SIAM-TXLA 3RD ANNUAL MEETING
PROGRAM

Contents

Schedule

The detailed schedule along with the zoom link for the events are available on the conference website.

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	Career Panels
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03:30 pm - 03:55 pm	Academic / National Labs / Industry Career Panels Session I
04:00 pm - 04:25 pm	Academic / National Labs / Industry Career Panels Session II
05:00 pm - 06:00 pm	Public Lecture by Richard Baraniuk
06:00 pm - 06:30 pm	Break / Discussion with Plenary Speaker
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Saturday October 17

Time	Event
08:00 am - 10:00 am	Mini-symposia
10:00 am - 10:30 am	Break / Discussion
10:30 am - 11:30 am	Plenary Talk by Graeme Milton
11:30 pm - 12:00 pm	Break / Discussion with Plenary Speaker
12:00 pm - 12:30 pm	Lunch Break
12:30 pm - 02:30 pm	Mini-symposia
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03:00 pm - 04:00 pm	Plenary Talk by Xiao-Hui Wu
04:00 pm - 04:30 pm	Break / Discussion with Plenary Speaker
04:30 pm - 06:30 pm	Mini-symposia

Date: October 14, 2020.

Sunday October 18

Time	Event
08:30 am - 10:30 am	Mini-symposia
10:30 am - 11:00 am	Break / Discussion
11:00 am - 12:00 pm	Plenary Talk by Thaleia Zariphopoulou
12:00 pm - 12:30 pm	Break / Discussion with Plenary Speaker
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01:00 pm - 03:00 pm	Mini-symposia
03:00 pm - 03:30 pm	Break / Discussion

Plenary Speakers

Public Talk: Going Off the Deep End with Deep Learning

Richard Baraniuk, Rice

Abstract. A grand challenge in machine learning is the development of computational algorithms that match or outperform humans in perceptual inference tasks that are complicated by nuisance variation. For instance, visual object recognition involves the unknown object position, orientation, and scale, while speech recognition involves the unknown voice pronunciation, pitch, and speed. Recently, a new breed of deep learning algorithms have emerged for high-nuisance inference tasks that routinely yield pattern recognition systems with super-human capabilities. Similar results in language translation, robotics, and games like Chess and Go plus billions of dollars in venture capital have fueled a deep learning bubble and public perception that actual progress is being made towards general artificial intelligence. But fundamental questions remain, such as: Why do deep learning methods work? When do they work? And how can they be fixed when they don't work? Intuitions abound, but a coherent framework for understanding, analyzing, and synthesizing deep learning architectures remains elusive. This talk will discuss the important implications of this lack of understanding for consumers, practitioners, and researchers of machine learning. We will also briefly overview recent progress on answering the above questions based on probabilistic graphs and splines.

Research Talk: Untangling in time: designing time varying applied fields to reveal interior structure

Graeme Milton, University of Utah

Abstract. In two phase materials, each phase having a non-local response in time, we were surprised to discover that for appropriate driving fields the response somehow untangles at specific times, allowing one to directly infer useful information about the geometry of the material, such as the volume fractions of the phases. The underlying mathematics, showing how the appropriate driving fields may be designed, rests on the existence of approximate, measure independent, linear relations between the values that Markov functions take at a given set of possibly complex points, not belonging to the interval [-1,1] where the measure is supported. The problem is reduced to simply one of polynomial approximation of a given function on the interval [-1,1]. This allows one to obtain explicit estimates of the error of the approximation, in terms of the number of points and the minimum distance of the points to the interval [-1,1]. In the context of the motivating problem, the analysis also yields bounds on the response at any particular time for any driving field, and allows one to estimate the response at a given frequency using an appropriately designed driving field that effectively is turned on only for a fixed interval of time. The approximation extends directly to Markov-type functions with a positive semi-definite operator valued measure, and this has applications to determining the shape of an inclusion in a body from boundary flux measurements at a specific time, when the time-dependent boundary potentials are suitably tailored. This is joint work with Ornella Mattei and Mihai Putinar.

Research Talk: Decision Support under Subsurface Uncertainty

Xiao-Hui Wu, ExxonMobil Upstream Integrated Solutions

Abstract. Almost all decisions made in the upstream oil and gas industry, from exploration to development and production, must account for subsurface uncertainty. Despite advances in computational and data sciences, effective decision support under subsurface uncertainty remains extremely challenging. In this talk, a holistic view of the key components, both technical and cognitive, involved in the decision support process are presented. Both decision making and inference are approached from a Bayesian point of view. We review the computational challenges and some recent progresses. The need to manage computational complexity through goal-oriented inference (GOI) is highlighted. In addition, we examine the challenges associated with specification of priors and validation of the efficacy of the decision process, which are of fundamental importance in practice but have received relatively little attention in research.

Research Talk: "Real-time" optimization under forward rank-dependent processes: time-consistent optimality under probability distortions

Thaleia Zariphopoulou, University of Texas at Austin

Abstract. Forward performance processes are defined via time-consistent optimality and incorporate "real-time" incoming information. On the other hand, popular performance criteria - for example, mean-variance optimization, hyperbolic discounting, probability distortions - are by nature time-inconsistent. How to define forward performance criteria in time-inconsistent settings then becomes a challenging problem, both conceptually and technically. In this talk, I will discuss the case of probability distortions and introduce the concept of forward rank-dependent performance processes. Among others, I will show how forward probability distortions are affected by "real-time" changes in the stochastic environment and, also, present a striking equivalence between forward rank-dependent criteria and time-monotone forward processes under appropriate measure-changes. A byproduct of the work is a novel result on the so-called dynamic utilities and on time-inconsistent problems in the classical (backward) setting.

List of Mini-symposia

Mini-symposium
Stochastic processes on graphs and networks

Organizer(s): *Patricia Alonso Ruiz*

Abstract. Graphs and networks provide the mathematical framework to model a wide variety of structures present in nature. Stochastic processes provide the framework to model (random) interactions between the constituents of that network such as the propagation of epidemics, the evolution of DNA sequences, neural flows and opinion dynamics [1, 4, 3, 2, 5]. The leitmotiv of this mini-symposium is the study of linear and non-linear diffusion processes in graphs and networks that appear in the modeling of the above mentioned settings. The questions under investigation usually involve random environments and trees, ergodic measures, limit theorems and stochastic differential equations. The session aims to bring together specialists in this topic and in adjacent areas of research, and to promote an exchange of ideas and methods with potential for further applications.

References

[1] F. Baccelli and T. Taillefumier. Replica-mean-field limits for intensity-based neural networks. *SIAM Journal of Applied Dynamical Systems*, 4 (18), 2019.

[2] F. Baccelli, M. Davydov and T. Taillefumier. Replica-Mean-Field Limits of Fragmentation-Interaction-Aggregation Processes. arXiv:2005.07962, 2020.

[3] W.-T. Fan and S. Roch. Statistically consistent and computationally efficient inference of ancestral DNA sequences in the TKF91 model under dense taxon sampling *Bulletin of Mathematical Biology*, 82:21, 2020.

[4] N. Gantert, M. Heydenreich and T. Hirscher. Strictly weak consensus in the uniform compass model on $\mathbb{Z}$. *Bernoulli*, 26 (2), 2020.

[5] D. Lacker, K. Ramanan and R. Wu. Large sparse networks of interacting diffusions. arXiv:1904.02585, 2019.

Participants

- ▷ W.-T. Fan, Indiana University, *Wave propagation for reaction-diffusion equations on infinite random trees*;
- ▷ N. Gantert, Technical University of Munich, *Exclusion processes on trees*;
- ▷ K. Ramanan, Brown University, *Limits of Interacting Particle Systems on Sparse Graphs.*
- ▷ T. Taillefumier, Texas A&M University, *The Pair-Replica-Mean-Field Limit for Intensity-based Neural Networks*;

Mini-symposium
New Developments in PDE Constrained Optimization

Organizer(s): *Matthias Heinkenschloss*

Abstract. The speakers in this minisymposium will present new developments in the solution of optimization problems governed by partial differential equations (PDEs). These problems arise in many of science and engineering applications and their efficient numerical solution presents a number of analytical and numerical challenges. The talks in this minisymposium will present new algorithmic approaches, discuss new applications of PDE constrained optimization. Topics range from efficient treatment of Dirichlet optimal control problems with divergence-free constraints, to multigrid-in-time methods, to optimal control of block copolymer systems governed by nonlocal Cahn Hilliard equations.

Participants

- ▷ G. Bornia, Texas Tech University, *On the treatment of full Dirichlet optimal control problems with divergence-free constraints*;
- ▷ S. Lin, Rice University, *ALESQP: An Augmented Lagrangian Equality-constrained SQP Method for Function-space Optimization with General Constraints.*
- ▷ D. Luo, University of Texas at Austin, *Optimal control of block copolymer systems governed by nonlocal Cahn Hilliard equations*;
- ▷ D. Ridzal, Sandia National Labs, *ALESQP: An Augmented Lagrangian Equality-constrained SQP Method for Function-space Optimization with General Constraints*;

Mini-symposium
Nonlinear Waves and Applications

Organizer(s): *Jonas Luhrmann, Nguyen Cong Phuc, Minh-Binh Tran*

Abstract. Nonlinear wave and dispersive equations model a variety of wave phenomena in nature - from the dynamics of Bose-Einstein condensates to the spreading of gravitational waves. Despite sharing many common features, these equations have rich and varied dynamics, many of which are still far from understood. In this session we hope to bring together both junior and senior researchers from broadly related fields to discuss recent progress on nonlinear waves dynamics and to share new insights and techniques from the disparate corners of the subject.

Participants

- ▷ R. Booth, Texas A&M University, *Long-Time Asymptotics for the Massless Dirac-Coulomb Equation*;
- ▷ J. Chong, University of Texas at Austin, *Dynamics of Large Boson Systems with Attractive Interaction and A Derivation of the Cubic Focusing NLS in* $\mathbb{R}^3$;
- ▷ M. Ntekoume, Rice University, *Symplectic non-squeezing for the KdV flow on the line*
- ▷ R. Parker, Southern Methodist University *Instability bubbles for multi-pulse solutions to Hamiltonian systems on a periodic domain*;
- ▷ A. Tarfulea, Lousiana State University, *Self-generating lower bounds for the Boltzmann equation*;
- ▷ K. Yamazaki, Texas Tech University, *Non-uniqueness in law for two-dimensional Navier-Stokes equations with diffusion weaker than a full Laplacian*;
- ▷ G. Young, Rice University, *Uniqueness of solutions of the KdV-hierarchy via Dubrovin-type flows*;
- ▷ L. Zhang, Columbia University, *An energy-based discontinuous Galerkin method for semilinear wave equations*;

Mini-symposium
Theoretical and computational studies of PDEs driven by random processes

Organizer(s): *Akif Ibragimov, Nguyen Phuong*

Abstract. Our mini-symposium will be dedicated to PDE driven model of Random Processes in different media (see classical paper by A. Einstein [1]). This will include but not limited by topics of localization and formation of the pattern characterized by the solution of non-linear stochastic PDE, and equations which can degenerate w.r.t. solution and its gradients, existence, stability and smoothness of the solutions of non-linear PDE, numerical methods for equations associated with random processes, such as non-divergent, linear and non-linear parabolic and elliptic equations.

The goal of this mini symposium is to bring together leading researchers in the field of stochastic partial differential equations and experts in numerical methods to discuss and disseminate the latest results and envisage future challenges in traditional and new areas of science. The topics of the mini-symposium cover a broad range of problems, including qualitative and quantitative properties of the solutions of the deterministic and stochastic equations as well as foundations in numerical methods. Below are some related papers by organizers [2, 3].

References

[1] Albert Einstein. On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat] (PDF). *Annalen der Physik (in German).* , 322 (8): 549–560.1905.

[2] Ivan C. Christov, Akif Ibraguimov, Rahnuma Islam. Long-time asymptotics of non-degenerate non-linear diffusion equations *arXiv:2002.07937 , to be apeare in the JMP* , 2020.

[3] Justin Cyr, Phuong Nguyen and Roger Temam. Local martingale solutions to the stochastic one layer shallow equations perturbed by Levy noise *Discrete and Continuous Dynamical System Series B,*,(24), N.8, 2019, no. 8, 3765-3818.

Participants

- ▷ A. Kh. Balci, Bielefeld Unievrsity, Germany, *Elliptic equations with degenerate weights*;
- ▷ R. Islam, Texas Tech University, *Discontinuous Galerkin methods for a dispersive wave hydro-sediment-morphodynamic model*;
- ▷ G. Iyer, Carnagie Mellon University, *Bounds on the heat transfer rate via passive advection*;
- ▷ E. Kara, Texas Tech University, *Diffusion Tensor Imaging (DTI) Based Drug Diffusion Model in a Solid Tumor*;
- ▷ Y. Klevtsova, Siberian Regional Hydrometeorological Research Institute, *Determing Protein Structure by the Method of Moments*;
- ▷ P. Nguyen, Texas Tech University, *The Stampacchia maximum principle for stochastic partial differential equations forced by Levy Noise*;
- ▷ J. Padgett, University of Arkansas, *Beating the curse of dimensionality in high-dimensional stochastic fixed-point equations*
- ▷ M. Surnachev, Keldysh Institute of Applied Mathematics RAS, *Green's function estimates for the stationary convection-diffusion equation*;
- ▷ J. Touboul, Brandeis University; *Limit and Spatio-temporal Dynamics of Interacting Markov Jump or diffusion Processes, with Applications to Ecology and Neurosciences*;

- ▷ J. Walton, Texas A&M University, *A Coupled Nonlinear Reaction-Diffusion, First-Order-Hyperbolic System Arising from a New Approach to Structured Population Dynamics*;
- ▷ C. Wang, Texas Tech University, *Structure Probing Neural Network Deflation*;
- ▷ K. Yamazaki, Texas Tech University, *Approximating three-dimensional magnetohydrodynamics system forced by space-time white noise*.

Mini-symposium
Dynamical Systems and Mathematical Biology

Organizer(s): *Xiang-Sheng Wang*

Abstract. Dynamical systems have been playing an important role in understanding biological processes such as population growth, spatial invasions, disease outbreaks and viral dynamics. Over the past decades, the area of mathematical biology has gained an increasing attention and received a growing momentum. The special session will focus on interdisciplinary research fields of dynamical systems and mathematical biology. In this session, we will bring together mathematical researchers from various backgrounds to work together and contribute to the study of dynamical systems with applications to biological dynamics. It will serve as a platform to present recent progresses, exchange research ideas, extend academic networks, and seek future cooperation. Speakers and talks are carefully selected to make the session interesting and attractive to a diverse audience.

Participants

- ▷ R. Cantrell, University of Miami, *Perspective on the connection between ideal free dispersal and the evolution of dispersal*;
- ▷ J. Cushing, University of Arizona, *Does Evolution Select Against Chaos?*;
- ▷ Y. Jin, University of Nebraska - Lincoln, *The dynamics of a zooplankton-fish system in aquatic habitats*;
- ▷ P. De Leenheer, Oregon State University, *The basic reproduction number for linear maps that preserve a cone*;
- ▷ S. Lenhart, University of Tennessee, *Optimal Control of Directed Flow in a PDE Model of an Invasive Species in a River*;
- ▷ Y. Lou, Ohio State University, *On R0 in heterogeneous environment*;
- ▷ J. Shi, College of William & Mary, *Spatial modeling and dynamics of organic matter biodegradation in the absence or presence of bacterivorous grazing*;
- ▷ H. Thieme, Arizona State University, *Discrete-time population dynamics of spatially distributed semelparous two-sex populations*;
- ▷ N. Vaidya, San Diego State University, *Modeling Transmission Dynamics of COVID-19 in Nepal*
- ▷ X.-S. Wang, University of Lousiana at Lafayette, *Resonance of periodic combination antiviral therapy and intracellular delays in virus model.*

Mini-symposium
Structure preserving techniques for nonlinear conservation equations

Organizer(s): *Jean-Luc Guermond, Bojan Popov, Matthias Maier*

Abstract. Numerical methods that deliver approximate solutions within the expected physical bounds, reproduce steady state solutions, and behave correctly on asymptotic regimes are said to be structure preserving. Methods that are structure preserving are expected to deliver solutions that are physical. They also do not need fudging (user-dependent) parameters to deliver reasonable outputs. This is unfortunately rarely the case for many numerical techniques and dedicated softwares. The objective of this minisymposium is to identify the current state of the knowledge on structure preserving methods dedicated to solving nonlinear conservation equations. The minisymposium will particularly focus on systems of the following type: compressible Euler, shallow water, magnetohydrodynamics, radiation transport, gray radiation hydrodynamics.

Participants

- ▷ D. Appelo, Michigan State University, *An Energy-Based Discontinuous Galerkin Method for A Nonlinear Variational Wave Equation Modelling Nematic Liquid Crystal*;
- ▷ J. Chan, Rice University, *Efficient computation of Jacobian matrices for entropy stable summation-by-parts schemes*;
- ▷ T. Dzanic, Texas A&M University, *A Riemann Difference Scheme for Shock Capturing in Discontinuous Finite Element Methods*;
- ▷ J.-L. Guermond, Texas A&M University, *Second-order invariant domain preserving approximation of the compressible Navier-Stokes equations*;
- ▷ M. Maier, Texas A&M University, *Massively parallel 3D computation of the compressible Euler equations with an invariant-domain preserving second-order finite-element scheme*;
- ▷ B. Popov, Texas A&M University, *Accurate upper bound for the maximum speed of propagation in the Riemann problem*;
- ▷ E. Valseth, University of Texas at Austin, *An unconditionally stable space-time FE method for the Shallow Water Equations*;
- ▷ X. Zeng, University of Texas at El Paso, *A hybrid-variable discretization method for hyperbolic problems.*

Mini-symposium
Topics in qualitative and quantitative properties of partial differential equations

Organizer(s): *Jiuyi Zhu, Jinping Zhuge*

Abstract. Partial differential equations play a prominent role in many disciplines including engineering, physics, economics, and biology. Understanding the qualitative and quantitative information for solutions is fundamental and essential to the study of partial differential equations, which has far-reaching applications. Techniques and insights from various fields of mathematical analysis and partial differential equations cross-fertilize each other in a fruitful way in the study of Partial differential equations play a prominent role in many disciplines including engineering, physics, economics, and biology. Understanding the qualitative and quantitative information for solutions is fundamental and essential to the study of partial differential equations, which has far-reaching applications. Techniques and insights from various fields of mathematical analysis and partial differential equations cross-fertilize each other in a fruitful way in the study of qualitative and quantitative properties of the solutions. The qualitative properties of solutions include, but are not limited to, existence, uniqueness, regularity and asymptotic behavior. Usually, these properties can also be characterized quantitatively. This special session will concentrate on the recent trends of homogenization theory, and the qualitative and quantitative study of linear and nonlinear partial differential equations that arise from material science and fluid dynamics. This symposium provides a marketplace to disseminate recent research achievements, identify areas of new opportunities in mathematical analysis and partial differential equations, and form new collaborations.

Participants

- ▷ H. Dong, Brown University, *Evolutionary equations with nonlocal time derivatives*;
- ▷ W. Feldman, University of Utah, *Mean curvature flow with positive random forcing in 2-d*;
- ▷ C. Gui, University of Texas at San Antonio, *Propagation acceleration in reaction diffusion equations with fractional Laplacians*;
- ▷ E. Malinnikova, Stanford University, *On the Landis conjecture on the plane*
- ▷ S. Patrizi, University of Texas at Austin, *From the Peierls-Nabarro model to the equation of motion of the dislocation continuum*;
- ▷ C. Prange, CNRS, Cergy Paris University, *Quantitative regularity vs. concentration near potential singularities in incompressible viscous fluids*;
- ▷ Z. Shen, University of Kentucky, *Overall equilibrium in the coupling of peridynamics and classical continuum mechanics*;
- ▷ Y. Zhang, University of California at San Diego, *Long Time Dynamics for Combustion in Random Media*;

Mini-symposium
Multiphase Flows in Porous Media at the Darcy Scale

Organizer(s): *Beatrice Riviere*

Abstract. This minisymposium presents recent advances in computational methods for solving multiphase flows at the Darcy scale. Challenges in modeling two-phase or three-phase flows include discontinuous permeability fields that vary across several orders of magnitude, anisotropy, gravity effects, different rock types and local features such as pinch-outs that require the use of unstructured meshes. Numerical approximations of the phase saturation should also satisfy maximum principle and monotonicity. In addition to being accurate for realistic porous media, the scheme should be efficient to be competitive. This minisymposium highlights the new developments in algorithms that address the challenges described above.

Participants

- ▹ T. Arbogast, University of Texas at Austin, *A Self-Adaptive Theta Method for Conservation Laws using Discontinuity Aware Quadrature*;
- ▹ A. Firoozabadi, Rice University, *Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface*
- ▹ R. Masson, University Cote d'Azur, *Gradient discretization of two-phase flows coupled with mechanical deformation in fractured porous media*;
- ▹ M. Sarraf Joshaghani, Rice University, *Maximum-principle-preserving vertex-based method for two phase flows in porous media*;

Mini-symposium
Numerical Methods and Deep Learning for PDEs

Organizer(s): *Wei Guo, Chunmei Wang*

Abstract. Numerical Methods for partial differential equations and their analysis are important and challenging topics in applied and computational mathematics. Deep learning is a method of data analysis that automates analytical model building, which is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention. This mini-symposium is focused on recent developments in numerical methods and deep learning for PDEs, including new developments in finite element methods, deep learning and relevant applications. The goal of this mini-symposium is to bring together leading researchers in the field of numerical methods and deep learning to discuss and disseminate the latest results and envisage future challenges in traditional and new areas of science. The topics of the mini-symposium cover a broad range of numerical methods and deep learning, including but not limited to finite element methods, finite difference methods, discontinuous Galerkin methods, weak Galerkin methods.

Participants

- ▷ G. Capodaglio, Los Alamos National Laboratory, *Substructuring-based domain decomposition methods for nonlocal problems*;
- ▷ L. Cappanera, University of Houston, *An artificial compression method for incompressible flows with variable density and viscosity*;
- ▷ W. Guo, Texas State University, *Low Rank Tensor Methods for Vlasov Simulations*;
- ▷ W. Hao, Penn State University, *A randomized Newton's method for solving differential equations based on the neural network discretization*;
- ▷ G. Sosa Jones, University of Houston, *A space-time hybridizable discontinuous Galerkin method for linear free-surface waves*;
- ▷ C. Wang, Texas Tech University, *Structure Probing Neural Network Deflation*;
- ▷ D. Xiu, Ohio State University, *Data Driven Governing Equations Recovery with Deep Neural Networks*;
- ▷ H. Yang, Purdue University, *A Few Thoughts on Deep Learning-Based Scientific Computing.*

Mini-symposium
Recent advances in numerical methods for shallow water flows

Organizer(s): *Eric Tovar*

Abstract. As urbanization is encroaching more and more on flood prone regions and paved surfaces are ever expanding, more catastrophic flash floods occurring in urban environments are expected in the near future. These risks are compounded by global changes in the climate. Applied mathematics can help better predict and understand these situations through modeling and numerical simulations. The aim of this mini-symposium is to discuss the current state of numerical methods and mathematical modeling of shallow water flows with applications in coastal hydraulics, large-scale oceanography, and river and estuary hydraulics. The particular partial differential equations we have in mind are the shallow water equations augmented with various corrections to model dispersive waves, rolling waves, shear flows, sediment transport, rain and other relevant phenomenons. The models describing such physical phenomena are strongly nonlinear and pose numerous challenges when one tries to discretize and solve them numerically.

Participants

- ▷ K. Kashyken, Oden Institute, *Discontinuous Galerkin methods for a dispersive wave hydro-sediment-morphodynamic model*;
- ▷ C. Kees, Louisiana State University, *A simple CutFEM implementation with applications to shallow water waves and fluid-structure interaction*;
- ▷ E. Tovar, Texas A&M University, *Hyperbolic relaxation technique for solving the dispersive Serre–Saint-Venant equations with topographyr*;
- ▷ T. Wu, University of Texas at San Antonio, *Equilibrium Preserving Schemes for Shallow Water Models.*

Mini-symposium
Recent advances in the numerical approximation of geometric partial differential equations

Organizer(s): *Andrea Bonito, Diane Guignard*

Abstract. Geometric partial differential equations (PDEs) are used as the mathematical model in many scientific, engineering and industrial problems. The solution of such equations is challenging and has received a lot of interest recently. The aim of this minisymposium is to present recent advances in the numerical approximation of geometric PDEs, as well as their applications to real-life problems.

Participants

- ▷ S. Bartels, University of Freiburg, *Simulation of nonlinear bending phenomena for plates in the presence of contact*;
- ▷ A. Caboussat, University of Applied Sciences Western Switzerland, *Numerical approximation of orthogonal maps with adaptive finite elements. Application to paper folding*;
- ▷ P. Plucinsky, University of Southern California, *New tests for minimal border rank tensors*;
- ▷ S. Yang, University of Maryland, College Park, *LDG approximation of large deformations of prestrained plates*;
- ▷ V. Yushutin, University of Maryland, *Are colloidal particles immersed in liquid crystals attracted to the walls?*;
- ▷ S. Walker, Louisiana State University, *Optimal Control of Volume-Preserving Mean Curvature Flow*;
- ▷ W. Zhang, Rutgers University, *Rates of convergence for optimal transport problem with quadratic cost in two or three dimensions*;
- ▷ A. Zhiliakov, University of Houston, *Inf-sup stability of the trace $\mathbf{P}_2 - P_1$ Taylor–Hood elements for surface PDEs*

Mini-symposium
Scientific Machine Learning

Organizer(s): *Hwan Goh, Tan Bui-Thanh*

Abstract. The fast growth in practical applications of machine learning in a range of contexts has fueled a renewed interest in machine learning methods over recent years. Subsequently, scientific machine learning is an emerging discipline which merges scientific computing and machine learning. Whilst scientific computing focuses on large-scale models that are derived from scientific laws describing physical phenomena, machine learning focuses on developing data-driven models which require minimal knowledge and prior assumptions. With the contrast between these two approaches follows different advantages: scientific models are effective at extrapolation and can be fit with small data and few parameters whereas machine learning models require "big data" and a large number of parameters but are not biased by the validity of prior assumptions. Scientific machine learning endeavours to combine the two disciplines in order to develop models that draw from the advantages from their respective disciplines. Specifically, it works to develop explainable models that are data-driven but require less data than traditional machine learning methods through the utilization of centuries of scientific literature. The resulting model therefore possesses knowledge that prevents overfitting, reduces the number of parameters, and promotes extrapolatability of the model while still utilizing machine learning techniques to learn the terms that are unexplainable by prior assumptions. This minisymposium aims to attract researchers at the forefront of scientific machine learning, inviting them to present their latest work on this growing field.

Participants

- ▷ J. Actor, Rice University, *Upwind Schemes and Neural Networks for Image Segmentation*;
- ▷ E. Gildin, Texas A&M University, *Physics-aware Deep-learning-based Proxy Reservoir Simulation Model Equipped With State And Well Output Prediction*;
- ▷ H. Goh, Oden Institute of Computational Sciences and Engineering, *Solving Forward and Inverse Problems with Model-Aware Autoencoders*;
- ▷ B. Hanin, Princeton University, *Data Augmentation as Stochastic Optimization*;
- ▷ A. Henriksen, University of Texas at Austin, *Components and principles of streaming principal components*;
- ▷ L. Liu, Southern Methodist University, *A Phase Shift Deep Neural Network for High Frequency Approximation and Wave Problems*;
- ▷ A. Mang, University of Houston, *Classification of 3D Shapes and Shape Deformations*;
- ▷ Z. Zhang, Texas A&M University, *Multiagent Reinforcement Learning Accelerated MCMC on Multiscale Inversion Problem.*

Mini-symposium
Recent Advances in Inverse Problems: Numerics, Theory, and Applications

Organizer(s): *Shashank Subramanian, Andreas Mang*

Abstract. Inverse problems are of paramount interest in computational sciences and engineering. Despite formidable advances in recent years on all frontiers, significant challenges remain, especially in large-scale and/or data-intensive inverse problems. Due to ill-conditioning, non-convexity, large problem sizes, infinite-dimensional structure, and the need for adjoint operators, these types of problems are challenging to solve. On top of the computational complexity and the vast number unknowns, we also have to deal with model and data uncertainties. In this mini-symposium, we discuss recent advances in theory and computational methods to address these challenges, and showcase results for challenging applications.

Participants

- ▷ U. Albertin, Chevron, *Stochastic Optimization in Full Waveform Inversion*;
- ▷ A. Alghamdi, University of Texas at Austin, *Reduced order models for inversion and imaging with waves.*
- ▷ W. Baines, Texas A&M University, *Deep learning for 2D passive source detection in presence of complex cargo*;
- ▷ C. Borges, University of Central Florida, *Reconstruction of a Three-Dimensional Axis-Symmetric Scatterer*;
- ▷ A. Mamonov, University of Houston, *Reduced order models for inversion and imaging with waves*;
- ▷ S. Minkoff, University of Texas at Dallas, *Neural Network–Enhanced Two-Stage Hamiltonian Monte Carlo*;
- ▷ A. Saibaba, North Caroina State University, *Randomized approaches to accelerate MCMC algorithms for Bayesian Inverse Problems*;
- ▷ S. Subramanian, University of Texas at Austin, *Ensemble inversion for calibrating biophysical tumor growth models with mass effect*;

Mini-symposium
Spectral Theory and Mathematical Physics

Organizer(s): *Jake Fillman, Wencai Liu*

Abstract. Spectral theory is at the core of quantum mechanics, and it has connections to many fields of mathematics, including integrable systems, harmonic analysis, quantum dynamics, orthogonal polynomials, and random matrices. One of the main goals of spectral theory is understanding the intricate nonlinear dependence of the spectral measure on operator coefficients and vice versa. The focus subjects for the proposed mini-symposium are the following areas of spectral theory:

- ▷ analysis of disordered media, spectral and dynamical localization;
- ▷ periodic, quasi-periodic, and almost-periodic operators;
- ▷ connections between the Fermi surface and algebraic geometry;
- ▷ spectral theory of elliptic operators and quantum graphs;
- ▷ non-uniformly hyperbolic cocycle dynamics;
- ▷ scattering theory and inverse problems;

Recent research in each of these areas has greatly benefited from a synthesis of ideas from the other areas. The mini-symposium intends to facilitate scientific exchange of ideas and recent trends among researchers in the TX-LA area. The meeting will bring together both senior and junior researchers (including postdocs and students). Speakers from groups underrepresented in mathematics will be invited.

Participants

- ▷ D. Baskin, Texas A&M University, *Propagation of singularities for the Dirac–Coulomb system*;
- ▷ G. Berkolaiko, Texas A&M University, *Locating conical degeneracies in the spectra of parametric self-adjoint matrices*;
- ▷ T. Chen, University of Texas at Austin, *Dynamics of a heavy quantum tracer particle in a Bose gas*;
- ▷ M. Ettehad, Texas A&M University, *Three Dimensional Elastic Frames: Rigid Joint Conditions in Variational and Differential Formulation*
- ▷ F. Gesztesy, Baylor University, *The limiting absorption principle and continuity properties of the spectral shift function for massless Dirac-type operators*;
- ▷ R. Han, Georgia Tech University *Graphene models in magnetic fields*;
- ▷ B. Hatinoglu, University of California at Santa Cruz, *A complex analytic approach to inverse spectral problems for Jacobi operators*;
- ▷ I. Jauslin, Princeton University, *An effective equation to study Bose gasses at all densities*;
- ▷ P. Kuchment, Texas A&M University, *Spectral shift via lateral perturbation*;
- ▷ W. Li, DePaul University, *Infinitely Many Embedded Eigenvalues for the Neumann-Poincaré Operator in 3D*;
- ▷ R. Matos, Texas A&M University, *Finite volume criterion for localization on correlated environments*;
- ▷ M. Ntekoume, Rice University, *Integrable dispersive PDE at low regularity*;
- ▷ S. Shipman, Louisiana State University, *Depicting Spectra of Quantum Trees via Orthogonal Polynomials: Rogue Eigenvalues*;
- ▷ F. Sottile, Texas A&M University, *Numerical homotopies from Khovanskii bases*;

- ▷ S. Sukhtaiev, Auburn University, *Anderson localization for Kirchhoff and discrete Laplacians on random trees*;
- ▷ G. Young, Rice University, *Orthogonal rational functions with real poles, root asymptotics, and GMP matrices*;

Mini-symposium
Graph Theory

Organizer(s): *Chun-Hung Liu*

Abstract. Graph theory is one of the central topics in combinatorics and algorithms. Graphs are useful model widely used in different diciplines such as in computer science, biology, electrical engineering and economics.

This minisymposium addresses structual graph theory, extremal graph theory and their interplay. These areas not only are the main reasearch directions in combinatorics but also strongly influence other branches of mathematics. To name a few,

- ▷ the Graph Minor Theorem and the resolution of its variations, such as Nash-Williams' Weak Immersion Conjecture and Robertson's conjecture on topological minors, are far extensions of Kruskal's Tree Theorem in well-quasi-order theory which is important in logics, theoretical computer science, and category theory;
- ▷ the recent developments on asymptotic dimension on minor-closed famlies of graphs determine the asymptotic dimension of Riemann surfaces and more general metric spaces with minor-closed properties, where the asymptotic dimension is an important notion in geometric group theory and topology;
- ▷ the comination of the structural and extremal approaches leads to a recent breakthrough on Hadwiger's conjecture which is a far generalization of the Four-Color-Theorem proposed in 1943;
- ▷ the recent developments of hypergraph containers and graph limits have strong influences on the study of Ramsey theory, additive combinatorics and theoretical computer science.

The aim of this minisymposium is to gather experts in graph theory and share their recent work. A decent portion of confirmed speakers in this minisymposium are underrepresented minorities and are in early-career stage.

Participants

- ▷ M. Delcourt, Ryerson University, *Progress towards Nash-Williams' Conjecture on Triangle Decompositions*;
- ▷ B. Lidicky, Iowa State University, *Flexibility in planar graphs*;
- ▷ C.-H. Liu, Texas A&M University, *Asymptotic dimension of minor-closed families and beyond*;
- ▷ R. Luo, University of California - San Diego, *Forbidden traces in hypergraphs*;
- ▷ K. Milans, West Virginia State University, *Longest Path Transversals and Gallai Families*
- ▷ J. Park, Institute for Advanced Study, *Tuza's Conjecture for random graphs*;
- ▷ L. Postle, University of Waterloo, *Edge Colouring with Local List Sizes*;
- ▷ F. Wei, Princeton University, *3D multi-parameter visco-elastic full waveform inversion: methods and application for a near-surface case-study*;

Mini-symposium
Analytic and computational approaches for metamaterial and nanoscale optics

Organizer(s): *Robert Lipton, Matthias Maier*

Abstract. In the past few years the dream of manipulating the laws of optics at will has evolved into a (near) reality with the use of metamaterials. These are specifically engineered, periodically-aligned nanostructures that have made it possible to observe extraordinary optical and electronic behavior not present in naturally occurring structures. Metamaterial interfaces are promising ingredients in the design of novel optical applications promising *subwavelength optics* beyond the diffraction limit.

There is a compelling need for rigorous analytical modeling and the development of controllable numerical schemes which can reliably describe nanoscale optical devices. This minisymposium aims to bring together researchers interested in the development and analysis of novel models, as well as associated numerical methods for nanoscale optical devices.

Participants

- ▷ A. Drouot, University of Washington, *Integrable dispersive PDE at low regularity*;
- ▷ J. Lee, Baylor University, *Finite element methods for wave propagation in anisotropic acoustic metamaterials*;
- ▷ W. Li, DePaul University, *Lorentz Resonance in the Homogenization of Plasmonic Crystals*;
- ▷ J. Lin, Auburn University, *A Super-Resolution Imaging Approach By Using Subwavelength Hole Resonances*;
- ▷ D. Margetis, University of Maryland, *A flavor of plasmonics in the time domain*;
- ▷ M. Maier, Texas A&M University, *Finite-element computation of the conductivity feedback of nanoscale optical devices*;
- ▷ D. Nicholls, University of Illinois - Chicago, *Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface*;
- ▷ R. Perera, Lousiana State University, *Band structure for phononic media*;
- ▷ S. Shipman, Lousiana State University, *Fano Resonance in in a periodic array of narrow slits in metal*;
- ▷ R. Viator, Swarthmore College, *Bloch waves in 3-dimensional high-contrast photonic crystals*
- ▷ A. Watson, University of Minnesota, *Existence and computation of exponentially localized Wannier functions for non-periodic insulators*;
- ▷ A. Welters, Florida Institute of Technology, *Simplification of Bessmertnyi realizability for rational functions of several complex variables*;

Mini-symposium
Mathematical and Computational Models for Understanding Emerging Epidemics and Evaluating Intervention Strategies

Organizer(s): *Zhuolin Qu, Asma Azizi*

Abstract. The emergence and re-emergence of infectious diseases bring renewed urgency to infectious disease modeling. Approaches such as mathematical and computational modeling have broad applications in characterizing the complex systems of the epidemics, which help public health workers better understand the disease dynamics, predict the course of an outbreak, and assess the effectiveness of the public intervention strategies. These models are in increasing demand to respond to emerging threats, as they offer new into infection emergence, transmission, and control. The focus of this session is on modeling the transmission dynamics and on evaluating potential control strategies for infectious diseases. We aim to bring together mathematical epidemiologists to discuss their recent results in modeling the emerging epidemics, such as the ongoing COVID-19 pandemic and invasive Non-typhoidal Salmonella disease in Africa.

Participants

- ▷ A. Azizi, UCI, *Optimizing COVID-19 Awareness and Testing Strategy*;
- ▷ J. Gutierrez, University of Texas at San Antonio, *A model for COVID-19 Community Transmission Considering Asymptomatics and Mitigation*;
- ▷ Z. Qu, University of Texas at San Antonio, *Staged progression epidemic model for the transmission of invasive nontyphoidal* Salmonella *(iNTS) with treatment*;
- ▷ L. Xue, Harbin Engineering University, *Assessing the impact of non-pharmatical intervention strategies for containing COVID-19.*

Mini-symposium
Numerical methods and applications for cardiovascular mechanics

Organizer(s): *Charles Puelz*

Abstract. The human cardiovascular system contains many complex components, including valve leaflets, dissolved and transported solutes, electromechanics, and branching vessel networks. Numerical models for cardiovascular mechanics have the power to provide detailed information about this system, with a goal of improving care for patients with cardiovascular problems. This minisymposium will focus on models for blood flow, solute transport, and tissue mechanics within cardiovascular physiology. Emphasis will be placed on the derivation of models, analysis of numerical methods, assimilation of data for model calibration, and application of these models and methods to challenging biomedical problems. Applications will range in spatial scales, from detailed models of a local region within the heart or lungs to large-scale models of vessel networks. Some highlights include blood transport in vessels described by a nonlinear hyperbolic system as well as fluid-structure interaction models of cardiac tissue.

