ is given by

$$\begin{cases} \rho\partial_{tt}\mathbf{u} - \mu\Delta\mathbf{u} - (\lambda + \mu)\nabla(\nabla \cdot \mathbf{u}) + \beta\nabla\theta = \mathbf{p} & \text{in } Q_T \\ \rho c_s\partial_t\theta - \kappa\nabla\theta - (k * \Delta\theta) + T_0\beta\nabla \cdot \partial_t u = h & \text{in } Q_T \end{cases} \tag{1}$$

where $Q_T = \Omega \times (0, T]$. The functions $\mathbf{p}$ and h denote the load source and heat source respectively, and the coefficients in (1) are material dependent constants. Supplied with initial and boundary conditions, the well-posedness of the direct problem for (1) was proven in [1].

In this talk, we focus on the recovery of the spatial dependent parts of the sources, that is we assume the forms $\mathbf{p}(\mathbf{x}, t) = g(t)\mathbf{f}(\mathbf{x}) + \mathbf{r}(\mathbf{x}, t)$ and $h(\mathbf{x}, t) = g(t)f(\mathbf{x}) + s(\mathbf{x}, t)$ and aim to recover $\mathbf{f}$ and/or f based on a suitable measurement and conditions on g. Unique identifiability for the corresponding inverse source problems will be discussed [2]. Additionally, some numerical reconstruction methods based on iterative schemes including the Landweber method and the gradient descent algorithm for minimizing the associated cost functional will be presented [3]. This contribution is based on joint work with dr. Karel Van Bockstal.

References

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Scattering and Asymptotics for Critically Weakly Hyperbolic and Singular System

Bolys Sabitbek[1], **Arick Shao**[2]

[1]Ghent University

[2]Queen Mary University of London

Abstract. We study a very general class of first-order linear hyperbolic systems that both become weakly hyperbolic and contain singular lower-order coefficients at a single time $t = 0$. In "critical" weakly hyperbolic settings, it is well-known that solutions lose a finite amount of regularity at $t = 0$. Here, we both improve upon the analysis in the weakly hyperbolic setting, and we extend this analysis to systems containing critically singular coefficients, which may also exhibit modified asymptotics and regularity loss at $t = 0$.

In particular, we give precise quantifications for (1) the asymptotics of solutions as t approaches 0, (2) the scattering problem of solving the system with asymptotic data at $t = 0$, and (3) the loss of regularity due to the degeneracies at $t = 0$. Finally, we discuss a wide range of applications for these results, including weakly hyperbolic wave equations (and equations of higher order), as well as equations arising from relativity and cosmology (e.g. at big bang singularities).

This is joint work with Arick Shao (QMUL, UK).

References

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An algorithmic polynomial Freiman-Ruzsa theorem from stabilizer learning

Srinivasan Arunachalam[1], Jop Briët[2], Davi Castro-Silva[3], Arkopal Dutt[1] and Tom Gur[3]

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Abstract. In a recent breakthrough in additive combinatorics, Gowers, Green, Manners, and Tao (Annals of Mathematics, 2025) resolved the polynomial Freiman-Ruzsa conjecture. This talk is a about recent work (QIP'26) that *algorithmizes* their main result by *dequantizing* the stabilizer learning algorithm of Chen et al. (QIP'25).

Quantum Fourier transforms

Dmitry Grinko[1,2]

[1]QuSoft, Amsterdam
[2]ILLC & KdVI, University of Amsterdam

Abstract. In this talk, I will review recent progress on the implementation of several important quantum Fourier transforms. I will explain why the search for efficient quantum Fourier transforms is an important problem in quantum algorithms, and how recent advances in quantum computing have influenced some old questions in representation theory and combinatorics. As concrete examples, I will discuss the quantum Fourier transform over the symmetric group, the Schur transform, and Clebsch–Gordan transforms for both unitary and symmetric groups. Beyond surveying these developments, I hope to convey that this area contains many challenging old open problems, and to motivate the audience to take an interest in them.

Generating Pseudorandomness: Limitations and New Constructions

Lisa Kohl[1]

[1]CWI Amsterdam

Abstract. Randomness is essential in cryptography, forming the foundation of secure communication and advanced privacy-preserving protocols. A key tool for generating randomness on demand is a pseudorandom function (PRF), which expands a short random seed into a virtually unbounded supply of (pseudo)randomness. But how complex do these functions need to be? Learning theory tells us that certain function classes are "easy" to learn - and therefore easy to distinguish from random - imposing fundamental limits on PRF constructions. However, even when considering function classes that are not easy to learn, constructing concrete PRF candidates that are plausibly secure remains a challenging problem. In this talk, I will introduce the concept of PRFs and explore both theoretical limitations and explicit constructions of PRFs computable by shallow circuits.

Based on joint work with Marshall Ball, Clément Ducros, Saroja Erabelli, and Nicolas Resch [1].

