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Program

Local feature filtering for scalable and well-conditioned domain-decomposed random feature methods

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Random Feature Methods (RFMs), including extreme learning machine finite-basis PINNs (ELM-FBPINNs), offer a scalable approach to PDEs by approximating solutions with localized, overlapping random neural bases and training via structured least-squares minimization of PDE residuals. While efficient and parallelizable, the resulting systems are often severely ill-conditioned due to redundancy and overlap-induced correlations. We introduce a block rank-revealing QR (RRQR) filtering and preconditioning strategy applied directly to the structured least-squares problem. Local RRQR factorizations remove redundant basis functions, reduce problem size, and improve conditioning, while enabling a block-sparse, numerically stable right preconditioner. We derive deterministic condition-number bounds with probabilistic refinements. Experiments on multi-scale PDEs in 1D–3D show condition-number reductions up to eleven orders of magnitude, LSQR speedups of 10–1000×, and higher accuracy than unpreconditioned and additive Schwarz methods at lower cost.

Convergence of explicit Runge-Kutta/discontinuous Galerkin approximations of the first-order form of Maxwell's equations

Alexandre Ern

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We establish a convergence result for the approximation of low-regularity solutions to time-dependent PDE systems that have an involution structure similar to Maxwell's equations and the linear wave equations. The approximation is based on an explicit Runge–Kutta (ERK) time-stepping and the discontinuous Galerkin (dG) method with stabilization (so-called upwind fluxes) in space. The regularity setting only assumes that the exact solution and its first time-derivative are in $L^\infty(0,T;H^s)$ with a Sobolev regularity index s in $(0,\frac{1}{2})$ (here, $(0,T)$ is the time interval), and that its second time-derivative is in $L^\infty(0,T;L^2)$. The two main tools for the convergence analysis are a Ritz projection in space that leverages recent convergence results in operator norm for the dG approximation of the steady form of the PDE, and the L^2-stability under a standard CFL condition of three-stage, third-order and four-stage, fourth-order ERK schemes. These latter results are known in the literature, but we provide here a somewhat simpler argumentation to prove the L^2-stability. This is joint work with Jean-Luc Guermond (Texas A&M University).

Model order reduction and sensitivity analysis for complex ocular simulations

Marcela Szopos

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TBA (Uploaded during the registration process?)

Operator learning for flow field predictions on non-parametric domains

Andrei Gasparovici

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Approximating solution operators for partial differential equations on non-parametric domains remains a fundamental challenge in scientific computing. In this talk, we propose a hybrid architecture that couples a Deep Operator Network (DeepONet) with a neural implicit shape representation model to learn the mapping from domain geometry to PDE solution fields.

The shape representation component provides a data-driven parametrisation of the domain geometry, representing the boundary of each domain as the zero level set of a learned signed distance function, conditioned by a low-dimensional latent vector. This latent representation is then incorporated into the DeepONet, which approximates the corresponding solution operator. We focus on incompressible flow in patient-specific aortic geometries as a motivating application, where anatomical differences lead to substantial variability in the geometry of the domains. However, this method is applicable to similar problems.

We discuss the motivation behind this approach, including the connection to universal approximation results for operators and the role of the implicit geometry parametrisation in constructing a low-dimensional representation of the space of admissible domains. We outline the training strategy, the challenges we anticipate in handling the geometric variability of realistic aortic shapes, and discuss the capability of the proposed model to generalise to new geometries. We conclude by discussing the potential and limitations of this framework as a general strategy for operator learning on parameterised domains.

Regularity and breaking the curse of dimensionality for Dirichlet boundary problems via stochastic representations

Ionel Popescu

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We will show two main results about theDirichlet boundary problem. The first one is global Holder regularity all the way upt to boundary with a nice control of the Holder exponent. The second one is how one can break the curs of dimensionality using the walk on spheres to construct approximations of the solutions which are proven to converge in uniform norm to the solution. This approximation can be easily be turned into a neural network approximation. This is joint work with L. Beznea, I. Cîmpean, O. Lupascu and A. Zarnescu.

A Feynman-Kac numerical approach to the Calderon inverse problem for the stationary Schrödinger equation

Iulian Cîmpean

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In this talk we introduce and discuss a probabilistic numerical method aimed to recover the unknown potential in the Schrodinger equation for the Laplace operator in a bounded domain, from discrete boundary/interior measurements. This problem is strongly related to the Calderon problem of recovering the diffusion coefficients of a domain from the Dirichlet-to-Neumann operator, which is well known to have important applications such as non-invasive medical image reconstruction through Electrical Impedance Tomography.

Solving such inverse problems numerically is challenging and requires significant stabilizing interventions, as they are severely ill-posed in the sense of Hadamard. Our plan is to introduce and explore a simple numerical method that uses the Feynman-Kac formula in order to associate a least-squares cost functional for the corresponding inverse problem with discrete measurements. One main advantage of the proposed approach is that the gradient of the associated cost functional has again an explicit probabilistic representation that can be used in a gradient-based optimization scheme through Monte Carlo simulations. We shall present the method and test its efficiency on several examples.