Participants

- ▷ M. Colebank, North Carolina State University, *Predicting hemodynamics and perfusion deficits in chronic thromboembolic pulmonary hypertension*;
- ▷ J. Lee, Johns Hopkins University, *Locating conical degeneracies in the spectra of parametric self-adjoint matrices*;
- ▷ R. Masri, Rice University, *Derivation and simulation of solute transport and blood flow in one dimensional vessel networks*;
- ▷ C. Puelz, Baylor School of Medicine, *A fluid-structure interaction model of the human heart.*

Mini-symposium
Nonlocal Models in Mathematics and Computation

Organizer(s): *Patrick Diehl, Prashant K. Jha, Robert Lipton*

Abstract. Nonlocal models have drawn increasing interest from both the mathematical and computational science communities in recent years. This is due to their ability to describe physical processes which lie outside classical local theories. Over the last fifteen years, mathematicians have begun to identify the mathematical theory behind these approaches. These efforts complement the advances in model development, computational methods and experiment necessary to validate nonlocal modeling. The objectives of this mini-symposia is to bring together experts in nonlocal models from mathematics, computational science, and mechanics, in order to further the dialogue between these communities.

Participants

- ▷ B. Aksoylu, CCDC Army Research Laboratory & Texas A&M University - San Antonio, *The Choice of Kernel Function in Nonlocal Wave Propagation with Local Boundary Conditions*;
- ▷ D. Bhattacharya, Louisiana State University, *Modeling particle beds using peridynamics*;
- ▷ M. D'Elia, Sandia National Laboratory, *Substructuring-based domain decomposition methods for nonlocal problems*;
- ▷ P. Diehl, Louisiana State University, *On the treatment of boundary conditions for bond-based peridynamic models*;
- ▷ P. Jha, University of Texas at Austin, *Application of peridynamics to fracture in solids and granular media*
- ▷ R. Lipton, Louisiana State University, *Recovery of Linear Elastic Fracture Mechanics from Nonlocal Dynamics*;
- ▷ A. Martowicz, AGH University of Science and Technology, *Peridynamic model for shape memory alloys*;
- ▷ E. Oterkus, University of Strathclyde, *Utilisation of Euler-Lagrange Equation to Derive Dual-Horizon Peridynamic Equations*;
- ▷ S. Oterkus, University of Strathclyde, *Peridynamic Polycrystalline Ice Model*;
- ▷ F. Scabbia, University of Padova, *A note on the surface effect in OSB-PD models*;
- ▷ J. Scott, University of Pittsburgh, *Asymptotic analysis of a coupled system of nonlocal equations with oscillatory coefficients*;
- ▷ P. Seleson, Oak Ridge National Laboratory, *Overall equilibrium in the coupling of peridynamics and classical continuum mechanics*;
- ▷ S. Silling, Sandia National Laboratory, *Using Nonlocality to Predict the Rate of Material Failure*;
- ▷ X. Tian, University of California - San Diego, *Reproducing kernel collocation methods for nonlocal models: asymptotic compatibility and numerical stability*;
- ▷ Y. Yu, Lehigh University, *An asymptotically compatible treatment of traction loads in peridynamics*;

Mini-symposium
Dynamics of Nonlinear PDE and Applications

Organizer(s): *Vesselin Vatchev, Erwin Suazo, Dambaru Bhatta*

Abstract. Variety of physical phenomena are described by nonlinear PDEs. The properties of the solutions of these PDEs reflect the physical properties of the observed systems but also can provide details which are not easily observable. The aim of the minisymposium is to report theoretical and numerical results on dynamical properties of solutions to nonlinear PDEs and their relations to solitary waves and other physical systems.

Participants

- ▷ D. Bhatta, University of Texas - Rio Grande Valley, *Nonlinear Free surface Condition Due to Wave Diffraction By a Pair of Cylinders*
- ▷ H. Ibdah, Texas A&M University, *Strong solutions to a modified Michelson-Sivashinsky equation*;
- ▷ H. Leiva, Yachay Tech University, *Solvability of Semilinear Equations in Hilbert Spaces and Applications to Control System Governed by PDEs*;
- ▷ S. Li, UTRGV, *Lax representation and Hamiltonian structure for integrable systems*;
- ▷ Q. Lin, Texas A&M University, *3D Inviscid Primitive Equations With Rotation*;
- ▷ E. Lopera, Universidad Nacional de Colombia, *Existence of positive solutions for a semipositone Φ-Laplacian problem*;
- ▷ Z. Qiao, University of Texas - Rio Grande Valley, *Peridynamic Polycrystalline Ice Model*;
- ▷ E. Suazo, University of Texas - Rio Grande Valley, *On explicit and numerical solutions for stochastic partial diferential equations: Fisher and Burger type equations*;
- ▷ A. Tedeef, South Mathematical Institute of VSC RAS, *Asymptotic Properties of Solutions to the Cauchy Problem for Degenerate Parabolic Equations with Inhomogeneous Density on Manifolds*;
- ▷ V. Vatchev, UT Rio Grande Valley, *On the Dynamics of solitons for the 'good' Boussinesq equation*;
- ▷ J. Galvis, Universidad Nacional de Colombia, *Fast multiscale contrast independent preconditioner for linear elastic topology optimization problems*;

Mini-symposium
Analytical aspect of nonlinear wave equations

Organizer(s): *Baofeng Feng*

Abstract. Nonlinear wave equations have been studied extensively in related to many fields both pure mathematics and applied mathematics. Meanwhile, they also promises applications ranging from water waves, nonlinear optics to plasma physics. Especially, analytical results including exact solutions of these nonlinear wave equations are of very important in understanding the associated physical phenomena.

The purpose of this minisymposium is to bring together researchers to discuss recent advances on the analytical aspect of nonlinear wave equations.

Participants

- ▷ D. Mantzavinos, University of Kansas, *The Nonlinear Schrödinger Equation on the Half-Plane*;
- ▷ C. Rickard, University of Southern California, *Global existence of the non-isentropic compressible Euler equations with vacuum boundary surrounding a variable entropy state*;
- ▷ Y. Shen, University of Kansas, *Well-posedness of 1D Quasilinear Wave Equation*
- ▷ A. Stukopin, University of Texas - Rio Grande Valley, *Solitary and periodic wave solutions for several short wave model equations*;
- ▷ C. Wu, Shenzhen University, *Elliptic functions and their applications in integrable and nonintegrable systems*;
- ▷ C. Wu, Sun Yat-Sen University, China, *An extension of Kadomtsev-Petviashvili hierarchy*;
- ▷ S.-L. Wu, Xidian University, *Propagation direction for the bistable traveling front in a three species competition system*;
- ▷ P. Zhang, Xidian University, *Symmetry properties of solutions of Hamiltonian system on Compact Convex Hypersurfaces in* R^8.

Mini-symposium
Biological Oscillations: From Genes to Populations

Organizer(s): *Bhargav Karamched, William Ott*

Abstract. Oscillations are ubiquitous in biology, occurring at all scales and performing a plethora of functions. Proteins produced from genes responding to an oscillatory signal are less susceptible to stochastic fluctuations than when those genes respond to a constant input [1]. Protein oscillations help establish an organism's circadian rhythm [2]. Multi-strain microbial consortia display population-level oscillations when adapting to disparate environmental cues [3].

Such oscillatory phenomena are often finely tuned in terms of frequency and amplitude [4]. Biological oscillations whose characteristics differ from what they need to be often result in catastrophic ends, such as protein over-expression, sleep disorders, and hormonal problems [5, 6, 7]. Understanding the mechanisms underlying biological oscillations is therefore of great importance. Mathematical models provide excellent tools in this regard.

This mini-symposium will feature talks describing models of biological oscillations at a multitude of scales. The benefits of such oscillations will be discussed, as well as the challenges in understanding them, to help progress scientific disciplines such as medicine, physiology, biochemistry, and synthetic biology.

References

[1] F. Tostevin, W. de Ronde, and P. R. ten Wolde. Reliability of Frequency and Amplitude Decoding in Gene Regulation. *Physical Review Letters*, **108**, 108104, 2012.
[2] J. K. Kim, Z. P. Kilpatrick, M. R. Bennett, and K. Josić. Molecular mechanisms that regulate the coupled period of the mammalian circadian clock. *Biophysical Journal*, **106**, 9, 2071-2081, 2014
[3] M. Sadeghpour, A. Veliz-Cuba, G. Orosz, K. Josić, and M. R. Bennett. Bistability and oscillations in co-repressive synthetic microbial consortia. *Quantitative Biology*, 1-12, 2017.
[4] D. C. Krakauer, K. M. Page, and S. Sealfon. Module dynamics of the GnRH signal transduction network *Journal of Theoretical Biology*, **218**, 4, 457-470, 2002
[5] K. Kruse and F. Jülicher. Oscillations in cell biology *Current Opinion in Cell Biology*, **17**, 1, 20-26, 2005
[6] N. Kraus. Atypical brain oscillations: a biological basis for dyslexia? *Trends in Cognitive Sciences*, **16**, 1, 12-13, 2012
[7] Y. Cao, A. Lopatkin, and L. You Elements of biological oscillations in time and space. *Nature Structural and Molecular Biology*, **23**, 1030-1034 , 2016

Participants

- ▷ B. Karamched, Florida State University, *Bacterial Cell-Shape Modulation and Induced Population Dynamics of Synthetic Microbial Consortia*;
- ▷ J. MacLaurin, New Jersey Institute of Technology, *A Different Approach to Model Oscillatory Blood Glucose Behavior*
- ▷ W. Ott, University of Houston, *Delay-induced uncertainty in physiological systems*
- ▷ M. Sirlanci, University of Colorado Anschutz Medical Campus, *A Different Approach to Model Oscillatory Blood Glucose Behavior*;

Mini-symposium
Clustering Analysis of Novel Corona Virus (COVID-19) Cases in U.S. States and Territories

Organizer(s): *Chandra Manivannan, Guoqing Tang*

Abstract. The Centers for Disease Control and Prevention (CDC) confirmed the first case of the novel corona virus (COVID-19) in the United States on January 21, 2020, in the state of Washington. To date (August 31, 2020) at least 5,998,000 COVID-19 cases have been reported and at least 180,000 individuals have died from the novel corona virus in the United States. This mini-symposium will discuss applying hierarchical clustering techniques to cluster U.S. states and territories with respect to number of confirmed cases, number of recovered patients, and number of deaths. The resulting clusters of states and territories will prove useful to various government, healthcare, and private sector stakeholders as the clusters can help prioritize different needs for different regions [1]. We will showcase visualizations that depict confirmed cases, recovered cases, and deaths over time. The visualizations and clusters that resulted from from study can identify resource or policy needs of various clusters (including ventilators, testing kits, masks, and lock down measures) to mitigate the spread and threat of COVID-19. We will discuss analytical methods and algorithms implemented in Python as well as R, with a focus on principal component analysis (PCA). Presenting our research in a mini-symposium format will allow various stakeholders in the public and private sectors, as well as academia, to view clusters of U.S. regions and make appropriate policy decisions [2].

References

[1] S. Kumar. Monitoring Novel Corona Virus (COVID-19) Infections in India by Cluster Analysis. *Annals of Data Science*, 1(9), 2020.

[2] V. Zarikas, S.G. Poulopoulos, Z. Gareiou, E. Zervas. Clustering analysis of countries using the COVID-19 cases dataset. *Data in Brief*, 31, 2020.

Participants

- ▷ B. Chhatrala, North Carolina State University, *Weight Function Progress*;
- ▷ C. Manivannan, North Carolina Agricultural and State University, *Clustering Analysis of Novel Corona Virus (COVID-19) Cases in U.S. States and Territories*;
- ▷ A. Mohideen, North Carolina A&T State University, *Police Funding and Fatal Police Shootings in the United States*;
- ▷ M. Parker, North Carolina Agricultural and Technical State University, *Regression Analysis of Statewide COVID-19 Data in the U.S.*.

Mini-symposium
Mathematical Advances in Ecology and Evolution

Organizer(s): *Angela Peace, Lale Asik, Md Nazmul Hassan*

Abstract. The complexities of ecological systems, including feedbacks scaling from populations to ecosystem processes and transient environmental conditions invites mathematical approaches to deepen understanding and further the field. Dynamical systems and ecology have a rich collaborative history including modeling population and community dynamics, exploring ecosystem functions, and studying drivers of biodiversity. This session presents a variety of current mathematical approaches and frameworks addressing problems arising in population dynamics, ecology and evolution.

Participants

- ▷ L. Asik, University of The Incarnate Word, *The Effects of Excess Food-Nutrient Content on the Coexistence of Competing Consumer Species*;
- ▷ Y. Kang, Arizona State University, *The role of demographic and environmental stochasticity in a population model with a component Allee effect*
- ▷ A. Laubmeier, Texas Tech University, *An annual model for Astragalus scaphoides and its parameterization*;
- ▷ A. Peace, Texas Tech University, *Integrating Disease and Ecosystem Ecology Theory.*

Mini-symposium
Applications of Algebraic Geometry

Organizer(s): *Frank Sottile, Elise Walker*

Abstract. At its core, algebraic geometry is the study of polynomial equations and their solutions. The need to understand these solutions has become common in applications and over the last twenty years, algebraic geometers have made significant contributions to problems by combining their tools with techniques from other areas of mathematics, including numerical analysis and optimization. The growth of this field was witnessed by the 2019 SIAM Conference on Applied Algebraic Geometry in Bern whose attendance of 750 was a 60% increase over the 2017 meeting. Texas A&M will host the next meeting in August 2021.

At the SIAM TX-LA meeting in October 2020, there are plans for sister minisymposia in this area in algebraic complexity (J.M. Landsberg) and in mathematical biology (Nida Obatake and Alexander Ruys de Perez). This minisymposium will have a slight focus on numerical methods in algebraic geometry, and on the use of these methods in applications, but will include others in this area; two expected speakers have recently joined UT Austin as assistant professors. We expect to have two sessions with four speakers in each.

Participants

- ▷ T. Brysiewicz, Max Planck Institute for Mathematics in the Sciences, *Nodes on quintic spectrahedra*;
- ▷ J. Coons, North Carolina State University, *Quasi-Independence Models with Rational Maximum Likelihood Estimates*;
- ▷ T. Duff, Georgia Tech University, *Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface*;
- ▷ J. Kileel, University of Texas at Austin, *Fast Symmetric Tensor Decomposition*;
- ▷ M. Regan, Duke University, *Fast Symmetric Tensor Decomposition*
- ▷ S. Sherman, University of Notre Dame, *Generating cognates for 6, 8, and 10-bar mechanisms*;
- ▷ N. Tran, University of Texas at Austin, *A simple and effective method for low-rank completion for the shared response model in fMRI experiment design*;
- ▷ E. Walker, Texas A&M University, *Numerical homotopies from Khovanskii bases*;

Mini-symposium
Algebraic, geometric, and combinatorial methods in mathematical biology

Organizer(s): *Nida Obatake, Alexander Ruys de Perez*

Abstract. In recent years, symbolic and discrete methods are increasingly utilized to solve problems from systems biology. For instance, real algebraic geometry and convex geometry are powerful tools for understanding polynomial ODEs arising from bio-chemical reaction networks, while applied algebraic topology provides a framework for studying neural codes. The proposed 2-session minisymposium will highlight recent developments in the application of algebra, geometry, and combinatorics to problems in biology.

Algebraic, geometric, and combinatorial methods give theoretical models for structures throughout mathematical biology. Applied mathematicians develop tools that characterize models based on structural properties or other "minimal" properties of the model. These minimal properties are in general computationally easy to check and can thus be implemented for use by biologists. Current research pushes beyond specific data sets and allows for an overarching view of the structure of these biological problems. Consequently, we obtain a better prediction of experimental outcomes and an insight into experimental design.

Participants

- ▷ J. Austin, University of Texas at Austin, *Not Just a Knot*;
- ▷ J. Kileel, University of Texas at Austin, *Determining Protein Structure by the Method of Moments* ;
- ▷ A. Kunin, Baylor College of Medicine, *Oriented Matroids and Combinatorial Neural Codes*;
- ▷ C. Lienkaemper, Penn State University, *Identifying low rank structure preserved by nonlinear transformations*;
- ▷ B. Pascual Escudero, Universidad Carlos III de Madrid, *Necessary conditions for ACR in Reaction Networks*;
- ▷ P. Yu, University of Wisconsin - Madison, *Geometry of Geometric Rank*.

Mini-symposium
Geometry and complexity

Organizer(s): *Joseph Landsberg*

Abstract. Recently there have been exciting developments in the study of the geometry and complexity of tensors, due to input from modern algebraic geometry and quantum information theory. This minisymposium will cover these developments and include tutorials on the background material.

Participants

- ▷ K. Bari, Texas A&M University, *On the structure tensor of* $\mathfrak{sl}_n$;
- ▷ R. Geng, Texas A&M University, *Geometry of Geometric Rank*;
- ▷ H. Huang, Texas A&M University, *Vanishing Hessian and Wild Polynomials*;
- ▷ J. Jelisiejew, University of Warsaw, *Components of varieties of commuting matrices*;
- ▷ J. Landsberg, Texas A&M University, *From linear to multi-linear algebra*;
- ▷ A. Pal, Texas A&M University, *New tests for minimal border rank tensors.*

Mini-symposium
Numerical methods for Stokes and Navier-Stokes equations

Organizer(s): *Alan Demlow, Maxim Olshanskii*

Abstract. Talks in this session will highlight recent progress in finite element technologies for simulating fluid systems modeled Stokes or Navier-Stokes equations. Potential topics include development of structure-preserving methods such as divergence-conforming schemes, simulation of fluid systems on surfaces, and methods for time-dependent problems.

Participants

- ▹ A. Demlow, Texas A&M University, *A unified theoretical and computational nonlocal framework: generalized vector calculus and machine-learned nonlocal models*;
- ▹ J. Gopalakrishnan, Portland State University, *New techniques to approximate viscous stresses in Stokes flow*
- ▹ P. Lederer, Technical University of Vienna, *Guaranteed upper bounds for the velocity error of pressure-robust Stokes discretisations*;
- ▹ C. Lehrenfeld, University of Göttingen, *Finite element discretizations with exactly tangential vector fields for incompressible flows on surfaces*;
- ▹ M. Neilan, University of Pittsburgh, *Scott-Vogelius finite elements on curved domains*;
- ▹ M. Olshanskii, University of Houston, *Speed-direction description of flow motion*;
- ▹ L. Rebholz, Clemson University, *Longer time accuracy for incompressible Navier-Stokes simulations with the EMAC formulation*;
- ▹ A. Reusken, RWTH Aachen university, *Finite Element Methods for Surface Stokes Equations.*

Mini-symposium
Advances in Seismic Imaging and Inversion

Organizer(s): *William W. Symes*

Abstract. The inversion of seismic data - interpretation by model based data fitting - has evolved through incorporation of accurate physics of seismic waves, and development of increasingly effective computational techniques. This session will review recent progress in several parts of this subject, including: conditioning data for effective inversion; extended modeling approaches to compensate for non-convexity of data misfit functions; and UQ for geologic information extracted from inverted models or images.

Participants

- ▷ D. Li, University of Calgary, *Incorporating Multiple A Priori Information for Seismic Inversion*;
- ▷ M. Louboutin, Georgia State University, *Time-domain Wavefield Reconstruction Inversion in Tilted Transverse Isostropic media*;
- ▷ J. Popa, University of Texas at Dallas, *Peridynamic Polycrystalline Ice Model*;
- ▷ A. Siahkoohi, Georgia State University, *Unsupervised data-guided uncertainty analysis in imaging and horizon tracking*;

Mini-symposium
Elastic Imaging and Full waveform inversion for hydrocarbon exploration and production

Organizer(s): *Xukai Shen*

Abstract. There is a trend in the oil & gas industry to acquire more and more seismic data with low frequency and long offset, so we can use full waveform inversion to overcome the challenges of complex subsurface imaging and model building. In this workshop, we?ll present and discuss whether we will need to include elastic phenomena as part of the physics description and what that means for the data processing and inversion.

Participants

- ▷ O. Aragao, Colorado School of Mines, *Elastic full-waveform inversion with petrophysical Information in a probabilistic approach*;
- ▷ R. Brossier, University Grenoble Alpes, *3D multi-parameter visco-elastic full waveform inversion: methods and application for a near-surface case-study*
- ▷ Y. Liu, Colorado School of Mines, *Methodology of time-lapse elastic full-waveform inversion for VTI media*.
- ▷ R. Biswas, British Petroleum, *Two-step velocity inversion using trans-dimensional tomography and elastic FWI*.

List of Contributors

- ▷ J. Actor, Rice University, *Upwind Schemes and Neural Networks for Image Segmentation*
- ▷ B. Aksoylu, CCDC Army Research Laboratory & Texas A&M University - San Antonio, *The Choice of Kernel Function in Nonlocal Wave Propagation with Local Boundary Conditions*;
- ▷ U. Albertin, Chevron, *Stochastic Optimization in Full Waveform Inversion*;
- ▷ A. Alghamdi, University of Texas at Austin, *Reduced order models for inversion and imaging with waves.*
- ▷ D. Appelo, Michigan State University, *An Energy-Based Discontinuous Galerkin Method for A Nonlinear Variational Wave Equation Modelling Nematic Liquid Crystal*;
- ▷ O. Aragao, Colorado School of Mines, *Elastic full-waveform inversion with petrophysical Information in a probabilistic approach*;
- ▷ T. Arbogast, University of Texas at Austin, *A Self-Adaptive Theta Method for Conservation Laws using Discontinuity Aware Quadrature*;
- ▷ L. Asik, University of The Incarnate Word, *The Effects of Excess Food-Nutrient Content on the Coexistence of Competing Consumer Species*;
- ▷ J. Austin, University of Texas at Austin, *Not Just a Knot*;
- ▷ A. Azizi, UCI, *Optimizing COVID-19 Awareness and Testing Strategy*;
- ▷ W. Baines, Texas A&M University, *Deep learning for 2D passive source detection in presence of complex cargo*;
- ▷ K. Bari, Texas A&M University, *On the structure tensor of* $\mathfrak{sl}_n$;
- ▷ S. Bartels, University of Freiburg, *Simulation of nonlinear bending phenomena for plates in the presence of contact*;
- ▷ D. Baskin, Texas A&M University, *Propagation of singularities for the Dirac–Coulomb system*;
- ▷ G. Berkolaiko, Texas A&M University, *Locating conical degeneracies in the spectra of parametric self-adjoint matrices*;
- ▷ D. Bhattacharya, Louisiana State University, *Modeling particle beds using peridynamics*;
- ▷ D. Bhatta, University of Texas - Rio Grande Valley, *Nonlinear Free surface Condition Due to Wave Diffraction By a Pair of Cylinders*
- ▷ R. Biswas, British Petroleum, *Two-step velocity inversion using trans-dimensional tomography and elastic FWI*;
- ▷ R. Booth, Texas A&M University, *Long-Time Asymptotics for the Massless Dirac-Coulomb Equation*;
- ▷ C. Borges, University of Central Florida, *Reconstruction of a Three-Dimensional Axis-Symmetric Scatterer*;
- ▷ G. Bornia, Texas Tech University, *On the treatment of full Dirichlet optimal control problems with divergence-free constraints*;
- ▷ R. Brossier, University Grenoble Alpes, *3D multi-parameter visco-elastic full waveform inversion: methods and application for a near-surface case-study*
- ▷ T. Brysiewicz, Max Planck Institute for Mathematics in the Sciences, *Nodes on quintic spectrahedra*;
- ▷ A. Caboussat, University of Applied Sciences Western Switzerland, *Numerical approximation of orthogonal maps with adaptive finite elements. Application to paper folding*;
- ▷ R. Cantrell, University of Miami, *Perspective on the connection between ideal free dispersal and the evolution of dispersal*;

- ▷ G. Capodaglio, Los Alamos National Laboratory, *Substructuring-based domain decomposition methods for nonlocal problems*;
- ▷ L. Cappanera, University of Houston, *An artificial compression method for incompressible flows with variable density and viscosity*;
- ▷ J. Chan, Rice University, *Efficient computation of Jacobian matrices for entropy stable summation-by-parts schemes*;
- ▷ T. Chen, University of Texas at Austin, *Dynamics of a heavy quantum tracer particle in a Bose gas*;
- ▷ B. Chhatrala, North Carolina State University, *Weight Function Progress*;
- ▷ J. Chong, University of Texas at Austin, *Dynamics of Large Boson Systems with Attractive Interaction and A Derivation of the Cubic Focusing NLS in* $\mathbb{R}^3$;
- ▷ M. Colebank, North Carolina State University, *Predicting hemodynamics and perfusion deficits in chronic thromboembolic pulmonary hypertension*;
- ▷ J. Coons, North Carolina State University, *Quasi-Independence Models with Rational Maximum Likelihood Estimates*;
- ▷ J. Cushing, University of Arizona, *Does Evolution Select Against Chaos?*;
- ▷ M. D'Elia, Sandia National Laboratory, *Substructuring-based domain decomposition methods for nonlocal problems*;
- ▷ P. De Leenheer, Oregon State University, *The basic reproduction number for linear maps that preserve a cone*;
- ▷ M. Delcourt, Ryerson University, *Progress towards Nash-Williams' Conjecture on Triangle Decompositions*;
- ▷ A. Demlow, Texas A&M University, *A unified theoretical and computational nonlocal framework: generalized vector calculus and machine-learned nonlocal models*;
- ▷ P. Diehl, Louisiana State University, *On the treatment of boundary conditions for bond-based peridynamic models*;
- ▷ H. Dong, Brown University, *Evolutionary equations with nonlocal time derivatives*;
- ▷ A. Drouot, University of Washington, *Integrable dispersive PDE at low regularity*;
- ▷ T. Duff, Georgia Tech University, *Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface*;
- ▷ T. Dzanic, Texas A&M University, *A Riemann Difference Scheme for Shock Capturing in Discontinuous Finite Element Methods*;
- ▷ M. Ettehad, Texas A&M University, *Three Dimensional Elastic Frames: Rigid Joint Conditions in Variational and Differential Formulation*
- ▷ W.-T. Fan, Indiana University, *Wave propagation for reaction-diffusion equations on infinite random trees*;
- ▷ W. Feldman, University of Utah, *Mean curvature flow with positive random forcing in 2-d*;
- ▷ A. Firoozabadi, Rice University, *Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface*
- ▷ J. Galvis, Universidad Nacional de Colombia, *Fast multiscale contrast independent preconditioner for linear elastic topology optimization problems*;
- ▷ N. Gantert, Technical University of Munich, *Exclusion processes on trees*;
- ▷ R. Geng, Texas A&M University, *Geometry of Geometric Rank*;

- ▷ F. Gesztesy, Baylor University, *The limiting absorption principle and continuity properties of the spectral shift function for massless Dirac-type operators*;
- ▷ E. Gildin, Texas A&M University, *Physics-aware Deep-learning-based Proxy Reservoir Simulation Model Equipped With State And Well Output Prediction*;
- ▷ H. Goh, Oden Institute of Computational Sciences and Engineering, *Solving Forward and Inverse Problems with Model-Aware Autoencoders*;
- ▷ J. Gopalakrishnan, Portland State University, *New technqiues to approximate viscous stresses in Stokes flow*
- ▷ J.-L. Guermond, Texas A&M University, *Second-order invariant domain preserving approximation of the compressible Navier–Stokes equations*;
- ▷ C. Gui, University of Texas at San Antonio, *Propagation acceleration in reaction diffusion equations with fractional Laplacians*;
- ▷ W. Guo, Texas State University, *Low Rank Tensor Methods for Vlasov Simulations*;
- ▷ J. Gutierrez, University of Texas at San Antonio, *A model for COVID-19 Community Transmission Considering Asymptomatics and Mitigation*
- ▷ B. Hanin, Princeton University, *Data Augmentation as Stochastic Optimization*;
- ▷ R. Han, Georgia Tech University *Graphene models in magnetic fields*;
- ▷ W. Hao, Penn State University, *A randomized Newton's method for solving differential equations based on the neural network discretization*;
- ▷ B. Hatinoglu, University of California at Santa Cruz, *A complex analytic approach to inverse spectral problems for Jacobi operators*;
- ▷ A. Henriksen, University of Texas at Austin, *Components and principles of streaming principal components*;
- ▷ H. Huang, Texas A&M University, *Vanishing Hessian and Wild Polynomials*;
- ▷ H. Ibdah, Texas A&M University, *Strong solutions to a modified Michelson-Sivashinsky equation*;
- ▷ R. Islam, Texas Tech University, *Discontinuous Galerkin methods for a dispersive wave hydro-sediment-morphodynamic model*;
- ▷ G. Iyer, Carnagie Mellon University, *Bounds on the heat transfer rate via passive advection*;
- ▷ I. Jauslin, Princeton University, *An effective equation to study Bose gasses at all densities*;
- ▷ J. Jelisiejew, University of Warsaw, *Components of varieties of commuting matrices*;
- ▷ P. Jha, University of Texas at Austin, *Application of peridynamics to fracture in solids and granular media*
- ▷ Y. Jin, University of Nebraska - Lincoln, *The dynamics of a zooplankton-fish system in aquatic habitats*;
- ▷ Y. Kang, Arizona State University, *The role of demographic and environmental stochasticity in a population model with a component Allee effect*
- ▷ B. Karamched, Florida State University, *Bacterial Cell-Shape Modulation and Induced Population Dynamics of Synthetic Microbial Consortia*;
- ▷ E. Kara, Texas Tech University, *Diffusion Tensor Imaging (DTI) Based Drug Diffusion Model in a Solid Tumor*;
- ▷ K. Kashyken, Oden Institute, *Discontinuous Galerkin methods for a dispersive wave hydro-sediment-morphodynamic model*;
- ▷ C. Kees, Louisiana State University, *A simple CutFEM implementation with applications to shallow water waves and fluid-structure interaction*

- ▷ A. Kh.Balci, Bielefeld Unievrsity, Germany, *Elliptic equations with degenerate weights*;
- ▷ J. Kileel, University of Texas at Austin, *Determining Protein Structure by the Method of Moments* ;
- ▷ J. Kileel, University of Texas at Austin, *Fast Symmetric Tensor Decomposition*;
- ▷ Y. Klevtsova, Siberian Regional Hydrometeorological Research Institute, *Determing Protein Structure by the Method of Moments*;
- ▷ P. Kuchment, Texas A&M University, *Spectral shift via lateral perturbation*;
- ▷ A. Kunin, Baylor College of Medicine, *Oriented Matroids and Combinatorial Neural Codes*;
- ▷ J. Landsberg, Texas A&M University, *From linear to multi-linear algebra*;
- ▷ A. Laubmeier, Texas Tech University, *An annual model for Astragalus scaphoides and its parameterization*;
- ▷ P. Lederer, Technical University of Vienna, *Guaranteed upper bounds for the velocity error of pressure-robust Stokes discretisations*;
- ▷ J. Lee, Baylor University, *Finite element methods for wave propagation in anisotropic acoustic metamaterials*;
- ▷ J. Lee, Johns Hopkins University, *Locating conical degeneracies in the spectra of parametric self-adjoint matrices*;
- ▷ C. Lehrenfeld, University of Göttingen, *Finite element discretizations with exactly tangential vector fields for incompressible flows on surfaces*;
- ▷ H. Leiva, Yachay Tech University, *Solvability of Semilinear Equations in Hilbert Spaces and Applications to Control System Governed by PDEs*;
- ▷ S. Lenhart, University of Tennessee, *Optimal Control of Directed Flow in a PDE Model of an Invasive Species in a River*;
- ▷ S. Li, UTRGV, *Lax representation and Hamiltonian structure for integrable systems*;
- ▷ B. Lidicky, Iowa State University, *Flexibility in planar graphs*;
- ▷ C. Lienkaemper, Penn State University, *Identifying low rank structure preserved by nonlinear transformations*;
- ▷ J. Lin, Auburn University, *A Super-Resolution Imaging Approach By Using Subwavelength Hole Resonances*;
- ▷ S. Lin, Rice University, *ALESQP: An Augmented Lagrangian Equality-constrained SQP Method for Function-space Optimization with General Constraints.*
- ▷ Q. Lin, Texas A&M University, *3D Inviscid Primitive Equations With Rotation*;
- ▷ R. Lipton, Louisiana State University, *Recovery of Linear Elastic Fracture Mechanics from Nonlocal Dynamics*;
- ▷ Y. Liu, Colorado School of Mines, *Methodology of time-lapse elastic full-waveform inversion for VTI media*;
- ▷ L. Liu, Southern Methodist University, *A Phase Shift Deep Neural Network for High Frequency Approximation and Wave Problems*;
- ▷ C.-H. Liu, Texas A&M University, *Asymptotic dimension of minor-closed families and beyond*;
- ▷ W. Li, DePaul University, *Infinitely Many Embedded Eigenvalues for the Neumann-Poincaré Operator in 3D*;
- ▷ W. Li, DePaul University, *Lorentz Resonance in the Homogenization of Plasmonic Crystals*;
- ▷ D. Li, University of Calgary, *Incorporating Multiple A Priori Information for Seismic Inversion*;

- ▷ E. Lopera, Universidad Nacional de Colombia, *Existence of positive solutions for a semipositone Φ-Laplacian problem*;
- ▷ M. Louboutin, Georgia State University, *Time-domain Wavefield Reconstruction Inversion in Tilted Transverse Isostropic media*;
- ▷ Y. Lou, Ohio State University, *On R0 in heterogeneous environment*;
- ▷ R. Luo, University of California - San Diego, *Forbidden traces in hypergraphs*;
- ▷ D. Luo, University of Texas at Austin, *Optimal control of block copolymer systems governed by nonlocal Cahn Hilliard equations*;
- ▷ M. Maier, Texas A&M University, *Finite-element computation of the conductivity feedback of nanoscale optical devices*;
- ▷ M. Maier, Texas A&M University, *Massively parallel 3D computation of the compressible Euler equations with an invariant-domain preserving second-order finite-element schemes*;
- ▷ E. Malinnikova, Stanford University, *On the Landis conjecture on the plane*;
- ▷ A. Mamonov, University of Houston, *Reduced order models for inversion and imaging with waves*;
- ▷ A. Mang, University of Houston, *Classification of 3D Shapes and Shape Deformations*;
- ▷ C. Manivannan, North Carolina Agricultural and State University, *Clustering Analysis of Novel Corona Virus (COVID-19) Cases in U.S. States and Territories*;
- ▷ D. Mantzavinos, University of Kansas, *The Nonlinear Schrödinger Equation on the Half-Plane*;
- ▷ D. Margetis, University of Maryland, *A flavor of plasmonics in the time domain*;
- ▷ A. Martowicz, AGH University of Science and Technology, *Peridynamic model for shape memory alloys*;
- ▷ R. Masri, Rice University, *Derivation and simulation of solute transport and blood flow in one dimensional vessel networks*;
- ▷ R. Masson, University Cote d'Azur, *Gradient discretization of two-phase flows coupled with mechanical deformation in fractured porous media*;
- ▷ R. Matos, Texas A&M University, *Finite volume criterion for localization on correlated environments*;
- ▷ J. MacLaurin, New Jersey Institute of Technology, *A Different Approach to Model Oscillatory Blood Glucose Behavior*
- ▷ K. Milans, West Virginia State University, *Longest Path Transversals and Gallai Families*
- ▷ S. Minkoff, University of Texas at Dallas, *Neural Network–Enhanced Two-Stage Hamiltonian Monte Carlo*;
- ▷ A. Mohideen, North Carolina A&T State University, *Police Funding and Fatal Police Shootings in the United States*;
- ▷ M. Neilan, University of Pittsburgh, *Scott-Vogelius finite elements on curved domains*
- ▷ P. Nguyen, Texas Tech University, *The Stampacchia maximum principle for stochastic partial differential equations forced by Levy Noise*;
- ▷ D. Nicholls, University of Illinois - Chicago, *Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface*;
- ▷ M. Ntekoume, Rice University, *Integrable dispersive PDE at low regularity*;

- ▹ M. Ntekoume, Rice University, *Symplectic non-squeezing for the KdV flow on the line*;
- ▹ M. Olshanskii, University of Houston, *Speed–direction description of flow motion*;
- ▹ E. Oterkus, University of Strathclyde, *Utilisation of Euler-Lagrange Equation to Derive Dual-Horizon Peridynamic Equations*;
- ▹ S. Oterkus, University of Strathclyde, *Peridynamic Polycrystalline Ice Model*;
- ▹ W. Ott, University of Houston, *Delay-induced uncertainty in physiological systems*
- ▹ J. Padgett, University of Arkansas, *Beating the curse of dimensionality in high-dimensional stochastic fixed-point equations*;
- ▹ A. Pal, Texas A&M University, *New tests for minimal border rank tensors*;
- ▹ M. Parker, North Carolina Agricultural and Technical State University, *Regression Analysis of Statewide COVID-19 Data in the U.S.*;
- ▹ R. Parker, Southern Methodist University *Instability bubbles for multi-pulse solutions to Hamiltonian systems on a periodic domain*;
- ▹ J. Park, Institute for Advanced Study, *Tuza's Conjecture for random graphs*;
- ▹ B. Pascual Escudero, Universidad Carlos III de Madrid, *Necessary conditions for ACR in Reaction Networks*;
- ▹ S. Patrizi, University of Texas at Austin, *From the Peierls-Nabarro model to the equation of motion of the dislocation continuum*;
- ▹ A. Peace, Texas Tech University, *Integrating Disease and Ecosystem Ecology Theory*;
- ▹ R. Perera, Lousiana State University, *Band structure for phononic media*;
- ▹ P. Plucinsky, University of Southern California, *New tests for minimal border rank tensors*;
- ▹ J. Popa, University of Texas at Dallas, *Peridynamic Polycrystalline Ice Model*;
- ▹ B. Popov, Texas A&M University, *Accurate upper bound for the maximum speed of propagation in the Riemann problem*;
- ▹ L. Postle, University of Waterloo, *Edge Colouring with Local List Sizes*;
- ▹ C. Prange, CNRS, Cergy Paris University, *Quantitative regularity vs. concentration near potential singularities in incompressible viscous fluids*;
- ▹ C. Puelz, Baylor School of Medicine, *A fluid-structure interaction model of the human heart*;
- ▹ Z. Qiao, University of Texas - Rio Grande Valley, *Peridynamic Polycrystalline Ice Model*;
- ▹ Z. Qu, University of Texas at San Antonio, *Staged progression epidemic model for the transmission of invasive nontyphoidal* Salmonella *(iNTS) with treatment*;
- ▹ K. Ramanan, Brown University, *Limits of Interacting Particle Systems on Sparse Graphs*;
- ▹ L. Rebholz, Clemson University, *Longer time accuracy for incompressible Navier-Stokes simulations with the EMAC formulation*;
- ▹ M. Regan, Duke University, *Fast Symmetric Tensor Decomposition*;
- ▹ A. Reusken, RWTH Aachen university, *Finite Element Methods for Surface Stokes Equations*;
- ▹ C. Rickard, University of Southern California, *Global existence of the non-isentropic compressible Euler equations with vacuum boundary surrounding a variable entropy state*;