References

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Hyperbolicity of a Hermite-Laguerre Moment Model for the Plasma Edge in Slab Geometry

Julian Koellermeier[1]

[1]UGent

Abstract. Simulating the plasma edge of magnetic confinement fusion devices requires a stable and efficient numerical approach. Particle dynamics can be modeled by a kinetic equation, which is difficult to solve due to the high dimensionality of the phase space. In this paper we derive a moment model for a reduced kinetic equation to elucidate the question of hyperbolicity of the system, which is necessary to create a stable numerical model. The system matrix of an infinite set of moment equations is derived, after which the hyperbolicity of the model is investigated through the characteristic polynomial of said matrix. Hyperbolicity regions of the models are calculated and loss of hyperbolicity is investigated in scenarios relevant to magnetic confinement fusion. Regularization procedures that make the system globally hyperbolic are used to overcome that loss of hyperbolicity leading to a stable moment model hierarchy for plasma edge simulations.

Structure-preservation through direct discretization of characteristic maps for transport-dominated plasma dynamics

R.-Paul Wilhelm[1]

[1]KU Leuven

Abstract. Simulation of plasmas in rarefied or high temperature regimes often requires modelling via the kinetic Vlasov equation. Not only is it a high-dimensional, non-linear system but it is also prone to strong turbulent dynamics. The lack of strong physical dissipation mechanism means that dynamically relevant instabilities are often triggered by fine-scale structures, which however, are hard to capture with traditional grid- or particle-based approaches as they tend to lie on a subgrid scale.

Recently developed numerical approaches show that it is possible to discretize the underlying characteristic (sub-)maps, which avoids the direct discretization of the complicated distribution function and therefore allows to resolve fine scale features even with a moderate amount of degrees of freedom. In this talk we discuss their properties and showcase how they can be efficiently implemented.

A semi-Lagrangian method for the polyatomic ESBGK model

Klaas Willems[1]

[1]KULeuven

Abstract. Polyatomic kinetic models are essential for accurately capturing the thermodynamic behavior of real gases, as internal energy modes significantly influence transport coefficients, relaxation processes, and non-equilibrium effects that cannot be represented by monoatomic models. The polyatomic ESBGK model describes molecular collisions as a relaxation towards a generalized Gaussian distribution with an anisotropic covariance matrix and an exponentially decaying internal energy distribution. We present a new semi-Lagrangian scheme for the polyatomic Ellipsoidal Statistical BGK (ESBGK) model of the Boltzmann equation.

The semi-Lagrangian framework, being deterministic and grid-based, removes the time-step restriction associated with the linear transport term by following the method of characteristics. The potentially stiff relaxation term is treated using an implicit A-stable linear multistep method which, owing to the structure of the BGK operator, can be reformulated into a cheap time-stepping scheme. This yields a highly efficient and numerically stable method. The numerical method is asymptotic preserving and stiffly accurate, meaning the scheme asymptotically converges to a scheme for the Euler equations in the vanishing Knudsen limit. In addition, we prove that the first-order scheme, asymptotically converges to the compressible Navier-Stokes equation with correct transport coefficients. Finally, we propose inflow and outflow boundary conditions suitable for BGK-type kinetic equations. We perform simulations of the Fourier and Couette test case to compare the BGK model with Direct Simulation Monte Carlo (DSMC). To conclude, we demonstrate the method on a challenging orifice flow test case with moving boundaries.

The trivariate wrapped Cauchy copula

Sophia Loizidou[1], Christophe Ley[1], Shogo Kato[2], Kanti Mardia[3]

[1]University of Luxembourg
[2]Institute of Statistical Mathematics
[3]University of Leeds

Abstract. We propose a new flexible distribution for data on the three-dimensional torus which we call a trivariate wrapped Cauchy copula. The proposed copula has the following advantages: (i) a simple form of density, (ii) an adjustable degree of dependence between every pair of variables, (iii) parameters with clear interpretation, (iv) well-known marginal and conditional distributions, (v) a straightforward data generating mechanism, (vi) a closed-form expression for trigonometric moments, and (vii) a simple implementation procedure for obtaining maximum likelihood estimates. As is the case with general copula models, the proposed copula can be extended to have any specific marginal distributions and hence can be utilized for flexible modeling. Moreover, our construction allows for linear marginals, implying that our copula can also model cylindrical data, which consist of both angular and linear observations. As an application of the extended copula model on the three-dimensional torus, we consider a dataset of trivariate dihedral angles of amino acids in bioinformatics.

Nonparametric estimation of the cross-ratio function under right censoring

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[1]Data Science Institute, Interuniversity Institute for Biostatistics and statistical Bioinformatics, Hasselt University, Diepenbeek, Belgium

Abstract. The cross-ratio function is a commonly used local dependence measure describing locally the strength of association between two time-to-event variables. One might for example be interested in quantifying locally the dependence between infection times for two pathogens in the same individual, or failure times for system components in reliability theory.

We propose a non-parametric estimator for the cross-ratio function under right censoring and illustrate its performance on simulated as well as real-life data.

Characterizing extremal dependence on a hyperplane

Phyllis Wan[1]

[1]Erasmus University Rotterdam

Abstract. In this talk, I characterize the extremal dependence of d asymptotically dependent variables by a class of random vectors on the $(d-1)$-dimensional hyperplane perpendicular to the diagonal vector $\mathbf{1} = (1, \ldots, 1)$. This translates analyses of multivariate extremes to that on a linear vector space, opening up possibilities for applying existing statistical techniques that are based on linear operations. As an example, I demonstrate obtaining lower-dimensional approximations of the tail dependence through principal component analysis. Additionally, the widely used Hüsler-Reiss family is characterized by a Gaussian family residing on the hyperplane.

