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Approximation properties of a class of linear operators involving Laguerre-type weights

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Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca

Abstract

The starting point is a generalization of Szász-Mirakyan operators in the Durrmeyer sense. Over time, various polynomial weights have been used such as Jacobi or Appell functions. The last class is comprehensive containing as special classes a large number of sequences as for example Bernoulli, Euler, Hermite polynomials. Following a construction defined in 2025 by P. G. Patel, in this talk we study a family of operators that depends on two parameters and involves associated Laguerre-type kernels $\omega_{\alpha,\beta}(t) = e^{\beta t}t^{\alpha}$, $\alpha > -1$, $\beta < 0$. The weight ensures that the sequence of operators converges for a wide class of functions acting on $[0, \infty)$ and preserves the positivity of the operators.

We investigate in detail approximation properties of the new class. The main objectives aimed to establish the moments of these operators, to derive their recurrence relations in differential form and to investigate their convergence in suitable weighted spaces. Both quantitative estimate on compact intervals and weighted approximation for unbounded functions having a polynomial growth are highlighted.

A distinct section is focused on numerical application. The experiments are carried out for various functions confirming that the new operators provide stable and convergent approximations with errors consistently decreasing as the discretization parameter increases.

Oscillatory behavior in convection-diffusion discretization

Constantin Băcuță
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Abstract

For a model convection-diffusion problem, we address the presence of oscillatory discrete solutions using the relation between the exact solution and the two solutions of the related transport problems. We identify difficulties in recovering standard approximation results for the exact solution in global energy norms. We justify the presence of non-physical oscillations and propose ways to eliminate oscillations. One important idea is that oscillation free discretization is related to approximation of the exact solution in the discrete infinity norm or the closeness property. We present a bubble upwinding discretization of a two dimensional convection diffusion problem using the efficient discretization of the corresponding one dimensional problem along each stream line. Our results are essential to building new and robust discretizations for multi-dimensional convection dominated problems.

Isoperimetric problems for extremal diameter graphs in 3D: theoretical and numerical aspects

Beniamin Bogoșel
Aurel Vlaicu University of Arad

Abstract

We study finite sets in dimension three realizing the maximum number of diameters. These sets provide a framework for constructing a dense family of finite parameter constant width shapes that are useful for the study of shape optimization problems.

In this context it is natural to optimize functionals depending on extremal diameter graphs in dimension three, which we develop in this project. We provide a numerical framework together with computational results and conjectures that provide a rich basis for future work. In particular the three dimensional Blaschke-Lebesgue problem enters into this framework.

Numerical diffusion in classical and neural solvers for advection-dominated transport problems

Imre Boros
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Abstract

Solvers for advection-dominated transport can go wrong in two ways: they invent mixing that the physics does not contain (numerical diffusion), or they produce negative concentrations. For $u_t + Vu_x = Du_{xx}$ the variance of the exact solution equals $\sigma_0^2 + 2Dt$, so any extra variance growth of the computed solution, measured with negative values included, is invented diffusion. This diagnostic needs no exact solution and applies to any solver. For linear grid schemes it is exact: the effective diffusion is the variance of the weights of one time step, scaled by $\Delta x^2/(2\Delta t)$. Hence a linear scheme that never produces negative values and moves the solution by a fraction θ of a cell per step has an effective diffusion of at least $\Delta x^2\,\theta(1-\theta)/(2\Delta t)$; at $\mathrm{Pe} = 5000$ on a 500-cell grid at Courant number $1/2$ this means a numerical diffusion of at least 99 times the physical one. The global random walk escapes this bound by moving in whole cells; nonlinear TVD and WENO schemes beat it, but their numerical diffusion depends on the data and can even be negative. For 360 physics-informed neural networks the error in variance growth over the whole domain is dominated by small output values far from the pulse. Near the pulse it is 10 to 100 times smaller, yet at $\mathrm{Pe} = 5000$ still comparable to or larger than the physical diffusion, while the training loss is roughly the same at every Péclet number and the cost is about 10^5 to 10^6 times that of the grid schemes.