- ▷ D. Ridzal, Sandia National Labs, *ALESQP: An Augmented Lagrangian Equality-constrained SQP Method for Function-space Optimization with General Constraints*;
- ▷ A. Saibaba, North Caroina State University, *Randomized approaches to accelerate MCMC algorithms for Bayesian Inverse Problems*;
- ▷ M. Sarraf Joshaghani, Rice University, *Maximum-principle-preserving vertex-based method for two phase flows in porous media*;
- ▷ F. Scabbia, University of Padova, *A note on the surface effect in OSB-PD models*;
- ▷ J. Scott, University of Pittsburgh, *Asymptotic analysis of a coupled system of nonlocal equations with oscillatory coefficients*;
- ▷ P. Seleson, Oak Ridge National Laboratory, *Overall equilibrium in the coupling of peridynamics and classical continuum mechanics*;
- ▷ Y. Shen, University of Kansas, *Well-posedness of 1D Quasilinear Wave Equation*;
- ▷ Z. Shen, University of Kentucky, *Overall equilibrium in the coupling of peridynamics and classical continuum mechanics*;
- ▷ S. Sherman, University of Notre Dame, *Generating cognates for 6, 8, and 10-bar mechanisms*;
- ▷ S. Shipman, Louisiana State University, *Depicting Spectra of Quantum Trees via Orthogonal Polynomials: Rogue Eigenvalues*;
- ▷ S. Shipman, Lousiana State University, *Fano Resonance in in a periodic array of narrow slits in metal*;
- ▷ J. Shi, College of William & Mary, *Spatial modeling and dynamics of organic matter biodegradation in the absence or presence of bacterivorous grazing*;
- ▷ A. Siahkoohi, Georgia State University, *Unsupervised data-guided uncertainty analysis in imaging and horizon tracking*;
- ▷ S. Silling, Sandia National Laboratory, *Using Nonlocality to Predict the Rate of Material Failure*;
- ▷ M. Sirlanci, University of Colorado Anschutz Medical Campus, *A Different Approach to Model Oscillatory Blood Glucose Behavior*;
- ▷ G. Sosa Jones, University of Houston, *A space-time hybridizable discontinuous Galerkin method for linear free-surface waves*;
- ▷ F. Sottile, Texas A&M University, *Numerical homotopies from Khovanskii bases*;
- ▷ A. Stukopin, University of Texas - Rio Grande Valley, *Solitary and periodic wave solutions for several short wave model equations*;
- ▷ E. Suazo, University of Texas - Rio Grande Valley, *On explicit and numerical solutions for stochastic partial diferential equations: Fisher and Burger type equations*;
- ▷ S. Subramanian, University of Texas at Austin, *Ensemble inversion for calibrating biophysical tumor growth models with mass effect*;
- ▷ S. Sukhtaiev, Auburn University, *Anderson localization for Kirchhoff and discrete Laplacians on random trees*;
- ▷ M. Surnachev, Keldysh Institute of Applied Mathematics RAS, *Green's function estimates for the stationary convection-diffusion equation*;
- ▷ T. Taillefumier, Texas A&M University, *The Pair-Replica-Mean-Field Limit for Intensity-based Neural Networks*;
- ▷ A. Tarfulea, Lousiana State University, *Self-generating lower bounds for the Boltzmann equation*;

- ▷ A. Tedeef, South Mathematical Institute of VSC RAS, *Asymptotic Properties of Solutions to the Cauchy Problem for Degenerate Parabolic Equations with Inhomogeneous Density on Manifolds*;
- ▷ H. Thieme, Arizona State University, *Discrete-time population dynamics of spatially distributed semelparous two-sex populations*;
- ▷ X. Tian, University of California - San Diego, *Reproducing kernel collocation methods for nonlocal models: asymptotic compatibility and numerical stability*;
- ▷ J. Touboul, Brandeis University, *Limit and Spatio-temporal Dynamics of Interacting Markov Jump or diffusion Processes, with Applications to Ecology and Neurosciences*;
- ▷ E. Tovar, Texas A&M University, *Hyperbolic relaxation technique for solving the dispersive Serre–Saint-Venant equations with topographyr*;
- ▷ N. Tran, University of Texas at Austin, *A simple and effective method for low-rank completion for the shared response model in fMRI experiment design*;
- ▷ N. Vaidya, San Diego State University, *Modeling Transmission Dynamics of COVID-19 in Nepal*;
- ▷ E. Valseth, University of Texas at Austin, *An unconditionally stable space-time FE method for the Shallow Water Equations*;
- ▷ V. Vatchev, UT Rio Grande Valley, *On the Dynamics of solitons for the ?good? Boussinesq equation*;
- ▷ R. Viator, Swarthmore College, *Bloch waves in 3-dimensional high-contrast photonic crystals*;
- ▷ S. Walker, Louisiana State University, *Optimal Control of Volume-Preserving Mean Curvature Flow*;
- ▷ E. Walker, Texas A&M University, *Numerical homotopies from Khovanskii bases*;
- ▷ J. Walton, Texas A&M University, *A Coupled Nonlinear Reaction-Diffusion, First-Order-Hyperbolic System Arising from a New Approach to Structured Population Dynamics*;
- ▷ C. Wang, Texas Tech University, *Structure Probing Neural Network Deflation*;
- ▷ X.-S. Wang, University of Lousiana at Lafayette, *Resonance of periodic combination antiviral therapy and intracellular delays in virus model*;
- ▷ A. Watson, University of Minnesota, *Existence and computation of exponentially localized Wannier functions for non-periodic insulators*;
- ▷ F. Wei, Princeton University, *3D multi-parameter visco-elastic full waveform inversion: methods and application for a near-surface case-study*;
- ▷ A. Welters, Florida Institute of Technology, *Simplification of Bessmertnyi realizability for rational functions of several complex variables*;
- ▷ C. Wu, Shenzhen University, *Elliptic functions and their applications in integrable and nonintegrable systems*;
- ▷ C. Wu, Sun Yat-Sen University, China, *An extension of Kadomtsev-Petviashvili hierarchy*;
- ▷ T. Wu, University of Texas at San Antonio, *Equilibrium Preserving Schemes for Shallow Water Models*;
- ▷ S.-L. Wu, Xidian University, *Propagation direction for the bistable traveling front in a three species competition system*;
- ▷ D. Xiu, Ohio State University, *Data Driven Governing Equations Recovery with Deep Neural Networks*;
- ▷ L. Xue, Harbin Engineering University, *Assessing the Impact of Non-Pharmaceutical Intervention Strategies for Containing COVID-19 Epidemics*;

- ▷ K. Yamazaki, Texas Tech University, *Non-uniqueness in law for two-dimensional Navier-Stokes equations with diffusion weaker than a full Laplacian*;
- ▷ K. Yamazaki, Texas Tech University, *Approximating three-dimensional magnetohydrodynamics system forced by space-time white noise*;
- ▷ H. Yang, Purdue University, *A Few Thoughts on Deep Learning-Based Scientific Computing*;
- ▷ S. Yang, University of Maryland, College Park, *LDG approximation of large deformations of prestrained plates*;
- ▷ G. Young, Rice University, *Orthogonal rational functions with real poles, root asymptotics, and GMP matrices*;
- ▷ G. Young, Rice University, *Uniqueness of solutions of the KdV-hierarchy via Dubrovin-type flows*;
- ▷ V. Yushutin, University of Maryland, *Are colloidal particles immersed in liquid crystals attracted to the walls?*;
- ▷ Y. Yu, Lehigh University, *An asymptotically compatible treatment of traction loads in peridynamics*;
- ▷ P. Yu, University of Wisconsin - Madison, *Geometry of Geometric Rank*
- ▷ X. Zeng, University of Texas at El Paso, *A hybrid-variable discretization method for hyperbolic problems*;
- ▷ L. Zhang, Columbia University, *An energy-based discontinuous Galerkin method for semilinear wave equations*;
- ▷ W. Zhang, Rutgers University, *Rates of convergence for optimal transport problem with quadratic cost in two or three dimensions*;
- ▷ Z. Zhang, Texas A&M University, *Multiagent Reinforcement Learning Accelerated MCMC on Multiscale Inversion Problem.*
- ▷ Y. Zhang, University of California at San Diego, *Long Time Dynamics for Combustion in Random Media*;
- ▷ P. Zhang, Xidian University, *Symmetry properties of solutions of Hamiltonian system on Compact Convex Hypersurfaces in* R^8;
- ▷ A. Zhiliakov, University of Houston, *Inf-sup stability of the trace* $\mathbf{P}_2 - P_1$ *Taylor-Hood elements for surface PDEs.*

List of Abstracts

Exclusion processes on trees
N. Gantert

Abstract. As a model for current on (random) networks, we study the totally asymmetric simple exclusion process on trees where particles are generated at the root. Particles can only jump away from the root, and they jump from x to y at rate $r_{x,y}$, provided y empty. Starting from the all empty initial condition, we show that the distribution of the configuration at time t converges to an equilibrium. We study the current and give conditions on the transition rates such that the current is of linear order or such that there is zero current, i.e. the particles block each other. A key step, which is of independent interest, is to bound the first generation at which the particle trajectories of the first n particles decouple.
The talk is based on joint work with Nicos Georgiou and Dominik Schmid.

A model for COVID-19 Community Transmission Considering Asymptomatics and Mitigation
J. Gutierrez

Abstract. Asymptomatic carriers of the SARS-CoV-2 virus display no clinical symptoms but are known to be contagious. Recent evidence reveals that this subpopulation, as well as carriers with mild disease, are major contributor in the propagation of COVID-19. In this talk, we present a traditional compartmentalized mathematical model taking into account asymptomatic carriers. We also present a modeling framework to account for government-driven mitigation strategies. This model was used to estimate projections of cases for every county in the USA.

Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface
A. Firoozabadi

Abstract. Flow of complex hydrocarbon fluids in multiphases with capillary and Fickian diffusion and complex geometries including non-planar fracture and heterogenous and layered rocks is among the most challenging problems. The working expression are highly non-linear and discretization can introduce large errors. Finite elements are natural choice. The combination of physical concepts and powerful features of the combined mixed finite element for flux calculation and discontinuous Galerkin methods allow ease of accurate numerical solution of a vast group of problems in CO2 sequestration in the aquifers, fluid injection in hydrocarbon formations as well precipitation modeling. This presentation will cover some recent modeling of complex flows in the lab scale and large scale. We will also cover briefly the potential of the method in modeling of rock fracturing. The basic physical concepts that will facilitate numerical solution of complex problems will be emphasized.

Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface
D. Nicholls

Abstract. Graphene is now a crucial component of many device designs in electronics and optics. Just like the noble metals, this single layer of carbon atoms in a honeycomb lattice can support surface plasmons which are central to several sensing technologies in the mid–infrared regime. As with classical metal plasmons, periodic corrugations in the graphene sheet itself can be used to launch these surface waves, however, as graphene plasmons are tightly confined, the role of unwanted surface roughness, even at a nanometer scale, cannot be ignored. In this talk, we revisit our previous numerical experiments on metal plasmons launched by vanishingly small grating structures, with the addition of graphene to the structure. These simulations are conducted with a recently devised, rapid and robust High–Order Spectral scheme of the author, and with it we carefully demonstrate how the plasmonic response of a perfectly flat sheet of graphene can be significantly altered with even a tiny corrugation (on the order of merely 5 nm). With these results we demonstrate the primary importance of fabrication techniques which produce interfaces whose deviation from flat are on the order of Angstroms.

Mixed Finite Element and Discontinuous Galerkin Methods for Complex Multiphase Flow Problems and Complex Geometries in the Subsurface
T. Duff

Abstract. In computer vision, the study of minimal problems is critical for many 3D reconstruction tasks. Solving minimal problems comes down to solving systems of polynomial equations of a very particular structure. "Structure" can be understood in terms of the Galois/monodromy group of an associated branched cover. For classical problems such as homography estimation and five-point relative pose, efficient solutions exploit imprimitivity of the Galois groups; in these cases, the imprimitivity comes from the existence of certain rational deck transformations. In general, Galois groups can be computed with numerical homotopy continuation using a variety of software. I will highlight joint work with Viktor Korotynskiy, Tomas Pajdla, and Maggie Regan that studies an ever-expanding zoo of minimal problems and their Galois groups, with a view towards identifying new minimal problems that may be useful in practice.

A complex analytic approach to inverse spectral problems for Jacobi operators

B. Hatinoglu

Abstract. We consider semi-infinite Jacobi matrices with discrete spectrum. After a brief review of inverse spectral theory of one dimensional Schrödinger and Jacobi operators, we will discuss the following Borg-Marchenko type problem as a complex analysis problem: Can one spectrum together with subsets of another spectrum and norming constants recover the Jacobi operator?

The Nonlinear Schrödinger Equation on the Half-Plane

D. Mantzavinos

Abstract. The initial-boundary value problem for the nonlinear Schrödinger (NLS) equation on the half-plane is studied by advancing into two dimensions an approach recently developed for the well-posedness of NLS on the half-line. Using the solution formula produced via the unified transform of Fokas for the associated linear problem, it will be shown that the nonlinear problem is well-posed in the Hadamard sense for initial data in Sobolev spaces and boundary data in appropriate Bourgain spaces. This is joint work with Alex Himonas.

Bounds on the heat transfer rate via passive advection

G. Iyer, S. Van

Abstract. In heat exchangers, an incompressible fluid is heated initially and cooled at the boundary. The goal is to transfer the heat to the boundary as efficiently as possible. In this talk we study a related steady version of this problem: Consider the steady state temperature of in a fluid that is stirred, uniformly heated and cooled on the boundary. For a given large Péclet number, how should one stir to minimize the total heat? This problem was studied by Marcotte, Doering, Thiffeault and Young in '18, where the authors provided many heuristics and numerical simulations. In this talk we will show that when the Péclet number is large, one can always find a stirring velocity field so that the total heat is at most $O(\text{Pe}^9/\text{Pe}^{1/2})$. We suspect this is optimal (up to a logarithmic correction), but are presently unable to prove a matching lower bound. This is joint work with Son Van.

Locating conical degeneracies in the spectra of parametric self-adjoint matrices

G. Berkolaiko, A. Parulekar

Abstract. A generic 2-parameter family of real symmetric matrices has isolated points in the parameter space where a pair of eigenvalues coincides. A simple iterative scheme is proposed for locating these parameter values. The convergence is proved to be quadratic. An extension of the scheme to complex Hermitian matrices (with 3 parameters) and to location of triple eigenvalues (5 parameters for real symmetric matrices) is also described. Algorithm convergence is illustrated in several examples: a real symmetric family, a complex Hermitian family, a family of matrices with an "avoided crossing" (no convergence) and a 5-parameter family of real symmetric matrices with a triple eigenvalue. Joint work with Advait Parulekar, arXiv:2001.02753.

Locating conical degeneracies in the spectra of parametric self-adjoint matrices

J. Lee, L. Scotten, R. Hunt, T. Caranasos, J. Vavalle, B. Griffith

Abstract. Bioprosthetic heart valves (BHVs) are commonly used in surgical and percutaneous valve replacement. The durability of percutaneous valve replacement is unknown, but surgical valves have been shown to require reintervention after 10–15 years [1]. Further, smaller-diameter surgical BHVs generally experience higher rates of prosthesis-patient mismatch (PPM), which leads to higher rates of failure [2],[3],[4],[5]. Bioprosthetic aortic valves can flutter in systole [6],[7], and fluttering is associated with fatigue and failure in flexible structures. The determinants of flutter in BHVs have not been well characterized, however, despite their potential to impact durability. We use an experimental pulse duplicator and a computational fluid-structure interaction model of this system to study the role of device geometry on BHV dynamics [10]. The experimental system mimics physiological conditions, and the computational model enables precise control of leaflet biomechanics and flow conditions to isolate the effects of variations in BHV geometry on leaflet dynamics. We systematically characterize the impact of BHV diameter and leaflet thickness on fluttering dynamics. Ultimately, understanding the effects of device geometry on leaflet kinematics may lead to more durable valve replacements.

References

[1] D. Dvir et al. Standardized definition of structural valve degeneration for surgical and transcatheter bioprosthetic aortic valves. *Circulation*, 137(4):388-399, 2018.

[2] R. M. Reul et al. Transcatheter aortic valve-in-valve procedure in patients with bioprosthetic structural valve deterioration. *Methodist DeBakey Cardiovasc J*, 13(3):132–141, 2017.

[3] J. Rods-Cabau et al. Impact of aortic annulus size on valve hemodynamics and clinical outcomes after transcatheter and surgical aortic valve replacement. *Circ Cardiovasc Interv*, 7(5):701–711, 2014.

[4] H. B. Barner et al. Prosthetic valves for the small aortic root. *J Card Surg*, 9(s2):154–157, 1994.

[5] W. Flameng et al. Prosthesis-patient mismatch predicts structural valve degeneration in bioprosthetic heart valves. *Circulation*, 121(19):2123–2129, 2010.

[6] M. Alam et al. Echocardiographic evaluation of porcine bioprosthetic valve degeneration. *Henry Ford Hosp Med J*, 30(3):124–127, 1982.

[7] J. A. Peacock. An in vitro study of the onset of turbulence in the sinus of valsalva. *Circ Res*, 67:448–460, 1990.

[8] M. P. Padoussis. Fluid?Structure Interactions: Slender Structures and Axial Flow. Vol 2. London: Academic Press; 2016.

[9] P. Sun et al. Fatigue modeling via mammalian auditory system for prediction of noise induced hearing loss. *Comput Math Methods Med*, 2015:753864, 2015.

[10] J. H. Lee et al. Fluid-structure interaction models of bioprosthetic heart valve dynamics in an experimental pulse duplicator. *Ann Biomed Eng*, 48(5):1475–1490, 2020.

Discontinuous Galerkin methods for a dispersive wave hydro-sediment-morphodynamic model

K. Kazhyken, J. Videman, C. Dawson

Abstract. Sediment transport and bed morphodynamic processes attract a growing engineering interest as these processes, driven by currents and waves, expose coastal infrastructure and environment to potential hazards, e.g. elements of coastal infrastructure, such as bridges, levees and piers, can become structurally compromised due to excessive sediment bed scour. Capturing these processes in a mathematical model involves combining hydrodynamic, sediment transport, and bed morphodynamic models and their two-way interactions into a single set of equations. Although a three-dimensional hydro-sediment-morphodynamic model can capture the physics of the processes with a greater accuracy, their computational costs limit them to applications with shorter time and length scales. A more computationally efficient alternative is a two-dimensional depth-averaged model such as the shallow water hydro-sediment-morphodynamic (SHSM) equations, which couple the nonlinear shallow water equations (NSWE) with sediment transport and bed morphodynamic models. Although the NSWE provide an accurate approximation to shallow water flow dynamics, they do not possess a capacity to capture dispersive wave effects; and, thus, the model cannot be applied in coastal regions where the dispersive effects are prevalent. To overcome this limitation of the model, the NSWE part of the SHSM equations is augmented with dispersive terms from the Green-Naghdi equations, which have the capacity to resolve the dispersive effects. The resulting set of equations forms a dispersive wave hydro-sediment-morphodynamic model. A numerical solution algorithm is proposed for the developed model based on the second-order Strang operator splitting technique and discontinuous Galerkin methods. The solution algorithm is validated against a set of numerical experiments that model one- and two-dimensional dam breaks over mobile beds, and solitary wave runs over an erodible sloping beach.

Discontinuous Galerkin methods for a dispersive wave hydro-sediment-morphodynamic model

R. Islam, I. Christov, A. Ibraguimov, I. Garli Hevage

Abstract. We use the Einstein random-walk paradigm for diffusion to derive a degenerate nonlinear parabolic equation. The diffusion coefficient in our model depend on both the dependent variable and its gradient, and vanish when they do. We investigate a qualitative properties of the solution using maximum principle and energy method. Numerical results via a finite-difference scheme and a self-similarity analysis support the mathematical results and illustrate how the speed of propagation depends on the model's parameters.

References

[1] A. Einstein Uber die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen. *Ann. Phys. (Leipzig)*, 322(549-560), 1905.
[2] A. Einstein Investigations on the Theory of the Brownian Movement. *Dover Publication*, 1956.
[3] A. M. Ilyin, A. S. Kalashnikov, and O. A. Oleynik Linear Second-Order Partial Differential Equations of the Parabolic Type. *J. Math. Sci.*, 108(435-542), 2002.
[4] E. M. Landis Second Order Equations of Elliptic and Parabolic Type. *American Mathematical Society*, 171, 1998.

Nodes on quintic spectrahedra

T. Brysiewicz, K. Kozhasov, M. Kummer

Abstract. A quintic spectrahedron in $\mathbb{R}^3$ is the intersection of a 3-dimensional affine linear subspace of 5×5 real symmetric matrices with the cone of positive-semidefinite matrices. The algebraic boundary of a quintic spectrahedra is an algebraic surface of degree 5 in $\mathbb{C}^3$ called a symmetroid. Quintic symmetroids generically have 20 singular points and the real singularities are partitioned into those which lie on the spectrahedra and those which do not. We determine which such partitions are possible and compute explicit spectrahedra witnessing each. We do this using numerical algebraic geometry and an augmented hill-climbing algorithm.

A Self-Adaptive Theta Method for Conservation Laws using Discontinuity Aware Quadrature

T. Arbogast, C.-S. Huang

Abstract. We present a *discontinuity aware quadrature* (DAQ) rule, and use it to develop implicit *self-adaptive theta* (SATh) schemes for the approximation of scalar hyperbolic conservation laws. Our SATh schemes require the solution of a system of two equations, one controlling the cell averages of the solution at the time levels, and the other controlling the space-time averages of the solution. These quantities are used within the DAQ rule to approximate the time integral of the hyperbolic flux function accurately, even when the solution may be discontinuous somewhere over the time interval. The result is a finite volume scheme using the theta time stepping method, with theta defined implicitly (or self-adaptively). Two schemes are developed, SATh-up for a monotone flux function using simple upstream stabilization, and SATh-LF using the Lax-Friedrichs numerical flux. DAQ is accurate to second order when there is a discontinuity in the solution and third order when it is smooth. SATh-up is unconditionally stable provided that theta is at least 1/2, and satisfies the maximum principle and is total variation diminishing under appropriate monotonicity and boundary conditions. General flux functions require the SATh-LF scheme, so we assess its accuracy through numerical examples in one and two space dimensions. These results suggest that SATh-LF is also stable and satisfies the maximum principle (at least at reasonable CFL numbers). Compared to solutions of finite volume schemes using Crank-Nicolson and backward Euler time stepping, SATh-LF solutions often approach the accuracy of the former but without oscillation, and they are numerically less diffuse than the later.

Nodes on quintic spectrahedra

B. Chhatrala, D. Park

Abstract. Abstract. In this talk, we describe how interpolation on graphs has been applied in two different ways: predicting the results of matches in the Overwatch League, a professional esport, and predicting the outcomes of breast cancer cases. Interpolation is the act of estimating a value based on other known values. In these projects, we worked with a complete set of match data from the 2019 Overwatch League season and breast cancer data from the UNC Lineberger Comprehensive Cancer Center to develop and test our predictive functions. We used data science techniques to gather and organize our data. Then, drawing inspiration from previous, related research, we used a derivative matrix [1] to construct splines [2], and a weight function to make predictions with linear algebra. We conducted lots of testing on our weight function in order to make it as accurate as possible, and we learned the limits of predictive modeling. This research talk will describe, in detail, the specific techniques and models we used and their applications to both of our projects.

References

[1] J. J. Benedetto and P. J. Koprowski Graph theoretic uncertainty principles *2015 International Conference on Sampling Theory and Applications (SampTA)*, 2015

[2] Interpolating splines on graphs for data science applications *Applied and Computational Harmonic Analysis*, 2020

Weight Function Progress

B. Chhatrala

Abstract. This document serves to log the changes to the weight function in the Overwatch project. The weight function is a crucial part of the project, as it describes how similar or different two matches are. We use the weights to populate our derivative matrix and then use scipy's linear algebra functions to make predictions on the score differences of a certain number of matches. To test the effectiveness of the weight function on my set of 280 matches, I will test it 4 times:

1. Using the first 200 matches to predict the last 80 matches
2. Using the first 230 matches to predict the last 50 matches
3. Using the first 250 matches to predict the last 30 matches
4. Using the first 270 matches to predict the last 10 matches

The test results are recorded as a fraction and a percentage, denoting how many of the predictions had the correct winner (i.e. the score difference had the correct sign).

Finite volume criterion for localization on correlated environments
R. Matos

Abstract. In the context of the Anderson model with correlated potentials, we shall present an abstract finite volume criterion which yields sub-exponential dynamical localization as long as a finite volume condition is verified and suitable decorrelation assumptions are met. As a corollary, in the above setting, polynomial decay of the Green's function fractional moments at a finite scale implies sub-exponential decay of them at any scale. As an application, the Hubbard model within Hartree-Fock theory will be discussed.

Utilisation of Euler-Lagrange Equation to Derive Dual-Horizon Peridynamic Equations
E. Oterkus, B. Wang, S. Oterkus

Abstract. Peridynamics [1] is a non-local continuum mechanics formulation where a material point can interact with other material points which are located at a finite distance with respect to each other. The equations of peridynamics are in integro-differential equation form and it is difficult to obtain closed-form solutions for these equations. The numerical solution of peridynamic equations is generally obtained by using meshless method and uniform spatial discretisation. The implementation of uniform discretisation is usually straightforward. However, this approach can increase computational time significantly for specific problems. On the other hand, non-uniform discretisation can also be utilised and different discretisation sizes can be used at different parts of the solution domain. In peridynamics, there is also a length scale parameter called "horizon" which defines the range of non-local interactions. In addition to non-uniform discretisation, variable horizon size may also be required. For such cases, a new peridynamic formulation, Dual Horizon Peridynamics [2],[3], was introduced so that both non-uniform discretisation and variable horizon size can be utilised. In this presentation, the derivation of Dual Horizon Peridynamics formulation by using Euler-Lagrange equation will be presented for state-based peridynamics. Moreover, application of boundary conditions and determination of surface correction factors will also be discussed. Finally, the capability of Dual Horizon Peridynamics formulation will be demonstrated by considering plate under tension and plate vibration problems.

References

[1] Silling, S.A. Reformulation of elasticity theory for discontinuities and long-range forces. *Journal of the Mechanics and Physics of Solids*, 48(1), pp.175-209, 2000.

[2] Ren, H., Zhuang, X., Cai, Y. and Rabczuk, T. Dual-horizon peridynamics. *International Journal for Numerical Methods in Engineering*, 108(12), pp.1451-1476, 2016.

[3] Wang, B., Oterkus, S. and Oterkus, E. Derivation of dual-horizon state-based peridynamics formulation based on EulerLagrange equation. *Continuum Mechanics and Thermodynamics*, pp.1-21, 2020.

Peridynamic Polycrystalline Ice Model
Selda Oterkus, Wei Lu, Mingyang Li, Bozo Vazic and Erkan Oterkus

Abstract. Arctic region has started being considered as an alternative shipping route due to its advantages such as being a shorter route. However, it also introduces additional challenges due to its harsh environment. For instance, ships must be designed to withstand ice loads if a collision between a ship and ice occurs. Although experimental studies can provide very useful information, full scale tests are very expensive for ice-structure interactions. Instead, computer simulations can be utilized as alternative option. However, modelling ice as a material has also its own challenges because its material behavior depends on many different factors such as applied-stress, strain-rate, temperature, grain-size, salinity, porosity and confining pressure. Moreover, microcracks occurring at the micro-scale may have significant influence on the macroscopic behavior. Therefore, a multi-scale methodology may also be necessary especially to capture the correct physics around the ice-structure interaction region. Within finite element framework, there are various techniques which are available for numerical analysis of ice-structure interaction problem including cohesive zone model (CZM) and extended finite element method (XFEM). Although these are powerful techniques, they have certain limitations. As an alternative, peridynamics [1] can be utilized. Peridynamics is a non-local continuum mechanics formulation which is very suitable for failure analysis of materials due its mathematical structure. Furthermore, due to its non-local character, it can capture the physical phenomena at multiple scales. Therefore, in this presentation, a new peridynamic polycrystalline ice model [2] will be presented to be used for ice-structure interaction analysis.

A Super-Resolution Imaging Approach By Using Subwavelength Hole Resonances
J. Lin

Abstract. Based on our recent studies on subwavelength hole resonances, we present a new imaging modality with illumination patterns generated from a collection of coupled resonant holes. When the incident frequencies are close to the resonant frequencies, the corresponding patterned illuminations encompass both low frequency and highly oscillatory waves, which allow for probing both the low and high spatial frequencies components of the imaging sample to achieve super-resolution. Under the weak scattering scenario, the linear imaging problem essentially boils down to a deconvolution problem that can be solved efficiently. The imaging setup, the underlying mathematical framework and the computational results will be exemplified in two dimensions.

Derivation and simulation of solute transport and blood flow in one dimensional vessel networks

R. Masri, C. Puelz, B. Riviere

Abstract. We present a derivation of a reduced solute transport model from the three dimensional convection diffusion equation with an arbitrary velocity profile in a compliant blood vessel. The resulting one dimensional equation is coupled to a reduced model of blood flow. This coupled model is a computationally feasible approach to simulate blood momentum, solute concentration and vessel cross sectional area in large vascular networks. An interior penalty discontinuous Galerkin method with a new locally implicit time stepping scheme is used to discretize the transport model. We discuss the improvement in stability of this scheme as compared to a fully explicit time discretization. We solve these equations numerically for different shapes of the velocity profile in a model of the systemic arterial tree with physiological boundary data.

A Different Approach to Model Oscillatory Blood Glucose Behavior

M. Sirlanci, M. Levine, A. Stuart, D. Albers

Abstract. It is a long-known fact that blood glucose (BG) levels show oscillatory behavior. Hence, researchers who use the mechanistic modeling approach to describe BG dynamics have been building models to represent this phenomenon. It is obviously important for a model to represent the realistic behavior of the corresponding system, however, in many cases it is hard to use these models within computational frameworks including real-world data. For the glucose-insulin system, there are two main reasons for this: (1) insulin is almost never measured, which requires the corresponding insulin state to be severely constrained for meaningful model identification and forecasting, and (2) the real-world data is generally sparse that makes identification even harder. In order to address this type of data constraints, which is very common in real-world settings, we propose a new modeling approach that uses a stochastic differential equation [1]. In this approach, rather than modeling the trajectory of oscillatory BG levels, we aim to create a model that resolves its mean behavior and the amplitude of the oscillations. In addition, the model can be specialized for different settings such as type 2 diabetes mellitus (T2DM) and intensive care unit (ICU) by appropriate modifications. Finally, we present numerical results for which the model is used in T2DM and ICU settings separately to forecast future BG levels with real-world data.

References

[1] Albers, D.J., Levine, M.E., Sirlanci, M., and Stuart, A.M. A Simple Modeling Framework For Prediction In The Human Glucose-Insulin System. arXiv preprint arXiv:1910.14193.

Scott-Vogelius finite elements on curved domains

M. Neilan, B. Otus

Abstract. We construct and analyze an isoparametric finite element pair for the Stokes problem in two dimensions. The pair is defined by mapping the Scott-Vogelius finite element space via a Piola transform. The velocity space has the same degrees of freedom as the quadratic Lagrange finite element space, and therefore, the proposed spaces reduce to the Scott-Vogelius pair in the interior of the domain. We prove that the resulting method converges with optimal order, is divergence–free, and is pressure robust.

A note on the surface effect in OSB-PD models

F. Scabbia, M. Zaccariotto, U. Galvenetto

Abstract. Peridynamics is a recently proposed continuum theory which has been devised to effectively describe fracture phenomena in solid bodies [1],[2],[3]. Due to the non-local nature of the theory, peridynamic models exhibit an undesired stiffness fluctuation near the boundaries, which is known as surface effect [4]. The authors will propose an innovative method to exploit the introduction of a fictitious boundary layer in order to mitigate the surface effect and properly impose the non-local boundary conditions. The basic idea is that the fictitious nodes are bound to move according to the displacements of the nodes of the real body close to the boundary. In this way the neighborhoods of all boundary points are completed in a rational way and the previously missing peridynamic interactions are provided. The proposed method is verified for a 1-dimensional ordinary state-based body under some constraints and loads for which the same solution of classical mechanics is expected: the numerical results recover exactly the classical solution in the whole domain, even near the boundaries.
U. Galvanetto and M. Zaccariotto would like to acknowledge the support they received from MIUR under the research project PRIN2017-DEVISU and from University of Padua under the research projects BIRD2018 NR.183703/18.

References

[1] S. A. Silling, M. Epton, O. Weckner, J. Xu, E. Askari. Peridynamic states and constitutive modeling. *Journal of Elasticity*, 88(2), 2007.
[2] E. Madenci, E. Oterkus. Peridynamic Theory and its Applications. *Springer-Verlag*, 2014.
[3] F. Bobaru, J. T. Foster, P. H. Geubelle, S. A. Silling. Handbook of Peridynamic Modeling. *CRC press*, Boca Raton (FL), 2016.
[4] Q. V. Le, F. Bobaru. Surface corrections for peridynamic models in elasticity and fracture. *Computational Mechanics*, 61(4), 2018.

Existence of positive solutions for a semipositone Φ-Laplacian problem

E. Lopera

Abstract. In this talk we present an overview of the Φ-Laplacian operator as well as some related boundary value problems. In particular we are interested in the study of positive solutions of semipositone problems.

References

[1] Castro, A., and Shivaji, R. Semipositone problems *In Semigroups of Linear and Non-linear Operations and applications. Springer, Dordrecht.*, 1993, 109-119.

[2] Castro, A., and Shivaji, R. Non-negative solutions for a class of radially symmetric nonpositone problems. *Proceedings of the American Mathematical Society*, 735-740.

[3] Cossio, J., Herrón, S., and Vélez, C. Infinitely many radial solutions for a p-Laplacian problem p-superlinear at the origin. *Journal of mathematical analysis and applications,* 376(2), 741-749.

[4] Herrón, S., and Lopera, E. Non-existence of positive radial solution for semipositone weighted p-Laplacian problems. *Electronic Journal of Differential Equations*, 2015(130), 1-9.

[5] Herrón, S., and Lopera, E. Signed radial solutions for a weighted p-superlinear problem. *Electronic Journal of Differential Equations*, 2014(24), 1-13.

[6] Zhang, Q. Existence of radial solutions for $p(x)$-Laplacian equations in R^N. *Journal of mathematical analysis and applications*, 315(2), 506-516.

Staged progression epidemic model for the transmission of invasive non-typhoidal *Salmonella* (iNTS) with treatment

Z. Qu, B. McMahon, D. Perkins, J. Hyman

Abstract. Abstract. We develop and analyze a stage-progression compartmental model to study the emerging invasive nontyphoidal *Salmonella* (iNTS) epidemic in sub-Saharan Africa. iNTS bloodstream infections are often fatal, and the diverse and non-specific clinical features of iNTS make it difficult to diagnose. We focus our study on identifying approaches that can reduce the incidence of new infections. In sub-Saharan Africa, transmission and mortality are correlated with the ongoing HIV epidemic and severe malnutrition. We use our model to quantify the impact that increasing antiretroviral therapy (ART) for HIV infected adults and reducing malnutrition in children would have on mortality from iNTS in the population. We consider immunocompromised subpopulations in the region with major risk factors for mortality, such as malaria and malnutrition among children and HIV infection and ART coverage in both children and adults. We parameterize the progression rates between infection stages using the branching probabilities and estimated time spent at each stage. We interpret the basic reproduction number $\mathcal{R}_0$ as the total contribution from an infinite infection loop produced by the asymptomatic carriers in the infection chain. The results indicate that the asymptomatic HIV+ adults without ART serve as the driving force of infection for the iNTS epidemic. We conclude that the worst disease outcome is among the pediatric population, which has the highest infection rates and death counts. Our sensitivity analysis indicates that the most effective strategies to reduce iNTS mortality in the studied population are to improve the ART coverage among high-risk HIV+ adults and reduce malnutrition among children.

Optimizing COVID-19 Awareness and Testing Strategy
A. Azizi

Abstract. It is essential to understand how human social distancing behavior could aid in limiting COVID-19 spread, and to find a systematic testing strategy that allows to fine-tune human behavior to slow epidemic in the most efficient way. We will use an agent based network model for predicting the spread of COVID-19 among a synthetic population. The synthetic real-life social network that is constructed based on data generated by Simfrastructure, captures demographics, activities, locations and interaction of individuals. We use this model to incorporate self-regulated social distancing of individuals as a function of their characteristic such as their number of friends, Centrality Social Distancing, and or the infection prevalence on their neighborhood, Adaptive Neighborhood Social Distancing. Then we introduce Random Test and Social Ring Awareness and Testing as a strategy of systematic testing individuals and their selected friends based on the level of friendship . This strategy utilize the information about self-regulated Adaptive Neighborhood Social Distancing to optimize infection characteristic using a limited number of test can be done per unit time. Our preliminary study, conducted on Scale Free and Small World networks, showed the efficiency of Adaptive Neighborhood Social Distancing in reducing the peak of infection, as it increases chance of reducing contact with infected cases. Random Test and Social Ring Awareness and Testing strategy defined on this self-regulated social distancing shows different impacts on networks with different structure, particularly different clustering coefficients, revealing the fact of need for implementing different testing efforts on different communities (subgraph) of the social network.

Band structure for phononic media

R. Perera, R. Lipton

Abstract. We develop analytic representation formulas and power series to describe the band structure inside periodic phononic crystals made from high contrast inclusions. Our basic approach for this is to identify and utilize the the resonance spectrum for source free modes. By using these modes we represent solution operators associated with elastic waves inside periodic high contrast media. We then recover the convergent power series for the Bloch wave spectrum from representation formulas. The lower bound on the convergence radius is established using derived explicit conditions on the contrast. Finally, the separation of spectral branches of the dispersion relation is achieved using these conditions [1],[2],[3].

References

[1] R. Lipton and R. Viator Bloch waves in crystals and periodic high contrast media. *ESAIM: Mathematical Modeling and Numerical Analysis*, 51, (2017), pp. 889–918.
[2] H. Ammari, H. Kang, and H.Lee Layer Potential Techniques in Spectral Analysis. *American Mathematical Society*, 201 Charles Street, Providence, RI, 2009.
[3] T. Kato Perturbation Theory for Linear Operators. Springer, Berlin Heidelberg, Germany, 1995.

Reduced order models for inversion and imaging with waves

A. Mamanov, L. Borcea, V. Druskin, M. Zaslavsky, J. Zimmerling

Abstract. We present a framework for inversion and imaging with waves based on the theory and techniques of model order reduction. In our framework, the reduced order model (ROM) is an orthogonal projection of the wave equation propagator on the subspace of discretely sampled time domain wavefield snapshots. Even though in imaging applications one typically has access only to the wavefields measured at a sensor array, without the knowledge of the wavefields in the bulk, the ROM can be computed just from the knowledge of the measured array waveform data using the block Cholesky factorization. Once the ROM is computed, its use is twofold.