Topological quantum field theories from complex locally compact quantum groups

Lucas Hataishi

University of Oxford

Abstract. The theory of locally compact quantum groups offers a framework to study analytical questions for quantized groups. It is for instance a natural setting in which to formulate a unitary representation theory for such objects, employing the machinery of operator algebras. In this context, complex locally compact quantum groups refer to the quantization of semi-simple complex Lie groups, for which the unitary representation categories have canonical braidings compatible with the unitary structure. This allows for the construction of a topological quantum field theory via factorization homology, producing a C*-category for each surface in a functorial manner. In this talk I will give a summary of this story and an overview of the state-of-the-art in the programm of explicitly computing this categories.

References

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Singular Soergel Calculus

Hankyung Ko

Abstract.

This talk discusses recent developments in a diagrammatic calculus for the 2-category of singular Soergel bimodules. The latter 2-category encodes the 'projective functors' in Lie theoretic representation theory such as category O for semisimple Lie algebras and generalizes the (regular) Soergel bimodules. In type A, Elias and Williamson had a conjectural and inexplicit presentation of the singular Soergel bimodules in around 2010, and major progresses were made in the last few years in [2] and related papers. A paper in preparation [1] is a completion of this calculus in type A, namely a proof of Elias-Williamson's conjectural presentation as well as a determination of explicit relations.

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How to solve the word problem in diagrammatic algebras?

Léo Schelstraete[1], Sigiswald Barbier[2]

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[2]Universteit Gent

Abstract. *Diagrammatic algebras* (formally, linear 2-categories) are the natural higher analogue of algebras: as the terminology suggests, their syntax is given by diagrams in the plane, replacing the familiar strings of letters in algebras. They appear throughout physics, computer science and mathematics, and in particular, representation theory.

Given a presentation of a linear structure, the *word problem* asks: can we find a basis? This question has a long history in classical algebra, from Gröbner bases to operads, nowadays automatized in algebra software.

In contrast, bases in diagrammatic algebras are usually constructed by example-specific methods. In this talk, we discuss general methods to solve the word problem in diagrammatic algebras [1], based on higher rewriting theory [2]. After reporting on applications to representation theory (including classification [3, 4] and categorification [1] results), we shall explain how to solve the word problem in the affine Brauer category. The latter is work in progress joint with Sigiswald Barbier.

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What does the Alexander polynomial know about minimal surfaces, and why should symplectic geometers care?

Joel Fine

Université libre de Bruxelles

Abstract. Let L be an oriented link in the 3-sphere, which we think of as the sphere at infinity of 4-dimensional hyperbolic space. I will describe a conjecture that the coefficients of the Alexander polynomial of L count connected oriented minimal surfaces in H^4 which have L as their ideal boundary. I will then explain why this is actually a statement about Gromov-Witten invariants of a certain symplectic 6-manifold. If there is time (which there won't be) I will talk about how one might try to prove the conjecture. I will also (not have time to) explain how to generalise this conjectural story to the HOMFLYPT polynomial and even potentially Khovanov-Rozansky homology.

Lagrangian Rabinowitz Floer homology in celestial mechanics

Jagna Wisniewska

University of Augsburg

Abstract. In this talk I will show how to apply Floer theoretical methods in the analysis of the Hamiltonian dynamics of the restricted three-body problem. Our research is motivated by the following practical question: can a rocket travel between any two points in the gravitational field of the Earth of the Moon, using its engines only at the beginning and at the end of the journey? I will show how to answer this question using the modern techniques of Lagrangian Rabinowitz Floer homology.

Rigidity/Flexibility of Symplectic Foliations

Lauran Toussaint[1]

[1]VU Amsterdam

Abstract. The aim of the talk is to illustrate that (conformal) symplectic foliations exhibit interesting rigidity/flexibility phenomena. To this end, I will discuss two results. First, a non-existence result for (strong) symplectic foliations, indicating that they are a good candidate for taut foliations in higher dimensions. Second, an existence result for (conformal) symplectic foliations in the style of the h-principle.

On the stability of solitary waves in a two-dimensional shallow water model

Anna Geyer[1], Yue Liu[2], Dmitry Pelinovsky[2]

[1]TU Delft, NL.
[2]University of Texas at Arlington, USA.
[3]McMaster University, Canada.

Abstract. The Camassa-Holm equation is a model for the unidirectional propagation of waves in shallow water. In this talk, we consider a two-dimensional generalisation of the Camassa-Holm equation in order to study the transversal stability of its solitary waves. Transverse stability refers the study of perturbations of the solitary wave solutions which are transverse to the direction of propagation. To this end we study the spectrum of an operator which arises after linearisation around a perturbation of the solitary wave in suitably weighted spaces. We prove that small-amplitude solitary waves are linearly stable with respect to transverse perturbations by performing careful resolvent estimates and making use of an asymptotic reduction of CH to KdV. The talk is based on joint work with Yue Liu and Dmitry Pelinovsky, see [1].

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Nonlinear diffusion equations for Hoemander sums of squares

Michael Ruzhansky[1]

[1]Ghent University

Abstract. In this lecture we will review known as well as recent results concerning the Fujita effect for nonlinear heat equations for Hormander sums of squares operators.