Optimal finite element error estimates and Newton convergence for a quasilinear elliptic problem with mixed boundary conditions

Mihai Bucătaru

University of Bucharest
&
"Gheorghe Mihoc – Caius Iacob" Institute of Mathematical Statistics and Applied Mathematics, Romanian Academy, Bucharest

Abstract

This talk presents finite element approximations of a quasilinear heat-conduction problem with inhomogeneous mixed boundary conditions and an anisotropic, temperature-dependent, possibly nonsymmetric conductivity tensor. Newton's method is supported by a computable Newton–Kantorovich criterion and a mesh-dependent stopping rule that makes the algebraic error asymptotically negligible. Despite possible nonuniqueness, optimal convergence rates are established for every discrete solution through elliptic regularity and a duality argument adapted to the quasilinear setting. Numerical experiments in two and three dimensions confirm the predicted rates and demonstrate the feasibility of the proposed criterion.

Stokes flow with injection in a thin T-like shaped structure

Renata Bunoiu
Université de Lorraine, Metz, France

Abstract

We consider the steady incompressible flow of a Newtonian fluid injected in a thin two-dimensional T-like shaped structure and also subjected to an external force. We study the asymptotic behavior of such a problem when the small parameter describing the thickness of the branches of the structure vanishes. We derive the limit problem satisfied by the limit velocity and the limit pressure. We obtain a flux coupling condition due to the injection. We prove that the limit pressure is defined and continuous on the T-graph underpinning the initial thin structure. If the external force depends only on the variable along the branches, we explicitly calculate the solution to the limit problem. Moreover, if the external force is zero, we obtain a Kirchhoff type relation for the derivatives of the pressure at the junction of the T-graph. This is a joint work with Antonio Gaudiello, Università degli Studi della Campania Luigi Vanvitelli, Caserta, Italy.

Comparing the speed of convergent sequences

Emil Cătinaș
Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca

Abstract

Abstract TBA

Data-driven equation discovery for nonlinear liquid film flows

Radu Cîmpeanu
University of Warwick, UK

Abstract

Data-driven equation discovery is a powerful alternative to standard first principles-based methodologies regularly used in mathematical modelling, particularly in regimes outside the reach of traditional approaches. We will explore the application of differential equation discovery techniques to liquid film flows as a rich canonical landscape, drawing on generated synthetic data from both models and direct numerical simulations for training purposes. We will discuss challenges for foundational established model equations, highlighting important derivation aspects to build analytical understanding that enhances the data-driven process. Finally, we consider the use of the developed framework towards new regimes of interest, such as thick liquid film flows (beyond the reach of traditional asymptotic methods), in which classical mathematical model-based understanding is well complemented by the present approach. The work was conducted as part of Sebastian Dooley's recently submitted doctoral thesis, with a preprint available on arXiv: 2606.13336.

Investigation of quasi-periodic variability in astronomical time series through enhanced self-correlation method

Maria Crăciun, Alexandru Pop

Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca
Astronomical Observatory Cluj-Napoca, Astronomical Institute, Romanian Academy

Abstract

The (Enhanced) Self-Correlation [(E)SC] method is designed for the analysis of astronomical (unevenly sampled) time series. After our previous approach (2015), we treat here stochastic signals: irregular ones modelled by CAR(1) and quasi-periodic ones modelled by CAR(2) processes. By analysing the features of ESC for the last type of signals we obtain estimates of the following parameters: noise level, variance, period and coherence time. We performed tests both on artificial and real astronomical data.

ASTERIX: software for water flow and soil erosion on vegetated surfaces

Ștefan-Gicu Cruceanu

"Gheorghe Mihoc – Caius Iacob" Institute of Mathematical Statistics and Applied Mathematics, Romanian Academy, Bucharest

Abstract

ASTERIX is a software package based on an integrated mathematical model that combines an extended Saint-Venant system of equations for water flow with a Hairsine–Rose-type model for erosion processes on plant-covered soil surfaces. Despite the complexity of the non-linear hyperbolic system of PDEs on which ASTERIX is based, we identify several configurations of soil-surface geometry and vegetation-density distributions for which analytical solutions can be obtained. These solutions provide useful benchmarks for assessing the performance of the numerical model implemented in ASTERIX. We present a series of numerical experiments aimed at validating both the continuous mathematical model and its discrete numerical formulation, and illustrate the capabilities of ASTERIX for simulating water flow and soil erosion under different vegetation and surface configurations.