First, the projected propagator can be backprojected to obtain a qualitative image of reflectors inside a domain of interest [1]. ROM computation implicitly orthogonalizes the wavefield snapshots. This highly nonlinear procedure differentiates our approach from the conventional linear migration methods (Kirchhoff, RTM). It allows to untangle the nonlinear interactions between the reflectors. As a consequence, the resulting images are almost completely free from the multiple reflection artifacts.

Second, the ROM can be used to image the reflectors quantitatively [2]. This is possible due to an almost affine dependency of the ROM on the reflectivity coefficient in a certain parametrization of the wave equation. Then, a ROM computed for a known kinematic background can be subtracted to yield an inverse problem very close to a linear one which can be solved in a few Gauss-Newton iterations. The proposed scheme compares favorably to the conventional approaches.

References

[1] V. Druskin, A. V. Mamonov, M. Zaslavsky A nonlinear method for imaging with acoustic waves via reduced order model backprojection. *SIAM Journal on Imaging Sciences*, 11(1):164-196, 2018.

[2] L. Borcea, V. Druskin, A. V. Mamonov, M. Zaslavsky, J. Zimmerling Reduced Order Model Approach to Inverse Scattering. *SIAM Journal on Imaging Sciences*, 13(2):685-723, 2020.

Does Evolution Select Against Chaos?
J. Cushing

Abstract. Despite the ubiquity of chaotic attractors in many theoretical equations of population dynamics, unequivocal evidence of its occurrence in biological populations is sparse and is, for the most part, limited to populations manipulated in laboratory settings. One of the numerous hypotheses offered to explain this is that evolution selects against complex dynamics in favor of equilibrium dynamics. We investigate this hypothesis by means of a Darwinian dynamics version of the iconic Ricker difference equation. We investigate how the threshold e^2 for the onset of complexity (i.e. the destabilization of an equilibrium and a period-doubling bifurcation cascade to chaos) is affected by allowing the model coefficients to evolve according to Darwinian principles. We find that when evolution is slow, the Darwinian Ricker equation has an onset of complexity threshold larger than e^2 and that, in this sense evolution, selects against complexity. On the other hand, when evolution is fast the threshold can be less than e^2 and, in this sense, evolution selects for complexity. In the latter case, the onset of complexity is by means of a Naimark-Sacker bifurcation, not a period-doubling bifurcation.

Asymptotic Properties of Solutions to the Cauchy Problem for Degenerate Parabolic Equations with Inhomogeneous Density on Manifolds
A. Tedeef

Abstract. We consider the Cauchy problem for doubly nonlinear degenerate parabolic equations with inhomogeneous density on noncompact Riemannian manifolds. We give a qualitative classification of the behavior of the solutions of the problem depending on the behavior of the density function at infinity and the geometry of the manifold, which is described in terms of its isoperimetric function. We establish for the solutions properties as: stabilization of the solution to zero for large times, finite speed of propagation, universal bounds of the solution, blow up of the interface. Each one of these behaviors of course takes place in a suitable range of parameters, whose definition involves a universal geometrical characteristic function, depending both on the geometry of the manifold and on the asymptotics of the density at infinity.

Stochastic Optimization in Full Waveform Inversion

U. Albertin, S. Singh, J. Chen, K. Nihei

Abstract. Full Waveform Inversion (FWI) has become a powerful technique for recovering high-resolution sound-propagation velocity models of the subsurface, which are critical for accurate seismic imaging in oil exploration. Because of the large size of the data sets involved, most FWI algorithms used in production today rely on gradient-descent techniques to converge. Although effective in many cases, these techniques may fall into local minima associated with the objective function if the starting model is not sufficiently close to the global solution. To mitigate this issue, there has been recent interest to extend FWI to incorporate stochastic inversion techniques in order to more effectively find a global minimum. In this work we view the standard L^2 FWI objective function, together with a multiplicative scaling factor taken as the temperature, as the factors determining a Gaussian distribution used in the acceptance criteria for a Metropolis-Hastings algorithm [2]. However, because of the high dimensionality of the model space we are using, standard Metropolis-Hastings is unable to search the model space sufficiently to locate a solution in reasonable time. Hence we extend our algorithm to incorporate Langevin dynamics through the use of the gradient of the FWI objective function [1]. Although this improves the convergence rate substantially, we find that the large dynamic range of the FWI objective function during convergence makes it difficult to establish an effective schedule for the temperature that avoids excessive fluctuations in the model or premature freezing of the model into a local minimum. To mitigate this issue we introduce a novel periodic renormalization of the temperature during the Metroplis-Hastings algorithm, which on synthetic tests substantially improves the convergence of the algorithm. We illustrate the effectiveness of our algorithm with two synthetic tests that illustrate how well the algorithm recovers the true velocity model relative to standard FWI techniques.

References

[1] J. Besag Comments on "Representations of knowledge in complex systems" by U. Greneander and M. Miller. *Journal of the Royal Statistical Society, Series B*, 56, p. 591-592, 1994.

[2] W. K. Hastings Monte Carlo sampling methods using Markov chains and their applications. *Biometrika*, 57, p. 97-109, 1970.

Police Funding and Fatal Police Shootings in the United States

A. Mohideen, K. Tse, S. Mostafa

Abstract. Fatal police shootings have been an interest in the political, social, and academic field, as there has been discrepancy of whether the police used force to protect the people. With the increased awareness of the Black Lives Matter Movement (BLM) and the movement of Defunding the Police, there are speculations of the legitimacy of police use-of-force. In this research, we will make use of statistical analysis methods to see whether police funding has a significant relation with fatal police shootings. At the same time, we will try to see which other factors might correlate to rate of police shootings either positively or negatively. We made use of multiple different datasets and using Exploratory Data Analysis we were able to see the univariate and multivariate distributions of all available variables. We will perform analysis on the state and the city levels by making use of Poisson Regression which better fits the data.

Simplification of Bessmertnyi realizability for rational functions of several complex variables

A. Welters, A. Stefan

Abstract. As part of M. F. Bessmertnyi's 1982 Ph.D. thesis (in Russian) [1], he proved that every rational matrix-valued function of several variables could be written as the Schur complement of a linear matrix pencil (i.e., a *Bessmerntyi long resolvent representation*). This theorem of his was unknown to Western readers until parts of it were translated into English beginning in 2002 with [2]. In this talk, we will discuss this result and its potential applications in the theory of composites especially toward resolving some open problems posed in 2002 by Graeme Milton in [3], on the characterization and realization of effective tensors. Moreover, we discuss our extension of Bessmertnyi's result and alternative proof of his main theorem using completely new techniques. As opposed to his approach and given our motivations, we have chosen a more "natural" approach which dramatically simplifies the proof, allows a constructive approach for further extensions of the theorem, and relies completely on elementary algebraic operations from systems theory especially those from linear models associated with electric circuits, networks, and composites. This is joint work with Anthony Stefan (Florida Institute of Technology).

References

[1] M. F. Bessmertnyi Functions of Several Variables in the Theory of Finite Linear Structures. Ph. D. Thesis, Kharkov University, Kharkov, 1982.

[2] M. F. Bessmertnyi On realizations of rational matrix functions of several complex variables. *Oper. Theory Adv. Appl.*, 134, 157-185. Birkhäuser-Verlag, Basel, 2002.

[3] G. W. Milton The Theory of Composites. Cambridge University Press, 2002.

Simulation of nonlinear bending phenomena for plates in the presence of contact

S. Bartels, F. Meyer, C. Palus

Abstract. The bending behavior of plates is usually described using dimensionally reduced models. We propose a practical method for the numerical simulation of bilayer plate bending that is based on a nonlinear two-dimensional plate model. Our method employs a discretization of the resulting energy using DKT (discrete Kirchhof triangle) elements in space and a discrete gradient flow restricted to appropriate tangent spaces for the minimization of the energy functional. Particularly, we discuss the simulation of (self)-contact and the applicability of the method for simulating plates of nematic liquid crystal elastomers. The talk extends methods developed in [1],[2].

References

[1] S. Bartels and C. Palus Stable gradient flow discretizations for simulating bilayer plate bending with isometry and obstacle constraints. arXiv, eprint 2004.00341, 2020.

[2] S. Bartels, A. Bonito, R. H. Nochetto Bilayer plates: model reduction, Γ-convergent finite element approximation, and discrete gradient flow. *Comm. Pure Appl. Math.*, 70(3), 2017.

Spectral shift via lateral perturbation

P. Kuchment, G. Berkolaiko

Abstract. Let $\mathcal{H}$ be a separable Hilbert space and $A : \mathcal{H} \to \mathcal{H}$ be a self-adjoint operator bounded from below. Assume that below its essential spectrum, A has an eigenvalue λ_0 with the eigenfunction f. Consider further a non-negative self-adjoint perturbation operator $K_0^* K_0$, where K_0 is a compact operator from $\mathcal{H}$ to an auxiliary Hilbert space $\mathcal{K}$ and $K_0 f = 0$ (sign-indefinite perturbations can also be included). Thus, λ is also an isolated eigenvalue of the perturbed operator $H = A + K_0^* K_0$, say $\lambda = \lambda_n(A + K_0^* K_0)$. We now allow the operator K_0 to vary, and consider the continuation of the eigenvalue λ_0 as a function of $K : \Lambda(K) := \lambda(A + K^* K)$ such that $\Lambda(K_0)\lambda$. Due to the standard perturbation theory, this function is (real-)analytic with respect to K. We establish that $\Lambda(K)$ has a critical point at $K = K_0$ and, if the family of variations K is "rich enough," the Morse index of this critical point is equal to the spectral shift σ, where $\lambda = \lambda_n + \sigma(A)$.

Nonlinear Free surface Condition Due to Wave Diffraction By a Pair of Cylinders
D. Bhatta

Abstract. In the computations of the nonlinear loads on offshore structures, the most challenging task is the computation of the free surface integral. The main contribution to this integrand is due to the non-homogeneous term present in the free surface condition for the second order potential function. Here we derive the non-homogeneous term involved in the free surface condition due to second order wave diffraction by a pair of cylinders. We also present computational aspect of the coefficients appearing in this expression and some computational results of the free surface term.

Long-Time Asymptotics for the Massless Dirac-Coulomb Equation
R. Booth

Abstract. We describe a work in progress regarding the long-time asymptotics of the massless Dirac-Coulomb equation. We obtain a complete joint asymptotic expansion for solutions near future null infinity, where the exponents of the expansion appear as resonances of a related hyperbolic operator. Key techniques include microlocal propagation estimates which reduce the proof to a Fredholm problem on variable coefficient Sobolev spaces. This work builds on prior related work by Baskin-Vasy-Wunsch. This project is joint with Dean Baskin and Jesse Gell-Redman.

Reconstruction of a Three-Dimensional Axis-Symmetric Scatterer

C. Borges

Abstract. We consider the problem of reconstructing the shape of a three-dimensional impenetrable sound-soft axis-symmetric obstacle from measurements of the scattered field at multiple frequencies [1]. There are several applications for this problem, the most important one is to find the location and identifying obstacles of land mines. We present a uniqueness result using a single measurement and based on this result, we propose a two-part framework for recovering the shape of the obstacle. In the first part, we introduce an algorithm to find the axis of symmetry of the obstacle by making use of the far field pattern. In the second part of the framework, we recover the shape of the obstacle by applying the recursive linearization algorithm (RLA) [2] with multifrequency measurements of the scattered field.

In the RLA, we solve a sequence of inverse scattering problems using increasing single frequency measurements. Since each of those problems is ill-posed and nonlinear, we apply the damped Gauss-Newton method using a band-limited representation for the shape of the obstacle. To apply the RLA, we must solve many forward problems. So, it is necessary to have a fast, efficient, and accurate forward problem solver. In this direction, we apply separation of variables in the azimuthal coordinate and Fourier decompose the resulting problem, leaving us with a sequence of decoupled simpler forward scattering problems to solve. We present numerical results to show the feasibility of our framework in different settings.

References

[1] C. Borges and J. Lai Inverse scattering reconstruction of a three dimensional sound-soft axis-symmetric impenetrable object. *Inverse Problems*, http://iopscience.iop.org/10.1088/1361-6420/abac9b, 2020.

[2] Y. Chen Inverse scattering via Heisenberg's uncertainty principle. *Inverse Problems*, 13 (2), 253–282, 1997.

Numerical approximation of orthogonal maps with adaptive finite elements. Application to paper folding

A. Caboussat

Abstract. Orthogonal maps are the solutions of the so-called origami problem [1], which consists of a system of first order fully nonlinear equations involving the gradient of the solution. The Dirichlet problem for orthogonal maps consists in finding a vector-valued function $\mathbf{u} : \Omega \subset \mathbb{R}^2 \to \mathbb{R}^2$ verifying

$$\begin{cases} \nabla \mathbf{u} \in \mathcal{O}(2) & \text{in } \Omega \\ \mathbf{u} = \mathbf{g} & \text{on } \partial\Omega. \end{cases}$$

where $\mathcal{O}(2)$ denotes the set of orthogonal matrix-valued functions, and $\mathbf{g}$ is a given, sufficiently smooth, function. The solution $\mathbf{u}$ is piecewise linear, with a singular set composed of straight lines representing the folding edges.

A variational approach relies on the minimization of a variational principle, which enforces the uniqueness of the solution [2]. We present a strategy based on a splitting algorithm for the flow problem derived from the first-order optimality conditions. It leads to decoupling the time-dependent problem into a sequence of local nonlinear problems and a global variational problem at each time step.

Within the splitting algorithm, adaptive techniques are introduced and rely on error estimate based techniques developed for the solution of linear Poisson problems [4]. Anisotropic adaptive techniques allow to obtain refined triangulations near the folding edges while keeping the number of vertices as low as possible [3]. Numerical experiments validate the accuracy and efficiency of the adaptive method in various situations. Appropriate convergence properties are exhibited, and solutions with sharp edges are recovered.

Joint work with Prof. M. Picasso, D. Gourzoulidis (EPFL), Prof. R. Glowinski (University of Houston).

References

[1] B. Dacorogna, P. Marcellini and E. Paolini Origami and Partial Differential Equations, *Notices of the American Math. Soc.*, 57, 598–606, (2010).

[2] A. Caboussat, R. Glowinski, D. Gourzoulidis, M. Picasso Numerical Approximation of Orthogonal Maps. *SIAM J. Sci. Comput.*, 41(6), B1341–B1367, (2019).

[3] A. Caboussat, D. Gourzoulidis, M. Picasso An anisotropic adaptive method for the numerical approximation of orthogonal maps. *J. Comput. Appl. Math.*, submitted, (2020).

[4] M. Picasso An anisotropic error indicator based on Zienkiewicz-Zhu error estimator: Application to elliptic and parabolic problems, *SIAM J. Sci. Comput.*, 24, 1328–1355, (2003).

Global existence of the nonisentropic compressible Euler equations with vacuum boundary surrounding a variable entropy state

C. Rickard, M. Hadžić, J. Jang

Abstract. Global existence for the nonisentropic compressible Euler equations with vacuum boundary for all adiabatic constants $\gamma > 1$ is shown through perturbations around a rich class of background nonisentropic affine motions. We reformulate the free boundary Euler equations in the Lagrangian framework as a nonlinear wave equation on a bounded domain. The notable feature of the nonisentropic motion lies in the presence of non-constant entropies, and it brings a new mathematical challenge to the stability analysis of nonisentropic affine motions. In particular, the estimation of the curl terms requires a careful use of algebraic, nonlinear structure of the pressure. With suitable regularity of the underlying affine entropy, we are able to adapt the weighted energy method developed for the isentropic Euler [1] to the nonisentropic problem. For large γ values, inspired by [2], we use time-dependent weights that allow some of the top-order norms to potentially grow as the time variable tends to infinity. We also exploit coercivity estimates here via the fundamental theorem of calculus in time variable for norms which are not top-order. In this talk, more recent developments in this direction will also be discussed.

References

[1] Mahir Hadžić and Juhi Jang Expanding large global solutions of the equations of compressible fluid mechanics. *Inventiones mathematicae*, 214(3):1205–1266, Dec 2018.

[2] Steve Shkoller and Thomas C Sideris Global existence of near-affine solutions to the compressible Euler equations. to appear in *Arch. Ration. Mech. Anal.* 2019

Substructuring-based domain decomposition methods for nonlocal problems

G. Capodaglio, M. D'Elia, M. Gunzburger, P. Bochev, M. Klar, C. Volmann

Abstract. I will present a mathematical framework for substructuring-based domain-decomposition applied to nonlocal problems, where interactions between points separated by a finite distance are allowed. The term substructuring is borrow from domain-decomposition methods for local PDEs and refers to a geometric configuration in which a computational domain is subdivided into non-overlapping subdomains. In a nonlocal setting, the proposed approach is substructuring-based in the sense that the subdomains interact over interface regions having finite volume, in contrast to the local PDE setting in which interfaces are lower dimensional manifolds separating abutting subdomains. Key results include the equivalence between the global, single-domain nonlocal problem and its multi-domain reformulation, both at the continuous and discrete levels. Numerical results on a nonlocal FETI method will also be presented that serve as a proof of concept for the proposed approach.

An artificial compression method for incompressible flows with variable density and viscosity
L. Cappanera

Abstract. We present a new approximation method for the incompressible Navier-Stokes equations with variable density and viscosity. This method uses the momentum $\mathbf{m} := \rho\mathbf{u}$, with ρ the density and $\mathbf{u}$ the velocity, as dependent variable for the Navier-Stokes equations which results in a time-independent mass matrix that is suitable for spectral methods. The incompressibility condition of the flow is enforced via an artificial compression method. To improve the efficiency of the method for large scale computations, the stiffness matrix is made time independent by rewriting appropriately the diffusion operator and the grad-div operator that enforces the incompressibility of the flow. A level set method is applied to reconstruct the density and viscosity of the fluid. After establishing the stability of the algorithm, we study its convergence properties numerically with manufactured solutions involving a large range of ratios of density and viscosity. Comparisons with a pressure-correction projection method introduced in [1] are also provided. Eventually, we extend the method to conducting fluids with variable electrical conductivity to study magnetohydrodynamics problems.

References

[1] L. Cappanera, J.-L. Guermond, W. Herreman, C. Nore Momentum based approximation of incompressible multiphase fluid flows. *Int. J. Numer. Meth. Fluids*, 86 (2018).

Elliptic functions and their applications in integrable and nonintegrable systems
C. Wu

Abstract. This talk focuses on the applications of elliptic functions in integrable and non-integrable systems. It consists of two parts. Part I is concerned with non-integrable systems. It has been shown by Eremenko that under certain conditions the only meromorphic solutions to some non-integrable autonomous algebraic ODEs are elliptic functions or their degenerations. We will present a class of ODEs that satisfy these conditions. Also, this result will be generalized and some examples including the Falkner-Skan equation will be discussed. This work is joint with R. Conte and T. W. Ng.

Recently, rogue waves on the double-periodic background have been studied for several integrable systems. Part II of this talk is devoted to this subject.

An extension of Kadomtsev-Petviashvili hierarchy
C. Wu

Abstract. In this talk, we present an extension of Kadomtsev-Petviashvili (KP) hierarchy via scalar pseudo-differential operators. For this hierarchy, its Hamiltonian structures, bilinear equation and additional symmetries is obtained.

Classification of 3D Shapes and Shape Deformations
R. Azencott, H. Dabirian, J. He, J. Herring, A. Mang, P. Zhang

Abstract. We present a mathematical framework and computational methods for classification and clustering of shapes and shape deformations in an infinite-dimensional shape space $\mathcal{S}$. Our goal is to discriminate between clinically distinct patient groups through the lens of anatomical shape variability. In a Riemannian setting, we can express the similarity between two k-dimensional ($k \in \{1,2,3\}$) shapes $s_i \in S$, $i = 0,1$, in terms of an energy minimizing $\mathbb{R}^3$-diffeomorphism $y \in \mathcal{Y}$ such that $y(s_0) = s_1$. We use an optimal control formulation, in which the diffeomorphism y is parameterized by a smooth, time-dependent velocity field $v \in L_2([0,1], \mathcal{V})$, with associated Hilbert space $\mathcal{V}$ of $\mathbb{R}^3$ vector fields. After computing an optimal v^*, we derive the strain distribution of y^* as well as a Hilbert norm of v^* to characterize the dissimilarities between s_0 and s_1. Using these features, we implement machine learning techniques to achieve a classification of shapes extracted from cardiac imaging.

Gradient discretization of two-phase flows coupled with mechanical deformation in fractured porous media

F. Bonaldi, K. Brenner, J. Droniou, R. Masson

Abstract. We consider a two-phase Darcy flow in a fractured porous medium consisting in a matrix flow coupled with a tangential flow in the fractures, described as a network of planar surfaces. This flow model is also coupled with the mechanical deformation of the matrix assuming that the fractures are open and filled by the fluids, as well as small deformations and a linear elastic constitutive law. The model is discretized using the gradient discretization method [2], which covers a large class of conforming and non conforming schemes. This framework allows for a generic convergence analysis of the coupled model using a combination of discrete functional tools. Here, we describe the model together with its numerical discretization, and we prove the convergence of the discrete solution to a weak solution of the model [1]. This is, to our knowledge, the first convergence result for this type of models taking into account two-phase flows and the nonlinear poromechanical coupling. Previous related works consider a linear approximation obtained for a single phase flow by freezing the fracture conductivity [3]. Numerical tests employing the Two-Point Flux Approximation (TPFA) finite volume scheme for the flows and $\mathbb{P}^2$ finite elements for the mechanical deformation are also provided to illustrate the behavior of the solution to the model.

References

[1] F. Bonaldi, K. Brenner, J. Droniou and R. Masson Gradient discretization of two-phase flows coupled with mechanical deformation in fractured porous media *preprint*, https://hal.archives-ouvertes.fr/hal-02549111, april 2020.

[2] J. Droniou, R. Eymard, T. Gallouët, C. Guichard and R. Herbin The Gradient Discretisation Method *Springer, Mathematics & Applications*, 82, 2018.

[3] V. Girault, M. F. Wheeler, B. Ganis and M. E. Mear A lubrication fracture model in a poro-elastic medium *Mathematical Models and Methods in Applied Sciences*, 25, 2015.

Incorporating Multiple A Priori Information for Seismic Inversion

D. Li, M. Lamoureux, W. Liao

Abstract. A scaled gradient projection method on adaptive constraint sets is proposed to solve the seismic inverse problem with multiple convex constraints. First, we formulate the feasible set as an intersection of multiple convex constraint sets which contains the a priori information for the model. Then an inexact projection algorithm by [1], [2] is introduced to project points onto the intersection of constraint sets. An adaptively increasing constraint set sequence is built to combine the scaled gradient projection method with the inexact projection algorithm. Numerical examples with cross well and reflection seismic experiments show that multiple constraint sets such as box constraint, total variation constraint, and l_1 constraint are suitable for the proposed method.

References

[1] Combettes P. L. A block-iterative surrogate constraint splitting method for quadratic signal recovery. *IEEE Transactions on Signal Processing*, 2003, 51(7): 1771-1782.

[2] Combettes P. L. Strong convergence of block-iterative outer approximation methods for convex optimization. *SIAM Journal on Control and Optimization*, 2000, 38(2): 538-565.

Optimal control of block copolymer systems governed by nonlocal Cahn Hilliard equations

D. Luo, L. Cao, J. Chen, P. Chen, D. Faghihi, O. Ghattas, J. Tinsley Oden

Abstract. Directed self-assembly (DSA) of block-copolymers (BCPs) is one of the most promising strategies for the cost-effective production of nanoscale devices [**?**]. The process makes use of the natural tendency for BCP mixtures to form nanoscale structures upon phase separation. Furthermore, this can be directed through the placement of chemically patterned substrates to promote the formation of morphologies of interest. Adopting a nonlocal Cahn-Hilliard equation to model the phase-separation of BCPs, the DSA process can be cast as a PDE constrained optimization problem in which one seeks an optimal design for the substrate pattern while respecting manufacturing constraints. In this talk, we present a formulation of this optimization problem and discuss its computational solutions as well as the associated challenges.

References

[1] Y. Chen, S. Xiong Directed self-assembly of block copolymers for sub-10 nm fabrication *International Journal of Extreme Manufacturing*, 2(3) 2020.

The basic reproduction number for linear maps that preserve a cone
P. De Leenheer

Abstract. We review some mathematical results that are part of the folklore about the basic reproduction number, a concept that is prevalent in epidemiology and population biology. The reason why the basic reproduction number is commonly used in applications, is that it is often easier to calculate than the spectral radius of the non-negative matrix to which it is associated. Moreover, its value helps to establish the stability or instability of the linear recursion defined by the matrix, because, as the saying goes, "the spectral radius of a non-negative matrix, and its associated basic reproduction number, lie on the same side of 1". Perhaps not as well-known in the community of mathematical biology, these results had already been obtained by Vandergraft in 1968 in [3], and are applicable to the more general class of linear maps that preserve a cone in R^n, and not just to linear maps described by a non-negative matrix. Note that Vandergraft's work was done well before the notion of the basic reproduction number became popular in mathematical biology, yet interestingly, Vandergraft attributes the ideas to even earlier work in optimization. We strengthen one of Vandergraft's results, albeit very slightly, using an idea in [2] that was proposed for linear maps which preserve the non-negative orthant cone. Looming in the background, and grounding all the proofs of these results, is the celebrated Perron-Frobenius Theorem for linear maps that preserve a cone, which is presented in a very nice, yet comprehensive way in [1].

References

[1] B. Lemmens, and R. Nussbaum Nonlinear Perron-Frobenius Theory, Cambridge University Press, 2012.
[2] C.-K. Li, and H. Schneider Applications of PerronFrobenius theory to population dynamics. *Journal of Mathematical Biology*, 44, p. 450-462, 2002.
[3] J. S. Vandergraft Spectral properties of matrices which have invariant cones, *SIAM Journal of Applied Mathematics* 16, p. 1208-1222, 1968.

A unified theoretical and computational nonlocal framework: generalized vector calculus and machine-learned nonlocal models
M. D'Elia

Abstract. Nonlocal models provide an improved predictive capability thanks to their ability to capture effects that classical partial differential equations fail to capture. Among these effects we have multiscale behavior (e.g. in fracture mechanics) and anomalous behavior such as super- and sub-diffusion. These models have become incredibly popular for a broad range of applications, including mechanics, subsurface flow, turbulence, heat conduction and image processing. However, their improved accuracy comes at a price of many modeling and numerical challenges.

In this talk I will first address the problem of connecting nonlocal and fractional calculus by developing a unified theoretical framework that enables the identification of a broad class of nonlocal models [1]. Then, I will present recently developed machine-learning techniques [2] for nonlocal and fractional model learning. These physics-informed, data-driven, tools allow for the reconstruction of model parameters or nonlocal kernels. Numerical tests illustrate our theoretical findings and the robustness and accuracy of our approaches.

References

[1] M. D'Elia, M. Gulian, H. Olson, G. E. Karniadakis A Unified Theory of Fractional, Nonlocal, and Weighted Nonlocal Vector Calculus. arXiv report, arXiv:2005.07686, 2020.
[2] G. Pang, M. D'Elia, M. Parks, G.E. Karniadakis. nPINNs: nonlocal Physics-Informed Neural Networks for a parametrized nonlocal universal Laplacian operator. Algorithms and Applications. *Journal of Computational Physics*, to appear, 2020.

A unified theoretical and computational nonlocal framework: generalized vector calculus and machine-learned nonlocal models
A. Demlow

Abstract. The Stokes equation posed on surfaces is important in some physical models, but its numerical solution poses several challenges not encountered in the corresponding Euclidean setting. These include the fact that the velocity vector should be tangent to the given surface and the possible presence of degenerate modes (Killing fields) in the solution. We consider an interior penalty method based on the well-known Brezzi-Douglas-Marini $H(\text{div})$-conforming finite element space which yield tangential but not H^1 conformity. We also describe challenges associated with filtering Killing fields out of the solution and describe a method for overcoming them. This talk is based on joint work with Andrea Bonito and Martin Licht [1].

References

[1] A. Bonito, A. Demlow, and M. Licht A divergence-conforming finite element method for the surface Stokes equation *SIAM J. Nume. Anal.*, to appear.

Not Just a Knot

J. Austin

Abstract. "...DNA can bend, twist, and writhe, can be knotted, catenated, and supercoiled (positive and negative), can be in A, B, and Z helical forms, and can breathe."-Arthur Kornberg

DNA topology is the study of those DNA forms that remain fixed for any deformation that does not involve breakage. DNA molecules that are chemically identical (same nucleotide length and sequence) but differ in their topology are called topoisomers. There are three topological DNA forms that are the natural consequence of the structure and metabolism of the double helix: knotted, catenated, and supercoiled DNA. Cellular DNA is either circular or constrained by being tethered at intervals to organizing structures. Thus, DNA knot and catenane resolution and supercoiling maintenance must occur locally. Controlling the topology of its DNA is critical to the cell. If unresolved, DNA knots could potentially have devastating effects on cells; DNA catenanes prevent genetic and cellular segregation. DNA negative supercoiling is essential for cell viability. Topoisomerases are enzymes within cells whose function is to control DNA topology.

In this session, we will see the amount of DNA in a strawberry as we appreciate the packaging challenges within cells, explore the topology of DNA, and learn how cells deal with DNA entanglements.

Physics-aware Deep-learning-based Proxy Reservoir Simulation Model Equipped With State And Well Output Prediction

E. Coutinho, E. Gildin, M. Dall'Aqua

Abstract. Sustainable hydrocarbon production demands complex decision-support strategies involving optimal production scheduling. At the core of these decisions is the prediction of reservoir performance, usually done by running computationally demanding complex reservoir simulators. As a substitute, physics-aware machine learning (ML) techniques have been used to endow data-driven proxy models with features closely related to the ones encountered in nature, especially conservation laws. They can lead to fast, reliable, and interpretable simulations used in many reservoir management workflows. In this talk, we build upon the recently developed deep-learning-based reduced-order modeling framework [1],[2] for fast and reliable proxy for reservoir simulation by adding a new step related to information of the input-output behavior (e.g., well rates) of the reservoir and not only the states (e.g., pressure and saturation). I will use here a combination of data-driven model reduction strategies and machine learning (deep-neural networks - DNN) to achieve simultaneously state and input-output matching. Such a non-intrusive method does not need to have access to reservoir simulation internal structure, so it can be easily applied in tandem with reservoir simulations. I will show preliminary results based on an oil-water model with heterogeneous permeability, 4 injectors, and 5 producers wells. Comparisons will be made regarding training, accuracy and speedups.

References

[1] Zhaoyang Larry Jin, Yimin Liu, Louis J. Durlofsky Deep-learning-based surrogate model for reservoir simulation with time-varying well controls. *Journal of Petroleum Science and Engineering*, 192, 2020.

[2] Manuel Watter, Jost Tobias Springenberg, Joschka Boedecker and Martin Riedmiller Embed to Control: A Locally Linear Latent Dynamics Model for Control from Raw Images. www.arxiv.org/abs/1506.07365., 2015.

Three Dimensional Elastic Frames: Rigid Joint Conditions in Variational and Differential Formulation

G. Berkolaiko, M. Ettehad

Abstract. We consider elastic frames constructed out of Euler-Bernoulli beams. Correct vertex conditions corresponding to rigid joints have been a subject of active interest in both mathematical and structural engineering literature, with consideration usually limited to planar frames. In this talk we will describe a simple process of generating joint conditions out of the geometric description of an arbitrary three-dimensional frame. The corresponding differential operator is shown to be self-adjoint. Furthermore, in the presence of symmetry, one can restrict the operator onto reducing subspaces corresponding to irreducible representations of the symmetry group. This decomposition is demonstrated in general planar frames and in a three dimensional example with rotational symmetry.

The limiting absorption principle and continuity properties of the spectral shift function for massless Dirac-type operators

F. Gesztesy

Abstract. We report on recent results regarding the limiting absorption principle for multi-dimensional, massless Dirac-type operators and continuity properties of the associated spectral shift function.

This is based on various joint work with A. Carey, J. Kaad, G. Levitina, R. Nichols, D. Potapov, F. Sukochev, and D. Zanin.

Propagation acceleration in reaction diffusion equations with fractional Laplacians

J. Coville, C. Gui, M. Zhao

Abstract. In this paper we consider the propagation speed in a reaction diffusion system with an anomalous Lévy process diffusion, modeled by a nonlocal equation with a fractional Laplacian and a generalized KPP type monostable nonlinearity. Given a typical Heavy side initial datum, we show that the speed of interface propagation displays an algebraic rate behavior in time, in contrast to the known linear rate in the classical model of Brownian motion and the exponential rate in the KPP model with the anomalous diffusion, and depends on the sensitive balance between the anomaly of the diffusion process and the strength of monostable reaction. In particular, for the combustion model with a fractional Laplacian $(-\Delta)^s$, we show that the speed of propagation transits continuously from being linear in time, when a traveling wave solution exists for $s \in (1/2, 1)$, to being algebraic in time with a power reciprocal to $2s$, when no traveling wave solution exists for $s \in (0, 1/2)$.

References

[1] Jerome Coville, Changfeng Gui, Mingfeng Zhao Propagation acceleration in reaction diffusion equations with anomalous diffusions preprint, 2020

[2] Changfeng Gui and Tingting Huan Traveling wave solutions to some reaction diffusion equations with fractional Laplacians *Calculus of Variations and Partial Differential Equations*, 54(1), 251-273, 2015.

A randomized Newton's method for solving differential equations based on the neural network discretization

W. Hao

Abstract. In this talk, I will present a randomized Newton's method for solving differential equations, based on a fully connected neural network discretization. In particular, the randomized Newto"s method randomly chooses equations from the overdetermined nonlinear system resulting from the neural network discretization and solves the nonlinear system adaptively. We prove theoretically that the randomized Newton's method has a quadratic convergence locally. I will also show various numerical examples, from one-to high-dimensional differential equations, in order to verify its feasibility and efficiency. Moreover, the randomized Newton's method can allow the neural network to "learn" multiple solutions for nonlinear systems of differential equations, such as pattern formation problems, and provides an alternative way to study the solution structure of nonlinear differential equations overall.

Solvability of Semilinear Equations in Hilbert Spaces and Applications to Control System Governed by PDEs

H. Leiva

Abstract. In this work we study the existence of solutions for a broad class of abstract semilinear equations in Hilbert spaces. This is done by applying Rothe's Fixed Point Theorem and a characterization of dense range linear operators in Hilbert spaces. As an applications, we study the approximate controllability of a semilinear control system governed by a semilinear evolution equations, and a particular case of this is a control system governed by a semilinear heat equation with interior control.

References

[1] R. F. Curtain, A. J. Pritchard Infinite Dimensional Linear Systems. *Lecture Notes in Control and Information Sciences*, Springer Verlag, Berlin (1978).
[2] R. F. Curtain, H. J. Zwart An Introduction to Infinite Dimensional Linear Systems Theory. *Text in Applied Mathematics, Springer Verlag, New York*, Vol. 1, 1995.
[3] G. Isac On Rothe's Fixed Point Theorem in General Topological Vector Space. *An. St. Univ. Ovidius Constanta*, Vol. 12(2), 2004, 127-134.
[4] H. Leiva, N. Merentes and J. L. Sanchez Approximate Controllability of Semilinear Reaction Diffusion. *MATHEMATICAL CONTROL AND RELATED FIELDS*, Vol. 2, No. 2, June 2012.
[5] H. Leiva, N. Merentes and J. L. Sanchez A Characterization of Semilinear Dense Range Operators and Applications. *Journal of Mathematics and Applications*, Vol. 2013, 1–11.
[6] H. Leiva, N. Merentes and J. L. Sanchez. Interior Controllability of the Benjamin-Bona-Mahony Equation. *Journal of Mathematics and Applications*, No. 33, 51-59 (2010).
[7] H. Leiva, N. Merentes and J. L. Sanchez. Approximate Controllability of a Semilinear Heat Equation. *International Journal of Partial Differential Equations Mathematics*, Vol. 2013, Art. ID 424309, 7 pages.
[8] Hugo Leiva Rothe's Fixed Point Theorem and Controllability of Semilinear Nonautonomous Systems. *System and Control Letters*, 67 (2014) 14-18.

Quasi-Independence Models with Rational Maximum Likelihood Estimates

J. Coons, S. Sullivant

Abstract. Let X and Y be random variables. Quasi-independence models are log-linear models that describe a situation in which some states of X and Y cannot occur together, but X and Y are otherwise independent. In [1], we characterize which quasi-independence models have rational maximum likelihood estimate based on combinatorial features of the bipartite graph associated to the model. In this case, we give an explicit formula for the maximum likelihood estimate.

References

[1] J. I. Coons, S. Sullivant. Quasi-independence models with rational likelihood estimates. arXiv:2006.06832

Beating the curse of dimensionality in high-dimensional stochastic fixed-point equations
J. Padgett

Abstract. In recent years, high-dimensional partial differential equations (PDEs) have become a topic of extreme interest due to their occurrence in numerous scientific fields. Examples of such equations include the Schrödinger equation in quantum many-body problems, the nonlinear Black-Scholes equation for pricing financial derivatives, and the Hamilton-Jacobi-Bellman equation in dynamic programming. In each of these cases, standard numerical techniques suffer from the so-called curse of dimensionality, which refers to the computational complexity of an employed approximation method growing exponentially as a function of the dimension of the underlying problem. This phenomenon is what prevents traditional numerical algorithms, such as finite differences and finite element methods, from being efficiently employed in problems with more than, say, ten dimensions. The purpose of this talk is to introduce a novel approximation algorithm known as the multilevel Picard (MLP) approximation method for beating the curse of dimensionality in the case of semilinear PDEs. We accomplish this task by considering the equivalent stochastic fixed-point equations associated to such PDEs. The primary focus of this talk will be motivating the development of this novel algorithm and then providing rigorous L^p-error and computational complexity analysis with optimal constants. Numerical examples will be provided in order to provide experimental verification of the obtained results.

Fast Symmetric Tensor Decomposition
J. Kileel

Abstract. We present a new method for low-rank symmetric tensor decomposition, building on Sylvester's catalecticant method from classical algebraic geometry and the power method from numerical linear algebra. The approach achieves a speed-up over the state-of-the-art by roughly one order of magnitude. We also sketch an "implicit" variant of the algorithm for the case of moment tensors, which avoids the explicit formation of higher-order moments. This talk is based on joint works with João Pereira and Tammy Kolda.

Determining Protein Structure by the Method of Moments

J. Kileel

Abstract. Cryo-electron microscopy and X-ray free electron lasers are imaging techniques to determine the three-dimensional structure of proteins from large data sets of noisy two-dimensional images. These methods give rise to very challenging inverse problems. We discuss a new framework for determining the protein structure based on the method of moments and solving nonlinear polynomial systems of equations. This talk is based on joint works with Amit Singer, Nir Sharon, Yuehaw Khoo, Boris Landa and Changshuo Liu.