Controllability cost of metastable systems

Vincent Laheurte[1]

[1]University of Luxembourg

Abstract. In this talk, we consider the issue of the null-controllability for some problems presenting a metastable behavior. We will in particular consider the one-dimensional Burgers equation linearized at a stationary shock, and the Allen–Cahn equation linearized at a n-node solution. We give an upper and a lowerbound on the control time required for the controllability cost to remain bounded as the viscosity term tends to 0, aswell as a rough description of an admissible control. The proof relies on complex analysis and a precisespectral analysis of the operators at stake, and adapts methods previously used to tackle similar issues with very regular terms.

Teaching practices to introduce the limits of functions in the first year of university

Stéphanie Bridoux[1]

[1]UMONS

Abstract. The introduction of the formal definition of the limit of a function in the first year of university constitutes a major source of difficulty for students. This presentation focuses on the analysis of lecturers' discourse when they introduce this concept, drawing on two didactical tools : the notion of relief, see [1], and that of discursive proximities, see [2], . It also aims to show how these tools are used to formulate hypotheses concerning the ways in which students may interpret and appropriate this discourse.

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Didactics of vector calculus: an argument for educational research

Tracy Craig[1]

[1]Fundamental Education Research in Mathematics at Twente (FERMAT), Department of Applied Mathematics, University of Twente

Abstract. A topic that many of our students need to study and many find very challenging is multivariable and vector calculus. It is my favourite topic to teach and I enjoy the challenge of trying to make the work accessible to students, while at the same time getting them to "up their game". In preceding calculus courses, procedural proficiency might have been sufficient to guarantee a good result, but in multivariable and in particular vector calculus, conceptual understanding is key.

I shall present three studies related to multivariable and vector calculus, carried out by the mathematics education research group, FERMAT, at the University of Twente. These studies relate to constructing bounds for double integrals [1], writing a plan for effective problem solving [2] and technology-mediated assessment underpinned by the principle of decision making [3]. These studies show that the geometric demands of constructing multivariable integrals are considerably higher than many mathematics teachers might suspect and that decision making in problem solving is possible to assess, but challenging to teach.

Top ranking universities' mission statements always include recognition of the importance of high quality education. For example "student-centred academic teaching" and "excellence emerging from a culture of quality" [4], or "strives to offer personalised education through continuous refinement of education and appraisal of learning processes" [5]. In all subjects, but we look here specifically at mathematics, high quality education must be informed by educational research. In short, to teach mathematics effectively, we need to understand how students learn mathematics. This ambition is easier to state than to achieve, however. I shall argue that these exemplar studies carried out by my group emphasise the importance for departments of mathematics to employ academics with a university-level mathematics background and training in educational sciences.

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AI in data science education: experiences from the classroom

Jos Hageman

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Abstract. In this talk, I will share our experiences with AI tools, particularly large language models like ChatGPT, and data science education at Wageningen University. Based on interviews with course coordinators, I will discuss what we have learned about both the opportunities and challenges that AI brings to the classroom. While these tools can enhance learning and help students work more efficiently, there are concerns that overreliance on AI may hinder the development of essential problem-solving skills. I will emphasize the importance of guiding students toward responsible AI usage, addressing ethical considerations, and adapting our assessment methods accordingly. The key message is that AI can be a valuable educational asset when used thoughtfully to complement, rather than replace, fundamental learning processes.

Keywords: AI, data science, learning outcomes, large language models, experiences, teaching statistics

Discrete-to-continuum variational analysis for lattice spin systems

Annika Bach[1]

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Abstract. This talk will give an overview on recent progress on the passage from lattice spin systems such as the classical XY-model to continuum models in a variational framework. In such a framework, spin systems are considered as energy-driven lattice systems where the order parameter takes values in the unit sphere. The main challenge is then to characterize the macroscopic behaviour of such systems as the lattice spacing vanishes, while keeping the scale-dependent relevant microscopic information. A crucial tool to approach this challenge is Γ-convergence, which allows to coarse-grain discrete energy functionals to their continuum counterparts as the discretisation parameter vanishes.

Discretizing the Fokker-Planck equation with second-order accuracy: a dissipation driven approach

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[2]Group of Mathematical Physics, Departamento de Matemática, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
[3]Université Paris–Saclay, CNRS, Inria, UMR 8628 – Laboratoire de Mathématiques d'Orsay, 91405 Orsay, France

Abstract. We proposed and analyzed mathematically in [1] a fully discrete finite volume scheme for the standard Fokker-Planck equation. The space discretization relies on the well-known square-root approximation, which falls into the framework of two-point flux approximation finite volumes. In this talk, I will focus on the time discretization is novel and relies on a tailored nonlinear mid-point rule, designed to accurately capture the dissipative structure of the model. Numerical simulations show that our scheme is second order accurate both in time and space, and that one can solve the discrete nonlinear systems arising at each time step using Newton's method with moderate computational cost.

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Sparse optimization for dynamic problems with Optimal Transport regularization

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Abstract. In this talk, I will review recent results in sparse methods for optimization problems posed in spaces of time-dependent measures [a,b,c,d]. Particular emphasis will be placed on formulations involving Optimal Transport regularization, which naturally arise in dynamic inverse problems with applications to microscopy, tracking and, more broadly, to flows reconstruction of probability measures and data-driven frameworks.

