

ApplMath²⁶

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Main information

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- Croatian Academy of Sciences and Arts
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Barbara Kaltenbacher, *Universität Klagenfurt, Austria*

Yuji Nakatsukasa, *Oxford University, UK*

Anna-Karin Tornberg, *KTH Royal Institute of Technology, Sweden*

Julien Vovelle, *CNRS, Université de Lyon, France*

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64. Mahima Yadav, *Ruhr University Bochum, Germany*

65. Tamar Zemach, *Tel-Hai University of Kiryat Shmona in the Galilee, Israel*
66. Josip Žubrinić, *University of Zagreb Faculty of Electrical Engineering and Computing, Croatia*

Program and schedule

Monday, September 21st

08:50 - 09:00	Opening
09:00 - 09:50	Plenary: Wick
09:50 - 10:30	Poster blitz #1
10:30 - 11:00	Coffee break
11:00 - 11:25	Lazar
11:25 - 11:50	Vlah
11:50 - 12:15	Drmač
12:15 - 13:30	Lunch
13:30 - 14:20	Plenary: Nakatsukasa
14:20 - 14:45	N. Bosner
14:45 - 15:45	Coffee break + Poster session #1
15:45 - 16:10	Gibali
16:10 - 16:35	Yadav
16:35 - 19:00	Free time
19:00 -	Welcome reception

Poster session #1: Damjanović, Huynh, Jankov Pavlović, Malinowski, Muha, Olić, Perić, Tolj, Tomljanović, Vlachkova, Vrdoljak, Vuković.

Tuesday, September 22nd

09:00 - 09:50	Plenary: Tornberg
09:50 - 10:30	Poster blitz #2
10:30 - 11:00	Coffee break
11:00 - 11:25	Fratrović
11:25 - 11:50	Kolyshkin
11:50 - 12:15	Radošević
12:15 - 13:30	Lunch
13:30 - 13:55	Lin
13:55 - 14:20	Bukač
14:20 - 14:45	Burazin
14:45 - 15:45	Coffee break + Poster session #2
15:45 - 16:10	Ljulj
16:10 - 16:35	Ogorzały

Poster session #2: Bujanović, Dilna, Đimoti, Kranjčević, Mikuš, Mughal, Mustafić, Novak, Tambača, Vlašić, Wu, Zemach.

Wednesday, September 23rd

09:00 - 09:50	Plenary: Vovelle
09:50 - 10:15	Antonić
10:15 - 10:45	Coffee break
10:45 - 11:10	Wang
11:10 - 11:35	Crnjac
11:35 - 12:00	Cvetković Ilić
12:00 - 13:30	Lunch
13:30 - 19:30	Free time
19:30 -	Conference dinner

Thursday, September 24th

09:00 - 09:50	Plenary: Kaltenbacher
09:50 - 10:15	Mlinarić
10:15 - 10:45	Coffee break
10:45 - 11:10	Žubrinić
11:10 - 11:35	Grbac
11:35 - 12:00	Kunštek
12:00 - 13:15	Lunch
13:15 - 14:05	Plenary: Güttel
14:05 - 14:30	Kressner
14:30 - 15:00	Coffee break
15:00 - 15:25	Rosenbaum
15:25 - 15:50	Mimica
15:50 - 16:15	Miloloža Pandur
16:15 - 18:30	Free time
18:30 -	AI open discussion & reception

Friday, September 25th

09:00 - 09:50	Plenary: Ehler
09:50 - 10:15	Grubišić
10:15 - 10:40	Begović Kovač
10:40 - 11:10	Coffee break
11:10 - 11:35	Ćurković
11:35 - 12:00	T. Bosner
12:00 - 12:10	Closing
12:10 - 14:00	Lunch

Plenary Talks

From Points to Curves: Discretization, Quadrature, and Mobile Sampling

Martin Ehler

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Many numerical methods begin by replacing a continuous object with finitely many samples. Usually, these samples are isolated points, so that information about a d -dimensional object is encoded by a 0-dimensional set. In mobile sampling, however, a single moving sensor may replace many stationary sensors by collecting data along a curve. This leads to a basic question: what makes a curve an accurate discretization of a higher-dimensional space?

In this talk, I will discuss a curve-based approach to quadrature, approximation, and sampling on compact manifolds. Starting from classical point sets and quadrature formulas, I will introduce measures supported on curves and discuss criteria for their quality. Spherical t -design curves provide a particularly natural model and extend the classical notion of spherical t -design point sets.

The broader message is that discretization need not be built only from points: curves offer structured and geometrically meaningful alternatives. And if none of this sounds appealing, there will at least be a few beautiful curves.

New Perspectives on Flexible and Randomized GMRES

Stefan Güttel

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Flexible GMRES is an iterative method for solving large-scale linear systems $Ax = b$ that allows for variable preconditioning. A key feature of flexibility is that the preconditioner itself may be an iterative method applied only approximately. Despite its widespread use, relatively little is known about the convergence behavior of flexible GMRES.

I will present new convergence results that help close this gap. I then use these results to construct a randomized Krylov method that solves general linear systems robustly and efficiently while requiring almost no parameter tuning. This is joint work

with Lauri Nyman (University of Manchester) and John W. Pearson (University of Edinburgh).

Forward and Inverse Problems in Nonlinear Acoustics

Barbara Kaltenbacher

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The importance of ultrasound is well established in the imaging of human tissue. In order to enhance image quality by exploiting nonlinear effects, recently techniques such as harmonic imaging and nonlinearity parameter tomography have been put forward. As soon as the pressure amplitude exceeds a certain bound, the classical linear wave equation loses its validity and more general nonlinear versions have to be used. Another characteristic property of ultrasound propagating in human tissue is frequency power law attenuation leading to fractional derivative damping models in time domain.

This talk we will first of all provide some background on modeling of nonlinearity on one hand and of fractional damping on the other hand, also giving an idea on the challenges in the analysis of the resulting PDEs. In the practically relevant case of periodic excitations with a source operating at a single or a few frequencies, it is useful to formulate the problem in frequency domain by means of a multiharmonic expansion. In order to justify this, existence of periodic solutions needs to be proven and we will report on recent joint work with Teresa Rauscher (University of Klagenfurt) and Benjamin Rainer (Austrian Institute of Technology) on this.

In the second part of the talk, we address some relevant inverse problems in this context, in particular the above mentioned task of nonlinearity parameter imaging, which leads to a coefficient identification problem for a quasilinear wave equation. In particular, we investigate the recovery of the nonlinearity coefficient commonly labeled as B/A in the literature, which is part of a space dependent coefficient κ in the Westervelt equation governing nonlinear acoustics. Corresponding to the typical measurement setup, the overposed data consists of time trace measurements on some manifold Σ representing the receiving transducer array. We will show some recent results pertaining to the formulation of this inverse problem in frequency domain and numerical reconstruction of piecewise constant coefficients in two space dimensions. The latter is joint work with Bill Rundell (Texas A&M University).

CUR approximation and Polynomial Interpolation: Connections and Applications

Yuji Nakatsukasa

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Low-rank approximation and polynomial (e.g. Chebyshev) interpolation are pillars of numerical analysis. They are usually introduced as distinct tools. In this talk, we reveal a surprising bridge between them via the CUR approximation, by showing that polynomial interpolation can be seen as a CUR approximation of an infinity-by-infinity matrix. This observation generalises naturally to various settings and leads to new insight and algorithms, often resulting in dramatically faster computation. I will present several illustrating examples in model-order reduction and randomized algorithms in numerical linear algebra.