Determing Protein Structure by the Method of Moments
Y. Klevtsova

Abstract. Abstract. We consider the system of equations for the quasi-solenoidal Lorenz model for a baroclinic atmosphere

$$\frac{\partial}{\partial t}A_1u + \nu A_2 u + A_3 u + B(u) = g, \qquad t > 0, \tag{1}$$

on the two-dimensional unit sphere S centered at the origin of the spherical polar coordinates (λ, φ), $\lambda \in [0, 2\pi)$, $\varphi \in -[\frac{\pi}{2}, \frac{\pi}{2}]$, $\mu = \sin\varphi$. Here $\nu > 0$ is the kinematic viscosity, $u(t, x, \omega) = (u_1(t, x, \omega), u_2(t, x, \omega))^T$ is an unknown vector function and $g(t, x, \omega) = (g_1(t, x, \omega), g_2(t, x, \omega))^T$ is a given vector function, $x = (\lambda, \mu), \omega \in \Omega(\Omega, P, F)$ is a complete probability space,

$$A_1 = \begin{pmatrix} -\Delta & 0 \\ 0 & -\Delta + \gamma I \end{pmatrix}, A_2 = \begin{pmatrix} \Delta^2 & 0 \\ 0 & \Delta^2 \end{pmatrix},$$
$$A_3 = \begin{pmatrix} -k\Delta & 2k\Delta \\ k\Delta & -(2k + k_1 + \nu\gamma)\Delta + \rho I \end{pmatrix},$$

$B(u) = (J(\Delta u_1 + 2\mu, u_1) + J(\Delta u_2, u_2), J(\Delta u_2 - \gamma u_2, u_1) + J(\Delta u_1 + 2\mu, u_2))^T$. Also, $\gamma, \rho, k_0, k_1 \geq 0$ are numerical parameters, I is the identity operator, $J(\Psi, \Theta) = \Psi\lambda\Theta\mu - \Psi\mu\Theta\lambda$ is the Jacobi operator and $\Delta\Psi = ((1-\mu^2)\Psi\mu)\mu + (1-\mu^2) - 1\Psi\lambda\lambda$ is the Laplace-Beltrami operator on the sphere S. A random vector function $g = f + \eta$ is taken as the right-hand side of (1); here $f(x) = (f_1(x), f_2(x))^T$ and $\eta(t, x, \omega) = (\eta_1(t, x, \omega), \eta^2(t, x, \omega))^T$ is a white noise in t. It was obtained in [1],[2] and in the present work the sufficient conditions on the right-hand side and the parameters of the system (1) with white noise perturbation for existence of a unique stationary measure of Markov semigroup defined by solutions of the Cauchy problem for the system (1), for the exponential convergence of the distributions of solutions to the stationary measure as $t \to +\infty$ and for the existence a limiting point for any sequence of the stationary measures for this system when any sequence of the kinematic viscosity coefficients goes to zero. Several integrals over such stationary measures were estimated by the set of the right-hand side and the parameters.

References

[1] Yu. Yu. Klevtsova. On the rate of convergence as $t \to +\infty$ of the distributions of solutions to the stationary measure for the stochastic system of the Lorenz model describing a baroclinic atmosphere. *Sb. Math.*, 208(7), 2017, 929-976.

[2] Yu. Yu. Klevtsova. On integral properties of stationary measures for the stochastic system of the Lorenz model describing a baroclinic atmosphere. *Sb. Math.*, to appear.

The Effects of Excess Food-Nutrient Content on the Coexistence of Competing Consumer Species

L. Asik, A. Peace

Abstract. Recent discoveries in ecological stoichiometry have indicated that food quality in terms of the phosphorus:carbon (P:C) ratio affects consumers whether the imbalance involves insufficient or excess nutrients. This phenomenon is called the "stoichiometric knife-edge." In this study, we develop and analyze two consumers feeding on one producer model, which captures this phenomenon. Criteria for local stability and instability of the non-negative equilibria are obtained. The coexistence of the three species is also discussed. Finally, computer simulations are performed to investigate the dynamics of the system.

Guaranteed upper bounds for the velocity error of pressure-robust Stokes discretisations

P. Lederer, C. Merdon

Abstract. We improve guaranteed error control for the Stokes problem with a focus on pressure-robustness, i.e. for discretisations that compute a discrete velocity that is independent of the exact pressure. A Prager-Synge type result relates the errors of divergence-free primal and $H(\mathrm{div})$-conforming dual mixed methods (for the velocity gradient) with an equilibration constraint that needs special care when discretised. To relax the constraints on the primal and dual method, a more general result is derived that enables the use of a recently developed mass conserving mixed stress discretisation to design equilibrated fluxes that yield pressure-independent guaranteed upper bounds for any pressure-robust (but not necessarily divergence-free) primal discretisation. Moreover, a provably efficient local design of the equilibrated fluxes is presented that reduces the numerical costs of the error estimator.

Finite element discretizations with exactly tangential vector fields for incompressible flows on surfaces

P. Lederer, C. Lehrenfeld, J. Schöberl

Abstract. Let Γ be a piecewise smooth connected two-dimensional and stationary surface embedded in $\mathbb{R}^3$. We consider the following surface Navier- Stokes model for a Newtonian surface fluid

$$\partial_t u - \nu P \mathrm{div}_\Gamma(\epsilon_\Gamma(u)) + (u \cdot \nabla_\Gamma)u + \nabla_\Gamma p = f \qquad \text{on } \Gamma, t \in (0,T],$$
$$\mathrm{div}_\Gamma u = 0 \qquad \text{on } \Gamma, t \in (0,T],$$

with $T > 0$ and $P = I - nn^T$ the orthogonal projection on the tangential plane where n is a unit normal to Γ. Here, the differential operators ∇_Γ and div_Γ are the usual surface derivatives and $\epsilon_\Gamma(u) = \frac{1}{2}\nabla_\Gamma u + \nabla_\Gamma u^T$. u is the fluid velocity on the surface which is tangential to the surface and p is the surface fluid pressure. For the discretization of the velocity field we use an $H(\mathrm{div}, \Gamma)$-conforming finite element space V_h. This is achieved by mapping finite element functions from the two-dimensional reference element by a straight-forward generalization of the well-known Piola transformation. This guarantees that the resulting vectorial basis functions are exactly tangential to the surface. This specifically means that no additional enforcement of the tangentiality condition is needed to be enforced through Lagrange multipliers or penalty formulations as it has been considered in the other recent publications. Moreover, by choosing the pressure space $Q_h = \mathrm{div}_\Gamma V_h$ (which results in standard piecewise polynomial spaces) we obtain exactly surface divergence-free finite element solutions. Only the tangential continuity is not enforced through the finite element space but is incorporated using DG and HDG techniques as in the plane.

References

[1] P. L. Lederer, C. Lehrenfeld and J. Schöberl. Divergence-free tangential finite element methods for incompressible flows on surfaces. *Int. J. Num. Meth. Eng.*, 121(11):2503–2533, 2020.

Optimal Control of Directed Flow in a PDE Model of an Invasive Species in a River

S. Lenhart

Abstract. Invasive species in rivers may be controlled by adjustment of flow rates. Using a parabolic PDE model representing an invasive population in a river, we investigate optimal control of the water discharge rate to keep an invasive population downstream. We show some numerical simulations to illustrate how far upstream the invasive population reaches.

Recovery of Linear Elastic Fracture Mechanics from Nonlocal Dynamics

R. Lipton, P. Jha

Abstract. Abstract. We introduce a peridynamic model for calculating dynamic fracture as emergent phenomina. The force interaction is derived from a double well strain energy density function, resulting in a non-monotonic material model. The material properties change in response to evolving internal forces and fracture emerges from the model. In the limit of zero nonlocal interaction the model recovers a sharp crack evolution characterized by the classic Griffith free energy of brittle fracture with elastic deformation satisfying the linear elastic wave equation off the crack set, zero traction on crack faces and the kinetic relation between crack tip velocity and crack driving force given in [1],[7],[8],[9]. These new nonlocal models and results are reported by the authors in [3],[2],[3],[4],[5],[6]. This research is funded through ARO Grant W911NF1610456.

References

[1] L. B. Freund. Energy flux into the tip of an extending crack in an elastic solid. *J. Elasticity*,2:341–349, 1972.
[2] P. K. Jha and R. P. Lipton. Numerical convergence of finite difference approximations for state based peridynamic fracture models. *Comput. Methods. Appl. Mech. Engrg.* 351:84–225, 2019.
[3] P. K. Jha and R. P. Lipton. Kinetic relations and local energy balance for LEFM from a nonlocal peridynamic model. *International Journal of Fracture.* DOI: 10.1007/s10704-020-00480-0, 2020.
[4] Jha, P. K., and Lipton, R. Numerical analysis of nonlocal fracture models in Hölder space. *SIAM J. Numer. Anal.* 56:906?941, 2018.
[5] Lipton, R., Lehoucq, R. and Jha, P. Complex Fracture Nucleation and Evolution with Nonlocal Elastodynamics. *Journal of Peridynamics and Nonlocal Modeling.* 1:122?130, 2019.
[6] Lipton, R. Dynamic brittle fracture as a small horizon limit of peridynamics. *Journal of Elasticity.* 117(1):21-50, 2014.
[7] B. V. Kostrov and L. V. Nikitin. Some general problems of mechanics of brittle fracture. *Arch. Mech. Stosowanej.* 22:749–775, 1970.
[8] A. Bonito. Y. Slepian. Models and Phenomena in Fracture Mechanics. *Foundations of Engineering Mechanics.* Springer-Verlag. Berlin, 2002.
[9] J. R. Willis Equations of motion for propagating cracks, The mechanics and physics of fracture. *The Metals Society.* 57–67, 1975.

Stahl–Totik regularity for continuum Schrödinger operators
M. Lukić

Abstract. This talk describes joint work with Benjamin Eichinger: a theory of regularity for one-dimensional continuum Schrödinger operators, based on the Martin compactification of the complement of the essential spectrum. For a half-line Schrödinger operator $-\partial_x^2+V$ with a bounded potential V, it was previously known that the spectrum can have zero Lebesgue measure and even zero Hausdorff dimension; however, we obtain universal thickness statements in the language of potential theory. Namely, we prove that the essential spectrum is not polar, it obeys the Akhiezer–Levin condition, and moreover, the Martin function at ∞ obeys the two-term asymptotic expansion $\sqrt{-z} + \frac{a}{2\sqrt{-z}} + o(\frac{1}{\sqrt{-z}})$ as $z \to -\infty$. The constant a in its asymptotic expansion plays the role of a renormalized Robin constant and enters a universal inequality $a \leq \liminf_{x\to\infty} \frac{1}{x}\int_0^x V(t)dt$. This leads to a notion of regularity, with connections to the exponential growth rate of Dirichlet solutions and limiting eigenvalue distributions for finite restrictions of the operator. We also present applications to decaying and ergodic potentials.

Equilibrium Preserving Schemes for Shallow Water Models
T. Wu

Abstract. Abstract. Shallow water models are widely used to describe and study free-surface water flow. They are hyperbolic systems of balance laws and are usually solved by finite volume methods, which are appropriate numerical tools for computing non-smooth solutions. One requirement when designing numerical schemes for shallow water models is to preserve a delicate balance between the flux and source terms since many physical related solutions are small perturbations of some steady-state solutions. I will present a general approach of designing well-balanced central-upwind schemes for shallow water models, from the "lake at rest" steady states to the moving steady-states with bottom frictions and illustrate their performance on a number of numerical examples.

References

[1] Y. Cheng, A. Chertock, M. Herty, A. Kurganov, and T. Wu. A New Approach for Designing Moving-Water Equilibria Preserving Schemes for the Shallow Water Equations *Journal of Scientific Computing*, 80(2019).
[2] X. Liu, X. Chen, S. Jin, A. Kurganov, T. Wu, and H. Yu Moving-Water Equilibria Preserving Partial Relaxation Scheme for the Saint-Venant System *SIAM Journal on Scientific Computing*, 42(2020).

Finite-element computation of the conductivity feedback of nanoscale optical devices

M. Maier

Abstract. In the terahertz frequency range, the effective (complex-valued) surface conductivity of atomically thick 2D materials such as graphene has a positive imaginary part that is considerably larger than the real part. This feature allows for the propagation of slowly decaying electromagnetic waves, called surface plasmon-polaritons (SPPs), that are confined near the material interface with wavelengths much shorter than the wavelength of the free-space radiation. SPPs are a promising ingredient in the design of novel optical devices, promising "subwavelength optics" beyond the diffraction limit. There is a compelling need for controllable numerical schemes which, placed on firm mathematical grounds, can reliably describe SPPs in a variety of geometries. In this talk we present an a finite element approach for the simulation of the nanoscale conductivity response of complex optical devices with nanoscale 2D material inclusions. The approach is based on a homogenization theory of layered optical heterostructures. We show analytical results for some prototypical geometries and a homogenization theory for layered heterostructures.

References

[1] M. Maier, M. Mattheakis, E. Kaxiras, M. Luskin, and D. Margetis, Homogenization of plasmonic crystals: Seeking the epsilon-near-zero effect, *Proceedings of the Royal Society A: Mathematical, Physical, and Engineering Sciences*, 475 (2019), p. 20190220.

[2] M. Maier, D. Margetis, and A. Mellet, Homogenization of time-harmonic Maxwell's equations in nonhomogeneous plasmonic structures, *Journal of Computational and Applied Mathematics*, (2020), p. 112909.

[3] W. Li, R. Lipton, and M. Maier, Lorentz resonance in the homogenization of plasmonic crystals, Submitted, (2020).

Massively parallel 3D computation of the compressible Euler equations with an invariant-domain preserving second-order finite-element schemes

M. Kronbichler, M. Maier

Abstract. Abstract. We discuss the efficient implementation of a high-performance second-order collocation-type finite-element scheme for solving the compressible Euler equations of gas dynamics on unstructured meshes. The solver is based on the *convex limiting* technique introduced by Guermond et al. (SIAM J. Sci. Comput. 40, A3211–A3239, 2018). As such it is *invariant-domain preserving*, i. e., the solver maintains important physical invariants and is guaranteed to be stable without the use of ad-hoc tuning parameters. This stability comes at the expense of a significantly more involved algorithmic structure that renders conventional high-performance discretizations challenging.

We demonstrate that it is nevertheless possible to achieve an appreciably high throughput of the computing kernels of such a scheme. We discuss the algorithmic design that allows a SIMD vectorization of the compute kernel, analyze the node-level performance and report excellent weak and strong scaling of a hybrid thread/MPI parallelization.

References

[1] M. Maier, M. Kronbichler, Massively parallel 3D computation of the compressible Euler equations with an invariant-domain preserving second-order finite-element scheme, Submitted, (2020).

On the Landis conjecture on the plane

E. Malinnikova

Abstract. We consider solutions to the two-dimensional Schrödinger equation $\Delta u + Vu = 0$ with a bounded real potential and show that they cannot decay too fast by confirming the conjecture of Landis from the 1960s, which states that a solution u satisfying $|u(x)| \leq C \exp(-|x|^{1+\epsilon})$ on the plane $\mathbb{R}^2$ is trivial. The vanishing order of solutions to the Schrödinger equations will be also discussed in the talk if time permits. The talk is based on a recent joint work with A. Logunov, N. Nadirashvili, and F. Nazarov [1].

References

[1] A. Logunov, E. Malinnikova, N. Nadirashvili, F. Nazarov The Landis conjecture on exponential decay, arXiv:2007.07034

Clustering Analysis of Novel Corona Virus (COVID-19) Cases in U.S. States and Territories

C. Manivannan, Q. Tang

Abstract. Abstract. The Centers for Disease Control and Prevention (CDC) confirmed the first case of the novel corona virus (COVID-19) in the United States on January 21, 2020, in the state of Washington. To date (August 31, 2020) at least 5,998,000 COVID-19 cases have been reported and at least 180,000 individuals have died from the novel corona virus in the United States. This mini-symposium will discuss applying hierarchical clustering techniques to cluster U.S. states and territories with respect to number of confirmed cases, number of recovered patients, and number of deaths. The resulting clusters of states and territories will prove useful to various government, healthcare, and private sector stakeholders as the clusters can help prioritize different needs for different regions [1]. We will showcase visualizations that depict confirmed cases, recovered cases, and deaths over time. The visualizations and clusters that resulted from from study can identify resource or policy needs of various clusters (including ventilators, testing kits, masks, and lock down measures) to mitigate the spread and threat of COVID-19. We will discuss analytical methods and algorithms implemented in Python as well as R, with a focus on principal component analysis (PCA). Presenting our research in a mini-symposium format will allow various stakeholders in the public and private sectors, as well as academia, to view clusters of U.S. regions and make appropriate policy decisions [2].

References

[1] S. Kumar. Monitoring Novel Corona Virus (COVID-19) Infections in India by Cluster Analysis. *Annals of Data Science*, 1(9), 2020.

[2] V. Zarikas, S. G. Poulopoulos, Z. Gareiou, E. Zervas. Clustering analysis of countries using the COVID-19 cases dataset. *Data in Brief*, 31, 2020.

A flavor of plasmonics in the time domain

D. Margetis

Abstract. In this talk, I will discuss aspects of the propagation of electric-field pulses generated by localized sources on homogeneous and isotropic, translation invariant two-dimensional (2D) materials such as monolayer graphene via linear response theory. To this end, I will introduce a spatially nonlocal evolution law for the 2D electron charge density in the quasi-electrostatic approach. In this context, I will show that the related propagator, or Green's function, in spacetime can exhibit self similarity, and describe related classical solutions for the electric field.

Peridynamic model for shape memory alloys

S. Kantor, P. Zdziebko, J. Roemer, J. Bryla, A. Martowicz

Abstract. Peridynamics offers unique capabilities for the computational tools used to simulate behavior of solid components [**?**]. The above mentioned modeling approach provides means for convenient handling various types of model nonlinearities, including material and geometric properties as well as boundary conditions. An integral based formulation of the governing equation assumes an extended region for the force interactions, i.e., the so-called long-range interactions, considered within the body of the nonlocally modeled solid component. The authors of the present work make use of the advantages of peridynamics and propose a nonlocal formulation for the model of shape memory alloys (SMA) [2],[3]. In particular, numerical aspects of the elaborated model are discussed in details to confirm its usability. The peridynamic model is applied to simulate phase transformations in SMA originating from the phenomenon of superelasticity. The phenomenological model is created using the concept of Gibbs free energy and thermoelasticity [4].
The authors acknowledge the project Mechanisms of stability loss in high-speed foil bearings – modeling and experimental validation of thermomechanical couplings, no. OPUS 2017/27/B/ST8/01822 financed by the National Science Center, Poland.

References

[1] S. A. Silling. Reformulation of elasticity theory for discontinuities and long-range forces. *Journal of the Mechanics and Physics of Solids*, 48, 2000, pp. 175-209.

[2] A. Martowicz, J. Bryla, W.J. Staszewski, M. Ruzzene, T. Uhl. Nonlocal elasticity in shape memory alloys modeled using peridynamics for solving dynamic problems. *Nonlinear Dynamics*, 97(3) 2019, pp. 1911-1935.

[3] A. Martowicz, S. Kantor, J. Pawlik, J. Bryla, J. Roemer. Dynamics assessment of mechanically induced solid phase transitions in shape memory alloys via nonlocal thermomechanical coupling. In: *J. Awrejcewicz, M. Kazmierczak, J. Mrozowski [eds.]: Theoretical approaches in non-linear dynamical systems. 15th International Conference Dynamical Systems Theory and Applications, Lodz, Poland, 2-5 December, 2019*, pp. 315-324.

[4] D. C. Lagoudas, Z. C. Bo, M. A. Qidwai. A unified thermodynamic constitutive model for SMA and finite element analysis of active metal matrix composites. *Mechanics of Composite Materials and Structures*, 3(2), 1996, pp. 153-179.

Methodology of time-lapse elastic full-waveform inversion for VTI media

Y. Liu, Y. Tsvankin

Abstract. Time-lapse full-waveform inversion (FWI) can provide high-resolution information about the variations of reservoir properties during hydrocarbon production and CO2 injection. However, most existing time-lapse FWI methods are limited to isotropic and, often, acoustic media. Here, we develop a time-lapse FWI methodology for elastic VTI (transversely isotropic with a vertical symmetry axis) media and evaluate several strategies for applying it to synthetic surface multicomponent and pressure wavefields from a 2D graben model. Using multicomponent data improves the resolution of the estimated temporal parameter variations, although the convergence of the inversion algorithm is hindered by the multimodality of the objective function. The time-lapse variations in the shear-wave vertical velocity Vs0 influence the estimated changes in the other VTI parameters, especially in the P-wave normal-moveout velocity. Application of conventional isotropic FWI to time-lapse data from typical VTI models leads to large errors in the inverted temporal variations of all parameters. Overall, our work demonstrates the importance of taking elasticity (in particular, the velocity Vs0) and anisotropy into account in time-lapse FWI algorithms.

Two-step velocity inversion using trans-dimensional tomography and elastic FWI

Reetam Biswas, Adrien F. Arnulf, Mrinal K. Sen

Abstract. Full Waveform Inversion (FWI) has become a powerful tool to generate high-resolution subsurface velocity models. FWI attempts to solve a non-linear and non-unique inverse problem, and is traditionally based on a local optimization technique. As a result, it can easily get stuck in a local minimum. To mitigate this deleterious effect, FWI requires a good starting model, which should be close enough to the optimal model to properly converge to the global minimum. Here, we investigate a two-step approach for solving this problem. In the first step, we generate a starting model for FWI, that includes the low-wavenumber information, from first-arrival traveltime tomography of downward extrapolated streamer data. We solve the tomography problem using a trans-dimensional approach, based on a Bayesian framework. The number of model parameters is treated as a variable, similar to the P-wave velocity information. We use an adaptive cloud of nuclei points and Voronoi cells to represent our 2D velocity model. We use Reversible Jump Markov Chain Monte Carlo (RJMCMC) to sample models from a variable dimensional model space and obtain an optimum starting model for local elastic FWI. We also estimate uncertainty in our tomography derived model. We solve for the Eikonal equation using a shortest path method for ray tracing in tomography and we solve the elastic wave equation using a time-domain finite-difference method in FWI. To compute the gradient we used the adjoint method. We demonstrate our algorithm on a real 2-D seismic streamer dataset from Axial Seamount, which is the most volcanically active site of the northeastern Pacific. We ran 17 Markov chains with different starting number of nuclei and convergence for all chains was attained in about 1000 iterations. Marginal posterior density plots of velocity models demonstrate uncertainty in the obtained starting velocity models. We then ran a local elastic FWI using the combined result from all chains.

Longest Path Transversals and Gallai Families

J. Long, K. Milans, A. Munaro

Abstract. A *longest path transveral* in a graph G is a set of vertices S such that every longest path in G contains a vertex in S. Let lpt(G) be the minimum size of a longest path transversal in G. Gallai asked whether lpt(G)= 1 when G is connected. The answer is no; the best known construction is due to Grünbaum (1973), giving a connected graph G with lpt(G)= 3. In 2014, Rautenbach and Sereni showed that lpt(G)$\leq \lceil \frac{n}{4} - \frac{n^{2/3}}{90} \rceil$ when G is an n-vertex connected graph. We show that lpt(G)$\leq O(n^{3/4})$ when G is an n-vertex connected graph. Our results also provide sublinear sets in G which intersect all maximum subdivisions of any fixed graph F.

A family of graphs is Gallai if every connected graph G in the family satisfies lpt(G)= 1. We present progress toward a characterization of the graphs H such that the H-free graphs form a Gallai family. We also show that lpt(G)= 1 when G is a sufficiently large k-connected graph with independence number at most $k + 2$.

Neural Network–Enhanced Two-Stage Hamiltonian Monte Carlo

S. Minkoff, G. Stuart, F. Pereira

Abstract. Seismic inverse problems suffer from many issues that lead to uncertainty about the estimated parameters. Bayesian seismic inversion allows us to quantify the uncertainty in the estimated solution without making limiting assumptions about the posterior distribution for the parameter of interest (in this case subsurface velocity). Bayes' Rule combines independent information (possibly well log data) before we have begun the inversion process (the prior distribution) and the information we glean from matching measured data (the likelihood function) to characterize the posterior distribution. Tens of thousands to millions of velocity models (samples) are tested to determine whether they should be included in the Markov chain which characterizes the posterior distribution, and many of these models are rejected in this process. Nonetheless each sample velocity is used as input for a solve of the wave equation in order to generate the data needed by the likelihood function. This process renders UQ computationally prohibitive. We describe using a two stage process to quickly reject unacceptable velocity proposals, and specifically the use of a neural network to more quickly evaluate velocity samples and the gradient of the likelihood function. We show that for some prototype example problems, the two-stage neural network can speed up the solution of the inverse problem by 80%. This cost savings includes the cost of generating training data and training the neural network.

Regression Analysis of Statewide COVID-19 Data in the U.S.
M. Parker, Q. Tang

Abstract. Pandemics can cause social, political, and economic turmoil that can interfere with the peoples' lives and everyday occupations. The COVID-19 pandemic is a virus spread from person to person through the release of respiratory substances generated by a cough or sneeze according to the Centers for Disease Control and Prevention (CDC) [1]. The virus's mode of transmission has inspired the creation of global social distancing laws and transitions to a form of virtual proceedings for many professional and educational settings. Researchers have been studying the COVID-19 pandemic in order to create models that predicts the total number of cases and deaths that caused by the virus. In this study, a multiple linear regression and nonlinear regression model was derived to predict the total number of COVID-19 deaths since January 2020 in daily increments for each state in the United States. Multiple linear regression and Nonlinear regression models developed in this study in R and Python and the data used to plot daily U.S. state data have been generated from the Johns Hopkins University's Github Repository. The performance of the linear regression model features a significant p-value of ¡2e-16 while the nonlinear regression holds a significant p-value of ¡0.001. This study will assist doctors and researchers in developing methods of mitigation to the spread of the COVID-19 pandemic. Based on the predictions received by the generated models, forecasting of COVID-19 deaths could be observed over various period of time.

References

[1] "How to Protect Yourself & Others." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html.

Machine learning the discriminant locus
M. Regan

Abstract. Parameterized systems of polynomial equations arise in many applications in science and engineering with the real solutions describing, for example, equilibria of a dynamical system, linkages satisfying design constraints, and scene reconstruction in computer vision. Since different parameter values can have a different number of real solutions, the parameter space is decomposed into regions whose boundary forms the real discriminant locus. In this talk, I will discuss a novel sampling method for multidimensional parameter spaces and how it is used in various machine learning algorithms to locate the real discriminant locus as a supervised classification problem, where the classes are the number of real solutions. Examples such at the Kuramoto model will be used to show the efficacy of the methods. Finally, an application to real parameter homotopy methods will be presented. This project is joint work with Edgar Bernal, Jonathan Hauenstein, Dhagash Mehta, and Tingting Tang.

Uniqueness of solutions of the KdV-hierarchy via Dubrovin-type flows
M. Lukić, G. Young

Abstract. We consider the Cauchy problem for the KdV hierarchy - a family of integrable PDEs with a Lax pair representation involving one-dimensional Schrödinger operators – under a local in time boundedness assumption on the solution. For reflectionless initial data, we prove that the solution stays reflectionless. For almost periodic initial data with absolutely continuous spectrum, we prove that under Craig-type conditions on the spectrum, Dirichlet data evolve according to a Lipschitz Dubrovin-type flow, so the solution is uniquely recovered by a trace formula. This applies to algebro-geometric (finite gap) solutions; more notably, we prove that it applies to small quasiperiodic initial data with analytic sampling functions and Diophantine frequency. This also gives a uniqueness result for the Cauchy problem on the line for periodic initial data, even in the absence of Craig-type conditions.

From the Peierls-Nabarro model to the equation of motion of the dislocation continuum
M. Patrizi, T. Sangsawang

Abstract. We consider a semi-linear integro-differential equation in dimension one associated to the half Laplacian whose solution represents the atom dislocation in a crystal. The equation comprises the evolutive version of the classical Peierls-Nabarro model. We show that for a large number of dislocations, the solution, properly rescaled, converges to the solution of a well known equation called by Head [1] "the equation of motion of the dislocation continuum". The limit equation is a model for the macroscopic crystal plasticity with density of dislocations. In particular, we recover the so called Orowan's law which states that dislocations move at a velocity proportional to the effective stress.

References

[1] A. K. Head, Dislocation group dynamics III. Similarity solutions of the continuum approximation, *Phil. Magazine*, 26, (1972), 65-72.

Symmetry properties of solutions of Hamiltonian system on Compact Convex Hypersurfaces in R^8
P. Zhang

Abstract. In this talk, We prove that when a Compact Convex Hypersurfaces carries exactly four geometrically distinct closed orbits, then all of them must be symmetric.

Peridynamic Polycrystalline Ice Model

M. Oterkus, W. Lu, M. Li, B. Vazic, E. Oterkus

Abstract. Arctic region has started being considered as an alternative shipping route due to its advantages such as being a shorter route. However, it so introduces additional challenges due to its harsh environment. For instance, ships must be designed to withstand ice loads if a collision between a ship and ice occurs. Although experimental studies can provide very useful information, full scale tests are very expensive for ice-structure interactions. Instead, computer simulations can be utilized as alternative option. However, modelling ice as a material has also its own challenges because its material behavior depends on many different factors such as applied-stress, strain-rate, temperature, grain-size, salinity, porosity and confining pressure. Moreover, microcracks occurring at the micro-scale may have significant influence on the macroscopic behavior. Therefore, a multi-scale methodology may also be necessary especially to capture the correct physics around the ice-structure interaction region. Within finite element framework, there are various techniques which are available for numerical analysis of ice-structure interaction problem including cohesive zone model (CZM) and extended finite element method (XFEM). Although these are powerful techniques, they have certain limitations. As an alternative, peridynamics [1] can be utilized. Peridynamics is a non-local continuum mechanics formulation which is very suitable for failure analysis of materials due its mathematical structure. Furthermore, due to its non-local character, it can capture the physical phenomena at multiple scales. Therefore, in this presentation, a new peridynamic polycrystalline ice model [2] will be presented to be used for ice-structure interaction analysis.

References

[1] Silling, S. A. Reformulation of elasticity theory for discontinuities and long-range forces. *Journal of the Mechanics and Physics of Solids*, 48(1), pp.175-209, 2000.
[2] Lu, W., Li, M., Vazic, B., Oterkus, S., Oterkus, E. and Wang, Q. Peridynamic modelling of fracture in polycrystalline ice. *Journal of Mechanics*, 36(2), pp.223-234, 2020.

Peridynamic Polycrystalline Ice Model

J. Popa, S. Minkoff, Y. Lou

Abstract. Physical and financial constraints can lead to gaps between receivers, motivating data reconstruction techniques to recover missing seismic data. We organize data into a multidimensional array or tensor and apply a low-rank model for completion. We improve the runtime of existing tensor singular value decomposition (tSVD) methods for data recovery by using the conjugate symmetry of the multidimensional Fourier transform. Furthermore, we find the optimal tensor orientation for reconstruction by relating tensor and matrix SVDs.

Peridynamic Polycrystalline Ice Model
Z. Qiao

Abstract. This talk will introduce integrable peakon and cuspon models. Those models include the well-known Camassa-Holm (CH), the Degasperis-Procesi (DP), and other new peakon equations recently developed. Some open problems will be addressed for discussion.

Long Time Dynamics for Combustion in Random Media
Y. Zhang, A. Zlatoš

Abstract. We study long time dynamics of combustive processes in random media, modeled by reaction-diffusion equations with random ignition reactions. One expects that under reasonable hypotheses on the randomness, large space-time scale dynamics of solutions to these equations is almost surely governed by a homogeneous Hamilton-Jacobi equation. While this was previously shown in one dimension as well as for radially symmetric reactions in several dimensions, we prove this phenomenon in the general non-isotropic multidimensional setting. Our results hold for reactions that are close to reactions with finite ranges of dependence (i.e., their values are independent at sufficiently distant points in space), and are based on proving existence of deterministic front (propagation) speeds in all directions for these reactions.

ALESQP: An Augmented Lagrangian Equality-constrained SQP Method for Function-space Optimization with General Constraints

D. Kouri, D. Ridzal, H. Antil

Abstract. Abstract. We present a new algorithm for infinite-dimensional optimization with general constraints, called ALESQP. In a nutshell, ALESQP is an aug- mented Lagrangian method that penalizes inequality constraints and solves equality-constrained nonlinear optimization subproblems at every iteration. The subproblems are solved using a matrix-free trust-region sequential quadratic programming (SQP) method [1] that takes advantage of iterative, i.e., inexact linear solvers and is suitable for PDE-constrained optimization and other large-scale applications. We analyze convergence of ALESQP under different assumptions. We show that strong accumulation points are stationary, i.e., in finite dimensions ALESQP converges to a stationary point. In infinite dimensions we establish that weak accumulation points are feasible in many practical situations. Under additional assumptions we show that weak accumulation points are stationary. In the context of optimal control problems, e.g., in PDE-constrained optimization, ALESQP provides a unified framework to efficiently handle general constraints on both the state variables and the control variables. A key algorithmic feature is a constraint decomposition strategy that allows ALESQP to exploit problem-specific variable scalings and inner products. We present several examples with state and control inequality constraints where ALESQP shows remarkable mesh-independent performance, requiring only a handful of outer (AL) iterations to meet constraint tolerances at the level of machine precision. At the same time, ALESQP uses the inner (SQP) loop economically, requiring only a few dozen SQP iterations in total.

References

[1] M. Heinkenschloss and D. Ridzal. A Matrix-Free Trust-Region SQP Method for Equality-Constrained Optimization, *SIAM Journal on Optimization*, 24(3):1507–1541, 2014.

Randomized approaches to accelerate MCMC algorithms for Bayesian Inverse Problems

A. Saibaba, P. Prasad, E. De Sturler, E. Miller, M. Kilmer

Abstract. Markov chain Monte Carlo (MCMC) approaches are traditionally used for uncertainty quantification in inverse problems where the physics of the underlying sensor modality is described by a partial differential equation (PDE). However, the use of MCMC algorithms is prohibitively expensive in applications where each log-likelihood evaluation may require hundreds to thousands of PDE solves corresponding to multiple sensors; i.e., spatially distributed sources and receivers perhaps operating at different frequencies or wavelengths depending on the precise application. In this talk, we show how to mitigate the computational cost of each log-likelihood evaluation by using several randomized techniques and embed these randomized approximations within MCMC algorithms. These MCMC algorithms are computationally efficient methods for quantifying the uncertainty associated with the reconstructed parameters. We demonstrate the accuracy and computational benefits of our proposed algorithms on a model application from diffuse optical tomography where we invert for the spatial distribution of optical absorption.

Overall equilibrium in the coupling of peridynamics and classical continuum mechanics

G. Ongaro, P. Seleson, U. Galvenetto, T. Ni, M. Zaccariotto

Abstract. Coupling peridynamics based computational tools with those using classical continuum mechanics can be very beneficial, because it can provide a means to generate a computational method that combines the efficiency of classical continuum mechanics with the capability to simulate crack propagation, typical of peridynamics. This talk presents an overlooked issue in this type of coupled computational methods: the lack of overall equilibrium. This can be the case even if the coupling strategy satisfies the usual numerical tests involving rigid body motions as well as uniform and linear strain distributions. We focus our investigation on the lack of overall equilibrium in an approach to couple peridynamics and classical continuum mechanics recently proposed by the authors. In our examples, the magnitude of the out-of-balance forces is a fraction of a per cent of the applied forces, but it cannot be assumed to be a numerical round-off error. We show analytically and numerically that the main reason for the existence of out-of-balance forces is a lack of balance between the local and nonlocal tractions at the coupling interface. This often results from the presence of a highly non-linear rate of change of displacements in the coupling zone.

Overall equilibrium in the coupling of peridynamics and classical continuum mechanics

Z. Shen

Abstract. We develop a new real-variable method for weighted L^p estimates. The method is applied to the study of weighted $W^{1,2}$ estimates in Lipschitz domains for weak solutions of second-order elliptic systems in divergence form with bounded measurable coefficients. It produces a necessary and sufficient condition, which depends on the weight function, for the weighted $W^{1,2}$ estimate to hold in a fixed Lipschitz domain with a given weight. Using this condition, for elliptic systems in Lipschitz domains with rapidly oscillating, periodic and VMO coefficients, we reduce the problem of weighted estimates to the case of constant coefficients.

Generating cognates for 6, 8, and 10-bar mechanisms

S. Sherman, J. Hauenstein, C. Wampler

Abstract. A coupler cognate of a planar linkage is a different mechanism that has the same coupler curve. Roberts showed that there are 3 four-bar mechanisms that trace out the same coupler curve [1]. Dijksman provided a list of cognates for six-bar mechanisms by way of intricate geometric drawings and without proof the list was complete [2],[3]. This talk will demonstrate how cognates can be easily understood and generated using kinematic equations. Then, we combine this with numerical algebraic geometry to give a method to produce a complete list of all coupler cognates for six-bar mechanisms. Examples on six-bar mechanisms will be shown to demonstrate the method as well as generating a cognate to eight and ten-bar mechanisms.

References

[1] Roberts, S. "On three-bar motion in plane space". *Proc. London Math. Soc.*, 7, pp. 14-23, 1875.

[2] Dijksman, E. "Six-bar cognates of watts form'. *J. Eng. Industry*, 93(1), pp. 183-190, 1971.

[3] Dijksman, E. "Six-bar cognates of a Stephenson mechanism". *J. Mechanisms*, 6(1), pp. 31-57, 1971.

Propagation direction for the bistable traveling front in a three species competition system

S.-L. Wu

Abstract. In bistable competition-diffusion models, the sign of the wave speed for the traveling waves has important biological significance since it can predict which species will eventually win the competition. To determine the sign of the bistable traveling front in a three species Lotka-Volterra competition-diffusion system, we first prove the existence and stability of the bistable traveling front. Based on the stability result and the comparison method, we give a range of the bistable wave speed. Then we establish some new criteria to determine the sign of the bistable wave speed. Our results provide more general sufficient conditions for the sign of wave speed to the bistable traveling front than the known literature.

Depicting Spectra of Quantum Trees via Orthogonal Polynomials: Rogue Eigenvalues

Z. Hess, S. Shipman

Abstract. We investigate the spectrum of Schrödinger operators on finite regular metric trees through a relation to orthogonal polynomials that provides a graphical perspective. The spectrum can be visualized as the intersection points of two objects in the plane - a spiral curve depending on the Schrödinger potential, and a set of curves depending on the branching factor, the diameter of the tree, and the Robin parameter. As the Robin vertex parameter tends to $-\infty$, a narrow cluster of finitely many eigenvalues tends to $-\infty$, while the eigenvalues above the cluster remain bounded from below. Certain "rogue" eigenvalues break away from this cluster and tend even faster toward $-\infty$. In addition, known results of Carlson [1],[2] and Solomyak [3],[4],[5] are cast in geometrically visualizable form. See a preprint of this work at [6].