Spectral bias reduction in local gated ReLU architectures

Victorița Dolean
Eindhoven University of Technology, The Netherlands

Abstract

Neural networks trained by gradient-based methods learn the low-frequency content of a target function faster than its high-frequency content. This spectral bias is well documented, but it is much less clear which architectural choices mitigate it and which cannot. We study the question for shallow ReLU models that are linear in their trainable parameters, where each mode is learned at a rate set by a Gram-matrix eigenvalue, and for a general symmetric bilinear form, so that least-squares regression and variational or physics-informed losses become two instances of one analysis.

Within this framework, we propose gated local ReLU dictionaries, obtained by multiplying each ReLU feature by a hat partition-of-unity weight, in the spirit of partition-of-unity finite elements and overlapping Schwarz methods. The resulting Gram matrices are block-banded for any local bilinear form, with a block-Toeplitz interior whose matrix-valued symbol governs the spectrum.

The two forms then behave very differently. For L2 regression, the symbol is bounded away from zero, the conditioning is uniform in the number of windows, and the measured spread of frequency-dependent learning rates falls from roughly 190,000 to 4.5 at matched model size. For the H1 stiffness matrix, the symbol vanishes at zero frequency: gating leaves the conditioning, which grows like the square of the number of windows, intact and inverts the frequency ordering instead of removing the bias. A preconditioner built from the same interior stencil does fix it, showing that architecture alone is not enough. Experiments on 1D regression and Poisson problems confirm the dichotomy, and the regression effect persists when the hidden-layer parameters are trained as well.

Preprint: arXiv:2611.10700 - https://arxiv.org/abs/2611.10700

The flow of thin films driven by the competing effects of a surface tension gradient and gravity. Analytical continuation of solutions

Călin-Ioan Gheorghiu

Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca

Abstract

Thin viscous film flows down an inclined plane under the competing influences of gravity and surface-tension gradients constitute a classical problem in fluid dynamics and have been a longstanding focus of our investigations. The mathematical model is a fourth-order nonlinear degenerate parabolic equation posed on the real line. We present a three-step computational strategy that substantially improves upon the traditional truncation approach. The method combines Chebyshev collocation, implemented through Chebfun, with AAA rational approximation and analytic continuation. Beyond providing highly accurate numerical solutions, the proposed framework offers a powerful tool for detecting and characterising hidden singularities. This, in turn, enables a detailed assessment of approximation errors and a deeper understanding of the analytic structure of solutions arising in nonlinear and singular boundary-value problems of practical as well as theoretical interest.

Strongly quasiconvex functions: what we know (so far)

Sorin-Mihai Grad
University of Duisburg-Essen, Germany

Abstract

Introduced by Polyak in 1966, the class of strongly quasiconvex functions includes some interesting nonconvex members, like the square root of the Euclidean norm or ratios with a nonnegative strongly convex numerator and a concave and positive denominator. In this talk we survey the most relevant examples of strongly quasiconvex functions and results involving them available in the literature at the moment. In particular, we recall some recent algorithms for minimizing such functions, and hint toward some directions where additional investigations would be welcome.

On higher-order weighted Stancu–Schurer operators: a complex approach (II)

Eduard Ștefan Grigoriciuc
Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca
&
Babeș-Bolyai University, Cluj-Napoca

Abstract

We introduce a new class of linear and positive operators, called weighted Stancu–Schurer operators of higher order. Together with general properties of the operators in the real case, we investigate also the complex version of them. In particular, we focus our attention on geometric properties of the associated mappings, such as univalence, Schwarz-type behavior, and starlikeness in the unit disc. This is a joint work with Andra Malina and Florin Albisoru.