A preconditioned method of fundamental solutions (MFS) for dense Stokes suspensions

Anna-Karin Tornberg

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The Stokes mobility and resistance problems for rigid particles in viscous flows appear in many natural phenomena and engineering applications. In this talk, I will present a method of fundamental solutions (MFS) that preserves several key advantages of boundary integral methods (BIMs), including spectral accuracy and a reduced number of degrees of freedom, while avoiding the need for special quadrature of singular integrals. This is achieved by placing source and collocation points on separate surfaces. For rigid particles, the flow field is represented by interior Stokeslets whose strengths are determined through a least-squares collocation procedure on the particle boundaries. With an appropriate preconditioner, the resulting formulation can be solved iteratively as a square linear system compatible with fast summation techniques such as the fast multipole method.

For any numerical method, the simulation of particles in near contact remains a major challenge, since discretizations become increasingly ill-conditioned and thin lubrication gaps require prohibitively fine global resolution. To address these difficulties, we consider spherical particles and introduce a two-body preconditioning approach that enriches the MFS with contact-adapted image representations. For each nearly touching particle pair, a localized fine-scale boundary value problem is solved and compressed into a smaller number of equivalent coarse sources that are incorporated into the global solve, allowing the global discretization to remain comparatively coarse. The resulting method maintains high accuracy in close-to-touching configurations, with robust and rapid GMRES convergence.

Joint work with Anna Broms, Imperial College London and Alex Barnett, The Flatiron Institute, New York.

Averaging lemma for transport equations with space dependent coefficients

Julien Vovelle

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Different works have recently considered the question of regularization via averaging phenomena, in the context of transport equations with space dependent coefficients. We will report on these works and give a relatively elementary proof, using no harmonic analysis, but rather geometric considerations and the local inversion theorem (joint work with Paul Alphonse and Billel Guelmame).

Space-time a posteriori goal-oriented error control and adaptivity for partial differential equations

Thomas Wick

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This presentation is on goal-oriented a posteriori error control, adaptivity and solver control for finite element approximations to boundary and initial-boundary value problems for stationary and non-stationary partial differential equations, respectively. In particular, coupled field problems with different physics may require simultaneously the accurate evaluation of several quantities of interest, which is achieved with multi-goal oriented error control. Sensitivity measures are obtained by solving an adjoint problem. Error localization is achieved with the help of a partition-of-unity. The resulting adaptive algorithms allow to balance discretization and non-linear iteration errors. Adaptivity is carried out in a classical isotropic fashion, but recent advances in non-isotropic refinement are discussed as well. Our developments are demonstrated with several numerical examples.

Contributed Talks

Propagation of oscillations and energy densities for semilinear equations

Nenad Antonić¹, Matko Grbac²

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Starting from our earlier computation of the transport equation satisfied by the H-measure associated to a sequence of oscillating solutions of partial differential equations [Antonić 1992, 1996; Antonić & Lazar 2003], we extend the results of [Tartar 1990; Francfort & Murat 1992; Gérard 1996] on propagation of oscillations for the wave equation. More precisely, we consider equations with coefficients depending both on space and time variables, and including the cubic nonlinearity which is of importance in quantum field theory.

This result is a consequence of newer results on the continuity of pseudodifferential operators [Antonić, Iveć, Vojnović 2019], and will hopefully be extended to symmetric hyperbolic systems, like the Dirac equation.

HPC approach to accelerate tensor diagonalizations

Erna Begović Kovač¹, Markus Hellgren², Roman Iakymchuk³, Hans O. Karlsson⁴

University of Zagreb Faculty of Chemical Engineering and Technology¹, Uppsala University^{2,3,4}

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We discuss a Jacobi-type algorithm for tensor diagonalization and present a high-performance CUDA implementation capable of processing tensors of arbitrary order on a single GPU. To assess its performance in a modern, accelerator-driven computing environment, the algorithm is benchmarked on the UPPMAX cluster equipped with NVIDIA H100 GPUs. We analyze the convergence behavior and evaluate runtime scalability across varying problem sizes. Our implementation demonstrates robust, predictable scalability when tested on increasingly large, arbitrary tensors. Furthermore, compared to the standard MATLAB reference implementation, the CUDA version achieves a speedup of over two orders of magnitude.

Blocking techniques for computing TT-cross approximation of a tensor

Nela Bosner

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Tensors are multidimensional arrays, and appear naturally in many fields. A d -dimensional array, for $d \geq 3$, requires memory storage for n^d data elements, which grows exponentially with the dimension d . Tensor train (TT) decomposition reduces these storage requirements to $\mathcal{O}(dnr^2)$, where r is the maximal TT rank. The TT-cross approximation is a low-parametric tensor approximation that uses only a small portion of its elements. In this way, the access to tensor elements is reduced even more. There are several existing algorithms for computing TT-cross approximations, and one of them proposed by Dolgov and Savostyanov (2020) minimizes the number of operations. On the other hand, this algorithm does not offer many possibilities for applying the blocking techniques, which optimize communication in the memory hierarchy. This makes it quite inefficient for higher ranks. Our ongoing work is focused on the development of a blocked TT-cross algorithm, parallelized on shared memory computers with GPU accelerators. In this talk we are going to present the basic ideas and building blocks of the new algorithm.

Multidegree CCC-splines

Tina Bosner

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When we observe splines of any kind, we usually assume that all pieces come from spaces of the same dimension. The idea of having splines with pieces coming from spaces of different orders started with polynomial splines, was then extended to Extended Complete Chebyshev (ECC)-spaces and piecewise ECC-spaces, and in this paper we generalize it to Canonical Complete Chebyshev (CCC)-spaces. We define the B-spline basis, introduce knot insertion together with a recursive way of calculating the single knot insertion matrices, and propose a de Boor-type algorithm based on it. Finally, we illustrate the proposed algorithm with examples.

Stochastic trace estimation with tensor train random vectors

Zvonimir Bujanović¹, Daniel Kressner², Hrvoje Olič³

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Stochastic trace estimation is a standard randomized technique for approximating the trace of a large matrix using only matrix-vector products. However, in tensor-structured settings, unstructured Gaussian or Rademacher test vectors may be too expensive to store and apply, while very cheap rank-one tensor-product vectors can suffer from sample complexities that grow exponentially with the tensor order. In this talk, we discuss random tensor train vectors as an intermediate structured alternative.

We present dimension-independent guarantees for Girard–Hutchinson trace estimation with Gaussian tensor train vectors, showing that the classical dependence on the accuracy and failure probability can be recovered when the tensor train rank is chosen appropriately. We describe an oblivious subspace injection result for sketches formed from independent random tensor train vectors, and discuss implications for Nyström++ trace estimation. The results show both the advantages and the limitations of tensor train random vectors: they can overcome the poor concentration of rank-one tensor-product sketches for Girard–Hutchinson estimation, but their use in Nyström++ requires additional numerical low-rank structure in the matrix.

The recursive correction method for fluid-structure interaction

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We propose a novel partitioned numerical method for simulating the interaction between a viscous, incompressible fluid and a thick, elastic structure. The method integrates a recently developed recursive correction approach with a Robin-based partitioning strategy and the Refactorized Midpoint method. Uniquely, this scheme achieves a second-order accuracy using only two subiterations per time step. We prove that the method is unconditionally stable and evaluate its performance on benchmark problems. Numerical results demonstrate that the proposed scheme matches the accuracy of a second-order strongly-coupled method while maintaining a computational cost comparable to that of a single loosely-coupled solve, offering a highly efficient solution strategy for challenging fluid–structure interaction problems.

H-convergence theory for anisotropic bending rods

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Homogenization theory in the sense of operators has been extensively developed for second-order elliptic problems, while corresponding results for higher-order models remain comparatively limited. In this talk, we present a homogenization theory for deformations of a one-dimensional elastic rod governed by a system of fourth-order equations with axially varying coefficients. The model arises through dimension reduction from three-dimensional linearized elasticity for thin rod-like structures with non-uniform cross-sections and is formulated in terms of transversal displacements and a matrix-valued bending tensor.