References

[1] Robert Carlson. Hill's equation for a homogeneous tree. *Electronic J. of Diff. Eq.*, 1997(23):1-30, 1997.

[2] Robert Carlson. Nonclassical Sturm-Liouville problems and Schrödinger operators on radial trees. *Electronic J. of Diff. Eq.*, 2000(71):1–24, 2000.

[3] K. Naimark and M. Solomyak. Eigenvalue estimates for the weighted Laplacian on metric trees. *Proc. London Math. Soc.*, 3(80):690–724, 2000.

[4] Alexander V. Sobolev and Michael Solomyak. Schrödinger operators on homogeneous metric trees: spectrum in gaps. *Rev. Math. Phys.*, 14(5):421–467, 2002.

[5] Michael Solomyak. *Laplace and Schrödinger operators on regular metric trees: the discrete spectrum case*, pages 161–182. Birkhäuser Verlag, 2003.

[6] Zhaoxia W. Hess and Stephen P. Shipman. Spectra of Regular Quantum Trees: Rogue Eigenvalues and Dependence on Vertex Condition. arXiv:2006.12377 [math-ph].

Fano Resonance in in a periodic array of narrow slits in metal

J. Lin, S. Shipman, H. Zhang

Abstract. We investigate resonant scattering by a perfectly conducting slab with periodically arranged subwavelength slits, with two slits per period. There are two classes of resonances, corresponding to poles of a scattering problem. A sequence of resonances has an imaginary part that is nonzero and on the order of the width ϵ of the slits; these are associated with Fabry-Perot resonance. The focus of this study is another class of resonances induced by symmetry; they become real valued at normal incidence, when the Bloch wavenumber κ is zero. These are spectrally embedded eigenvalues corresponding to surface waves of the slab that lie within the radiation continuum. When $0 < |\kappa| 1$, the real embedded eigenvalues are perturbed into complex resonances. We prove that Fano-type anomalies occur for the transmission of energy through the slab, and we show that the field enhancement is of order $1/(\kappa\epsilon)$, which is stronger than Fabry-Perot resonance, which is merely order $1/\epsilon$. This work is published in [1].

References

[1] Junshan Lin, Stephen P. Shipman, and Hai Zhang. A Mathematical Theory for Fano Resonance in a Periodic Array of Narrow Slits. *SIAM J. Appl. Math.* 80(5) (2020) 2045–2070.

Symplectic non-squeezing for the KdV flow on the line

M. Ntekoume

Abstract. We prove that the KdV flow on the line cannot squeeze a ball in $H^{-\frac{1}{2}}(\mathbb{R})$ into a cylinder of lesser radius. This is a PDE analogue of Gromov's famous symplectic non-squeezing theorem for an infinite dimensional PDE in infinite volume.

Integrable dispersive PDE at low regularity

M. Ntekoume

Abstract. In this talk, we will discuss recent results in the intersection of dispersive PDE and completely integrable systems at low regularity, exploiting the Lax pair formulation.

Integrable dispersive PDE at low regularity
A. Drouot

Abstract. Interfaces between topological insulators (and their photonic analogs) support asymetric currents. The fundamental generators of conduction, called edge states, are well-understood in translation-invariant settings. However they lack a mathematical framework in the presence of impurities.

I will introduce a novel concept, distorted edge states, and explain how these emerge in perturbed settings.

Geometry of Geometric Rank
R. Geng

Abstract. Geometric rank of tripartite tensors was introduced in [1]. In this talk I will present J.M. Landsberg and my recent study of geometric rank. I will introduce some properties to describe the varieties of tensors whose geometric ranks are at most any given number. I will give explicit geometric description of those varieties for $3 \times 3 \times 3$ tensors. The computation of geometric ranks of some specific tensors will be showed.

References

[1] Kopparty S, Moshkovitz G, Zuiddam J. Geometric rank of tensors and subrank of matrix multiplication[J]. arXiv preprint arXiv:2002.09472, 2020.

Geometry of Geometric Rank
P. Yu

Abstract. Abstract. Chemists and biologists often assume that steady states are discrete. Mathematically, it was believed that a weakly reversible mass-action system has at most finitely many positive steady states within each positive stoichiometric class. We constructed examples that demonstrated otherwise. More interestingly, our method explicitly links the differential equations with the structure of the reaction network. (Joint work with Balázs Boros and Gheorghe Craciun.)

A simple and effective method for low-rank completion for the shared response model in fMRI experiment design
N. Tran

Abstract. Low-rank matrix completion is a typical instance of the general problem of learning an algebraic variety from data. This talk presents a new low-rank matrix completion challenge stemming from the shared response model in the analysis fMRI data. In this application, the matrix has a special block structure dictated by a bipartite graph, which we exploit to give a simple, fast and provably optimal algorithm to learn the parameters of the shared response model under a sparse experiment design, where not all subjects are exposed to all stimuli. Our algorithm outperforms existing methods for low-rank matrix completion in simulations such as nuclear norm minimization. Our work opens up opportunities to run larger fMRI experiments on more subjects and stimuli on the same query budget, and raises interesting interesting theory questions on low-rank matrix completion, random graphs and experiment design. Joint work with Daniel Bernstein.

Dynamics of Large Boson Systems with Attractive Interaction and A Derivation of the Cubic Focusing NLS in $\mathbb{R}^3$
J. Chong

Abstract. The talk is based on a recent revision and improvement of an old work of mine (with the same title as the talk). We consider a system of N bosons where the particles experience a short range two-body interaction given by $N^{-1}v_N(x) = N^{3\beta-1}v(N^\beta x)$ where $v \in C\infty c(\mathbb{R})$, without a definite sign on v. We extend the results of M. Grillakis and M. Machedon, Comm. Math. Phys., 324, 601(2013) and E. Kuz, Differ. Integral Equ., 137, 1613(2015) regarding the second-order correction to the mean-field evolution of systems with repulsive interaction to systems with attractive interaction for $0 < \beta < \frac{1}{2}$. Our extension allows for a more general set of initial data which includes coherent states. We also provide both a derivation of the focusing nonlinear Schrödinger equation (NLS) in 3D from the many-body system and its rate of convergence toward mean-field for $0 < \beta < \frac{1}{3}$. In particular, we give two derivations of the focusing NLS, one based on the N-norm approximation proven in the work of P. T. Nam and M. Napiórkowski, Adv. Theor. Math. Phys., 21, 683(2017) and the other via a method introduced in P. Pickl, J. Stat. Phys., 140, 76(2010). Moreover, the talk will be delivered in English.

New tests for minimal border rank tensors

A. Pal

Abstract. We know if a collection of square matrices are simultaneously diagonalizable then they commute, however the converse does not hold. It has been a classical problem in linear algebra to classify the closure of the space of simultaneously diagonalizable matrices. This problem is closely related to a problem regarding tensors. In this talk, I will describe the problem, the relation to the classical question, and recent progress. This is joint work with JM Landsberg.

New tests for minimal border rank tensors

P. Plucinsky

Abstract. Shape-morphing finds widespread utility, from the deployment of small stents and large solar sails to actuation and propulsion in soft robotics. Origami structures provide a template for shape-morphing, but rules for designing and folding the structures are challenging to integrate into a broad and versatile design tool. Here, we address this challenge in the context of rigidly and flat-foldable quadrilateral mesh origami (RFFQM). First, we explicitly characterize the designs and deformations of all possible RFFQM [1]. Our key idea is a rigidity theorem that characterizes compatible crease patterns surrounding a single panel and enables us to march from panel to panel to compute the pattern and its corresponding deformations explicitly. The marching procedure is computationally efficient. So we also employ it in an inverse design framework to approximate a general surface by this family of origami [2]. The structures produced by our framework are "deployable": they can be easily manufactured on a flat reference sheet, deployed to their target state by a controlled folding motion, then to a compact folded state in applications involving storage and portability. We demonstrate the accuracy, versatility and efficiency of our framework through a rich series of examples.

References

[1] F. Feng, X. Dang, R. D. James, and P. Plucinsky. The designs and deformation of rigidly and flat-foldable quadrilateral mesh origami. *Journal of the Mechanics and Physics of Solids*, 142, 2020.

[2] F. Feng, X. Dang, P. Plucinsky, R. D. James, H. Duan, J. Wang, Inverse design for deployable origami structures that approximate a general surface. arXive.2008.02349, 2020

Oriented Matroids and Combinatorial Neural Codes

A. Kunin, C. Lienkaemper, Z. Rosen

Abstract. A combinatorial neural code, i.e. a subset of the boolean lattice, is called convex if it describes the intersection patterns of a family of convex subsets of a Euclidean space - a famous example arises from the activity of hippocampal place cells, which encode an animal's location in its environment. Here we relate the emerging theory of convex neural codes to the established theory of oriented matroids. We show that the map taking an oriented matroid to the positive parts of its topes is a faithful functor. Furthermore, we adapt the oriented matroid ideal introduced by Novik, Postnikov, and Sturmfels [1] into a functor from oriented matroids to rings, and show that the resulting ring maps naturally to the neural ring [2] of the matroid's corresponding code. Next, by considering the covectors of oriented matroids, we establish several new results in the theory of convex codes. We give a complete characterization of codes which can be realized by convex polytopes: a code is polytope convex if and only if it is the image of a representable oriented matroid under the composition of the covector map with a morphism of codes. Furthermore, we show that many previously published examples of non-convex codes are not the image of any oriented matroid under such a composition of maps. We also construct a new family of non-convex codes which are the image of non-representable oriented matroids only. Lastly, using these constructions, we show that deciding whether a combinatorial code is convex is NP-hard.

References

[1] Isabella Novik, Alexander Postnikov, and Bernd Sturmfels. Syzygies of oriented matroids. *Duke Mathematical Journal*, 111(2):287–317, 2002.

[2] Carina Curto, Vladimir Itskov, Alan Veliz-Cuba, and Nora Youngs.

[3] he neural ring: an algebraic tool for analyzing the intrinsic structure of neural codes. *Bulletin of mathematical biology*, 75(9):1571–1611, 2013.

On the treatment of boundary conditions for bond-based peridynamic models

P. Diehl, S. Prudhomme

Abstract. In this talk, we propose two approaches to apply boundary conditions for bond-based peridynamic models. There has been in recent years a renewed interest in the class of so-called non-local models, which include peridynamic models, for the simulation of structural mechanics problems as an alternative approach to classical local continuum models. However, a major issue, which is often disregarded when dealing with this class of models, is concerned with the manner by which boundary conditions should be prescribed. Our point of view here is that classical boundary conditions, since applied on surfaces of solid bodies, are naturally associated with local models. The paper describes two methods to incorporate classical Dirichlet and Neumann boundary conditions into bond-based peridynamics. The first method consists in artificially extending the domain with a thin boundary layer over which the displacement field is required to behave as an odd function with respect to the boundary points. The second method resorts to the idea that peridynamic models and local models should be compatible in the limit that the so-called horizon vanishes. The approach consists then in decreasing the horizon from a constant value in the interior of the domain to zero at the boundary so that one can directly apply the classical boundary conditions. We present the continuous and discrete formulations of the two methods and assess their performance on several numerical experiments dealing with the simulation of a one-dimensional bar.

References

[1] Prudhomme, Serge, and Patrick Diehl. "On the treatment of boundary conditions for bond-based peridynamic models." arXiv preprint arXiv:2008.09725, 2020.

Predicting hemodynamics and perfusion deficits in chronic thromboembolic pulmonary hypertension

M. Colebank

Abstract. One-dimensional (1D) fluid dynamics models are able to predict network level hemodynamics at a fraction of the cost of traditional three-dimensional (3D) models. Under an assumption of axially dominated flow, the model consists of a mass conservation, momentum balance, and constitutive law equation, forming a hyperbolic system of partial differential equations (PDEs). The hyperbolic nature of the system naturally allows for the study of wave propagation, which is critical in understanding the development of peripheral artery disease and heart failure. For this reason, 1D models are a promising tool for studying how abnormalities (e.g., stenoses and vascular lesions) elevate wave reflections, alter shear stress, and increase pressure throughout a given cardiovascular circuit.

In this talk, we consider a multi-scale model of the pulmonary circulation, simulating pressure-flow dynamics in both the large arteries and the small arteries and arterioles. The former model is a system of nonlinear, hyperbolic PDEs which are solved in a reconstructed pulmonary arterial tree, obtained from computed tomography imaging data. The latter model, the structured tree model [1], is a linearized system of the aforementioned PDEs that reduces to the wave equation. In addition, we couple this multi-scale framework with two algebraic pressure loss terms, representing ring-like and web-like lesions that are common in chronic thromboembolic pulmonary hypertension (CTEPH), a rare but debilitating pulmonary vascular disease.

Several disease scenarios are simulated via the addition of the stenosis pressure loss models and changes in vascular tissue parameters. Results show that 1D predictions can be projected into 3D space, allowing for both qualitative predictions of perfusion deficits as well as quantitative measures of flow heterogeneity (e.g., using the Kullback-Leibler divergence) in CTEPH. Wave intensity analysis reveals that mechanical obstructions to flow introduce large backward traveling waves, though these obstructions alone are not enough to elevate pressures to CTEPH levels. Model predictions in both the large and small arteries are shown and contrasted between disease scenarios. Lastly, we show how this model framework will be used in future patient-specific modeling studies.

References

[1] Olufsen M S, Peskin C S, Kim W Y, Pedersen E M, Nadim A & Larsen J. Numerical simulation and experimental validation of blood flow in arteries with structured-tree outflow conditions. *Ann Biomed Eng*, 28, 1281-1299, 2000.

Scalable Bayesian Inversion for Heterogeneous Permeability Field in 3D Poroelastic Groundwater Aquifer Models Using InSAR Surface Deformation Data

A. Alghmadi, M. Hesse, J. Chen, U. Villa, O. Ghattas

Abstract. Abstract. Uncertainty quantification (UQ) of groundwater (GW) aquifer parameters is critical for efficient GW resources management and, hence, for mitigating the global-scale problem of unsustainable GW extraction. These uncertainties stem from uncertainties in the data, model, and prior information on the parameters, along with the loss of information in the mapping from parameters to observables. Here we develop a Bayesian inversion framework that uses Interferometric Synthetic Aperture Radar (InSAR) surface deformation data to infer the laterally heterogeneous permeability of a transient linear poroelastic model of GW aquifers. The Bayesian solution of this inverse problem takes the form of a posterior probability density quantifying uncertainties in the aquifer permeability. Exploring the posterior distribution (e.g. finding the maximum a posteriori (MAP) point and sampling via classical Markov chain Monte Carlo (MCMC) methods) is computationally prohibitive due to the large dimension of the discretized permeability field and the expensive poroelasticity forward solves. However, in many partial differential equation (PDE)-based Bayesian inversion problems, the data are informative in only relatively few directions in parameter space and thus this intrinsic low dimensionality can be exploited to explore the posterior distribution scalably. For the poroelasticity problem, we prove this property theoretically for an idealized 1D problem and demonstrate it numerically for the 3D aquifer model.

We first determine the maximum a posteriori (MAP) point of this posterior distribution for problems with up to 1, 322, 067 state variable degrees of freedom (DOFs) and 67, 133 parameter DOFs. The scalability of our method to high parameter dimension is achieved through the use of adjoint-based derivatives, inexact Newton methods which exploit the aforementioned intrinsic low dimensionality, and a Matérn class sparse prior precision operator. Together, these guarantee that the MAP point is found at a cost, measured in number of forward/adjoint poroelasticity solves, that is independent of the parameter dimension. We then present a generalized preconditioned Crank–Nicolson (gpCN) MCMC method that exploits this intrinsic low dimensionality by using a low-rank based Laplace approximation of the posterior as a proposal. We build this proposal scalably using adjoint-based derivatives, and randomized algorithms to obtain a low-rank based approximation of the Hessian of the negative log posterior evaluated at the MAP point. We carry out the implementation using the FEniCS library for finite element discretization in space and the hIPPYlib library for state-of-the-art Bayesian and deterministic PDE-constrained inversion algorithms. The feasibility of our approach is demonstrated by applying this Bayesian inversion framework to a real GW aquifer test site in Nevada. We find that the use of InSAR data improves characterization of lateral aquifer heterogeneity considerably, compared to prior characterization, and the InSAR-based aquifer characterization recovers complex lateral displacement trends observed by independent daily GPS measurements. Additionally, InSAR data significantly reduces the uncertainty in the permeability field and chosen posterior predictive quantities of interest (QoI).

Components and principles of streaming principal components
A. Henriksen, R. Ward

Abstract. Big data is big. A consequence of this fact, of course, is that principal component analysis is itself one of the principal components of many algorithms that process large data sets. Unfortunately, it is much harder to choose how to implement principal component analysis than whether or not you should use it - especially when your data so large it has to be processed in a stream. In this presentation, we examine key approaches to streaming principal component analysis: methods based on Oja's subspace method [1] and methods based on random projections. We illustrate the advantages and disadvantages of both approaches, and address specific ways to overcome some of the traditional disadvantages of Oja-based streaming PCA. In particular, we discuss the advantages of AdaOja–a new adaptive form of Oja's subspace method that solves one of the biggest disadvantages of the algorithm: the need to choose a step-size scheme.

References

[1] Erkki Oja. Simplified neuron model as a principal component analyzer. *Journal of Mathematical Biology*, 15(3):267–273, Nov 1982.

A Riemann Difference Scheme for Shock Capturing in Discontinuous Finite Element Methods
T. Dzanic, W. Trojak, F. Witherden

Abstract. We will present a novel structure-preserving numerical scheme for discontinuous finite element approximations of nonlinear hyperbolic systems. The method can be understood as a generalization of the Lax-Friedrichs flux to a high-order staggered grid of flux and solution points and does not depend on any tunable parameters. Under a presented set of conditions, we will show that the method is conservative, invariant domain preserving, and satisfies the entropy condition. Numerical experiments on the Burgers' and Euler equations show the ability of the scheme to resolve discontinuities without introducing excessive spurious oscillations or dissipation.

Integrating Disease and Ecosystem Ecology Theory
A. Peace

Abstract. An obvious outcome of disease is death, and host death is integral to disease ecology theory. However, disease models typically assume dead hosts exit the system and disappear into a void. This assumption of a fully open system is rarely valid, because dead hosts can alter population dynamics and host-pathogen interactions through a variety of pathways. For example, dead hosts may serve as sources of pathogen propagules that can infect susceptible hosts potentially increasing transmission rates. Dead hosts also may directly reduce host population growth by interfering with access to limiting resources such as light or space. Here we extend disease ecology theory by explicitly accounting for the recycling of dead host biomass, and its impacts on pathogen transmission and host growth rates. To do this, we combine simple disease and ecosystem models, in order to investigate the feedbacks between disease dynamics and ecosystem processes. We use this model to investigate how host-pathogen interactions may be altered by allowing for feedbacks between the living and non-living pools of matter including two potential pathways though which dead host biomass may mediate host-pathogen dynamics; 1.) direct effects of dead hosts on pathogen transmission, and 2.) suppressive effects of dead host biomass on host growth rates.

Deep learning for 2D passive source detection in presence of complex cargo
W. Baines, P. Kuchment, J. Ragusa

Abstract. Methods for source detection in high noise environments are important for single-photon emission computed tomography (SPECT) medical imaging and especially crucial for homeland security applications, which is our main interest. In the latter case, one deals with passively detecting the presence of low emission nuclear sources with significant background noise (with Signal To Noise Ratio (SNR) 1% or less). In passive emission problems, direction sensitive detectors are needed, to match the dimensionalities of the image and the data. Collimation, used for that purpose in standard Anger - cameras, is not an option. Instead, Compton γ-cameras (and their analogs for other types of radiation) can be utilized. Backprojection methods suggested before by two of the authors and their collaborators enable detection in the presence of a random uniform background. In most practical applications, however, cargo packing in shipping containers and trucks creates regions of strong absorption and scattering, while leaving some streaming gaps open. In such cases backprojection methods prove ineffective and lose their detection ability. Nonetheless, visual perception of the backprojection pictures suggested that some indications of presence of a source might still be in the data. To learn such features (if they do exist), a deep neural network approach is implemented in 2D, which indeed exhibits higher sensitivity and specificity than the backprojection techniques in a low scattering case and works well when presence of complex cargo makes backprojection fail completely.

A hybrid-variable discretization method for hyperbolic problems
X. Zeng, H. Mahmudal

Abstract. In this work, we extend a recently developed superconvergent hybrid-variable (HV) discretization method [1],[2] to solve nonlinear hyperbolic conservation laws in one and two space dimensions. Particularly, the artificial viscosity approach is adopted to capture the strong discontinuities that frequently occurs in nonlinear conservation problems. To this end, our exploration begins with the investigation of using HV methods to solve the model advection-diffusion equation while confirming the universal superconvergence property; next, the previous analysis is utilized to construct artificial viscosities that efficiently suppress spurious oscillations.

References

[1] X. Zeng. A high-order hybrid finite difference-finite volume approach with application to inviscid compressible flow problems: A preliminary study. *Comput. Fluids*, 98, 2014.
[2] X. Zeng. Linear hybrid-variable methods for advection equations. *Adv. Comput. Math.*, 45, 2019.

Finite element methods for wave propagation in anisotropic acoustic metamaterials
J. Lee

Abstract. We consider finite element methods for time-transient wave propagation in anisotropic acoustic metamaterials. Extending the approaches in [1],[2] we transform the governing equations to a system of first order symmetric hyperbolic system with appropriate auxiliary variables. A stable finite element method for the system is proposed with the a priori error estimates, and numerical experiments will be presented.

References

References

[1] Jeonghun J. Lee. A mixed method for time-transient acoustic wave propagation in metamaterials. *Journal of Scientific Computing*, 84(1), 2020.
[2] C. Bellis, B. Lombard. Simulating transient wave phenomena in acoustic metamaterials using auxiliary fields. *Wave Motion*, 86, 2019.

The role of demographic and environmental stochasticity in a population model with a component Allee effect

T. Feng, H. Zhou, Y. Kang

Abstract. We study the effects of demographic and environmental stochasticity on a population model with a component Allee effect. Our theoretical results show the stochastic dynamics of the population under random fluctuations, including the stochastic persistent, the extinction, the existence of an ergodic stationary distribution, and the existence of a periodic solution. The numerical research also yielded some interesting results: (a) Both demographic and environmental stochasticity have potential to promote or inhibit the survival of the population. (b) In the weak Allee effect case, the demographic stochasticity from the attack rate plays a positive role in the survival of the population, while the demographic stochasticity from the handling rate as well as the environmental stochasticity play the opposite role. (c) In the strong Allee effect case, demographic and environmental stochasticity play a similar role in the survival of the population, and both are related to the initial population density: given a large initial population level, large demographic and environmental stochasticity can lead to population extinction; given a small initial population level, demographic and environmental stochasticity with appropriate intensity contribute to the viability of the population. (d) In the extinction case, demographic and environmental stochasticity can not change the population being extinct, but they can delay or advance the population being extinct.

Using Nonlocality to Predict the Rate of Material Failure

S. Silling

Abstract. All solid materials fail under sufficiently large stress. If a large mechanical loading is applied, the process of failure is not instantaneous, but evolves over time. In many engineering applications, it is important to understand this time evolution, which gives rise to rate effects in material strength. In this work, it is shown that a nonlocal model of mechanics can give insight into the amount of time it takes for a small crack to nucleate, which is the first step in the process of material failure. To study this, the formation of a crack under dynamic loading in a peridynamic material is investigated as an outcome of material instability. The material model is nonlinear elastic and has a non-convex strain energy density function. With this model, application of loads may take the material into a dynamically unstable regime. Within this regime, there may fail to be real-valued wave speeds, resulting in the exponential growth of small perturbations in displacement. But in peridynamics, unlike the local theory, the growth of these unstable waveforms can occur at a finite rate, rather than blowing up instantaneously. By accounting for the finiteness of the rate of growth of the various Fourier components in the initial data, we can determine a finite time to failure of such a system. The main result is that with a nonlocal continuum model, material instability can be used as a tool to reproduce realistic features of material failure

References

[1] S. A. Silling. Kinetics of failure in an elastic peridynamic material. *Journal of Peridynamics and Nonlocal Modeling*, https://doi.org/10.1007/s42102-020-00031-0, accepted.

New technqiues to approximate viscous stresses in Stokes flow
J. Gopalkrishnan, P. Lederer, J. Schöberl

Abstract. This talk will summarize the recent results in [1],[2] on approximating fluid stresses using a mass conserving mixed formulation. The punchline is that a non-standard Sobolev space H(curl div), defined by requiring the second derivative curl o div to be in a dual space, is suited for approximating viscous stresses in Stokes flow. We will show that finite elements for this space can be made using matrix-valued functions whose normal-tangential components are continuous at the element interfaces. This stress space pairs well with H(div)-conforming approximations of the fluid velocity. We will show that structure-preservation properties like mass conservation and pressure robustness are immediate in the newly introduced formulations.

References

[1] J. Gopalakrishnan, P. Lederer, and J. Schöberl, A mass conserving mixed stress formulation for Stokes flow with weakly imposed stress symmetry, *SIAM J Numer Anal*, 58 (2020), pp. 706–732.
[2] J. Gopalakrishnan, P. Lederer, and J. Schöberl, A mass conserving mixed stress formulation for the Stokes equations, *IMA J. Numer. Anal.*, 40 (2020), pp. 1838–1874.

Critical points of discrete periodic operators
F. Sotille, M. Faust

Abstract. It is believed that the dispersion relation of a Schrödinger operator with a periodic potential has non-degenerate critical points. In work with Kuchment and Do [1], we considered this for discrete operators on a periodic graph Γ, for then the dispersion relation is an algebraic hypersurface. A consequence is a dichotomy; either almost all parameters have all critical points non-degenerate or almost all parameters give degenerate critical points, and we showed how tools from computational algebraic geometry may be used to study the dispersion relation. With Matthew Faust, we use ideas from combinatorial algebraic geometry to give an upper bound for the number of critical points at generic parameters, and also a criterion for when that bound is obtained. The dispersion relation has a natural compactification in a toric variety, and the criterion concerns the smoothness of the dispersion relation at toric infinity.

References

[1] Ngoc T. Do, Peter Kuchment, and Frank Sottile. Generic properties of dispersion relations for discrete periodic operators. *Journal of Mathematical Physics*, to appear, 2020.

Orthogonal rational functions with real poles, root asymptotics, and GMP matrices

B. Eichinger, M. Lukič, G. Young

Abstract. There is a vast theory of the asymptotic behavior of orthogonal polynomials with respect to a measure on R and its applications to Jacobi matrices. That theory has an obvious affine invariance and a very special role for ∞. We extend aspects of this theory in the setting of rational functions with poles on $\overline{\mathbb{R}} = \mathbb{R} \cup \{\infty\}$, obtaining a formulation which allows multiple poles and proving an invariance with respect to $\mathbb{R}$-preserving Möbius transformations. We obtain a characterization of Stahl–Totik regularity of a GMP matrix in terms of its matrix elements; as an application, we provide an alternative proof of a theorem about a Cesáro–Nevai property of regular Jacobi matrices on finite gap sets.

On explicit and numerical solutions for stochastic partial diferential equations: Fisher and Burger type equations

J. Huerta, T. Oraby, J. Palacio, E. Suazo

Abstract. We will introduce exact and numerical solutions to some stochastic Fisher and Burgers equations with variable coefficients. The solutions are found using a coupled system of deterministic Burgers equations and stochastic differential equations.

References

[1] Stephanie Flores, Elijah Hight, Everardo Olivares-Vargas, Tamer Oraby, Jose Palacio, Erwin Suazo, Jasang Yoon. Exact and numerical solution of stochastic Burgers equations with variable coefficients. *Discrete Continuous Dynamical Systems - S*, 2020, 13 (10) : 2735-2750.

FINITE ELEMENT METHODS FOR SURFACE STOKES EQUATIONS

A. Reusken

Abstract. In this presentation we consider the stationary surface Stokes equations and present an overview of different finite element techniques for discretization of these equations. Higher order variants of the surface finite element method and of the trace FEM are treated. Furthermore, a finite element method based on a stream function reformulation is discussed. Results of numerical experiments with these methods are presented and certain efficiency and accuracy issues are addressed. Results of rigorous error analyses of these methods are also briefly discussed.

References

[1] T. Jankuhn, M. A. Olshanskii, A. Reusken. Incompressible fluid problems on embedded surfaces: modeling and variational formulations. *Interfaces and Free Boundaries*, 20, 353–377, 2018.
[2] T. Jankuhn, M. A. Olshanskii, A. Reusken, A. Zhiliakov. Error analysis of higher order trace finite element methods for the surface Stokes equations. arXiv:2003.06972v1, 2020.
[3] P. Brandner, A. Reusken. Finite element error analysis of surface Stokes equations in stream function formulation. ESAIM: M2AN, DOI: https://doi.org/10.1051/m2an/2020044, 2020.

Dynamics of a heavy quantum tracer particle in a Bose gas

T. Chen

Abstract. We consider the dynamics of a heavy quantum tracer particle coupled to a non-relativistic boson field in $\mathbb{R}^3$. The pair interactions of the bosons are of mean-field type, with coupling strength proportional to $1/N$ where N is the expected particle number. Assuming that the mass of the tracer particle is proportional to N, we derive generalized Hartree equations in the limit where N tends to infinity. Moreover, we prove the global well-posedness of the associated Cauchy problem for sufficiently weak interaction potentials. This is joint work with Avy Soffer (Rutgers University), [1].

References

[1] T. Chen, A. Soffer. Mean field dynamics of a quantum tracer particle interacting with a boson gas. *Journal of Functional Analysis*, 276 (3), 971-1006, 2019.

Inf-sup stability of the trace $\mathbf{P}_2 - P_1$ Taylor–Hood elements for surface PDEs

M. Olshanskii, A. Ruesken, A. Zhiliakov

Abstract. We present a geometrically unfitted finite element method (FEM), known as trace FEM or cut FEM, for the numerical solution of the Stokes system posed on a closed smooth surface. A trace FEM based on standard Taylor–Hood (continuous $\mathbf{P}_2 - P_1$) bulk elements is proposed. A so-called volume normal derivative stabilization, known from the literature on trace FEM, is an essential ingredient of this method. The key result is an inf-sup stability of the trace $\mathbf{P}_2 - P_1$ finite element pair, with the stability constant uniformly bounded with respect to the discretization parameter and the position of the surface in the bulk mesh. Optimal order convergence of a consistent variant of the finite element method follows from this new stability result and interpolation properties of the trace FEM. Properties of the method are illustrated with numerical examples.

Existence and computation of exponentially localized Wannier functions for non-periodic insulators

A. Watson

Abstract. Wannier functions, spatially localized basis functions for the Fermi projection, are a fundamental tool in the study of materials electronic properties. Conditions guaranteeing existence of exponentially localized Wannier functions in one, two and three-dimensional crystalline insulators are now known rigorously. It is expected that, under appropriate assumptions, similar results will hold for non-periodic insulators e.g. crystalline insulators with local defects. So far, such results have only been proven in one dimension by Nenciu-Nenciu [1] (following Kivelson [2]). In this talk I will present rigorous proof of a generalization of Nenci-Nenciu's result to two dimensions and higher, where the situation is significantly more complex and new ideas are necessary [3]. I will also discuss ramifications of our result for numerical computation of Wannier functions. Joint work with Kevin Stubbs and Jianfeng Lu (Duke).

References

[1] A. Nenciu and G. Nenciu, The existence of generalised Wannier functions for one-dimensional systems, *Communications in Mathematical Physics*, 190(3), 1998.

[2] S. Kivelson, Wannier functions in one-dimensional disordered systems: Application to fractionally charged solutions, *Physical Review B*, 26(8), 1982.

[3] K. Stubbs, A. Watson, and J. Lu, Existence and computation of generalized Wannier functions for non-periodic systems in two dimensions and higher, arxiv.org/abs/2003.06676, 2020

Unsupervised data-guided uncertainty analysis in imaging and horizon tracking

A. Siahkoohi, G. Rissuti, M. Louboutin, F. Herrman

Abstract. Imaging typically is the first stage of a sequential workflow, and uncertainty quantification becomes more relevant when applied to subsequent tasks. We propose a Bayesian approach to horizon tracking uncertainty analysis, where we deploy a deep prior [1] instead of adhering to handcrafted priors. By passing samples from the posterior distribution obtained via stochastic gradient Langevin dynamics [2] to an automatic horizon tracker, we are able to incorporate the uncertainty on model parameters into horizon tracking.

References

[1] V. Lempitsky, A. Vedaldi, and D. Ulyanov. Deep Image Prior. *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 9446–9454, 2018.

[2] M. Welling and Y. W. Teh. Bayesian Learning via Stochastic Gradient Langevin Dynamics. *Proceedings of the 28th International Conference on Machine Learning (ICML)*, 681–688, 2011.

An annual model for Astragalus scaphoides and its parameterization

A. Laubmeier, R. Rebarber, B. Tenhumberg

Abstract. In this work, we explore the viability of a discrete model for the annual abundance of a flowering plant, *Astragalus scaphoides*, during a decades- long study. Building on prior models [1], we incorporate realistic survival rates for young plants with density-dependent competition and environmental drivers. We fit the model using abundances from multiple life stages and individual-level demographic data. Ultimately, we explore whether the model can be sustained by ignoring demographic information and only tracking large, flowering plants. Obtaining counts of only flowering plants is simpler, reducing the time and cost associated with long-term population monitoring. Although this is not always a viable strategy, we are interested in the conditions under which we can trade data richness for expediency. In preliminary tests, we compare results using reduced data and two different types of state estimates.

References

[1] B. Tenhumberg, E. E. Crone, S. Ramula, and A. J. Tyre. Time-lagged effects of weather on plant demography: Drought and Astragalus scaphoides. *Ecology*, 99(4), 2018.

Self-generating lower bounds for the Boltzmann equation
A. Tarfulea

Abstract. The Boltzmann equation arises in statistical physics and plasma dynamic. It models the space and velocity distribution of the particles in a diffuse gas. The particles collide with each other at microscopic scales, leading to a quadratic, nonlocal (in velocity), collision operator that behaves somewhat like a fractional Laplacian. In recent years there has been substantial progress on the regularity and continuation program for the Cauchy problem (see, for instance, [1]). Notably, a smooth and unique solution exists for as long as the so-called hydrodynamic quantities remain "under control": the mass, energy, and entropy densities must stay bounded above uniformly in space and the mass density must stay bounded below uniformly in space. The last condition is crucial for smoothing since it gives the collision operator elliptic properties in certain velocity directions.

In this work, we show that the solution to the Boltzmann equation (even starting from initial data that contains large regions of vacuum) instantaneously fill space. That is, the gas diffuses and spreads positive mass to every space and velocity coordinate at any positive times. We obtain this result dynamically through barrier arguments for moving mass through space and a De Giorgi type iteration for spreading mass to arbitrary velocities. A consequence is that the above continuation criterion can now be weakened; it is no longer necessary to assume that the mass density is bounded from below (or, as a side result, that the entropy density is bounded from above) for continuation of smooth solutions; those bounds are now available a priori.

Joint work with Christopher Henderson and Stanley Snelson.

References

[1] C. Imbert and L. Silvestre. Global regularity estimates for the Boltzmann equation without cut-off, Preprint, arXiv:1909.12729, 2019.

Elliptic equations with degenerate weights
A. Kh.Balci

Abstract. In recent years Calderón-Zygmund type regularity estimates were established for solutions of different classes of linear weighed degenerate elliptic problems with matrix coefficients. For non-linear setting

$$-\mathrm{div}(|M\nabla u|^{p-2}\mathbb{M}^2\nabla u) = -\mathrm{div}(|\mathbb{M}G|^{p-2}\mathbb{M}^2 G),$$

where $1 < p < \infty, \mathbb{M} : \Omega \to \mathbb{R}^{n\times n}_{\mathrm{sym}}$ is a symmetric, positive definite, matrix-valued weight and $G : \Omega \to \mathbb{R}^n$ is the given data, the results known till now do not allow degenerate weights (for example, $\mathbb{M}(x) := |x|^{-\epsilon}I$ with small ϵ). We establish new kind of condition on the weight $\mathbb{M}$: Instead of a BMO smallness condition for $\mathbb{M}$, we use a BMO smallness condition on its logarithm log $\mathbb{M}$, which is new even for the linear case. This allows us as well to include the weights $\mathbb{M}(x) := |x|^{\epsilon}I$ and $\mathbb{M}(x) := |x|^{-\epsilon}I$ for small $\epsilon > 0$ and get the local higher integrability of weak solutions.

The talk is based on joint work with Lars Diening, Raffaella Giova and Antonia Passarelli di Napoli.

References

[1] A. Kh.Balci, L. Diening, R. Giova, A. Passarelli di Napoli. Elliptic equations with degenerate weights. Arxiv, arXiv:2003.10380 , 2020

Necessary conditions for ACR in Reaction Networks

P. Escudero

Abstract. A biological system has absolute concentration robustness (ACR) for some molecular species if the concentration of this species does not vary among the different steady states that the network admits. In particular, this concentration is independent of the initial conditions. This interesting feature confers the system a highly desirable property in order to adapt to environmental conditions, which makes it useful in synthetic biology, for example. Some classes of networks with ACR have been described [**?**],[**?**], as well as some techniques to check a network for ACR. However, deciding upon ACR is a difficult problem in general. Motivated by this problem, we studied local and global notions of robustness on the set of (real positive) solutions of a system of polynomial equations [3], and in particular on the set of steady states of a reaction network. Algebraic geometry allowed us to provide a practical test on necessary conditions for ACR. Properties of real and complex algebraic varieties are necessary for the results, while the test ends up being a linear algebra computation. This is based on joint work with E. Feliu [3].

References

[1] G. Shinar and M. Feinberg. Structural sources of robustness in biochemical reaction networks. *Science*, 327(5971):1389–1391, 2010.

[2] R. L. Karp, M. Pérez Millán, T. Dasgupta, A. Dickenstein, and J. Gunawardena. Complex-linear invariants of biochemical networks. *J. Theoret. Biol.*, 311:130–138, 2012.

[3] B. Pascual-Escudero, E. Feliu. Local and global robustness in systems of polynomial equations. arXiv:2005.08796

Flexibility in planar graphs

B. Lidický, T. Masařík,K. Murphy, S. Zerbib

Abstract. Recently, Dvok, Norin, and Postle introduced flexibility as an extension of list coloring on graphs [1]. In this new setting, each vertex v in some subset of $V(G)$ has a request for a certain color $r(v)$ in its list of colors $L(v)$. The goal is to find an L coloring satisfying many, but not necessarily all, of the requests.