I will first present sparse representation results that extend classical super-resolution theory to the considered setting [b,c,d]. These results rely on superposition principles for solutions of the continuity equation and provide structural insights into the complexity and the geometry of the optimization problem. I will then show how these theoretical insights can be exploited to design grid-free optimization methods for solving dynamic inverse problems [a,c] with a particular focus on applications in microscopy.

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Learning, Controlling, and Transferring Stochastic Dynamics

Kostic R. Vladimir[1], Karim Lounici[2], Hélène Halconruy[3], Timothée Devergne [1], Michele Parrinello [1], Massimiliano Pontil [1]

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Abstract. Learning the infinitesimal generator of a stochastic diffusion is key to capturing long-time behavior in physics and machine learning. Yet its unbounded and spectrally delicate nature defeats classical Hilbert–Schmidt methods, especially in high-dimensional or partially observed regimes. We propose an energy-based framework grounded in the intrinsic Dirichlet form of the diffusion, leading to reduced-rank RKHS estimators with finite-sample, dimension-independent spectral guarantees and controlled metric distortion [1]. This spectral control becomes essential when the goal is no longer to train models, but to adapt pretrained ones toward new objectives that are implicit, non-differentiable, or accessible only through black-box feedback. Viewing such models as samples from an underlying diffusion, transfer amounts to reshaping their generator. We therefore introduce a generator-driven transfer paradigm that leverages importance weighting to recover and steer along the slow manifold, enabling principled, low-variance adaptation without retraining [2].

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Fractional stable randoms fields on fractals

Fabrice Baudoin[1]**, Céline Lacaux**[2]

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Abstract. In this talk, we introduce fractional stable random fields on the Sierpinski gasket in the sense of distributions. We first focus on the existence of a density with respect to the Hausdorff measure. When this density field exists, we then study the smoothness of its sample paths. In the Gaussian framework, such a field always admits a modification with Hölder continuous sample paths. However, roughly speaking, in the non-Gaussian framework, the sample paths cannot be smoother than the Riesz fractional kernel. As a consequence, in this case, the density field either has unbounded sample paths or admits a modification with Hölder continuous sample paths. In the stable framework, Hölder regularity follows from an upper bound on the modulus of continuity, which we obtain using a LePage series representation.

Universal cancellations in Uniform Random Waves

Francesca Pistolato

Université du Luxembourg

Abstract. Motivated by quantum chaos theory, we introduce the class of *uniform* random waves, obtained by dividing a Gaussian random wave by its L^2-norm. We provide two main results: an explicit chaotic decomposition for functionals of uniform random fields; the exact cancellation of the second chaotic component for a broad class of geometric functionals. To conclude, we provide a lower bound for the variance of the excursion area of uniform random waves on the 2-sphere, showing that the second chaos cancels at *any* level, and detect the appearance of a *second-order* Berry's cancellation. The talk is based on [1].

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Moduli of lattice-polarized K3 surfaces and boundedness of Brauer groups

Abstract. Around 1970, torsion points on elliptic curves were studied by using the relation between topological and algebraic structures of their moduli spaces. In this project, we replace elliptic curves with K3 surfaces, which are certain higher-dimensional analogues of elliptic curves. The torsion points are replaced by the torsion part of the Brauer group of the K3 surface, a group which plays an important role in the study of rational points. Using moduli spaces, we give a new proof of a uniform boundedness result for Brauer groups of K3 surfaces in 1-dimensional families over number fields. This is joint work with A. Várilly-Alvarado and D. Bragg.

References

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Recent advances in enumerative geometry

Alberto Cobos Rábano[1]

[1]KU Leuven

Abstract. The goal of enumerative geometry is to count curves inside a smooth projective variety X subject to topological and geometric conditions. Gromov-Witten (GW) invariants satisfy this goal for genus zero curves, but do not succeed in positive genus. In genus one, Vakil and Zinger explained the discrepancy between GW invariants and actual curve counts using reduced GW invariants. I will explain the geometric picture behind this problem and how to generalize reduced GW invariants to any genus. This talk is based on [1].

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Boomerangs, elliptic curves and del Pezzo surfaces

Pierrick Bousseau[1], **Tom Bridgeland**[2], **Luca Giovenzana**[3]

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Abstract. We introduce boomerangs in the derived category of an elliptic curve C, defined as filtrations of the zero object whose factors are polystable objects with increasing phase. The numerical invariants of a boomerang are the Chern characters of the direct summands of its factors, which determine a lattice polygon. When this polygon is reflexive, we show that the moduli space of boomerangs with prescribed polystable factors is the complement of the anti-canonical embedding of C inside a del Pezzo surface Z. The proof relies on exceptional collections on Z. This is joint work in progress with Pierrick Bousseau and Tom Bridgeland.

Mathematics at work and mathematics on vacation

Relinde Jurrius[1]

[1]Netherlands Defence Academy

Abstract. When I took my first course in combinatorics during my bachelor studies, my friend from math camp described it as 'Vierkant voor gevorderden'. This might explain why my research is now focussed on combinatorics, and why I still go to math camp with Vierkant voor Wiskunde. In this talk I give a brief introduction to both and discuss how these activities do (and do not) influence each other.