We introduce an appropriate notion of H-convergence for this fourth-order setting and establish its fundamental properties, including compactness, locality, preservation of ellipticity bounds, and independence of boundary conditions. A distinctive feature of the one-dimensional framework is that strong convergence of the stress sequence replaces the compensated compactness arguments typically required in higher dimensions. As a consequence, the effective bending tensor can be identified explicitly: the H-limit of any bounded sequence of uniformly elliptic bending tensors is given by its harmonic mean, even in the absence of periodicity.

Finally, we illustrate the theory with an example of a rod with variable cross-sections, showing how the homogenized stiffness matrix can be computed and interpreted within the proposed framework.

Homogenization of δ -horizon fractional diffusion

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Fractional differential operators have become an important tool for modelling non-local phenomena, including anomalous diffusion, transport in heterogeneous media, and continuum mechanics models such as peridynamics and fracture mechanics. We consider a finite δ -horizon fractional stationary diffusion problem on a bounded domain and study its homogenisation for highly oscillatory coefficients.

We characterise $H^{s,\delta}$ -convergence in terms of classical H -convergence and weak-* convergence which provides a precise description of the effective operator arising in

the homogenisation limit. Furthermore, we establish several properties of $H^{s,\delta}$ -convergence, including uniqueness of the limit, metrisability and energy convergence. Finally, we analyse the limiting regime as $\delta \rightarrow \infty$, thereby establishing a connection between finite-horizon and infinite-horizon fractional diffusion models.

Numerical radius and Birkhoff-James orthogonality and symmetry for different classes of operators and C^* -algebra elements

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In this talk we will consider symmetry on the set of all bounded linear operators $\mathcal{B}(\mathcal{H})$, with respect to numerical radius orthogonality. Although there is a complete characterization of the sets of all right and left symmetric operators from $\mathcal{B}(\mathcal{H})$ with respect to Birkhoff-James orthogonality, in the case of numerical radius orthogonality we have only partial answers for some specific classes of operators (positive, Hermitian, compact). In this talk, we will completely characterize the set of all left symmetric operators from $\mathcal{B}(\mathcal{H})$ with respect to numerical radius orthogonality. Also, we will discuss the relationship between Birkhoff-James and numerical radius orthogonality for different classes of operators as well as the relationship with polar decomposition and different transforms of operators. All results will be consider for the C^* -algebra case.

[1] D. Cvetković Ilić, H. Stanković, Numerical radius symmetry and relations of Birkhoff-James and numerical radius orthogonality for different classes of operators, Journal of Math. Anal. Appl. 541, (2025) 128690.

Hierarchical Spline with Compact Displacement for Highly Rough Surfaces

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We present a hierarchical spline representation for highly rough 3D surfaces that combines a coarse B-spline base with a compact displacement field encoded as a 24-bit RGB image. Truncated hierarchical B-splines (THB-splines) enable adaptive local refinement without increasing global control points. The method reduces memory footprint, supports smooth multi-patch coupling, and allows efficient rendering. Applications include medicine, cultural heritage documentation, and industrial engineering. Experimental results on challenging engineering geometries confirm high fidelity and low storage, making the approach suitable for inspection, archiving, and further geometric analysis.

Asymptotic Analysis of Perforated Elastic Plates

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We are interested in the study of elliptic problems in perforated domains, as done by L. Tartar in the context of general diffusion equations with homogeneous Dirichlet (or Neumann) conditions imposed on the boundaries of the holes. In this setting, one considers sequences of second-order elliptic problems posed on domains containing an increasing number of small perforations. The resulting analysis reveals a delicate interplay between the geometry of the perforations, Poincaré-type inequalities, and the asymptotic behavior of solutions. A central question is to determine the critical scaling regimes leading to nontrivial homogenized limits and to characterize the corresponding effective equations. This framework also provides corrector results and offers insight into the combined effects of oscillating coefficients and varying domain geometry.

In this work, we extend this perspective to models arising in linear elasticity, with particular emphasis on the asymptotic analysis of perforated elastic plates, described by classical higher-order plate models such as the Kirchhoff–Love theory.

On the application of Ulam–Hyers stability to initial value problems for second-order functional differential equations

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We study Ulam–Hyers stability of initial value problems for second-order functional differential equations, working in a C^2 setting on a fixed bounded interval, for $\mathbb{R}^n$ -valued functions. We prove unique solvability via the Banach fixed-point theorem under a global Lipschitz condition on the nonlinear operator. A key insight is that, for the class of problems considered and our proof technique, Ulam–Hyers stability requires that the initial conditions of the differential equation should be coupled to those of the associated differential inequality. Under this coupling, we obtain an explicit Ulam–Hyers bound that enables accurate estimation of the exact solution. To illustrate our findings, we present several examples of the application of the obtained results to linear and nonlinear equations, demonstrating how the bound can be used in practice to estimate unknown solutions.

This research is supported by the Slovak Grant Agency VEGA-SAV Grant No. 2/0062/24 and The Slovak Research and Development Agency APVV Grant No. VV-MVP-24-0424.

[1] N. Dilna, I. Jadlovská. On the Correct Application of Ulam–Hyers Stability to Initial Value Problems for Second-Order Functional Differential Equations, *Mathematical Methods in the Applied Sciences*, (2026), V. 46, No. 7.

Robust Streaming Dynamic Mode Decomposition

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Dynamic Mode Decomposition (DMD) is a data-driven method that can be used to identify, analyse and forecast nonlinear dynamics. If we can sample data snapshots $s_1, s_2, \dots, s_{n+1}$ from a complex or unknown dynamical system, DMD reveals the dynamics solely based on the observed snapshots. By denoting $X := (s_1 \ s_2 \ \dots \ s_n)$, $Y := (s_2 \ s_3 \ \dots \ s_{n+1})$, finite-dimensional approximation of the dynamics is contained in DMD matrix A such that $AX \approx Y$.

In a streaming application, new data becomes available in discrete time intervals. DMD has to be recomputed over a widening window, or, in the case of shifting dynamics, narrowing window. For that reason it is important to have a fast and robust method to add and discard snapshots without starting from scratch. Unlike the existing streaming DMD methods that make use of the Woodbury formula and the matrix $(XX^T)^{-1}$ to update DMD matrix A , we propose a more robust method that relies on rank-revealing UTV decomposition of $X = Q_x T \tilde{Q}^T$ and its simple updates and downdates. This way, we avoid squaring the condition number ($\kappa_2(XX^T) = \kappa_2(X)^2$) resulting in a more robust method while maintaining similar time complexity. Our analysis and numerical experiments demonstrate better numerical properties that result in better forecasting skill.

On the Extended DMD for the Koopman and Perron-Frobenius operators

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In many applications, in particular in a data-driven framework, nonlinear dynamical systems are often linearized using the Koopman (for tracking changes of selected observables) and the Perron-Frobenius (for tracking changes of distributions over the state space) operators. These two operators have become tools of the trade in the computational data-driven analysis of complex nonlinear dynamical systems. For example, in computational fluid dynamics, the Koopman operator can be used to reveal coherent structures by decomposing the flow field into component fluid structures, called Koopman modes, that describe the evolution of the flow.

For practical numerical analysis, numerical algorithms are derived as variations of the Extended Dynamic Mode Decomposition (EDMD). The numerical realizations and software implementations of EDMD-based algorithms pose several challenges to numerical linear algebra, and this contribution discusses a few selected ones. Then, we present new robust numerical implementations of finite dimensional approximations

to the Koopman and Perron-Frobenius operators and their spectral information (eigenvalues and eigenfunctions). We also provide theoretical analysis with error estimates.