A Monte Carlo discretization method for nonlinear variational PDEs

Andreea Grecu

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We introduce and test a numerical method for solving boundary value problems for some classes of second order partial differential equations in a bounded open set in $D \subset \mathbb{R}^d$, including, for example, those that arise as the Euler-Lagrange equation associated to some energy functional of the type $J(u) = \int_D F(x, u(x), \nabla u(x))\, dx, \quad u \in D(J) \subset W^{1,2}(D)$, with prescribed boundary conditions $u = g$ on ∂D. Our approach is based on the orthogonal decomposition of $H^1(D)$, probabilistic representations and the Monte Carlo method. We test our method for solving various PDEs, such as (non-)symmetric second order linear elliptic PDEs, semilinear PDEs that admit multiple solutions, quasilinear PDEs such as Poisson problems for the $p(x)$-Laplace equation. Some of these examples will be presented in this talk. Based on a joint work with I. Cîmpean and A. Zărnescu.

Programming with Chebfun. Case study: Richards equation

Nicolae Suciu

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The Chebfun software system is a Matlab extension essentially based on representations of (piecewise) smooth one-variable functions by expansions in Chebyshev polynomials. One of Chebfun's attractive features is the ability to provide solutions to nonlinear boundary value problems (BVP) with accuracy close to the machine precision. This is done by the 'chebop' class which provides automatic solutions by performing linearizations with a Newton method in function spaces of the nonlinear BVP, automatic differentiation, and using Fast Fourier Transform computations for the coefficients of the Chebyshev polynomials. A drawback of chebop automatic approach is the possible lack of convergence of the Newton method if the initial guess is not close enough to the exact solution. An explicit functional linearization done for each particular shape of the differential operator (i.e. without automatic differentiation) proves to be more robust than the chebop class and allows an enlargement of the range of convergence. Another alternative is the implicit L-scheme (quasi-Newton approach with derivatives replaced by suitable positive constants L), with a much simpler implementation and globally convergent. While chebop is the easiest way to solve the BVP, provided that it converges, the last two approaches largely overcome the convergence issues, yielding accurate solutions to a wide class of steady-state one-dimensional problems governed by Richards' equation. Chebfun2 and Chebfun3, which at the current stage cannot solve BVPs, provide efficient tools for accuracy and convergence assessments of the non-steady solutions in one or two spatial dimensions obtained by classical discretization schemes.

Numerical identification of coefficients in an elliptic problem

Muriel Boulakia

Université Paris-Saclay, UVSQ, CNRS, Laboratoire de Mathématiques de Versailles, France

In this talk, I will present a numerical method for the reconstruction of coefficients in second-order scalar or vector elliptic partial differential equations. This problem has applications for instance in the field of elastography. Whether for the scalar or for the vector case, error estimates that are known to be sharp are proved. The theoretical results are illustrated by numerical examples. It is a work in collaboration with Erik Burman (UCL) and Miguel Fernandez (Inria Paris).

Inverse problems enriched by population data

Corrie James

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Many inverse problems are studied in the context of individual-specific frameworks. For example, given a certain patient's data or the results from a single experiment, unknown quantities, such as model parameters or boundary conditions, might need to be estimated. However, the same kind of measurements are often taken on groups of patients and experiments are frequently performed multiple times under similar conditions. We assume access to this collection of measurements, called population data. Though our goal is still the resolution of an inverse problem for an individual set of measurements or patient, we investigate to what extent knowing the population data can improve the resolution of the individual-specific inverse problem. We will start by discussing a unique continuation problem for a fluid modelled by the Stokes equations, in which the population is incorporated geometrically into the resolution. Then, we will finish with a model correction and Bayesian parameter estimation method, in which the population is integrated via its statistical information.

On regularization for the elliptic Cauchy problem

Rareș Răhăian

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The elliptic Cauchy problem is a classical example of a severely ill-posed inverse problem, in which the solution of an elliptic PDE must be reconstructed from incomplete and noisy boundary data. In this talk, we consider regularization approaches formulated as PDE-constrained optimization problems, where the weak form of the constraint is enforced through a Lagrange multiplier. Building on well-posedness results for the associated saddle-point system, we focus on the setting in which the unknown boundary data is assumed to belong to a finite-dimensional space, as arises naturally in some applications. We examine how this structural assumption interacts with the regularization framework and affects stability. We also explore the incorporation of data-driven priors and investigate their potential to further improve reconstruction. Numerical experiments are presented to illustrate the approaches. Joint work with Mihai Nechita.

Observability of the wave equation under higher order finite difference discretizations

Ana-Maria Oriță

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This presentation concerns uniform observability for spatial semi-discretizations of the one-dimensional wave equation and the Euler–Bernoulli beam equation obtained using high-order compact finite-difference schemes. While these schemes provide higher-order accuracy compared to standard discretizations, they do not fundamentally resolve the difficulties caused by high-frequency modes, which remain poorly observable as the mesh is refined. This phenomenon has important implications for the numerical control and monitoring of wave propagation in discrete systems.

We show that uniform observability can be restored by filtering out the high-frequency components of the discrete solutions. The analysis combines explicit expressions for the eigenvalues and eigenvectors of the discretization matrices with a discrete multiplier method and an application of Ingham's inequality. The results highlight both the limitations of high-order schemes and the effectiveness of frequency filtering in ensuring uniform observability. This work is joint with Nicolae Cindea and Ionel Roventa.