Mathematics through stories

Raffaella Mulas[1,2]

[1]Vrije Universiteit Amsterdam
[2]Nora – Center for Science Communication

Abstract. Sharing stories can help us connect mathematical ideas to the people and creative processes behind them. In this talk, I reflect on storytelling as a tool across research, teaching, and outreach.

Mathematics on the headphones: can we talk about mathematics without a blackboard?

Marcello Seri[1]

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Abstract. In this work we will explore the opportunities and challenges in creating a mathematical podcast and trying to explain what we do, also in terms of our research, without the visual help of a blackboard or a beamer.

Interplay of delay, topology and noise in coupled oscillator networks

Otti D'Huys

Maastricht University, Dept. of Advanced Computing Sciences [1em]

Abstract. Time-delay networks are omnipresent in nature, as information transmission takes a finite time, for example between neurons in the brain, optical elements, in gene regulatory or communication networks. Here, we study small network motifs of phase oscillators coupled with delay. The coupling delay gives rise to coexisting stable oscillation patterns, under influence of noise, the network can switch between these coexistent orbits with different frequencies and different oscillation patterns. We compare the effect of additive noise in the oscillators (network nodes) and stochastic variations of the delays (network links).

When considering noise in (continuously coupled) oscillators, we can approximate the delay system by a non-delayed Langevin equation. This allows to analytically compute the distribution of frequencies, and their corresponding residence times. In a ring network, we show that the dynamics can be embedded in that of a single oscillator with delayed feedback, and that all oscillatory patterns are equally stable (in terms of relative attendance and lifetime), while the interplay of coupling delay and noise can induce in-phase synchronisation in other network motifs.

In oscillators with pulsatile interaction, we can apply multiple types of stochastic perturbations: noise acting on the oscillator, stochastically varying connection delays, and variations of the pulse magnitude. These different sources of noise all induce switching between stable coexisting states, but the system shows different scaling properties for different noise sources. Using a linear model, we provide qualitative explanations for the switching dynamics due to each of the noise sources.

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Characteristic Operators and Spectral Properties for Periodic Linear DDEs

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Abstract. Characteristic matrices are widely recognized as a powerful tool for studying the stability of equilibria in delay differential equations (DDE), both theoretically and numerically. In particular, Kaashoek and Verduyn Lunel developed in [1] a framework that reduces a challenging spectral problem in the infinite-dimensional state space $X = C([-h, 0], \mathbb{C}^n)$ to a simpler linear problem in the finite-dimensional codomain $\mathbb{C}^n$. Specifically, they established an equivalence after extension between $zI - A$, where A denotes the generator of the linear variational DDE around the equilibrium, and the characteristic matrix $\Delta(z) \in \mathbb{C}^{n\times n}$, showing that all spectral information of A is in fact encoded in $\Delta(z)$. Furthermore, the connection between A and $\Delta(z)$ serves as the foundation of (numerical) bifurcation analysis for DDEs near equilibria.

A natural question is whether a characteristic matrix approach can also be applied to study the stability of periodic orbits in DDEs. Results from the literature suggest that this is possible only under strict conditions or that the resulting characteristic matrices may exhibit undesired artifacts. Very recently, Lentjes et al. [2] observed that all spectral information around a T-periodic orbit in DDEs is captured by a generalized generator $\mathcal{A}$ and a characteristic operator $\Delta(z)$, where $\mathcal{A}$ and $\Delta(z)$ are unbounded linear operators acting on the function spaces $C_T(\mathbb{R}, X)$ and $C_T(\mathbb{R}, \mathbb{C}^n)$, respectively. These findings indicate that there should exist a deeper connection between $zI - \mathcal{A}$ and $\Delta(z)$ in terms of an equivalence, analogous to the autonomous case.

In this talk, we will extend the framework of Kaashoek and Verduyn Lunel from autonomous linear DDEs to periodic linear DDEs, addressing the various technical and interesting challenges that arise in this construction. As a surprising consequence of our general construction, we (partially) answer a conjecture by Hupkes and Verduyn Lunel regarding the discrete spectral structure of the Floquet exponents for mixed functional differential equations [3].

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Analysing Linear Time-Delay Systems with Lanczos' Tau Method

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Abstract. To incorporate internal transport phenomena into a model, one often uses delays, leading to a so-called time-delay system. As such a system not only depends on its current state, but also on its history, it is described by a functional differential equation (FDE). When we try to study these systems numerically, the inherent infinite dimensionality of FDEs generally leads to needing a discretization scheme. Although Lanczos tau methods were already proposed for the forward solution [1], optimal control [2], and stability analysis [3] of FDEs in the 80s, their use appears only limited compared to the collocation strategies for such analysis popularized in the early 2000s [4]. In the presented work [5], we revisit the former by reinterpreting it as a pencil of operators. In doing so, we can make novel connections between this approach, Padé approximation at the level of the associated nonlinear eigenvalue problem, collocation methods, and ultraspherical methods. To demonstrate the importance of the chosen discretization scheme, we conclude with an application to the approximation of the H^2-norm, an important system measure in robust control and model approximation. We note significant improvement to convergence rates, and sometimes super convergence, when using certain Lanczos tau methods, motivating our renewed interest in this technique.