Quadratic correction to the Darcy-type boundary condition on a porous wall

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We derive a nonlinear Forchheimer-type boundary condition at the interface between a free fluid and a rigid porous wall using homogenization of the Navier–Stokes equations. The equations are considered on a rectangular, two-dimensional domain with a periodically perforated bottom boundary where Dirichlet conditions on the solid parts alternate with pressure conditions on the porous openings. The resulting law includes a quadratic correction in the normal velocity, accounting for the inertial effects. This generalizes classical linear models and provides a rigorous framework for nonlinear interface dynamics. The formal asymptotic expansion and the error estimates that justify the result are accompanied by numerical computations of the effective coefficients.

Harnessing Superiorization in Projection Methods

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Why choose between the speed of feasibility and the precision of optimization? This talk unveils the Superiorization Methodology, a game-changing framework that "piggybacks" on robust projection methods to find high-quality solutions with minimal overhead. We explore how "steering" simple iterative steps can solve massive, non-convex scientific challenges—from medical physics to complex logic puzzles. Discover a mathematically elegant way to achieve superior results where traditional solvers fail due to scale or complexity. A new frontier for efficient scientific computing.

Classical Optimal Designs for Stationary Diffusion with Multiple Phases

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We study optimal design problems for stationary diffusion involving one or more state equations and mixtures of an arbitrary number of anisotropic materials. Since such problems typically do not admit classical solutions, we adopt a homogenization-based relaxation framework. The objective considered is the maximization of a weighted sum of the energies associated with each state equation, with particular emphasis on identifying cases in which the optimal design is classical, that is, of bang-bang type, composed solely of the original pure materials. Such cases provide valuable benchmarks for numerical methods in optimal design.

A simplified optimization problem expressed in terms of local material proportions is analyzed through a dual formulation in terms of fluxes. Using a saddle-point characterization, we establish a complete description of its optimal solutions. The proposed approach is applied in detail to spherically symmetric problems. In the case of a ball, the method yields explicit classical solutions of the homogenization-based relaxation problem.

Rational quasi-Hermite approximation and applications in acoustic scattering

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In this talk, we present a computational approach for finding quasi-resonances in acoustic scattering based on the discretization of second-kind boundary integral operators. A quasi-resonance is characterized as a local minimum of the function that maps the real wave number to the smallest singular value of the Calderón operator. To locate these minima efficiently, we construct an adaptive piecewise rational approximation of this function, incorporating Hermite interpolation conditions in a weak sense.

Derivative information can be obtained efficiently in this setting: the dominant computational cost lies in assembling the discretized Calderón operator, while assembling its derivatives requires solely a postprocessing step. The main algebraic task is therefore the solution of a family of singular-value problems, for which we employ a subspace-accelerated randomized algorithm. Our approach extends standard randomized techniques to the computation of the smallest singular value, with particular attention paid to balancing the resulting algebraic error against the approximation error of the rational surrogate. For this purpose, the required linear systems are solved using BiCGSTAB with an H-matrix-based preconditioner.

This is joint work with Luka Marohnić (TVZ).

Inverse iterations for a class of nonlinear eigenvalue problems

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In this talk, we introduce a nonlinear inverse iteration method for computing constrained minimizers of functionals, the solution of a class of eigenvalue problems that involve nonlinearities in the eigenfunctions. Conventional numerical approaches, such as generalized inverse iterations or gradient descent, often converge very slowly. The method presented mimics a Newton-type iteration while preserving the structure of an inverse iteration. It overcomes the issue of slow convergence by making use of spectral shifting. We illustrate this method by considering spin-orbit coupled Bose-Einstein condensates and prove local linear convergence for fixed shift parameters. The analytical results are verified in numerical experiments. Moreover, we observe superlinear convergence for adaptively chosen shifts.

An adaptive procedure for defect identification in elastic plates

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Inverse problems often arise when measurements are available only on part of the boundary, making the identification of interior defects particularly challenging. We consider the problem of defect identification in thin elastic plates described by the Kirchhoff–Love model.

We focus on the small-amplitude regime, where the defect and the surrounding material are not very different, i.e. the ratio of their relevant physical properties is close to one. This setting is relevant for the detection of weak inhomogeneities that may occur during the fabrication process. Starting from displacement measurements corresponding to a given loading configuration and sensor placement, an optimization procedure provides an initial estimate of the defect location. This estimate is then used to adaptively update the loading zone and sensor locations.

Numerical examples illustrating the performance of the proposed method will be presented.

Linear and weakly nonlinear instability of convective flows in vertical channels

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Consider a convective flow of an incompressible fluid in a tall vertical channel generated by internal heat sources. Different kinds of heat sources are analysed (including nonlinear heat sources as a result of a chemical reaction taking place in the fluid). The problem is described by the system of the Navier-Stokes equations under the Boussinesq approximation. The properties of the corresponding nonlinear boundary value problem for the base flow solution are analysed. Linear stability problem of the base flow is solved using the method of normal modes (discretization is performed by means of a collocation method based on Chebyshev polynomials). Two types of vertical channels are considered: (a) plane vertical channel formed by two infinite parallel planes and (b) annulus between two concentric cylinders. Marginal stability boundary is found numerically for different values of the parameters of the problem. Method of multiple scales is used to derive an amplitude evolution equation for the most unstable mode assuming that the parameter controlling the flow (the Grashof number) is slightly larger than the critical value. It is shown that the amplitude evolution equation is the complex Ginzburg-Landau equation. The coefficients of the equation are expressed in terms of integrals containing solutions obtained at the previous steps of the expansion procedure. Results of numerical calculations are presented.

A numerical investigation of spectral properties of the heat-wave operator

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We investigate the spectrum of a coupled heat-wave operator on various domains. The eigenvalue problem is discretized and solved in FreeFEM and mesh convergence is demonstrated. On the rectangular domain the numerical spectrum is compared with an independent modal calculation based on separation of variables, confirming convergence of the finite-element eigenvalues to the modal values.

Halving the size of structured eigenvalue problems via the polar decomposition

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Matrix eigenvalue problems $Ax = \lambda x$ can often be solved much more efficiently when the matrix A has additional structure. In particular, owing to their importance in applications, real symmetric and complex Hermitian eigenvalue problems have been studied extensively, leading to efficient algorithms that are implemented in major software packages such as LAPACK. For other structures, efficient algorithms are often known, but they are less commonly available in well-tuned, high-performance standard software. Examples include real skew-symmetric and real orthogonal eigenvalue problems, which arise occasionally in applications but apparently not often enough to warrant highly tuned software implementations.

In this talk, we discuss how polar decompositions and randomization can be used to halve the size of such eigenvalue problems while transforming them into Hermitian eigenvalue problems that can be handled by standard software. Polar decompositions can be computed efficiently, for example by QDWH iterations, using only a small number of matrix inversions and multiplications. This leads to simple, highly performant, and parallelizable eigensolvers for a range of structured eigenvalue problems.

This presentation is based on joint work with Simon Maitagne and Haoze He.

Optimal Design of Kirchhoff–Love Plates Using Shape Derivatives and Homogenization

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We investigate an optimal design problem for thin elastic plates governed by the Kirchhoff–Love model subjected to transverse loading. The goal is to minimize compliance by simultaneously optimizing the plate’s outer boundary and the spatial distribution of two isotropic materials within the domain. Our methodology integrates shape calculus and homogenization theory within a single numerical framework. Shape derivatives drive the boundary evolution via a level set method, while interior material design is based on optimality conditions obtained from homogenized compliance minimization. The proposed hybrid algorithm is validated through numerical experiments, demonstrating its accuracy and efficiency in identifying optimal configurations.