The main studied question is whether there exists a universal constant $\epsilon > 0$ such that any graph G in some graph class $\mathcal{C}$ satisfies at least proportion of the requests. More formally, for $k > 0$ the goal is to prove that for any graph $G \in \mathcal{C}$ on vertex set V, with any list assignment L of size k for each vertex, and for every $R \subset V$ and a request vector $(r(v) : v \in R, r(v) \in L(v))$, there exists an L-coloring of G satisfying at least $\epsilon|R|$ requests. If this is true, then C is called *ϵ-flexible for lists of size k*.

In this talk, we explain the notion, describe methods for obtaining results and survey the known results.

References

[1] Zdeněk Dvořák, Sergey Norin, and Luke Postle. List coloring with requests, *Journal of Graph Theory*, 92,191206, 2019.

Bacterial Cell-Shape Modulation and Induced Population Dynamics of Synthetic Microbial Consortia

B. Karamched, J. Winkle, M. Bennett, W. Ott, K. Josić

Abstract. Rod-shaped bacteria exhibit remarkable regularity in their cell shape while also demonstrating notable plasticity in these characteristics when subjected to environmental changes. However, spatiotemporal cell shape uniformity and its selective advantage to bacteria are not well understood. Likewise, cell shape mutations and the mechanisms of cooperation in bacterial consortia of different shapes have received limited attention. Here, we presenta lattice model of synthetic microbial consortia in microfluidic traps where cell aspect ratio is dynamically modulated in a simulated genetic circuit via quorum sensing signaling. Our results show that population dynamics in bacterial consortia can be altered by asserting an aspect ratio change in one of the strains. Experimental synthetic biology often relies on distributed functionality among distinct engineered strains whose spatial separation or relative population fraction is critical to maintaining desired functionality. Our simulations demonstrate controllable alteration of a population's strain fraction in a microfluidic trap while using a purely mechanical interaction. When strains are coupled through quorum sensing, we show how interesting spatiotemporal dynamics emerge, such as spatial population oscillations. The ability to control a bacterial strain's population fraction will better understanding of the role of cell shape in spatial orderings exhibited by microbial consortia in natural and synthetic settings. We also discuss a more detailed agent-based model that confirms predictions of our simple lattice model.

Accurate upper bound for the maximum speed of propagation in the Riemann problem

B. Popov

Abstract. We will present a derivation of a guaranteed upper bound for the maximum speed of propagation in the Riemann solution for the Shallow water system and the Euler system of gas dynamics with the co-volume equation of state. The novelty is that an accurate upper bound on the speed is given explicitly, hence no iterative solver is needed to compute a good estimate for the the maximum speed. The bound for the Euler system of gas dynamics is guaranteed for gasses with a heat capacity ratio γ in the physical range, $1 < \gamma \leq \frac{5}{3}$. This is a joint work with Jean-Luc Guermond.

Identifying low rank structure preserved by nonlinear transformations

C. Curto, C. Lienkaemper, J. Londoño-Álvarez, R. Santa Cruz

Abstract. Measurements of biological data are often distorted by unknown nonlinear transformations. Often, these transformations are monotone, preserving the ordering of elements. While these nonlinearities make detecting low-dimensional structure using traditional matrix analysis impossible, we can recover some of this hidden structure using combinatorial and topological techniques. In this talk, we explore the monotone rank of a matrix A, which we define as the smallest value of r such that there is a rank r matrix B and monotone functions $f_1, ..., f_n$ such that $A_{ij} = f_j(B_{ij})$. We give several methods for calculating lower bounds on monotone rank. To derive these bounds, we decompose matrices as pairs of point configurations, and use the order of matrix entries to extract geometric information about these point configurations.

A fluid-structure interaction model of the human heart

C. Puelz, M. Davey, M. Smith, D. Wells, S. Rossi, B. Griffith

Abstract. This talk will discuss the on-going development of a fluid-structure interaction model for the human heart. This model includes all four chambers, valves, great vessels, and blood. Numerical discretization and simulations are performed with the immersed boundary method. In this approach, the blood is approximated by the Navier-Stokes equations and handled in Eulerian form. The tissues are described as hyperelastic and anisotropic solids and are treated in Lagrangian form. Tissue displacements and forces are calculated on volumetric finite element meshes, and the Navier-Stokes equations are numerically approximated on a locally-refined Cartesian grid. Results for an entire cardiac cycle will be presented.

A simple CutFEM implementation with applications to shallow water waves and fluid-structure interaction

C. Kees, J. Collins, A. Zhang

Abstract. Simulating wave attenuation by natural and engineered coastal structures with complex and deforming geometry, such as vegetation [1], is an increasingly important application of coastal hydrodynamic models. Geometry for structures of interest can come in the form of CAD, LIDAR, and photogrammetry data, which are problematic input sources for automated, boundary-conforming mesh generation. While a range of immersed and embedded interface methods avoiding boundary-conforming mesh generation have been advanced in recent decades, attainment of optimal accuracy or practical implementation of the methods have proven difficult. In this work, we present an alternative implementation of the CutFEM approach [2] for embedded solid boundaries, which was analyzed and verified to achieve $O(h^2)$ accuracy for smooth solutions of the Navier-Stokes equation using linear polynomials on tetrahedra in [3]. Our implementation does not explicitly cut mesh cells or use special quadrature rules. Instead, we employ polynomial approximations of the Dirac and Heaviside functions appearing in the CutFEM formulation following the equivalent polynomials construction from [4], which have the suprising property that FEM integrals on cut cells and cut cell boundaries is exact to machine precision. This approach yields a practical implementation for embedding solid obstacles in unstructured FEM for a range of 2D and 3D nonlinear wave models.

References

[1] S. A. Mattis, C. E. Kees, M. V. Wei, A. Dimakopoulos, and C. N. Dawson. Computational model for wave attenuation by flexible vegetation. *ASCE Journal of Waterway, Port, Coastal, Ocean Engineering*, 145(1), 2019.

[2] E. Burman, S. Claus, M. G. Larson, and A. Massing, CutFEM: Discretizing geometry and partial differential equations. *International Journal for Numerical Methods in Engineering*, 104(7), 2016.

[3] A. Massing, B. Schott, and W. A. Wall. A stabilized Nitsche cut finite element method for the Oseen problem. *Computer Methods in Applied Mechanics and Engineering*, 328, 2018.

[4] G. Ventura and E. Benvenuti. Equivalent polynomials for quadrature in Heaviside function enriched elements, *International Journal for Numerical Methods in Engineering*, 102(3-4), 2015.

Asymptotic dimension of minor-closed families and beyond
C.-H. Liu

Abstract. The asymptotic dimension of metric spaces is an important notion in geometric group theory. The metric spaces considered in this talk are the ones whose underlying spaces are the vertex-sets of (edge-)weighted graphs and whose metrics are the distance functions in weighted graphs. A standard compactness argument shows that it suffices to consider the asymptotic dimension of classes of finite weighted graphs. We prove that the asymptotic dimension of any minor-closed family of weighted graphs, any class of weighted graphs of bounded tree-width, and any class of graphs of bounded layered tree-width are at most 2, 1, and 2, respectively. The first result solves a question of Fujiwara and Papasoglu; the second and third results solve a number of questions of Bonamy, Bousquet, Esperet, Groenland, Pirot and Scott. These bounds for asymptotic dimension are optimal and generalize and improve some results in the literature, including results for Riemannian surfaces and Cayley graphs of groups with a forbidden minor.

STRUCTURE PROBING NEURAL NETWORK DEFLATION
Y. Gu, C. Wang, H. Yang

Abstract. Deep learning is a powerful tool for solving nonlinear differential equations, but usually, only the solution corresponding to the flattest local minimizer can be found due to the implicit regularization of stochastic gradient descent. This paper proposes Structure Probing Neural Network Deflation (SP-NND) to make deep learning capable of identifying multiple solutions that are ubiquitous and important in nonlinear physical models. First, we introduce deflation operators built with known solutions to make known solutions no longer local minimizers of the optimization energy landscape. Second, to facilitate the convergence to the desired local minimizer, a structure probing technique is proposed to obtain an initial guess close to the desired local minimizer. Together with neural network structures carefully designed in this paper, the new regularized optimization can converge to new solutions efficiently. Due to the mesh-free nature of deep learning, SP-NND is capable of solving high-dimensional problems on complicated domains with multiple solutions, while existing methods focus on merely one or two-dimensional regular domains and are more expensive than SP-NND in operation counts. Numerical experiments also demonstrate that SP-NND could find more solutions than exiting methods.

An energy-based discontinuous Galerkin method for semilinear wave equations

D. Appelo, T. Hagstrom, Q. Wang, L. Zhang

Abstract. We generalize the energy-based discontinuous Galerkin method proposed in [1] to second-order semilinear wave equations. A stability and convergence analysis is presented along with numerical experiments demonstrating optimal convergence for certain choices of the interelement fluxes. Applications to the sine-Gordon equation include simulations of breathers, kink, and anti-kink solutions.

References

[1] D. Appelo and T. Hagstrom. A new discontinuous Galerkin formulation for wave equations in second-order form. *SIAM J. Num. Anal.*, 53(6):2705?2726, 2015.

Propagation of singularities for the Dirac–Coulomb system

D. Baskin

Abstract. The Dirac equation describes the relativistic evolution of electrons and positrons. We consider the (time-dependent!) Dirac equation in three spatial dimensions coupled to a potential with Coulomb-type singularities. We describe how singularities of solutions propagate, leading to a diffractive effect arising from the singularities of the Coulomb potential.

Modeling particle beds using peridynamics

D. Bhattacharya, P. Jha, R. Lipton

Abstract. We model the interaction of particle beds with a plate due to gravity, where the particle shapes are allowed to be non-convex. The intra-particle force is modeled using peridynamics and inter-particle repulsive, friction, and damping forces are incorporated when the particles are close by. The collision between non-convex grains is detected dynamically to allow large displacements and breakage. The plate acts as a peridynamic material that settles under its own weight. This work is a part of a MURI project for predicting and controling the response of particulate systems through grain-scale engineering.

Data Driven Governing Equations Recovery with Deep Neural Networks

D. Xiu

Abstract. We present effective numerical algorithms for recovering unknown governing equations from measurement data. Several recovery strategies using deep neural networks (DNNs) are presented. We demonstrate that residual network (ResNet) is particularly suitable for equation discovery, as it can produce exact time integrator for numerical prediction. We also discuss extensions to learning systems with missing variables and learning partial differential equations.

Numerical homotopies from Khovanskii bases

M. Burr, F. Sottile, E. Walker

Abstract. Homotopies are useful numerical methods for solving systems of polynomial equations. Embedded toric degenerations are one source for homotopy algorithms. In particular, if a projective variety has a toric degeneration, then linear sections of that variety can be optimally computed using the polyhedral homotopy. Any variety whose coordinate ring has a finite Khovanskii basis is known to have a toric degeneration [1]. We provide embeddings for this Khovanskii toric degeneration to compute general linear sections of the variety. This is joint work with Michael Burr and Frank Sottile.

References

[1] D. Anderson. Okounkov bodies and toric degenerations. *Online Journal*, 356, 1183–1202, 2021.

Diffusion Tensor Imaging (DTI) Based Drug Diffusion Model in a Solid Tumor

E. Kara, A. Rahman, E. Aulisa, S. Ghosh

Abstract. Abstract. In this work, we study the effect of drug distribution on tumor cell death when the drug is internally injected in the tumorous tissue. We derive a full 3-dimensional inhomogeneous - anisotropic diffusion model. To capture the anisotropic nature of the diffusion process in the model, we use an MRI data of a 35-year old patient diagnosed with Glioblastoma multiform(GBM) which is the most common and most aggressive primary brain tumor. After preprocessing the data with a medical image processing software, we employ finite element method in MPI-based parallel setting to numerically simulate the full model and produce dose-response curves. We then illustrate the apoptosis (cell death) fractions in the tumor region over the course of simulation and proposed several ways to improve the drug efficacy. Our model also allows us to visually examine the toxicity. Since the model is built directly on the top of a patient-specific data, we hope that this study will contribute to the individualized cancer treatment efforts from a computational bio-mechanics viewpoint [1].

References

[1] Erdi Kara, Aminur Rahman, Eugenio Aulisa, Souparno Ghosh, Tumor ablation due to inhomogeneous – anisotropic diffusion in generic 3-dimensional topologies, (Submitted:preliminary version https://arxiv.org/abs/1912.04993)

Hyperbolic relaxation technique for solving the dispersive Serre–Saint-Venant equations with topographyr

E. Tovar

Abstract. We propose a relaxation technique for solving the dispersive Serre–Saint-Venant equations (also known as the Serre equations or fully non-linear Boussinesq equations) that accounts for the full topography effects introduced in [1]. This is done by revisiting the techniques introduced in [2] and its dry-state compliant version from [3]. We then give a space/time approximation of the relaxed model using continuous finite elements and explicit time stepping. Finally, we illustrate the performance of the proposed method.

References

[1] Seabra-Santos, F., Renouard, D., Temperville, A. Numerical and experimental study of the transformation of a solitary wave over a shelf or isolated obstacle, *Journal of Fluid Mechanics*, 176, 117-134. 1987.

[2] Favrie, N., Gavrilyuk, S. A rapid numerical method for solving Serre-Green-Naghdi equations describing long free surface gravity waves. *Nonlinearity*, 30(7), 2017.

[3] Guermond, J-L., Popov, B., Tovar, E., Kees, C. Robust explicit relaxation technique for solving the Green-Naghdi equations, *Journal of Computational Physics*, 399:108917, 2019.

3D multi-parameter visco-elastic full waveform inversion: methods and application for a near-surface case-study

R. Brossier, T. Irnaka, L. Métevier, Y. Pan, T. Bohlen

Abstract. F Full Waveform Inversion (FWI) [Virieux and Operto, 2009, Tromp, 2019] has become one of the most popular seismic inversion techniques amongst geophysical scales from the near-surface to the global Earth scale, through crustal exploration scales. FWI is a PDE-constrained non-linear inverse problem, which tries to update an earth subsurface model subjected to the wave-equation constraint. At the exploration scale, FWI is now an industrial standard in the velocity model building workflow, mostly under the acoustic approximation of the wave-equation. For shallow seismic scale, challenges of FWI rely on usually sparse acquisitions, weak signal to noise ratio, lack of high frequency, complex wave propagation with strong elastic effects and strong attenuation [Wittkamp et al., 2018, Köhn et al., 2018, Smith et al., 2018].

In this work, we implement and apply 3D visco-elastic FWI scheme in order to invert a unique nine-components seismic data. The experiment's target is the Ettlingen Line (EL), a defensive trench-line which was built by the German Troop in 1707, located at Rheinstetten, Germany. Led by Karlsruhe Institute of Technology, in collaboration with Univ. Grenoble Alpes, GFZ Potsdam, and ETH Zurich, a dense 3D seismic survey with three-component sources (128 shot points) and three-component receivers (888 receiver position), leading to 9-C data, has been acquired in 2017 on the target of 30×30 meters.

Our scheme relies, for the forward problem, on a spectral element implementation of the 3D viscoelastic wave-equation [Komatitsch et al., 2000, Trinh et al., 2019]. The inverse problem uses an adjoint-based approach to evaluate the gradient of the misfit function [Plessix, 2006], l-BFGS [Byrd et al., 1995] for the optimization scheme implemented in the SEISCOPE non-linear toolbox [Métivier and Brossier, 2016]. In addition to these rather standard schemes, specific functionalities have been implemented for the simultaneous reconstruction of P and S-wave velocity models on this dataset. First, because the dataset is strongly dominated by surface-waves (sensitive mostly to S-wave velocity), a first inversion step has been focused on V_S reconstruction with an assumed prior V_P/V_S ratio which is taken into account in the V_S update. In a second step, the two parameters are simultaneously and independently reconstructed, while satisfying prior bound constraints and non-linear V_P/V_S ratio constraint through a Dykstra algorithm [Boyle and Dykstra, 1986].

On the dataset preprocessing side, matching-filter stratgey has been implemented to account for the fact that the dataset has been acquired as six separated subsets (during five days) with uncontrolled 4-D effects. FWI has then been performed from low ([3-15]Hz) to high frequency ([3-65]Hz for the last frequency band) from a homogenous background, thanks to the rich low-frequency content. The final model makes it possible to identify the trench structure of the near-surface, as well as one additional trench-like shape previouly unknown. A sensitivity study on the multi-component interest has also been performed.

References

[Boyle and Dykstra, 1986] Boyle, J. P. and Dykstra, R. L. (1986). A method for finding projections onto the intersection of convex sets in Hilbert spaces. In Dykstra, R., Robertson, T., and Wright, F. T., editors, *Advances in Order Restricted Statistical Inference: Proceedings of the Symposium on Order Restricted Statistical Inference held in Iowa City, Iowa, September 11–13, 1985*, pages 28–47. Springer New York, New York, NY.

[Byrd et al., 1995] Byrd, R. H., Lu, P., and Nocedal, J. (1995). A limited memory algorithm for bound constrained optimization. *SIAM Journal on Scientific and Statistical Computing*, 16:1190–1208.

[Köhn et al., 2018] Köhn, D., Wilken, D., De Nil, D., Wunderlich, T., Rabbel, W., and Werther, L. (2018). 2d full waveform inversion applied to a strongly-dispersive love wave field dataset. In *80th EAGE Conference and Exhibition 2018*.

[Komatitsch et al., 2000] Komatitsch, D., Barnes, C., and Tromp, J. (2000). Simulation of anisotropic wave propagation based upon a spectral element method. *Geophysics*, 65(4):1251–

3D multi-parameter visco-elastic full waveform inversion: methods and application for a near-surface case-study

F. Wei

Abstract. A graph H is k-common if the number of monochromatic copies of H in a k-edge-coloring of K_n is asymptotically minimized by a random coloring. A consequence of the famous Sidorenko's conjecture is that every graph that is Sidorenko is also k-common. In fact, we showed that a graph is k-common for every k if and only if the graph is Sidorenko (which implies the graph is bipartite). However, it is not known whether there is a k-common non-bipartite graph for some fixed k. In this talk, I will talk about a recent result which shows that for every k, there is a connected non-bipartite k-common graph. This resolves a problem raised by Jagger, Št'ovíček and Thomason. This is a joint work with Daniel Král', Jon Noel, Sergey Norin, and Jan Volec.

References

[1] A. Bonito. On whether zoom workshops are a good alternative. *Online Journal*, 1(1), 2021.
[2] A. Bonito. Exhaustive list of prime numbers smaller than 10. *Acta Trivia*, 1(1), 2021.

On the treatment of full Dirichlet optimal control problems with divergence-free constraints

G. Bornia

Abstract. Full Dirichlet boundary optimal control problems pose challenges when the state equations contain divergence-free constraints. Such constraints impose integral compatibility conditions on the Dirichlet controls. We compare two different approaches for the treatment of these compatibility conditions: one that is based on the use of a scalar Lagrange multiplier, the other one that uses lifting functions to treat boundary controls as distributed controls. The differences between the two formulations are described. Numerical results are presented for systems with divergence-free conditions, such as the incompressible Navier-Stokes equations or the incompressible elasticity equations. These results are obtained by solving the finite element approximation of the fully coupled optimality systems arising from the first-order necessary conditions. Preliminary comparisons with implementations involving fractional norms are also discussed.

References

[1] E. Aulisa, G. Bornia, and S. Manservisi. Boundary Control Problems in Convective Heat Transfer with Lifting Function Approach and Multigrid Vanka-Type Solvers. *Communications in Computational Physics*, 18:621–649, 9 2015.

A space-time hybridizable discontinuous Galerkin method for linear free-surface waves

G. Jones, J. Lee, S. Rhebergen

Abstract. Free-surface wave problems are mathematically described by a set of partial differential equations that model the movement of the fluid coupled with free-surface boundary conditions. In order to simplify the problem, certain assumptions on the flow can be made so that a linear problem is obtained. In this talk, we present a discretization of the linear free-surface problem for irrotational flows using a space-time hybridizable discontinuous Galerkin method. We present an *a priori* error analysis and various numerical tests that illustrate our analysis.

A Few Thoughts on Deep Learning-Based Scientific Computing

H. Yang

Abstract. The remarkable success of deep learning in computer science has evinced potentially great applications of deep learning in computational and applied mathematics. Understanding the mathematical principles of deep learning is crucial to validating and advancing deep learning-based scientific computing. We present a few thoughts on the theoretical foundation of this topic and our methodology for designing efficient solutions of high-dimensional and highly nonlinear partial differential equations, mainly focusing on the approximation and optimization of deep neural networks.

Evolutionary equations with nonlocal time derivatives

H. Dong, D. Kim

Abstract. I will discuss some recent results about fractional parabolic equations as well as fractional wave equations with Caputo time derivatives.

References

[1] Dong, Hongjie; Kim, Doyoon. L_p-estimates for time fractional parabolic equations with coefficients measurable in time. *Adv. Math.* 345 (2019), 289–345.

[2] Dong, Hongjie; Kim, Doyoon. L_p-estimates for time fractional parabolic equations in divergence form with measurable coefficients. *J. Funct. Anal.* 278 (2020), no. 3, 108338, 66 pp.

[3] Dong, Hongjie; Kim, Doyoon. An approach for weighted mixed-norm estimates for parabolic equations with local and non-local time derivatives. arXiv:2003.08000.

Discrete-time population dynamics of spatially distributed semelparous two-sex populations
H. Thieme

Abstract. Spatially distributed populations with two sexes may face the problem that males and females concentrate in different parts of the habitat and mating and reproduction does not happen sufficiently often for the population to persist. For simplicity, to explore the impact of sex-dependent dispersal on population survival, we consider a discrete-time model for a semelparous population where individuals reproduce only once in their life-time, during a very short reproduction season. The dispersal of females and males is modeled by Feller kernels [1] and the mating by a homogeneous pair formation function [2]. The spectral radius of a homogeneous operator is established as basic reproduction number of the population, $_0$. If $0 < 1$, the extinction state is locally stable, and if $0 > 1$ the population shows various degrees of persistence that depend on the irreducibility properties of the dispersal kernels. Special cases exhibit how sex-biased dispersal affects the persistence of the population.

References

[1] H. R. Thieme. Discrete-time population dynamics on the state space of measures. *Math. Biosci. Engin.*, 17 (1168-1217), 2020.

[2] H. R. Thieme. From homogeneous eigenvalue problems to two-sex population dynamics. *J. Math. Biol.*, 75(783-804), 2017.

Strong solutions to a modified Michelson-Sivashinsky equation
H. Ibdah

Abstract. I will explain how to obtain a global well-posedness and regularity result of strong solutions to a slight modification of the so called Michelson- Sivashinsky equation [3]. Regularity is shown to persist by studying the propagation of moduli of continuity, as introduced by Kiselev, Nazarov, Volberg and Shterenberg [1],[2] to handle the critically dissipative SQG and Burgers equation. Namely, the Lipschitz constant of the solution is shown to be under control by constructing a modulus of continuity that must be obeyed by the solution. If time permits, I will briefly explain how one can extend such ideas to drift-diffusion systems with nonlocal source terms, such as the incompressible NSE and viscous Burgers-Hilbert equations.

References

[1] A. Kiselev, F. Nazarov, and R. Shterenberg. Blow up and regularity for fractal Burgers equation. *Dyn. Partial Differ. Equ.*, 5(3):211-240, 2008.

[2] A. Kiselev, F. Nazarov, and A. Volberg. Global well-posedness for the critical 2D dissipative quasigeostrophic equation. *Invent. Math.*, 167(3):445-453, 2007.

[3] H. Ibdah. Strong solutions to a modified michelson-sivashinsky equation. Preprint, arXiv:2001.03842 [math.AP], 2020.

Solving Forward and Inverse Problems with Model-Aware Autoencoders

H. Goh, S. Sherriffdeen, T. Bui-Thanh

Abstract. This work develops model-aware autoencoder networks as a new method for solving scientific forward and inverse problems. Autoencoders are unsupervised neural networks that are able to learn new representations of data through appropriately selected architecture and regularization. The resulting mappings to and from the latent representation can be used to encode and decode the data. In our work, we set the input and output space to be space of observations of physically-governed phenomena. Further, we enforce the latent space of the autoencoder to be the parameter space of a parameter we wish to invert for. In doing so, the decoder acts as a regularizer for learning the inverse map from the observations to the parameter of interest. The results suggest that regularization using a learned forward map or a numerical model of a forward map improves the learning of the inverse map.

An effective equation to study Bose gasses at all densities

I. Jauslin

Abstract. I will discuss an effective equation, which is used to study the ground state of the interacting Bose gas. The interactions induce many-body correlations in the system, which makes it very difficult to study, be it analytically or numerically. A very successful approach to solving this problem is Bogolubov theory, in which a series of approximations are made, after which the analysis reduces to an integrable system, which incorporates the many- body correlations. The effective equation I will discuss is arrived at by making a very different set of approximations, and ultimately reduces to a one-particle problem. But, whereas Bogolubov theory is accurate only for very small densities or for large densities, but not both at once, the effective equation coincides with the many-body Bose gas at both low and at high densities. I will show some theorems which make this statement more precise, and present numerical evidence that this effective equation is remarkably accurate for all densities, small, intermediate, and large. That is, the analytical and numerical evidence suggest that this effective equation can capture many-body correlations in a one-particle picture beyond what Bogolubov can accomplish. Thus, this effective equation gives an alternative approach to study the low density behavior of the Bose gas (about which there still are many important open questions). In addition, it opens an avenue to understand the physics of the Bose gas at intermediate densities, which, until now, were only accessible to Monte Carlo simulations.

References

[1] Eric A. Carlen, Ian Jauslin, Elliott H. Lieb, Analysis of a simple equation for the ground state energy of the Bose gas, *Pure and Applied Analysis*, in press, 2020.

Synchronization of Biochemical Oscillators
J. MacLaurin, P. Vilanova

Abstract. Biochemical systems are often characterized by low copy numbers, with discrete stochastic switching between different states. In this talk I focus on biochemical systems that exhibit oscillatory behaviors. I outline a method for understanding the phase of these discrete systems. I then study different mechanisms by which separate oscillators can synchronize their phases. I determine accurate asymptotic estimates for the Lyapunov exponent (indicating the expected rate of synchronization). The systems to be studied include pure jump-Markov stochastic processes (which are purely discrete) and piece-wise deterministic Markov processes (with both a "discrete" component, and a "continuous" component). Applications include the Morris-Lecar neural oscillator and glycolytic oscillations.

Asymptotic analysis of a coupled system of nonlocal equations with oscillatory coefficients
J. Scott, T. Mengesha

Abstract. We examine the asymptotic behavior of solutions to strongly coupled systems of integral equations with oscillatory coefficients. The system of equations is motivated by a peridynamic model of the deformation of heterogeneous media that additionally accounts for short-range forces. We consider the vanishing nonlocality limit on the same length scale as the heterogeneity and demonstrate that the system's effective behavior is characterized by a coupled system of local equations that are elliptic in the sense of Legendre-Hadamard. This effective system is characterized by a fourth-order tensor that shares properties with Cauchy elasticity tensors that appear in the classical equilibrium equations for linearized elasticity.

A Coupled Nonlinear Reaction-Diffusion, First-Order-Hyperbolic System Arising from a New Approach to Structured Population Dynamics

B. Veena Shankara Narayana Rao, M. Fujiwara, J. Walton

Abstract. The classical modeling paradigm for space-time dependent population dynamics with individual morphological structure is to treat the population spatial density as a function of (n+1)-dimensional space-time plus additional functional dependence upon one or more structure parameters that quantify the particular morphological structural attributes being considered. In typical applications, if there are m structural attributes, then the population density is a function of $m+n+1$ variables given as the solution of a system of nonlinear PDEs defined on $m+n+1$ dimensional Euclidean space. The computational burdened of such models rises dramatically with the number of structural attributes incorporated into the model. This talk discusses an approach to structured population dynamics whereby morphological structure independent variables are replaced by additional dependent variables defined as average structure value per individual per unit volume. In typical applications, this modeling paradigm gives rise to a PDE system over $(n+1)$-dimensional space-time with m additional equations governing structural parameter evolution rather than m additional independent variables. An example is given showing how this approach works for classical size structured population dynamics with advective-diffusive transport and nonlinear growth.

Efficient computation of Jacobian matrices for entropy stable summation-by-parts schemes

J. Chan, C. Taylor

Abstract. Entropy stable schemes replicate an entropy inequality at the semi-discrete level. These schemes rely on an algebraic summation-by-parts (SBP) structure and a technique referred to as flux differencing. We provide simple and efficient formulas for Jacobian matrices for the semi-discrete systems of ODEs produced by entropy stable discretizations. These formulas are derived based on the structure of flux differencing and derivatives of flux functions, which can be computed using automatic differentiation (AD). Numerical results demonstrate the efficiency and utility of these Jacobian formulas, which are then used in the context of two-derivative explicit time-stepping schemes and implicit time-stepping.

References

[1] Chan, Jesse, and Christina Taylor. "Explicit Jacobian matrix formulas for entropy stable summation-by-parts schemes." arXiv preprint arXiv:2006.07504 (2020).

[2] Chan, Jesse. "On discretely entropy conservative and entropy stable discontinuous Galerkin methods." *Journal of Computational Physics* 362 (2018): 346-374.

Tuza's Conjecture for random graphs

J. Kahn, J. Park

Abstract. A celebrated conjecture of Zs. Tuza says that in any (finite) graph, the minimum size of a cover of triangles by edges is at most twice the maximum size of a set of edge-disjoint triangles. Resolving a recent question of Bennett, Dudek, and Zerbib, we show that this is true for random graphs; more precisely:

$$\text{for any } p = p(n), P(G_{n,p} \text{ satisfies Tuza's Conjecture}) \to 1(\text{ as } n \to \infty).$$

Upwind Schemes and Neural Networks for Image Segmentation

J. Actor, D. Fuentes, B. Riviere

Abstract. Two common techniques for image segmentation – level set methods and convolutional neural networks (CNN) – rely on alternating convolutions with nonlinearities to describe image features: neural networks with mean-zero convolution kernels can be viewed as upwind finite difference discretizations of differential equations. Such a comparison provides a well–established framework for proving properties of CNNs, such as stability and approximation accuracy. We test this relationship by constructing a level set network, a CNN whose structure is determined by an upwind discretization of the level set equation, so that by construction, each layer of the network becomes a timestep in our discretization. In this sense, forward propagation through the CNN is equivalent to solving the level set equation. We train our network on abdomen CT data from the MICCAI LiTS 2017 Challenge, with the goal of performing image segmentation of the liver and hepatocellular carcinoma tumors. The level set network achieves comparable segmentation accuracy to solving the level set equation, while requiring substantially fewer parameters than conventional CNN architectures.

Limit and Spatio-temporal Dynamics of Interacting Markov Jump or diffusion Processes, with Applications to Ecology and Neurosciences
J. Touboul

Abstract. Most deterministic macroscopic models in mathematical biology are construed as summarizing, at a macroscopic scale, a multitude of intrinsically random events occurring at a microscopic scale. I will present our recent efforts to bridge the gap between these scales by demonstrating convergence to a mean-field limit for a general class of stochastic models. Applications range from interacting neurons in brain to ecological competitions between species, in the limit of large system size. I will show how stochastic coupling techniques can begeneralized to cover spatially extended interactions, and derive mean-field limits given by spatially extended non-Markovian process. The probability density of the limiting object is characterized by complex nonlocal integro-differential equations generalizing McKean-Vlasov Fokker-Planck equations. In the ecological context, these equations describe the evolution of the probability for a patch of land to be in a given state (the generalized Kolmogorov equations of the process, GKEs). We thus provide an accessible general framework for spatially extending many classical finite-state models from ecology, population dynamics and neuroscience. We will demonstrate the practical effectiveness of our approach through a detailed comparison of our limiting spatial model and the finite-size version of a specific savanna-forest model, the so-called Staver-Levin model. There is remarkable dynamic consistency between the GKEs and the finite-size system, in spite of almost sure forest extinction in the finite-size system. To resolve this apparent paradox, we show that the extinction rate drops sharply when nontrivial equilibria emerge in the GKEs, and that the finite-size system's quasi-stationary distribution (stationary distribution conditional on non-extinction) closely matches the bifurcation diagram of the GKEs. Furthermore, the limit process can support periodic oscillations of the probability distribution, thus providing an elementary example of a jump process that does not converge to a stationary distribution. In spatially extended settings, environmental heterogeneity can lead to waves of invasion and front-pinning phenomena. More details can be found in [2],[3] and particularly [1] for applications to ecology.

References

[1] Probabilistic foundations of spatial mean-field models in ecology and applications, *SIAM Journal on Applied Dynamical Systems*, in press.
[2] J. D. Touboul. Propagation of chaos in neural fields. *Ann. Appl. Probab.* 24(3), 2014.
[3] J. D. Touboul, Spatially extended networks with singular multi-scale connectivity patterns. *Journal of Statistical Physics*, 156(3), 2014.

From linear to multi-linear algebra
J. Landsberg

Abstract. I will give an elementary introduction to tensors, their geometry, and their use in applications suitable for graduate students.

On the structure tensor of $\mathfrak{sl}_n$
K. Bari

Abstract. The border rank of the structure tensor of $\mathfrak{sl}_n$ has connections with the exponent of matrix multiplication as well as the "hay in a haystack" problem (finding sequences of generic tensors). We prove a new lower bound on the border rank on the structure tensor of $\mathfrak{sl}_3$ using border apolarity.

Limits of Interacting Particle Systems on Sparse Graphs
A. Ganguly, K. Ramanan

Abstract. We consider systems of interacting particles, which are indexed by the nodes of a large locally finite (possibly random) graph, and whose evolution is described by a (possibly non-Markovian) jump process on a countable state space, where the transition rate of each particle depends only on the states (or histories) of particles in its neighborhood. Such systems arise as models of diverse phenomena in a variety of fields including statistical physics, neuroscience, epidemiology and engineering. Under general conditions, we establish convergence of the empirical distribution of such processes and also provide an autonomous characterization of marginal dynamics on unimodular trees.

Non-uniqueness in law for two-dimensional Navier-Stokes equations with diffusion weaker than a full Laplacian
K. Yamazaki

Abstract. We study the two-dimensional Navier-Stokes equations forced by random noise with a diffusive term generalized via a fractional Laplacian that has a positive exponent strictly less than one. Because intermittent jets are inherently three-dimensional, we instead adapt the theory of intermittent form of the two-dimensional stationary flows to the stochastic approach presented by Hofmanová, Zhu & Zhu (2019, arXiv:1912.11841 [math.PR]) and prove its non-uniqueness in law.

Approximating three-dimensional magnetohydrodynamics system forced by space-time white noise

K. Yamazaki

Abstract. When an equation is well-posed, and it is approximated by replacing the differentiation operator by reasonable discretization schemes with a parameter, it is widely believed that a solution of the approximating equation should converge to the solution of the original equation as the parameter approaches zero. We prove otherwise in the case of the three-dimensional magnetohydrodynamics system forced by space-time white noise. Specifically, it is proven that the limit of the solution to the approximating system with an additional 32 drift terms solves the original system. These 32 drift terms depend on the choice of approximations, can be calculated explicitly in the process of renormalizations, and essentially represent a spatial version of Ito-Stratonovich correction terms. In particular, the proof relies on the technique of renormalization in pairs which are strategically chosen.

Longer time accuracy for incompressible Navier-Stokes simulations with the EMAC formulation

M. Olshanskii, L. Rebholz

Abstract. In this paper, we consider the recently introduced EMAC formulation for the incompressible Navier-Stokes (NS) equations, which is the only known NS formulation that conserves energy, momentum and angular momentum when the divergence constraint is only weakly enforced. Since its introduction, the EMAC formulation has been successfully used for a wide variety of fluid dynamics problems. We prove that discretizations using the EMAC formulation are potentially better than those built on the commonly used skew-symmetric formulation, by deriving a better longer time error estimate for EMAC: while the classical results for schemes using the skew-symmetric formulation have Gronwall constants dependent on $\exp(C \cdot \mathrm{Re} \cdot T)$ with Re the Reynolds number, it turns out that the EMAC error estimate is free from this explicit exponential dependence on the Reynolds number. Additionally, it is demonstrated how EMAC admits smaller lower bounds on its velocity error, since incorrect treatment of linear momentum, angular momentum and energy induces lower bounds for L^2 velocity error, and EMAC treats these quantities more accurately. Results of numerical tests for channel flow past a cylinder and 2D Kelvin-Helmholtz instability are also given, both of which show that the advantages of EMAC over the skew-symmetric formulation increase as the Reynolds number gets larger and for longer simulation times.

A Phase Shift Deep Neural Network for High Frequency Approximation and Wave Problems

W. Cai, X. Li, L. Liu

Abstract. In this talk [1], we propose a phase shift deep neural network, i.e., (PhaseDNN), which provides a uniform wideband convergence in approximating high frequency functions and solutions of wave equations. The PhaseDNN makes use of the fact that common DNNs often achieve convergence in the low frequency range first [2], and constructs a series of moderately-sized DNNs trained for selected high frequency ranges. With the help of phase shifts in the frequency domain, each of the DNNs will be trained to approximate the function's specific high frequency range at the speed of learning for low frequency. As a result, the proposed PhaseDNN is able to convert high frequency learning to low frequency one, allowing a uniform learning to wideband functions. The PhaseDNN is then applied to learn solutions of high frequency wave problems in inhomogeneous media through least square residual of either differential or integral equations. Numerical results have demonstrated the capability of the PhaseDNN as a meshless method in general domains in learning high frequency functions and oscillatory solutions of interior and exterior Helmholtz problems.

References

[1] Wei Cai, Xiaoguang Li, Lizuo Liu. A Phase Shift Deep Neural Network for High Frequency Approximation and Wave Problems. arXiv:1909.11759 (Sept. 23, 2019), and to appear in *SIAM J. Sci. Comput.*, 2020.

[2] Luo, Tao and Ma, Zheng and Xu, Zhi-Qin John and Zhang, Yaoyu. Theory of the Frequency Principle for General Deep Neural Networks. arXiv preprint arXiv:1906.09235 (2019)

Wave propagation for reaction-diffusion equations on infinite random trees

W. Fan, W. Hu, G. Terlov

Abstract. We consider the asymptotic wave speed for FKPP type reaction-diffusion equations on a class of infinite random metric trees. We show that a travelling wavefront emerges, provided that the reaction rate is large enough. The wavefront travels at a speed that can be quantified via a variational formula involving the random branching degrees $\vec{d}$ and the random branch lengths $\vec{\ell}$ of the tree $\mathbb{T}_{\vec{d},\vec{\ell}}$. This speed is slower than that of the same equation on the real line $\mathbb{R}$, and we estimate this slow down in terms of $\vec{d}$ and $\vec{\ell}$. Our key idea is to project the Brownian motion on the tree onto a one-dimensional axis along the direction of the wave propagation. The projected process is a multi- skewed Brownian motion with skewness and interface sets that encode the metric structure $(\vec{d}, \vec{\ell})$ of the tree. Combined with analytic arguments based on the Feynman-Kac formula, this idea connects our analysis of the wavefront propagation to the large deviations principle of the multi-skewed Brownian motion with random skewness and random interface set.