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Extreme spacings between random matrix eigenvalues

Christophe Charlier[1]

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Abstract. In this talk, I will survey recent results on extreme gaps between random matrix eigenvalues. I will discuss both the largest and the smallest spacings, for both Hermitian and non-Hermitian matrices. I will also compare these results with the behavior of extreme gaps for independent and identically distributed random variables.

The surprising phase transition of percolation on uniform attachment random graphs

Remco van der Hofstad[1]**, Sayan Banerjee**[2]**, Shankar Bhamidi**[2]**, Rounak Ray**[3]

[1]Eindhoven University of Technology
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[3]Brown University

Abstract. Percolation is a paradigmatic model for network resilience, in which edges are removed randomly. It is one of the simplest models having a *phase transition*, meaning that there is a qualitative difference when few edges are removed compared to when many edges are removed, with the change occurring at a specific threshold. This talk is about the surprising percolation phase transition on uniform attachment random graphs.

In uniform attachment graphs, vertices arrive one by one with a fixed number $m \geq 2$ of edges that connect independently to a uniform vertex already present in the graph. We study percolation in the large graph limit. Remarkably, as proved by Bollobás and Riordan (2005), this percolation phase transition turns out to be of so-called *infinite order*, which means that the proportion of vertices in the largest supercritical connected component is very small. This is sometimes informally referred to as *slow birth of the giant component.*

We focus on the subcritical behaviour, where remarkably, the behaviour in the entire subcritical regime appears to behave critically, with the largest connected component growing as the network size to a power that depends on the edge-retention probability. This is a novel sign of the infinite-order phase transition.

On the spectral determinacy of random graphs

Nikita Lvov[1], Nils van de Berg[2], **Alexander Van Werde**[3]

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[2]Eindhoven University of Technology
[3]University of Münster

Abstract.

How much about a network can be deduced from the eigenvalues of associated matrices? Is the graph uniquely characterized by its adjacency spectrum? Both positive and negative examples are known, but it remains poorly understood what happens in the typical case given by an Erdős-Rényi random graph. I will discuss the history of this problem as well as new conjectures and recent progress on rigorous results (based on [1, 2, 3, 4]).

References

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Risk or Replace: Efficient Asymptotics for Data-Driven Maintenance

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[1] Eindhoven University of Technology
[2] University of Luxembourg [3] Tilburg University

Abstract. Condition-based maintenance (CBM) is an approach that plans interventions for deteriorating systems according to their observed operational state. CBM reduces unplanned downtime, extends usable lifetime, avoids unnecessary replacement, and mitigates the environmental impact associated with manufacturing and transporting new equipment. We study a heterogeneous population of components that degrade over time. We consider a general class of stochastic degradation processes with non-negative and i.i.d. increments that are characterized by component-specific parameters that remain unobservable to the decision maker. We rely on degradation data to estimate these parameters and determine replacement actions at equidistant epochs. The goal is to minimize the long-run average cost, which incorporates fixed replacement costs, failure costs, and operating costs that increase as components degrade. This problem can be formulated as a high-dimensional partially observable Markov decision process (POMDP), which is generally intractable due to the "curse of dimensionality." We develop a tractable, data-driven CBM policy that estimates the optimal policy of a hypothetical Oracle that has full information of the underlying degradation parameters and call this policy the Estimated Oracle's Optimal Policy (EOP). We introduce a scaling regime where both the failure thresholds and cost parameters increase proportionally, reflecting practical settings in which component lifetimes and maintenance costs are large relative to the observation frequency of modern sensors. We show that the regret of the EOP, defined as the difference between its long-run average cost and that of the Oracle, converges to zero in the scaling regime when the parameter estimator is consistent. We benchmark our EOP against the POMDP Policy using real degradation data; our policy performs excellently. Through extensive numerical experiments on both discrete and continuous state spaces, we show that the EOP achieves remarkably low regret across all settings. In instances where the optimal policy can be computed using the POMDP method, the optimality gap of the EOP is statistically indistinguishable from zero in simulation studies. .

The Mathematics of Reinforcement Learning

Ann Nowé

Vrije Universiteit Brussel

Abstract. In this talk, I will discuss the connection between reinforcement learning (RL) and stochastic approximation, highlighting how this link can be used to establish convergence guarantees across a wide range of settings. I will then introduce a line of research that extends beyond tabular methods, enabling the development of formal guarantees in more general frameworks. Finally, I will turn to multi-agent reinforcement learning, showing how game theory—particularly evolutionary game theory—provides a foundation for rigorous analysis.

Scaled Cuts for Multistage Stochastic Mixed-Integer Programs

Ward Romeijnders[1], Niels van der Laan[1], Sumin Kang[1]

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Abstract. We consider multistage stochastic mixed-integer programs with general mixed-integer state variables in all time stages. We develop cutting-plane based algorithms that maintain convex polyhedral outer approximations for all expected cost to-go functions of the problem. We introduce so-called scaled cuts to iteratively improve these convex polyhedral outer approximations and prove that the outer approximation in the first stage converges uniformly to the convex envelope of the first-stage expected cost to-go function. Using numerical experiments we show that our scaled cuts outperform Lagrangian cuts.