An operator learning approach for parametric optimal control problems with slow decay of the Kolmogorov widths

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We consider a family of parameterized linear-quadratic optimal control problems with the aim of constructing reduced-order models (ROMs) that preserve the essential features of the underlying problems while significantly reducing their computational complexity.

We show that low-dimensional linear ROMs are unable to accurately capture the parametric behavior of the solution. To address this limitation, we propose a nonlinear surrogate model based on a U-Net architecture that incorporates ideas from operator learning. We discuss the key design choices underlying the neural network architecture and present extensive numerical experiments comparing the proposed approach with alternative methods. The results demonstrate its effectiveness on test cases that are particularly challenging for traditional linear reduced-order models.

Thermodynamically consistent phase-field models and their energy-law-preserving numerical schemes for vesicles and their interactions

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Under a thermodynamically consistent phase-field modeling framework for the binary incompressible (quasi-incompressible) fluid, which allows for the different properties (densities, viscosities and heat conductivities) of each fluid component, we will first show how to derive a model for motions and deformations of vesicles (e.g. red blood cells or RBCs) in a blood flow passing through a narrowed blood vessel. We will also propose a 2D Lennard-Jones type of interaction potential for vesicle-vesicle and vesicle-vessel wall interactions. Mass conserving and energy law preserving finite element schemes are designed and presented for these models. Many examples including the benchmark RBC deformation under stretching forces, RBC passing through a narrowed vessel wall, cell-vessel wall attraction, cell-cell interactions and cell aggregation, and how RBCs divide in the blood flow at a vessel bifurcation are computed and will be presented in the talk.

Thin-walled beams from Naghdi models

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In this talk, a derivation of elastic thin-walled beams in the context of linear elasticity will be presented. We observe a family of bodies of the form $[0, L] \times \varepsilon S^\varepsilon$, where L is the beam length and S^ε is an ε -thick strip around a curve $M : [0, L] \rightarrow \mathbb{R}$. We seek the limit as $\varepsilon \rightarrow 0$. We approach the problem in two ways: firstly, bodies are modeled as thin elastic shells of the Naghdi type with thickness ε^2 , and secondly, bodies are modeled as thin elastic rods of the Naghdi type with a cross-section dependent on ε . The Naghdi-type models used in the analysis are those for shells and rods with lower regularity, analyzed by the same authors in their previous works. In both approaches, we let $\varepsilon \rightarrow 0$, determine the limit, and compare it with results obtained in the literature.

On the Divergence Between Fuzzy and Classical Solutions in Stochastic Differential Models

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The development of a rigorous theory of fuzzy differential equations has, since its inception, encountered a number of fundamental mathematical obstacles. Early attempts to extend classical differential calculus to mappings with fuzzy values revealed intrinsic difficulties, most notably the lack of a satisfactory notion of subtraction for fuzzy sets and the resulting complications in defining a derivative of a fuzzy-valued function. These structural limitations manifested themselves in the geometry of solutions: even in simple deterministic settings, the diameter of fuzzy solution sets typically increases monotonically in time. This phenomenon has long been interpreted as an unavoidable growth of uncertainty inherent to the dynamics of systems modeled by fuzzy differential equations.

A further conceptual challenge emerged when researchers attempted to elevate deterministic fuzzy differential equations to the stochastic level. While classical stochastic analysis relies on the Itô integral as a cornerstone, constructing an analogue of the stochastic integral for fuzzy-valued processes proved to be mathematically problematic. Existing approaches either fail to preserve essential properties of the Itô integral or lead to definitions that are too weak, too restrictive, or incompatible with the established framework of stochastic calculus.

Despite these difficulties, a widely held belief persisted in the literature: whenever a fuzzy differential equation - deterministic or stochastic - admits a solution, the trajectory of the corresponding classical equation should be embedded within it. Formally,

it was assumed that any classical solution acts as a selection of the fuzzy solution mapping, implying that the fuzzy model generalizes and extends the classical one without altering its qualitative behavior.

The present contribution challenges this long-standing paradigm. Through a series of explicit examples and general theorems, we demonstrate that the classical solution associated with a given stochastic differential equation need not be a selection of the solution to the corresponding fuzzy stochastic differential equation. In fact, the two solutions may diverge significantly, even when the underlying stochastic dynamics are simple and well understood. This discrepancy reveals that the classical trajectory does not necessarily lie within the fuzzy solution set, contradicting the prevailing intuition and exposing a fundamental misconception in the interpretation of fuzzy differential models.

Our results show that the relationship between classical and fuzzy stochastic dynamics is far more intricate than previously assumed. The divergence between the two types of solutions is not an anomaly but a structural feature arising from the interaction between fuzziness and stochasticity. This insight calls for a more nuanced understanding of uncertainty propagation in fuzzy-stochastic systems. The findings presented in this talk thus overturn a persistent stereotype in the field and open new directions for the rigorous development of fuzzy dynamical models.

Analyticity of the data-to-solution map for a stationary Navier-Stokes fluid-structure interaction problem

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We study a stationary fluid–structure interaction problem coupling the steady Navier–Stokes equations with a Kirchhoff–Love beam through a free elastic interface. Focusing on a neighbourhood of the trivial configuration, we prove that the data-to-solution map is real analytic. The argument relies on a fixed-domain reformulation of the coupled system, a complexification procedure, and the holomorphic implicit function theorem.

Our analysis addresses the main sources of difficulty simultaneously: the geometric nonlinearity induced by the moving interface, the nonlinear convection term in the Navier–Stokes equations, and the dimensional mismatch between the fluid domain and the lower-dimensional elastic structure. As a consequence of the analytic regularity result, we also obtain a small-data existence and uniqueness theory for weak solutions of the coupled problem.

Beyond its theoretical interest, this regularity result is motivated by reduced-order and data-driven approximation of parametric PDEs, where the efficiency of surrogate models and the sample complexity of training procedures depend strongly on the smoothness of the parameter-to-solution map.

A mixed-precision preconditioned “naive” Jacobi eigenvalue algorithm for general complex matrices

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In this talk, we revisit a Jacobi-type algorithm, so called “naive” Jacobi algorithm [1], for solving the eigenvalue problem for general complex matrices with simple eigenvalues. The algorithm applies two elementary triangular similarity transformations to annihilate selected off-diagonal elements and, when convergent, produces highly accurate eigenvalue approximations.

We establish a new proof of the asymptotic quadratic convergence of the algorithm when applied to matrices that are sufficiently close to diagonal form. This closeness is characterized in terms of the diagonal entries of the current matrix and the off-diagonal entry of largest modulus. Since the algorithm is not guaranteed to converge for arbitrary matrices, we introduce a preconditioning strategy that transforms the original matrix into one that lies within the region of convergence.

To reduce computational costs, the preconditioner is computed in lower precision, while the associated similarity transformation and the main iterative process are carried out in double precision to preserve spectral information.

Numerical experiments demonstrate that the resulting mixed-precision preconditioned “naive” Jacobi algorithm is robust and that the use of mixed-precision arithmetic reduces computational costs without compromising the accuracy of the computed eigenvalues.

[1] Wolfgang Zacharias, Über die Eigenwertberechnung mittels primitiver Jacobi-Ähnlicher Verfahren, PhD thesis, Fernuniversität Hagen, 1989.

Does the Sylvester Criterion hold in the Infinite-dimensional setting?

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Sylvester’s criterion determines whether a Hermitian matrix is positive-definite by checking the sign of its leading principal minors. This seminal result holds in the finite-dimensional setting, but its generalization to infinite-dimensional matrices appears not to be fully explored in the existing literature.