Approximations of the best constants

Liviu Ignat
Simion Stoilow Institute of Mathematics, Romanian Academy, Bucharest

Abstract

In this talk we consider some well known quotients related with either eigenvalue problems, Sobolev or Hardy's inequality. We consider the infimum of these quotients and their discrete analogous in a finite element subspace. We estimate the difference between the best constants above as the discretization parameter goes to zero and obtain sharp convergence rates. This is joint work with Andreea Dima and Enrique Zuazua.

A two-level Galerkin reduced order model for nonlinear problems

Traian Iliescu
Virginia Tech, USA

Abstract

We propose, analyze, and investigate numerically a novel two-level Galerkin reduced order model (2L-ROM) for the efficient and accurate numerical simulation of nonlinear problems. In the first step, a relatively low-dimensional nonlinear system is solved. In the second step, the given nonlinear equations are linearized around the solution found in the first step, and the linearized problem is solved. Although the new 2L-ROM can be used for general nonlinear equations, in our theoretical investigation we consider the steady Navier–Stokes equations. We prove that, for appropriate parameters, the 2L-ROM error bound is of the same order as the error bound for the standard 1L-ROM. Furthermore, we develop 2L-ROM parameter scalings that balance the 2L-ROM's numerical accuracy and computational efficiency. In our numerical investigation, we consider the Burgers equation, which is a simplified computational setting that is often used in the ROM assessment. Our numerical investigation shows that the new 2L-ROM significantly decreases (by a factor of 2 and even close to 3) the 1L-ROM computational cost, without compromising its numerical accuracy. Furthermore, we show that the 2L-ROM parameters that yield the best numerical results are similar to those obtained from the theoretical scalings.

On the unique continuation at initial time for parabolic equations

Cătălin-George Lefter
Alexandru Ioan Cuza University, Iași
&
Octav Mayer Institute of Mathematics, Romanian Academy, Iași

Abstract

We show that solutions to parabolic equations or systems vanishing at initial time, in a small subdomain, sufficiently fast, must vanish in the whole domain at initial time. We apply this result to Navier–Stokes equations. The approach is based on a version of Carleman estimates for parabolic equations.

On higher-order weighted Stancu–Schurer operators: a real approach (I)

Andra Malina

Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca
&
Babeș-Bolyai University, Cluj-Napoca

Abstract

We introduce new weighted Stancu–Schurer operators of higher order, a family of linear positive operators that extends the Bernstein and Stancu–Schurer operators. This work's first part is devoted to the real case; the complex extension is treated in the second part. We present the basic properties of the operators, explicit moment formulas up to order two, and Korovkin-type convergence results. For equal weights, we discuss convexity preservation, modulus-of-continuity estimates, and a Voronovskaya-type formula, and we illustrate the results numerically. This is a joint work with Eduard Grigoriciuc and Florin Albisoru.

A (fast) fundamental solution method to solve parabolic equations

Victor Nistor
Université de Lorraine, France

Abstract

We explain how to obtain good approximations of the fundamental solution of a (uniformly) parabolic PDEs and how to use it to devise fast numerical methods for parabolic equations.

Ψ-resilience: model-free feature importance from 1D topological signals

Darian Onchiș
West University of Timișoara

Abstract

We introduce Ψ-Resilience, a model-free feature importance method that derives explanations directly from the data itself via 1D topological signals. Our method constructs a class-disagreement landscape by estimating class-conditional densities and taking their pointwise absolute difference along the feature axis. Then, the 0-dimensional persistence of this 1D signal defines a resilience functional that aggregates only those topological features that survive perturbations up to a robustness scale which is set by the user. This gives us a context-robust importance score that is inherently auditable via the underlying 1D landscapes and their persistence. The experimental results show that Ψ-Resilience is a stable explanation method that enables rigorous, distribution-level auditing of feature importance without relying on a predictive model. Joint work with Fabian Galis and Pedro Real.