E-values: the building blocks for all multiple testing methods

Rianne de Heide[1,2]

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[2]Centrum Wiskunde & Informatica, Amsterdam, The Netherlands

Abstract. We present a novel necessary and sufficient principle for multiple testing methods. This principle asserts that every multiple testing method is a special case of a general closed testing procedure based on e-values. It generalizes the standard closure principle, known to underlie all methods controlling familywise error and tail probabilities of false discovery proportions, to a large class of error rates — in particular, this generalized closure principle applies to methods controlling the false discovery rate (FDR). By writing existing methods as special cases of this procedure, we can achieve uniform improvements of these methods, and we show this in particular for the eBH and the BY procedures, as well as the self-consistent method of Su (2018). We also show that methods derived using the closure principle have several valuable properties. They generally control their error rate not just for one rejected set, but simultaneously over many, allowing post hoc flexibility for the researcher. Moreover, we show that because all multiple testing methods for all error rates are special cases of the same procedure, researchers may even choose the target error rate post hoc. Under certain conditions, this flexibility even extends to post hoc choice of the nominal error rate. This is joint work with Neil Xu, Aldo Solari, Lasse Fischer, Aaditya Ramdas, and Jelle Goeman. [1]

References

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Unifying Tests and E-values

Nick W. Koning[1]

[1]Erasmus University Rotterdam, the Netherlands

Abstract. While the e-value is swiftly rising in prominence in many applications of hypothesis testing and multiple testing, its formal relationship to the classical theory of testing is not yet fully settled. We unify e-values and classical testing, by describing how e-values naturally arise as the 'continuous' or 'fuzzy' generalization of a test. This cements the foundational role of the e-value in hypothesis testing. Such continuous tests may be viewed as directly interpreting the rejection probability of classical randomized tests as evidence, offering the benefits of randomized tests without the downsides of a randomized decision. By generalizing the traditional notion of power, we obtain a unified theory of optimal testing which nests both classical Neyman-Pearson-optimal tests and log-optimal e-values as special cases. This shows the only difference between typical classical tests and typical e-values is a different choice of power target.

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E-values: origins and combination

Vladimir Vovk

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Abstract. I will start from covering probabilistic and statistical origins of e-values and discussing their place in the statistics toolbox. Perhaps the main strength of e-values is that they are easy to combine. I will state some ways of and results about combining e-values under various assumptions on their dependency structure (arbitrary, sequential, and independent e-values) and briefly discuss their uses.

Hedging Power Purchase Agreements

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[1] University of Amsterdam
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Abstract.

Power purchase agreements (PPAs) play a pivotal role in the green energy transition by locking in energy prices for uncertain future production from renewable plants, often up to 10 or 15 years. The value of a PPA is largely determined by the joint distribution of future production rates and forward energy prices. In this talk, we present quantitative methods for pricing and hedging PPAs. For this, we develop a coupled model for forward electricity prices and renewable power production indices using an HJM formulation. The use of a Wishart-type stochastic covariance model allows us to capture the complex covariance structure between future production rates and forward energy prices. We derive semi-closed form solutions for the (semi-static) variance-optimal price and hedge and analyse the effectiveness of this integrated approach on mitigating the volume and price risks intrinsic to PPAs compared to a Delta-hedging strategy and a fully static one consisting of a portfolio of power and weather derivatives.

Numerical Valuation of European Options under Two-Asset Infinite-Activity Exponential Lévy Models

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Abstract.

A numerical method for approximating the values of European-style financial derivatives is proposed, based on a two-asset exponential Lévy model for the underlying dynamic. The scheme accounts for both finite- and infinite-activity in the jump component.

According to the Feynman-Kac theorem, the fair value of a derivative satisfies a two-dimensional partial-integro-differential equation (PIDE). Our numerical scheme is structured in two main parts. First, it replaces the integro-differential operator with a finite-difference approximation, reducing the PIDE to a system of ordinary differential equations (ODEs). Second, it solves this system numerically by a suitable time-stepping method.

Among others, two notable challenges are addressed in developing this method. First, the integral term in the PIDE leads to a large dense matrix in the system of ODEs. To efficiently handle this, a second-order implicit-explicit time-stepping method is proposed, enabling application the fast Fourier transform. Second, for jump processes with infinite-activity, the jumps below a small threshold are approximated by a diffusive term, which conveniently removes the singularity in the integral term. Numerical experiments are presented illustrating the effectiveness of our numerical approach.

This work is inspired by [I.R. Wang, J.W.L. Wan, and P.A. Forsyth, Robust numerical valuation of European and American options under the CGMY process, J. Comp. Finan., 4 (2007), 10 :31-69, 2007].

Numerical methods for solving PIDEs arising in swing option pricing

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Abstract. Swing options are widely traded derivative contracts in the energy markets, especially the electricity market. They grant the holder the right to, dynamically, buy electricity at a predetermined, fixed price and, hence, reducing exposure to strong price fluctuations. The holder is subject to constraints on the quantity that can be exercised at each exercise date as well as over the whole contract period. In our research, we are interested in the numerical valuation of swing options. The energy price is modelled using a two-factor model to capture its mean-reverting behaviour. In addition, the model incorporates price spikes and allows for the possibility of negative prices. We consider swing options with discrete and fixed-time exercise rights, which lead us to the study of a sequence of two-dimensional partial integro-differential equations (PIDEs). We investigate both numerically and theoretically a finite difference approach for solving these equations. Using robust numerical solutions, we analyse the impact of key model parameters on the optimal exercise strategy.