In this work, we provide a constructive counterexample showing that the Sylvester criterion does not extend to infinite-dimensional matrices. The construction is based on a bounded self-adjoint multiplication operator acting on a Hilbert space and its explicit matrix representation in an orthonormal basis of eigenfunctions of the Dirichlet

Laplacian. We demonstrate that the resulting infinite-dimensional matrix possesses a nontrivial kernel, while all of its finite leading principal minors remain strictly positive.

The analysis combines techniques from operator theory, functional analysis, Ingham-type inequalities, and special functions. This result highlights a limitation of Sylvester's criterion and opens interesting questions for further research.

Optimal Localized Damping for the 1D Wave Equation

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Vibrational structures are prone to resonance-induced damage, typically mitigated by dampers, leading to the problem of optimal damper design. While well understood in finite-dimensional systems, optimizing damper placement remains challenging. We address this by introducing a PDE-based model of the damped wave equation with a damper of viscosity g at position p , and develop a system-theoretic frequency-domain analysis. The model describes a string of length $\ell > 0$, with damping coefficient $d > 0$, stiffness $k > 0$, input (forcing) $u(t) \in \mathbb{R}^m$, input vector $b(x) \in \mathbb{R}^m$, and a damper of viscosity (gain) $g \geq 0$ at position $p \in (0, \ell)$:

$$q_{tt}(x, t) + (d + g\delta_p(x))q_t(x, t) = kq_{xx}(x, t) + b(x)^T u(t), \quad x \in (0, \ell), \quad t > 0,$$

with boundary conditions and initial conditions.

Here δ_p is the Dirac distribution concentrated at p and we interpret d as *internal damping* while $g\delta_p$ is *external damping*.

We develop a unified system-theoretic input-output framework for both uniform and boundary forcing. In the frequency domain, we derive explicit transfer functions parameterized by p and g , enabling optimal damping analysis via $\mathcal{H}_2$ and $\mathcal{H}_\infty$ norms. We also analyze relevant limiting cases, including the absence of internal damping, and provide explicit expressions. With our approach, the impact of the simultaneous variation of damper position and viscosity can be efficiently analyzed.

Finally, we compare finite- and infinite-dimensional formulations, showing that the proposed continuous approach avoids discretization artifacts and enables the simultaneous optimization of damper position and viscosity.

On the Performance of Physics-Based Neural Networks for Symmetric and Asymmetric Domains: A Comparative Study and Hyperparameter Analysis

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Physics-Informed Neural Networks (PINNs) have emerged as a powerful data-driven framework for solving differential equations by incorporating physical laws directly into the training of neural networks. In this work, we investigate the performance of PINNs across three representative problems: the one-dimensional Poisson equation on a symmetric domain, Burgers' equation on an asymmetric domain, and a fourth-order Volterra integro-differential equation. Using the DeepXDE framework, we benchmark PINNs solutions against established classical methods, including explicit and exact-explicit finite difference schemes for Burgers' equation and the variational iteration method for the Volterra equation. Our results show that PINNs achieve accuracy comparable to, and in the case of the Volterra equation substantially exceeding, traditional approaches, with mean error roughly 27 times smaller than the reference method. We further conduct a systematic hyperparameter analysis, varying network depth, width, and the number of training points, and find that the choice of domain symmetry meaningfully affects convergence behavior and error distribution: symmetric domains exhibit faster, more stable convergence, while asymmetric domains require denser collocation near regions of sharp solution behavior. These findings provide practical guidelines for selecting PINNs architectures and training strategies, positioning PINNs as a viable and, in several respects, advantageous alternative to classical numerical schemes for solving ordinary, partial, and integro-differential equations.

Resonance and periodic solutions for partially dissipative systems

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We consider the abstract evolution problem $u'(t) = Au(t) + f(t)$ in a Hilbert space, where A generates a strongly stable but not uniformly stable C_0 -semigroup, the typical situation for partially dissipative systems such as coupled heat-wave models. In this setting classical resonance, i.e. an eigenvalue of A on the imaginary axis, cannot occur. Nevertheless, time-periodic forcing f may fail to produce a bounded, or any, time-periodic response. We discuss several notions of resonance appropriate to this setting, the relations between them, and their connection to the solvability of the time-periodic problem and to the behavior of the resolvent of A along the imaginary axis. The general framework is illustrated by coupled hyperbolic-parabolic systems, where

the geometry of the dissipative region plays a decisive role. The talk is based on ongoing work.

Deformation of a blood vessel caused by an inserted stent

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This work presents a model of a blood vessel deformation constrained by the inserted stent. In the area of stenosis, stent with certain geometric properties is placed to widen the vessel and ensures normal blood flow. Deformed configuration of the stent constraints the deformed configuration of the vessel and presents the obstacle. We formulate this problem via variational inequality and show uniqueness of the solution. Numerical examples are provided that include various types of stents, as well as blood vessels with different stiffness and amplitude of stenosis.

Dafermos' maximal dissipation principle and conservation law systems with flux discontinuities

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A discontinuity in the flux function for a conservation law system produces an extra source term containing the Dirac delta function. The problem of its multiplication with a non-smooth function does not have a general solution. Our idea is to use approximations of that product controlled by the Dafermos' maximal dissipation principle to extract the proper result in the form of a standing wave.

That reduces the original problem to two (for one discontinuity) with smooth flux functions, connected by the standing wave. The new problem is analogous to the well-known one for scalar conservation laws with discontinuous flux, and the standing wave has the same role as the connections there.

We shall demonstrate our approach to the shallow water model with a jump in a bed.

Spatial small-RNA regulation with a limiting Argonaute pool: well-posedness and simulations

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Small-RNA regulatory pathways frequently compete for a finite pool of Argonaute proteins, coupling otherwise distinct targets through a shared and mobile molecular resource. We formulate a reaction–diffusion–advection system for multiple target mRNAs, free small RNAs, loaded Argonaute–small-RNA complexes, and free Argonaute. The model imposes genuine total no-flux boundary conditions and distinguishes catalytic recycling from stoichiometric loss of a loaded complex after target engagement.

Quasi-positivity and a weighted mass identity provide the main a priori structure: loading and dissociation cancel exactly, whereas production, degradation, and target engagement determine the total mass balance. For constant positive diffusivities and zero drift, we prove existence and uniqueness of a global nonnegative classical solution. For bounded measurable, symmetric, uniformly elliptic diffusion coefficients and zero drift, we obtain a unique global nonnegative weak solution with finite-time L^∞ bounds. A common positive degradation lower bound yields uniform-in-time boundedness. Positive kinetic equilibria reduce from $M+2N+1$ unknowns to an N -dimensional system in the loaded-complex variables. In the one-channel case, the positive equilibrium is unique and its parameter dependence can be characterised explicitly.

For computation, we use a conservative cell-centred finite-volume method with harmonic diffusion fluxes, upwind drift fluxes, and SSPRK2 time integration. The method preserves the discrete transport balance exactly and exhibits second-order convergence in a smooth zero-advection verification problem. Dimensionless two-dimensional experiments reveal a finite-time reversal of crosstalk: increasing a competing small RNA raises the mean target level by 3.87% under Argonaute scarcity, but lowers it by 7.20% when Argonaute is abundant. Complete catalytic recycling produces a 7.75-fold larger recorded peak response than complete stoichiometric loss. Localised pulses also create delayed nonlocal responses, while increased small-RNA mobility broadens spatial repression fronts. Thus, a limiting mobile Argonaute pool provides a concrete mechanism by which intracellular transport and resource availability jointly control the sign, magnitude, and timing of cross-target regulation.

Tykhonov Well-Posedness Result and Convergence Result

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We present the Tykhonov well-posedness of a variational-hemivariational inequality with history-dependent operators. Some theorems are deduced to illustrate the continuous dependence of the solution with respect to the data. Next, a concrete example of the model from contact mechanics is presented for which the tools presented in this paper can be applied.