Stochastic gradient descent on the space of distributions

Maria Oprea
Institute of Science and Technology Austria

Abstract

Abstract TBA

Existence results for systems of abstract evolution equations with nonlocal initial conditions

Diana Otrocol

Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca
&
Technical University of Cluj-Napoca

Abstract

Abstract TBA

Riemannian multilevel optimization

Ștefania Petra
Heidelberg University, Germany

Abstract

Abstract TBA

SQP without QP

Titus Pința
University of Duisburg-Essen, Germany

Abstract

Sequential Quadratic Programming is the standard Newton-type approach to solving a constrained optimization problem. In order to avoid the cost of solving a quadratic program, we propose an alternative formulation, based on replacing quadratic programs with a simple iterative linear equation solver. The proposed algorithm is based on a splitting scheme, which first produces an affine approximation of the constraints, and then uses an unconstrained Newton method to optimize the objective over this lower dimensional space.

The elliptic Cauchy problem with applications in electrocardiographic imaging

Rareș Răhăian

Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca & EPFL, Switzerland

Abstract

The elliptic Cauchy problem is a classical example of a conditionally stable inverse problem. Hölder and logarithmic stability estimates can be obtained under suitable a priori bounds on the solution. We show how Lipschitz stability can be recovered under the assumption that the unknown Dirichlet trace belongs to a finite-dimensional subspace.

We then exploit this conditional stability to develop a numerical method for the inverse problem of electrocardiographic imaging (ECGi), a particular instance of the elliptic Cauchy problem arising in medical imaging. In particular, we introduce a data-enriched stabilised finite element method (StabFEM), in which a database of simulated heart surface potentials is used to construct a finite-dimensional prior space for the unknown potential. We present theoretical error estimates and numerical results illustrating the performance of the proposed method.

This is joint work with Mihai Nechita.

Componentwise localization of positive periodic solutions for a general Bazykin-type system

Andrei Stan

Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca
&
Babeș-Bolyai University, Cluj-Napoca

Abstract

We consider a general Bazykin-type model that describes the interaction of two populations. We provide sufficient conditions for the existence of a positive periodic solution where each population is localized independently within a distinct conical annular region. We illustrate how our conditions can be verified for certain particular cases and support these results with numerical simulations.

Chebfun L-schemes for Richards equation

Nicolae Suciu
Tiberiu Popoviciu Institute of Numerical Analysis, Romanian Academy, Cluj-Napoca

Abstract

Implicit L-schemes in function spaces fix the convergence issues and render the Chebfun solvers for nonlinear one-dimensional BVPs globally convergent. Green-preconditioned explicit linearization schemes built with AI assistance, based on the tensor-product Chebyshev representation of the inverse Laplacian, solve nonlinear BVPs in higher spatial dimensions to roughly machine precision.

Reconstruction of the conformal factor in a two dimensional anisotropic current density impedance imaging problem

Alexandru Tămăşan
University of Central Florida, USA

Abstract

I will report on some recent progress on a theoretical and numerical method, which recovers an anisotropic conductivity within its conformal class, using the internal knowledge of one current density field. Numerical examples illustrate the feasibility of this method. This is joint work with A. Dimitriadis and A. Timonov.

Second-order in time decoupling for nonlinear heat transfer

Cătălin Trenchea
University of Pittsburgh, USA

Abstract

Abstract TBA

Feature selective model collapse in Stable Diffusion generative models

Gabriel Turinici
Université Paris Dauphine – PSL, France

Abstract

Training generative models on prior synthetic data leads to model collapse. We analyze finite-budget training pipelines and compare "total replacement" protocols (which cause rapid collapse) with "fixed-budget" sampling from a growing pool of real and synthetic data. Experiments on synthetic and image benchmarks (MNIST, Fashion-MNIST, CIFAR-10) reveal that while replacement causes severe degradation, fixed-budget sampling results in partial degradation: fragile features are lost, but robust features are preserved. Stochastic recursion analysis confirms these dynamics, challenging the inevitability of collapse and suggesting sustainable reuse of synthetic data is feasible.