On randomized trace estimation for linear operators

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The implicit trace estimation is a problem of approximating the trace of a matrix A accessed only through matrix-vector multiplication $x \mapsto Ax$, with the goal of using as few multiplications as possible to obtain an accurate approximation. Girard-Hutchinson's estimator computes the ε approximation using $\mathcal{O}(\varepsilon^{-2})$ products, while its variance-reducing improvement, known as Hutch++, only requires $\mathcal{O}(\varepsilon^{-1})$ products. In this talk, we propose an extension of those algorithms to estimate the trace of a trace-class operator by using operator-function multiplications. Our estimator is based on the notion of a Gaussian distribution on an arbitrary Hilbert space, so precise high-probability error bounds can be derived analogously to the matrix case estimators. We compare the performance of our method with an existing algorithm of this type, the ContHutch++ algorithm by Zvonek, Horning & Townsend. The theoretical results we prove concern mostly positive definite operators, but we provide empirical results that show potential in applications to general trace-class operators.

Regularity results for equations of ultraparabolic type by velocity averaging

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Velocity averaging techniques provide a fundamental mechanism for obtaining regularity of solutions to kinetic and degenerate partial differential equations. We consider equations of ultraparabolic type and study the regularity of velocity averages of their solutions. The symbols associated to ultraparabolic equations are not homogeneous in the classical sense, but instead reflect the anisotropic scaling intrinsic to the ultraparabolic structure. Using the truncation property condition introduced by Tadmor and Tao, we formulate an averaging result adapted to this anisotropic setting. This yields improved regularity for velocity averages of weak solutions and clarifies how structural properties of the symbol can compensate for degeneracies in the equation. The result provides an extension of velocity averaging techniques to a broader class of ultraparabolic problems.

This is joint work with Marko Erceg, Darko Mitrović and João F. C. Nariyoshi.

Self-Propulsion in a Navier–Stokes Fluid via Periodic Shape Deformations

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We consider a body B moving in a fluid governed by the Navier–Stokes equations, where the fluid occupies the entire space outside B . The motion of the body is generated only by a prescribed periodic deformation, while no external forces act on either the body or the fluid. The goal of this talk is to derive sufficient conditions for self-propulsion, namely, conditions ensuring that the center of mass of the body can cover any given finite distance in finite time. The obtained conditions are illustrated by an example in which an explicit formula for the displacement of the center of mass is derived in the case of self-propelled motion.

Learning fixed points of recurrent neural networks by reparameterizing the network model

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In computational neuroscience, recurrent neural networks are widely used to model neural activity and learning. In many studies, fixed points of recurrent neural networks are used to model neural responses to static or slowly changing stimuli, such as visual cortical responses to static visual stimuli. These applications raise the question of how to train the weights in a recurrent neural network to minimize a loss function evaluated on fixed points. In parallel, training fixed points is a central topic in the study of deep equilibrium models in machine learning. A natural approach is to use gradient descent on the Euclidean space of weights. We show that this approach can lead to poor learning performance due in part to singularities that arise in the loss surface. We use a re-parameterization of the recurrent network model to derive two alternative learning rules that produce more robust learning dynamics. We demonstrate that these learning rules avoid singularities and learn more effectively than standard gradient descent. The new learning rules can be interpreted as steepest descent and gradient descent, respectively, under a non-Euclidean metric on the space of recurrent weights. Our results question the common, implicit assumption that learning in the brain should be expected to follow the negative Euclidean gradient of synaptic weights.

Optimal design of elastic nanopore membranes for bioartificial kidneys

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Silicon nanopore membranes are an essential component of implantable bioartificial kidneys. While these membranes utilize micromachined slit-pores to achieve high-efficiency blood filtration, the inherent porosity significantly compromises their overall structural stiffness.

In this study, we explore several strategies to mitigate this loss of structural integrity. These include optimizing pore dimensions, tailoring pore orientation to account for material anisotropy, and introducing beam-modeled rib reinforcements. We rigorously formulate these design challenges as smooth parametric optimization problems aimed at minimizing global structural compliance. Furthermore, we establish the mathematical existence of optimal solutions and develop a robust gradient-based algorithm for numerical simulations.

A Forchheimer-Based Framework for Thin-Channel Flow with Thermal Effects

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We investigate a Forchheimer-extended Darcy–Brinkman–Boussinesq model describing fluid flow through a thin porous channel subject to heating or cooling by the surrounding medium. The flow is driven by a prescribed pressure difference between the channel ends. Using asymptotic analysis with respect to the small channel thickness, we derive a first-order asymptotic approximation of the velocity, pressure, and temperature fields. The obtained approximation explicitly captures both inertial effects associated with the Forchheimer correction and thermal effects arising from buoyancy and heat transfer. Numerical examples illustrate the influence of these mechanisms on the flow characteristics. Finally, rigorous error estimates are established in appropriate norms, providing a mathematical justification of the asymptotic approximation and quantifying its order of accuracy.

A Scalable Framework for Simultaneous Optimization of Damper Placement and Viscosities

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We consider damping optimization for vibrating systems described by a second-order differential equation. For given mass and stiffness matrices, the aim is to determine an external damping matrix such that unwanted vibrations decay as rapidly as possible. Most existing work fixes the number of dampers in advance and optimizes only their positions and viscosities. Here we consider damper placement in a broader sense: the number of dampers is itself part of the optimization, and is determined simultaneously with the positions and the viscosities, so that a given optimization criterion is minimized up to a prescribed accuracy.

We restrict ourselves to homogeneous systems and to the minimization of the average total energy. In order to optimize the number and the placement of the dampers at once, we modify the average total energy criterion by adding a penalization term that promotes sparse damping configurations. The resulting problem is non-convex, and combinatorial due to the discrete choice of damper positions, which gives rise to

a large number of local minima. We therefore replace the sparsity penalty by a convex surrogate: the proposed method combines weighted ℓ_1 minimization with a pruning strategy that successively discards ineffective dampers, so that no combinatorial search over position sets is required.

The efficiency and accuracy of the approach are illustrated on several numerical examples.

Interpolation of Convex Scattered 3D Data using Edge Convex Minimum L_p -Norm Networks, $1 < p < \infty$

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We study the extremal problem of interpolation of convex scattered 3D data using smooth curve networks with minimal L_p -norm of the second derivative, $1 < p < \infty$, while ensuring convexity along the edges of an associated triangulation. The corresponding unconstrained problem (without convexity constraint) for $p = 2$ was set and solved by Nielson (1983). Andersson et al. (1995) gave a new proof of Nielson’s result by using a different approach which allowed them to set and solve the constrained problem for $p = 2$. The unconstrained problem for $1 < p < \infty$ was solved by Vlachkova (2020). Here we provide a comprehensive solution to the constrained problem for $1 < p < \infty$. We present some numerical experiments that illustrate and support our results.

Parameter-Aware Vision Transformers for Stable Long-Horizon Autoregressive Modeling of Parametric PDEs

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This is a joint work with Iva Mikuš and Boris Muha (University of Zagreb).

We study deep-learning surrogates for time-dependent parametric PDEs in an autoregressive rollout setting, where long-horizon accuracy is limited by the accumulation of one-step prediction errors. We propose AE-ViT, a parameter-aware encoder-transformer-decoder architecture: a fully convolutional encoder maps each solution snapshot to a latent tensor, a vision transformer advances the latent representation in time, and a decoder reconstructs the fields. PDE parameters are injected at multiple stages, through FiLM-type modulations and a parameter token, while coordinate channels provide spatial information. Training uses short-window scheduled sampling to improve robustness to the model’s own predictions.

On a parametric advection–diffusion–reaction benchmark and on two-dimensional Navier–Stokes flow past a cylinder, where velocity and pressure are predicted jointly, AE-ViT improves long-horizon rollout accuracy over latent-vector reduced-order baselines and a plain full-field ViT. In particular, it keeps the efficiency of latent evolution while avoiding the parameter-heavy latent-vector projection layers used by the autoencoder baselines.

Controlability Scores for Twofold Control

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We study the joint optimization of the initial state and the control input in a linear control system by $x'(t) = Ax(t) + Bu(t)$, with the goal of reaching a target state $x(T) = x^T$ while minimizing the cost function

$$J(x_0, u) = \frac{1}{2} \left(\alpha \|x_0\|_{\mathbb{R}^n}^2 + \beta \|u\|_{L^2(0,T;\mathbb{R}^m)}^2 \right),$$

where $\alpha, \beta > 0$. We show the problem is well-posed, derive the optimality conditions and provide an operator-theoretic formulation of the solution.

Furthermore, we analyse the controllability scores for the two-fold control and compare it with those obtained for the standard approach. We show that by adding the additional control component the set of states reachable with a fixed control cost enlarges. At the same time, the average energy for reaching target vectors on the unit sphere decreases.

Optimal design with uncertainties: a risk-averse approach

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We study a class of stochastic optimal design problems for elliptic partial differential equations in divergence form, where the coefficients represent mixtures of two conducting materials. The objective is to minimize a generalized risk measure of the system response, incorporating uncertainty in the loading through probability distributions. We establish existence of relaxed optimal designs via homogenization theory and derive first-order stationarity conditions satisfied by the optima. Based on these necessary conditions, we develop an optimality criteria algorithm for numerical computations. The stochastic component is treated using a truncated Karhunen–Loève expansion, allowing evaluation of the value-at-risk (VaR) and conditional value-at-risk (CVaR) contributions arising from the sensitivity analysis and featured in the algorithm. The method is illustrated for an example involving CVaR-based compliance optimization.

Homogenization theory of the Reissner-Mindlin plate equation

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We consider the homogenization theory for the Reissner-Mindlin plate described by

$$\begin{aligned} -\operatorname{div}(P\nabla\vec{\varphi}) + S(\vec{\varphi} + \nabla w) &= \vec{f} \\ -\operatorname{div}(S(\vec{\varphi} + \nabla w)) &= g, \end{aligned}$$

where w denotes the transversal displacement and $\vec{\varphi} = (\varphi_1, \varphi_2)$ represents the rigid rotation of the transversal fibers. The fourth-order tensor P and matrix S describe properties of the material, while $\vec{f}$ and g represent external forces.

Homogenization theory in the sense of operators was initiated by Spagnolo through the notion of G-convergence and subsequently generalized by F. Murat and L. Tartar via H-convergence. While the classical theory has been extensively developed for second-order elliptic equations, corresponding homogenization results for plate models remain relatively scarce. Significant recent progress has been achieved for the Kirchhoff–Love plate model, which accounts only for transverse displacement and is therefore appropriate for thin plates.

In this contribution, we extend this approach to the Reissner–Mindlin plate model, a second-order elliptic system that incorporates shear deformation and is consequently suitable for moderately thick plates. We introduce an appropriate notion of H-convergence for the Reissner–Mindlin plate model and establish its fundamental properties, including compactness, locality, independence of boundary conditions, and corrector results.

Cut Galerkin Difference Methods for Hyperbolic Partial Differential Equations

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Over the past two decades, the cut finite element method (CutFEM) has seen considerable advances for the numerical solution of partial differential equations in spatial domains with complex geometries. The CutFEM framework handles complex geometries on Cartesian meshes that need not conform to the domain boundaries and material interfaces. While this geometrical flexibility has made CutFEM successful for a wide range of applications, important challenges remain for hyperbolic problems. Despite the use of classical ghost-penalty stabilization, both the condition number of the mass matrix and the spectral radius of the semidiscretization exhibit rapid growth as the polynomial degree increases, leading to severe timestep restrictions for explicit time integration methods. In this project, we address these challenges by developing a cut Galerkin difference method (CutGDM) for hyperbolic partial differential equations in spatial domains with complex geometries. The proposed approach employs a Galerkin difference basis, consisting of piecewise Lagrange polynomials with support in multiple cells. This construction enables timestep restrictions in explicit temporal discretizations essentially independent of the polynomial degree. In a series of numerical examples, we demonstrate that the timestep restrictions of CutGDM remain comparable to those of the corresponding uncut situations, i.e., essentially independent of the polynomial degree.

An oscillation-free summation-by-parts finite difference method for hyperbolic conservation laws

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Hyperbolic conservation laws are widely used to model transport phenomena in applications such as fluid dynamics, traffic flow, gas dynamics, and shallow water systems. Analytical solutions are generally unavailable for most realistic problems. Therefore, the development of accurate, stable and efficient numerical methods for hyperbolic conservation laws remains an important research topic in scientific computing.

High-order numerical methods are highly efficient for hyperbolic conservation laws. However, they often produce spurious oscillations in the vicinity of solution discontinuities, thereby destroying the accuracy and stability of the numerical solution. In recent

years, many techniques have been developed to suppress spurious oscillations while retaining the advantages of high-order methods.

In this talk, we present an oscillation-free finite difference method for hyperbolic conservation laws. The spatial discretization satisfies a summation-by-parts property, leading to discrete conservation as well as energy and entropy stability. Furthermore, we employ a carefully designed damping mechanism to effectively suppress spurious oscillations near solution discontinuities while preserving the conservation and stability properties of the scheme. The resulting discretization is provably stable, and retains high-order accuracy in the smooth region of the solution. Finally, we present a series of numerical examples to demonstrate the effectiveness of the proposed method and verify the theoretical results.

On Metric-driven Riemannian optimization methods for rotating Bose-Einstein condensates

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This talk focuses on metric-driven Riemannian optimization methods for computing ground states of rotating Bose-Einstein condensates, defined as minimizers of the Gross–Pitaevskii energy functional. The proposed approach builds on Riemannian gradient techniques, leveraging the idea that gradients can be represented in different metrics to enhance stability and accelerate convergence. Specializing this framework to two metrics tailored to the energy landscape, we study the energy-adaptive and Lagrangian-based Riemannian gradient methods. In particular, we present a precise characterization of the local convergence rates in a neighborhood of each ground state u and how these rates can be explicitly quantified in terms of the selected metric and spectral gaps involving $E''(u)$, where E is the energy functional. The main analytical challenge is the lack of isolation of ground states due to invariance under complex phase shifts. Theoretical findings are confirmed by numerical experiments.

On axisymmetric gravity currents with internal stratification

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We investigate the propagation of high-Reynolds-number internally-stratified axisymmetric gravity currents released from a lock into a homogeneous ambient. Using an inviscid Boussinesq shallow-water framework, we model how internal density variations enhance the driving buoyancy force, leading to thinner currents and increased propagation speeds compared to constant-density counterparts. Our results indicate that, for certain current stratifications, a unique “bare spot” phenomenon occurs in the similarity solutions—a region of zero thickness at the center of the domain ($r = 0$) that emerges due to radial divergence. The model is specifically presented for two-layer and linearly internal-stratified configurations, providing a comprehensive theoretical foundation for predicting the morphology and dynamics of complex stratified axisymmetric flows.

An Operator-Asymptotic Approach to Periodic Homogenization for Equations of Linearized Elasticity

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We present an operator-asymptotic approach to the problem of homogenization of periodic composite media in the setting of three-dimensional linearized elasticity. This is based on a uniform approximation with respect to the inverse wavelength for the solution to the resolvent problem. We develop an asymptotic procedure in powers of “quasimomentum”, combined with a new uniform version of the classical Korn inequality. As a consequence, we obtain higher-order norm-resolvent estimates in various operator norms.

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