References

[1] Wai-Tong Louis Fan, Wenqing Hu and Gregory Terlov. Wave propagation for reaction- diffusion equations on infinite random tree. arXiv preprint arXiv:1907.12962.

[2] Wai-Tong Louis Fan. Stochastic PDEs on graphs as scaling limits of discrete interacting systems. arXiv preprint arXiv:1708.01793.

Edge Colouring with Local List Sizes

L. Postle

Abstract. The well-known List Colouring Conjecture from the 1970s states that for every graph G the chromatic index of G is equal to its list chromatic index. In a seminal paper in 1996, Kahn proved that the List Colouring Conjecture holds asymptotically. Our main result is a local generalization of Kahn's theorem. More precisely, we show that, for a graph G with sufficiently large maximum degree Δ and minimum degree $\delta \geq \ln^{25} \Delta$, the following holds: For every assignment of lists of colours to the edges of G, such that $|L(e)| \geq (1 + o(1)) \cdot \max\{\deg(u), \deg(v)\}$ for each edge $e = uv$, there is an L-edge-colouring of G. Furthermore, Kahn showed that the List Colouring Conjecture holds asymptotically for linear, k-uniform hypergraphs, and recently Molloy generalized this to correspondence colouring. We also prove a local version of Molloy's result. In fact, we prove a weighted version that simultaneously implies all of our results. Joint work with Marthe Bonamy, Michelle Delcourt, and Richard Lang.

Speed–direction description of flow motion

M. Olshanskii

Abstract. Speed and direction of a flow describe the motion of fluid. In other words, one can use variables $u = |\mathbf{u}|$ and $\mathbf{r} = \mathbf{u}/|\mathbf{u}|$ to represent fluid velocity $\mathbf{u}$, i.e., $\mathbf{u} = u\mathbf{r}$. We shall consider a directional split of the Navier–Stokes equations for incompressible viscous fluid into a coupled system of equations for u and $\mathbf{r}$. Equation for u is particularly simple but solely maintains the energy balance of the system. We further illustrate the application of $u - \mathbf{r}$ variables to describe mean statistics of a shear turbulence. It is interesting that the standard (full) Reynolds stress tensor does not appear in resulting equation for the mean flow profile. Some further details can be found in [1].

References

[1] M. A. Olshanskii. Speed–direction description of turbulent flows. arXiv preprint, 2020.

Progress towards Nash-Williams' Conjecture on Triangle Decompositions

M. Delcourt

Abstract. Partitioning the edges of a graph into edge disjoint triangles forms a triangle decomposition of the graph. A famous conjecture by Nash-Williams [2] from 1970 asserts that any sufficiently large, triangle divisible graph on n vertices with minimum degree at least $0.75n$ admits a triangle decomposition. In the light of recent results, the fractional version of this problem is of central importance. A fractional triangle decomposition is an assignment of non-negative weights to each triangle in a graph such that the sum of the weights along each edge is precisely 1. We show that for any graph on n vertices with minimum degree at least $0.827327n$ admits a fractional triangle decomposition. Combined with results of Barber, Kühn, Lo, and Osthus [1], this implies that for every sufficiently large triangle divisible graph on n vertices with minimum degree at least $0.82733n$ admits a triangle decomposition. This is a significant improvement over the previous asymptotic result of Dross [3] showing the existence of fractional triangle decompositions of sufficiently large graphs with minimum degree more than $0.9n$. This is joint work with Luke Postle.

References

[1] B. Barber, D. Kühn, A. Lo, and D. Osthus. Edge-decompositions of graphs with high minimum degree. *Advances in Mathematics*, 288, 2016, 337–385.
[2] C. S. J. Nash-Williams. An unsolved problem concerning decomposition of graphs into triangles. Combinatorial Theory and its Applications, III, 1970, 1179–1183.
[3] F. Dross. Fractional triangle decompositions in graphs with large minimum degree. *SIAM Journal on Discrete Mathematics*, 30(1), 2015, 36–42.

Green's function estimates for the stationary convection-diffusion equation

M. Surnachev

Abstract. I will discuss some recent results on estimates of Green's function of the Dirichlet problem (and fundamental solution) for the stationary convection-diffusion equation $\operatorname{div}(\mathbf{a}(x)\nabla u) + \mathbf{b}(x) \cdot \nabla u = 0$ defined in $\Omega \subset \mathbb{R}^n, n \geq 3$, with bounded measurable matrix $\mathbf{a}$ satisfying the uniform ellipticity condition $\mathbf{a}(x)\zeta \cdot \zeta \geq \nu \xi|^2, \nu > 0$, for all $\zeta \in \mathbb{R}^n$ and a.e. $x \in \Omega$. The goal is to identify simple efficient conditions on the drift $\mathbf{b}$ that guarantee the existence of a fundamental solution with the Newtonian estimate, $C_1|x-y|^{2-n} \leq \Gamma(x, y) \leq C_2|x-y|^{2-n}$, which was obtained for $\mathbf{b} = 0$ in [1] (see also [2]). The simplest of such conditions is to require the boundedness of $\mathbf{b}$ together with $|\mathbf{b}(x)| \leq \Psi(|x|)|x|^{-1}, |x| > 1$, where the function ψ is nonincreasing and satisfies the Dini condition at infinity $\int_1^\infty \psi(s)s^{-1}ds < \infty$. For $\mathbf{a}$ with uniformly Hölder continuous coefficients this result follows from [3],[4] (even without ψ being monotone). This is joint work with Yurij Alkhutov.

References

[1] W. Littman, G. Stampacchia, H. Weinberger. Regular points for elliptic equations with discontinuous coefficients. *Ann. Scuola Norm. Sup. Pisa*, 17, 1963.

[2] G. Stampacchia, Le probleme de Dirichlet pour les equations elliptiques du second ordre a coefficients discontinus. *Annales de l'institut Fourier*, 15(1), 1965.

[3] Qi Zhang. A Harnack inequality for the equation $\nabla(a\nabla u) + b\nabla u = 0$, when $|b| \in K_{n+1}$. *Manuscripta Math.*, 89, 1995.

[4] Qi S. Zhang. Gaussian bounds for the fundamental solutions of $\nabla(A\nabla u) + B\nabla u - ut = 0$. *Manuscripta Math.*, 93, 1997.

Maximum-principle-preserving vertex-based method for two phase flows in porous media

M. Joshaghani, B. Riviere

Abstract. Abstract. This talk presents the numerical solution of immiscible two-phase flows in porous media, obtained by a first order finite element method equipped with mass-lumping and flux upwinding. The unknowns are the phase pressure and phase saturation. Recently, the theoretical convergence analysis of the method was derived in [3]. It was also shown that the numerical saturation satisfies a maximum principle. Our numerical experiments confirm that the method converges optimally for manufactured solutions. For both structured and unstructured meshes, we observe the high-accuracy wetting saturation profile that ensures minimal numerical diffusion at the front. Performing several examples of quarter-five spot problems in two and three dimensions, we show that the method can easily handle heterogeneities in the permeability field. Two distinct features that make the method appealing to reservoir simulators are:

(1) It respects the maximum principle by limiting the wetting phase saturation profile to a physical upper- and lower-bounds. In simulating two- phase flow, it is known that the major problem of classical formulations, when no limiting mechanism or mitigation technique is implemented, is the lack of monotonicity of the solution (i.e. "overshoot" of the solution right before and an "undershoot" right after the saturation front). These oscillations become significant in coarse meshes and non-homogeneous media.
(2) Similar to discontinuous Galerkin formulation, this formulation preserves element-wise (local) mass balance. Violation of mass balance is a known problem in continuous formulations. To solve the discrete system that arises from this vertex method, we choose the Schur complement preconditioning strategy due to the mass-lumped nature of the resulting stiffness matrix. Using the composable solvers feature available in PETSc [1] and the finite element libraries available under the FEniCS Project [2], we illustrate how to effectively precondition this system for large-scale problems.

References

[1] S. Balay, S. Abhyankar, M. Adams, J. Brown, P. Brune, K. Buschelman, L. Dalcin, V. Eijkhout, W. D. Gropp, D. Kaushik, M. G. Knepley, L. C. McInnes, K. Rupp, B. F. Smith, S. Zampini, H. Zhang, and H. Zhang. PETSc users manual. Technical Report ANL-95/11 - Revision 3.13. *Argonne National Laboratory*, 2020.
[2] M. S. Alnaes, J. Blechta, J. Hake, A. Johansson, B. Kehlet, A. Logg, C. Richardson, J. Ring, M. E. Rognes and G. N. Wells. The FEniCS Project Version 1.5. *Archive of Numerical Software*, 3(100), 2015
[3] V. Girault, B. Riviere, and L. Cappanera. Convergence of a finite element method for degenerate two-phase flow in porous media. arXiv:2001.08859, 2020.

Modeling Transmission Dynamics of COVID-19 in Nepal
N. Vaidya

Abstract. While ongoing COVID-19 pandemic remains disastrous all over the world, the situation of COVID-19 transmission in Nepal can be considered unique because of open-boarder provision with India and control programs implemented by Nepal Government. In this talk, I will present a dynamical system model to describe transmission dynamics of COVID-19 in Nepal. Using our model and case data from Nepal, we compute the basic reproduction number and the effective reproduction number. Furthermore, we analyze our model to evaluate the impact of open-boarder and control policies on the burden of COVID-19 cases in Nepal.

Bloch waves in 3-dimensional high-contrast photonic crystals
R. Viator, R. Lipton, S. Jiminez, A. Adili

Abstract. We investigate the Bloch eigenvalues of a 3-dimensional high-contrast photonic crystal. The Bloch eigenvalues (for a fixed quasi-momentum) can be expanded in a power series in the material contrast parameter k about $k = \infty$. We achieve this power series, together with a radius of convergence, by decomposing an appropriate vector-valued Sobolev space into three mutually orthogonal subspaces which are curl-free in certain subdomains of the period cell. We will also identify the limit spectral problem as contrast becomes large, and (time permitting) we will describe a class of crystal geometries which permit the power series structure of Bloch eigenvalues described above.

Instability bubbles for multi-pulse solutions to Hamiltonian systems on a periodic domain
R. Parker, B. Sandstede

Abstract. In this talk, I will look at multi-pulse solitary wave solutions to Hamiltonian systems which are translation invariant and reversible. The fifth order Korteweg-de Vries equation is a prototypical example. In particular, I will look at the spectral stability of these solutions on a periodic domain. Using Lin's method, an implementation of the Lyapunov-Schmidt reduction, the spectral problem can be reduced to computing the determinant of a block matrix which encodes both eigenvalues resulting from interactions between neighboring pulses (interaction eigenvalues) and eigenvalues associated with the background state. Using this matrix, we can compute the spectrum associated with single and double pulses on a periodic domain. In addition, for periodic double pulses, we prove that brief instability bubbles form when interaction eigenvalues and background state eigenvalues collide on the imaginary axis as the periodic domain size is altered. These analytical results are in good agreement with numerical computations.

Perspective on the connection between ideal free dispersal and the evolution of dispersal

R. Cantrell

Abstract. In this talk I will discuss our perspective on the study of the evolution of dispersal and its connections to the ecological notion of the ideal free distribution. This will include some insight into its development first in the context of spatially heterogeneous but temporally constant habitats and more recently into the case where temporal change is periodic. This work is in collaboration with Chris Cosner and Adrian Lam.

Graphene models in magnetic fields

S. Becker, R. Han, S. Jitomirskaya

Abstract. I will discuss some recent results [1],[2] on (quantum) graph models of graphene in magnetic fields. In particular, Cantor spectrum in irrational magnetic flux, Hausdorff dimension of spectrum, Dirac cones in rational flux, and existence of mobility edge in disorder.

References

[1] S.Becker, R. Han and S. Jitomirskaya, Cantor spectrum of graphene in magnetic fields. *Invent. Math.* 218 (2019)., 1(1), 2021.

[2] S. Becker, R. Han, Dynamical delocalization for discrete magnetic random Schrödinger operators. https://arxiv.org/abs/2004.06189.

Forbidden traces in hypergraphs

R. Luo

Abstract. Fix a graph F and a hypergraph H with $V(F) \subseteq V(H)$. We say that H is an F-trace if there exists a bijection φ between the edges of F and the edges of H such that for every $xy \in E(F), \varphi(xy) \cap V(F) = \{x, y\}$. In this talk, we show asymptotics for the maximum number of edges in an r-uniform hypergraph with no copy of an F-trace in terms of the generalized Turán number $ex(n, K_r, F)$. We also give better bounds for the case $F = K_{2,t}$. This is joint work with Zoltán Füredi and Sam Spiro.

Anderson localization for Kirchhoff and discrete Laplacians on random trees

S. Sukhtaiev

Abstract. In this talk, we will discuss a mathematical treatment of a disordered system modeling localization of quantum waves on metric and discrete trees. We will show that the transport properties of several natural Hamiltonians on metric and discrete trees with random branching numbers are suppressed by disorder. This is a joint work with D. Damanik (Rice University) and J. Fillman (Texas State University)

Ensemble inversion for calibrating biophysical tumor growth models with mass effect

S. Subramanian, K. Scheufele, N. Himthani, G. Biros

Abstract. We present a fully-automatic numerical scheme for the calibration of 3D partial differential equation (PDE) models of glioblastoma (GBM) with mass effect, the deformation of brain tissue due to the tumor. We quantify the tumor mass effect, proliferation, migration, and the localized tumor initial condition from a single multiparameteric Magnetic Resonance Imaging (mpMRI) patient scan. The single-scan calibration model is notoriously difficult because the precancerous (healthy) brain anatomy is unknown. To solve this inherently ill-posed and ill-conditioned optimization problem, we introduce a novel inversion scheme that uses multiple brain atlases as proxies for the healthy precancer patient brain resulting in robust and reliable parameter estimation. We apply our method on both synthetic and clinical datasets representative of the heterogeneous spatial landscape typically observed in glioblastomas to demonstrate the validity and performance of our methods. Our method uses a minimal set of parameters and provides both global and local quantitative measures of tumor dynamics and mass effect.

Optimal Control of Volume-Preserving Mean Curvature Flow

S. Walker, A. Laurain

Abstract. We develop a framework and numerical method for controlling the full space-time tube of a geometrically driven flow. We consider an optimal control problem for the mean curvature flow of a curve or surface with a volume constraint, where the control parameter acts as a forcing term in the motion law. The control of the trajectory of the flow is achieved by minimizing an appropriate tracking-type cost functional. The gradient of the cost functional is obtained via a formal sensitivity analysis of the space-time tube generated by the mean curvature flow. We show that the perturbation of the tube may be described by a transverse field satisfying a parabolic equation on the tube. We propose a numerical algorithm to approximate the optimal control and demonstrate it with several results in two and three dimensions.

References

[1] Antoine Laurain, Shawn W. Walker, Optimal control of volume-preserving mean curvature flow. https://hal.archives-ouvertes.fr/hal-02934959

ALESQP: An Augmented Lagrangian Equality-constrained SQP Method for Function-space Optimization with General Constraints

S. Lin, M. Heinkenschloss

Abstract. This talk introduces and analyzes an efficient multigrid-in-time parallel algorithm that reduces time and storage requirements for solving optimal control problems. The optimality system for such problems involves the forward-in-time state equation coupled with a backward-in-time adjoint equation. Therefore, solution of such problems is computing time and memory intensive. To introduce parallelism, I first introduce a two-grid approach based on a time-domain decomposition. This approach eliminates the variables in time subdomains, which can be done on parallel, and then replaces the resulting Schur complement by a less expensive coarse grid discretization. To further reduce the cost of the coarse grid approximation, I extended it to a multigrid algorithm using an algebraic multigrid approach. This reduces sequential computation therefore increases parallel efficiency. Finally, I will present convergence results for the two-grid algorithm and numerical result for the multigrid extension.

LDG approximation of large deformations of prestrained plates
A. Bonito, D. Guignard, R. Nochetto, S. Yang

Abstract. A reduced model for large deformations of prestrained plates consists of minimizing a second order bending energy subject to a nonconvex metric constraint. We discuss a formal derivation of this reduced model along with an equivalent formulation that makes it amenable computationally. We propose a local discontinuous Galerkin (LDG) finite element approach that hinges on the notion of reconstructed Hessian. We design discrete gradient flows to minimize the ensuing nonconvex problem.

The Pair-Replica-Mean-Field Limit for Intensity-based Neural Networks
F. Baccelli, T. Taillefumier

Abstract. Replica-mean-field models have been proposed to decipher the activity of neural networks via a multiply-and-conquer approach. In this approach, one considers limit networks made of infinitely many replicas with the same basic neural structure as that of the network of interest, but exchanging spikes in a randomized manner. The key point is that these replica-mean-field networks are tractable versions that retain important features of the finite structure of interest. To date, the replica framework has been discussed for first-order models, whereby elementary replica constituents are single neurons with independent Poisson inputs. Here, we extend this replica framework to allow elementary replica constituents to be composite objects, namely, pairs of neurons. As they include pairwise interactions, these pair-replica models exhibit nontrivial dependencies in their stationary dynamics, which cannot be captured by first-order replica models. Our contributions are two-fold: (i) We analytically characterize the stationary dynamics of a pair of intensity-based neurons with independent Poisson input. This analysis involves the reduction of a boundary-value problem related to a two-dimensional transport equation to a system of Fredholm integral equations - a result of independent interest. (ii) We analyze the set of consistency equations determining the full network dynamics of certain replica limits. These limits are those for which replica constituents, be they single neurons or pairs of neurons, form a partition of the network of interest. Both analyses are numerically validated by computing input/output transfer functions for neuronal pairs and by computing the correlation structure of certain pair-dominated network dynamics.

Are colloidal particles immersed in liquid crystals attracted to the walls?

V. Yushutin

Abstract. The answer, of course, depends on the shape of the wall. A flat wall generally repels a colloidal particle to minimize the liquid crystal energy by reducing the distortion of the orientation field caused by the boundary conditions. However, there is experimental evidence of the opposite behavior if the colloidal particle is put near a pit of comparable size. To address this question, we aim to develop an unfitted numerical scheme to model the motion of the particle that seeks an optimal position near a curved wall by conducting a geometric gradient flow along the shape gradient of the Frank's energy. In this talk we focus on finding harmonic maps, i.e. minimizers of the Dirichlet energy under the nonlinear, non-convex unit length constraint, accurate knowledge of which is required on each step of the shape optimization procedure. Dirichlet boundary conditions are weakly imposed on an unfitted mesh, and a second order in time technique is suggested to conduct a discrete gradient flow to find a harmonic map on a fixed domain.

Low Rank Tensor Methods for Vlasov Simulations

W. Guo, Y. Qiu

Abstract. In this talk, we present a low-rank tensor approach for solving the Vlasov equation. Among many existing challenges for Vlasov simulations (e.g. multi-scale features, nonlinearity, formation of filamentation structures), the curse of dimensionality and the associated huge computational cost have been a long-standing key obstacle for realistic high-dimensional simulations. In this work we propose to overcome the curse of dimensionality by dynamically and adaptively exploring a low-rank tensor representation of Vlasov solutions in a general high-dimensional setting. In particular, we develop two different approaches: one is to directly solve the unknown function, and the other is to solve the underlying flow map, aiming to obtain a low-rank approximation with optimal complexity. The performance of both proposed algorithms are benchmarked for standard Vlasov-Poisson/Maxwell test problems.

Lorentz Resonance in the Homogenization of Plasmonic Crystals
W. Li, R. Lipton, M. Maier

Abstract. We explain the sharp Lorentz resonances in plasmonic crystals that consist of 2D nano dielectric inclusions as the interaction between resonant material properties and geometric resonances of electrostatic nature. One example of such plasmonic crystals are graphene nanosheets that are periodically arranged within a non-magnetic bulk dielectric. We derive an analytic formula for the Lorentz resonances which decouples the geometric contribution and the frequency dependance. This formula comes rigorously from the corrector equation in the process of homogenization, and it can be used for efficient computation. This is joint work with Matthias Maier and Robert Lipton.

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vbox**Infinitely Many Embedded Eigenvalues for the Neumann-Poincaré Operator in 3D**
Wei Li, Karl-Mikael Perfekt, Stephen P. Shipman

Abstract. We construct a surface whose Neumann-Poincaré (NP) integral operator has infinitely many eigenvalues embedded in its essential spectrum. The surface is a sphere perturbed by smoothly attaching a conical singularity, which imparts essential spectrum. Rotational symmetry allows a decomposition of the operator into Fourier components. Eigenvalues of infinitely many Fourier components are constructed so that they lie within the essential spectrum of other Fourier components and thus within the essential spectrum of the full NP operator. The proof requires the perturbation to be sufficiently small, with controlled curvature, and the conical singularity to be sufficiently flat.

We construct a surface whose Neumann-Poincaré (NP) integral operator has infinitely many eigenvalues embedded in its essential spectrum. The surface is a sphere perturbed by smoothly attaching a conical singularity, which imparts essential spectrum. Rotational symmetry allows a decomposition of the operator into Fourier components. Eigenvalues of infinitely many Fourier components are constructed so that they lie within the essential spectrum of other Fourier components and thus within the essential spectrum of the full NP operator. The proof requires the perturbation to be sufficiently small, with controlled curvature, and the conical singularity to be sufficiently flat.

Rates of convergence for optimal transport problem with quadratic cost in two or three dimensions

W. Zhang

Abstract. We consider the optimal transport problem minimizing the quadratic transport cost between two probability measures. It is well known that the transport mapping is related to the gradient map of the solution ∇u of a Monge-Ampére-type of partial differential equations with second boundary condition. Based on the stability estimate established for the Monge-Ampére-type of problem [1], we establish a measure weighted W_1^1-norm for the numerical optimal transport mapping ∇u_h and show that if $u \in C^{2,\alpha}$ where $0 < \alpha \leq 2$, then the measure weighted W_1^1-error of u_h converges in order $\ln(\frac{1}{h})h^{\alpha}$. We will also present several results when measures contains vacuum region, in which case solution u is of low regularity.

References

[1] M. Neilan and W. Zhang, Rates of Convergence in W_p^2-Norm for the Monge-Ampére Equation. *SIAM J. Numer. Anal.*, 56(5), 2018.

Reproducing kernel collocation methods for nonlocal models: asymptotic compatibility and numerical stability

X. Tian

Abstract. Reproducing kernel (RK) approximations are meshfree methods that construct shape unctions from sets of scattered data. We present asymptotically compatible (AC) RK collocation methods for nonlocal models that are robust under the change of the nonlocal horizon parameter. The study of convergent non-variational AC schemes for nonlocal models was largely hindered by the lack of tools for the study of numerical stability. We show the numerical stability of a special class of RK collocation schemes by establishing connections between the collocation schemes and certain Galerkin schemes. The work applies to both nonlocal diffusion and the state-based peridynamics model [1],[2]. This is a joint work with Yu Leng, Nat Trask, and John Foster.

References

[1] Y. Leng, X. Tian, N. Trask and J. Foster, Asymptotically compatible reproducing kernel collocation and meshfree integration for nonlocal diffusion, arXiv preprint, 2019. (To appear in *SIAM J. Numer. Anal.*)

[2] Y. Leng, X. Tian, N. Trask and J. Foster, Asymptotically compatible reproducing kernel collocation and meshfree integration for the peridynamic, Navier equation arXiv preprint, 2020. (To appear in *Comput. Methods Appl. Mech. Eng.*)

Well-posedness of 1D Quasilinear Wave Equation
Y. Shen

Abstract. In this talk, we consider the global well-posedness of energy conservative Hölder continuous weak solution to a general quasilinear wave equation. We will construct a Finsler type optimal transport metric, then prove that the solution flow is Lipschitz under this metric.

An Energy-Based Discontinuous Galerkin Method for A Nonlinear Variational Wave Equation Modelling Nematic Liquid Crystal
L. Zhang, T. Hagstrom, D. Appelo

Abstract. We generalize the energy-based discontinuous Galerkin method proposed in [1] to compute solutions to the Cauchy problem for a nonlinear variational wave equation proposed as a model for the dynamics of nematic liquid crystals. The solution is known to form singularities in finite time. Beyond the singularity time, both conservative and dissipative Hölder continuous weak solutions exist. We present results with both energy-conserving schemes and energy-dissipating schemes. Numerical experiments demonstrating optimal convergence in energy norm for upwind fluxes.

References

[1] D. Appelö and T. Hagstrom, A new discontinuous Galerkin formulation for wave equations in second-order form. *SIAM Journal on Numerical Analysis*, 2705–2726, 53(6), 2015.

The Choice of Kernel Function in Nonlocal Wave Propagation with Local Boundary Conditions

B. Aksoylu, G. Gazonas

Abstract. It is a challenge to choose the appropriate kernel function in non-local problems. We tackle this challenge from the aspect of nonlocal wave propagation and study the dispersion relation at the analytical level. The kernel function enters the formulation as an input. Any effort to narrow down this function family is valuable. Dispersion relations of the nonlocal governing operators are identified. Using a Taylor expansion, a selection criterion is devised to determine the kernel function that provides the best approximation to the classical (linear) dispersion relation. The criterion is based on selecting the smallest coefficient in magnitude of the dominant term in the Taylor expansion after the constant term. The governing operators are constructed using functional calculus [1],[2] which provides the explicit expression of the eigenvalues of the operators. The ability to express eigenvalues explicitly allows us to obtain dispersion relation at the analytical level, thereby isolating the effect of discretization on the dispersion relation. With the presence of expressions of eigenvalues of the governing operator, the analysis is clear and accessible. The choices made to obtain the best approximation to the classical dispersion relation become completely transparent. We find that the truncated Gaussian family is the most effective compared to power and rational function families [3].

References

[1] B. Aksoylu, F. Celiker and O. Kilicer, Nonlocal problems with local boundary conditions in higher dimensions, *Adv. Comp. Math.*, (2019), 45:453–492.

[2] B. Aksoylu and G. A. Gazonas, On nonlocal problems with inhomogeneous local boundary conditions, *J. Peridyn. Nonlocal Model.*, (2020), 2:1–25.

[3] B. Aksoylu and G. A. Gazonas, On the choice of kernel function in nonlocal wave propagation, *J. Peridyn. Nonlocal Model.*, (2020), https://doi.org/10.1007/s42102-020-00034-x.

Data Augmentation as Stochastic Optimization

B. Hanin, Y. Sun

Abstract. Recent advancements in data augmentation have led to state-of-the-art performance on diverse machine learning tasks. In these cases, augmentation improves, sometimes dramatically, average-case performance and robustness. However, it remains unclear how to choose, compare, and schedule augmentations in a principled way. The present work provides a theoretical framework for data augmentation in which such issues can be studied directly, in contrast to ad-hoc, computationally intensive search typical in practice. Our framework is general enough to unify augmentations such as synthetic noise (additive noise, CutOut and label-preserving transformations (color jitter, geometric transformations) together with more traditional stochastic optimization methods (SGD, Mixup). The essence of our approach is that any augmentation corresponds to noisy gradient descent on a time-varying sequence of proxy losses.

Specializing our framework to overparameterized linear models, we obtain a Munro-Robbins type result, which provides conditions for jointly scheduling learning rate and augmentation strength. Although it holds only in this limited context, we emphasize that our framework as whole covers a broad family of models including kernels and neural networks. Our results in the linear case give a rigorous baseline to compare to more complex settings and uncover non-trivial scheduling phenomena even for linear models.

Components of varieties of commuting matrices

J. Jelisiejew

Abstract. The variety of commuting matrices $C_n(\mathbb{M}_d)$ consists of n-tuples of $d \times d$ matrices that pairwise commute. Seemingly an object of linear algebra, this variety has unexpectedly rich geometry and connections to ternary tensors of minimal brank and deformation theory. In the talk I will present the current knowledge about the irreducible components of $C_n(\mathbb{M}_d)$ and outline several open questions. This is a joint work with Klemen Šivic [1].

References

[1] Joachim Jelisiejew and Klemen Šivic. Components and singularities of Quot schemes and varieties of commuting matrices. *preprint*, 2020.

Assessing the Impact of non-Pharmaceutical Intervention Strategies for Containing COVID-19 Epidemics
L. Xue

Abstract. The current COVID-2019 pandemic has raised serious public health concerns and severely impacted the progress of economy worldwide. To contain current outbreaks and prevent future outbreaks, it is essential to project effective mitigation strategies. In this talk, I present the network-based models developed to examine the impact of multiple non-pharmaceutical intervention strategies.

Mean curvature flow with positive random forcing in 2-d
W. Feldman

Abstract. I will discuss some history, new results, and potential future directions in the study of the forced mean curvature flow in heterogeneous random media. I am interested in front propagation / homogenization in the de-pinned case. Techniques from Hamilton-Jacobi homogenization have been successful for "large" forcing, but near the pinning transition the level set equation loses coercivity and there are many open issues.

Quantitative regularity vs. concentration near potential singularities in incompressible viscous fluids
T. Barker, C. Prange

Abstract. In this talk I will focus on two related aspects of the regularity theory for the three-dimensional Navier-Stokes equations: quantitative regularity estimates on the one hand and concentration estimates for blow-up solutions on the other hand. This connection enables in particular a quantification of Seregin's 2012 regularity criterion in terms of the critical L^3 norm. A counterpart of this is that we are able to give lower bounds on the blow-up rate of certain critical norms near potential singularities. This talk is based on recent works [2],[1] in collaboration with Tobias Barker (University of Warwick).

References

[1] T. Barker and C. Prange. Quantitative regularity for the Navier-Stokes equations via spatial concentration. arXiv preprint, 2020.
[2] T. Barker and C. Prange. Localized smoothing for the Navier-Stokes equations and concentration of critical norms near singularities. *Arch. Ration. Mech. Anal.*, 236, 1487-1541 (2020).

The dynamics of a zooplankton-fish system in aquatic habitats
Y. Jin, F.-B. Wang

Abstract. Diel vertical migration is a common movement pattern of zooplankton in marine and freshwater habitats. In this paper, we use a temporally periodic reaction-diffusion-advection system to describe the dynamics of zooplankton and fish in aquatic habitats. Zooplankton live in both the surface water and the deep water, while fish only live in the surface water. Zooplankton undertake diel vertical migration to avoid predation by fish during the day and to consume sufficient food in the surface water during the night. We establish the persistence theory for both species as well as the existence of a time-periodic positive solution to investigate how zooplankton manage to maintain a balance with their predators via vertical migration. Numerical simulations discover the effects of migration strategy, advection rates, domain boundary conditions, as well as spatially varying growth rates, on persistence of the system.

Second-order invariant domain preserving approximation of the compressible Navier–Stokes equations

J.-L. Guermond, B. Popov, I. Thomas

Abstract. The objective of this talk is to present a fully-discrete approximation technique for the compressible Navier-Stokes equations. The method is implicit-explicit, second-order accurate in time and space, and guaranteed to be invariant domain preserving. The restriction on the time-step size is the standard hyperbolic CFL condition. To the best of our knowledge, this method is the first one that is guaranteed to be invariant domain preserving under the standard hyperbolic CFL condition and be second-order accurate in time and space.

Of course there are countless papers in the literature describing techniques to approximate the time-dependent compressible Navier-Stokes equations, but there are very few papers establishing invariant domain properties. Among the latest results in this direction we refer the reader to [1] where a first-order method using upwinding and staggered grid is developed (see Eq. (3.1) therein). The authors prove positivity of the density and the internal energy (Lem. 4.4 therein). Unconditional stability is obtained by solving a nonlinear system involving the mass conservation equation and the internal energy equation. One important aspect of this method is that it is robust in the low Mach regime. A similar technique is developed in [2] for the compressible barotropic Navier-Stokes equations (see § 3.6 therein). We also refer to [3] where a fully explicit dG scheme is proposed with positivity on the internal energy enforced by limiting. The invariant domain properties are proved there under the par- abolic time step restriction $\tau \leq \mathcal{O}(h^2)/\mu$, where μ is some reference viscosity scale.

The key idea of the present talk is to build on [4],[5] and use an operator splitting technique to treat separately the hyperbolic part and the parabolic part of the problem. The hyperbolic sub-step is treated explicitly and the parabolic sub-step is treated implicitly. This idea is not new and we refer for instance to [6] for an early attempt in this direction. The novelty of our approach is that each sub-step is guaranteed to be invariant domain preserving. In addition, the scheme is conservative and fully-computable (e.g. the method is fully-discrete and there are no open-ended questions regarding the solvability of the sub-problems). One key ingredient of our method is that the parabolic sub-step is reformulated in terms of the velocity and the internal energy in a way that makes the method conservative, invariant domain preserving, and second-order accurate.

References

[1] D. Grapsas, R. Herbin, W. Kheriji, and J.-C. Latché. An unconditionally stable staggered pressure correction scheme for the compressible Navier-Stokes equations. *SMAI J. Comput. Math.*, 2:51–97, 2016.

[2] T. Gallouët, L. Gastaldo, R. Herbin, and J.-C. Latché. An unconditionally stable pressure correction scheme for the compressible barotropic Navier-Stokes equations. *M2AN Math. Model. Numer. Anal.*, 42(2):303–331, 2008.

[3] X. Zhang. On positivity-preserving high order discontinuous Galerkin schemes for compressible Navier-Stokes equations. *J. Comput. Phys.*, 328:301–343, 2017.

[4] J.-L. Guermond, M. Nazarov, B. Popov, and I. Tomas. Second-order invariant domain preserving approximation of the Euler equations using convex limiting. *SIAM J. Sci. Comput.*, 40(5):A3211–A3239, 2018.

[5] J.-L. Guermond, B. Popov, and I. Tomas. Invariant domain preserving discretization independent schemes and convex limiting for hyperbolic systems. *Comput. Methods Appl. Mech. Engrg.*, 347:143–175, 2019.

[6] L. Demkowicz, J. T. Oden, and W. Rachowicz. A new finite element method for solving compressible Navier-Stokes equations based on an operator splitting method and $h-p$ adaptivity. *Comput. Methods Appl. Mech. Engrg.*, 84(3):275–326, 1990.

Spatial modeling and dynamics of organic matter biodegradation in the absence or presence of bacterivorous grazing

X. Chang, J. Shi, H. Wang

Abstract. Biodegradation is a pivotal natural process for elemental recycling and preservation of an ecosystem. Mechanistic modeling of biodegradation has to keep track of chemical elements via stoichiometric theory, under which we propose and analyze a spatial movement model in the absence or presence of bacterivorous grazing. Sensitivity analysis shows that the organic matter degradation rate is most sensitive to the grazer's death rate when the grazer is present and most sensitive to the bacterial death rate when the grazer is absent. Therefore, these two death rates are chosen as the primary parameters in the conditions of most mathematical theorems. The existence, stability and persistence of solutions are proven by applying linear stability analysis, local and global bifurcation theory, and the abstract persistence theory. Through numerical simulations, we obtain the transient and asymptotic dynamics and explore the effects of all parameters on the organic matter decomposition. Grazers either facilitate biodegradation or has no impact on biodegradation, which resolves the "decomposition-facilitation paradox" in the spatial context.

3D Inviscid Primitive Equations With Rotation

Q. Lin

Abstract. Large scale dynamics of the oceans and the atmosphere are governed by the primitive equations (PEs). It is well-known that the 3D viscous primitive equations are globally well-posed in Sobolev spaces. In this talk, I will discuss the ill-posedness in Sobolev spaces, the local well-posedness inthe space of analytic functions, and finite-time blowup of solutions to the 3D inviscid PEs with rotation (Coriolis force). Moreover, I will also show, in the case of "well-prepared" analytic initial data, the regularizing effect of the Coriolis force by providing a lower bound for the life-span of the solutions that grows toward infinity with the rotation rate. This is a joint work with Tej Eddine Ghoul (New York University in Abu Dhabi), Slim Ibrahim (University of Victoria), and Edriss S. Titi (Texas A&M and University of Cambridge).

The Stampacchia maximum principle for stochastic partial differential equations forced by Levy Noise

P. Nguyen

Abstract. In this work, we investigate the existence of positive (martingale and pathwise) solutions of stochastic partial differential equations (SPDEs) driven by a Levy noise. The proof relies on the use of truncation, following the Stampacchia approach to maximum principle. Among the applications, the positivity and boundedness results for the solutions of some biological systems and reaction diffusion equations are provided under suitable hypotheses, as well as some comparison theorems.

Application of peridynamics to fracture in solids and granular media

P. Jha, R. Lipton

Abstract. In this talk, we will present our recent work on peridynamics and its application. We consider a bond-based peridynamics with a nonlinear constitutive law relating the bond-strain to the pairwise force. For the model considered, we can show well-posedness and existence in the Hölder and Hilbert H^2 space under appropriate conditions and obtain apriori bounds on the finite-difference and finite-element discretization. We will present the application of the model to mode-I and mixed-mode fracture problems. One particular topic of interest is the kinetic relation for the crack tip velocity in the peridynamics and how it relates to the local kinetic relation (LEFM theory). We will show that in the limit of vanishing nonlocality, we recover the classical kinetic relation from the peridynamics formulation. We will present numerical results that support the theory. Another application of peridynamics recently gaining much attention is in the granular media. DEM based methods can describe the interaction in particulate media very well but lack the capacity to model the intra-particle fracture. We will discuss some advances on the development of hybrid model based on peridynamics and DEM for granular media.

Solitary and periodic wave solutions for several short wave model equations
A. Stukopin

Abstract. We study the periodic and solitary wave solutions to several short wave model equations arising from a so-called β-family equation for $\beta = 1, 2, 4$. These are integrable cases which possess Lax pair and multi-solution solutions. By phase plane analysis, either the loop or cuspon type solutions are predicted. Then, by introducing a hodograph, or reciprocal, transformation, a coupled system is derived for each β. Applying a travelling wave setting, we are able to find the periodic solutions exactly expressed in terms of Jacobi Elliptic functions. In the limiting cases of modulus $k = 1$, they all converge to the known solitary waves.

References

[1] Andrew N.W. Hone, Vladimir Novikov and Jing Ping Wang. Generalizations of the short pulse equation. *Lett Math Phys*, 108(927–947), 2017.
[2] Y.A. Stepanyants. On stationary solutions of the reduced Ostrovsky equation: Periodic waves, compactons and compound solitons. *Chao, Soliton & Fractals*, 28(193–204), 2005.
[3] Y. Matsuno. Cusp and loop soliton solutions of short-wave models for the Camassa-Holm and Degasperis-Procesi equations. *Phys. Lett. A*, 359(451–457), 2006.
[4] A. Degasperis and D.D. Holm and A.N.W. Hone. A new integrable equation with peakon solutions. *Theoretical and Mathematical Physics*, 133(1463–1474), 2002.
[5] M. Toda. Theory of Nonlinear Lattices. *Springer Science and Business Media*, 1989.
[6] E.T. Whittaker and G.N. Watson. A course of modern analysis. *Cambridge University Press,* 4 (452–453), 1935.
[7] R.M. Gundersen. Traveling wave solutions of nonlinear partial differential equations. *Journal of Engineering Mathematics*, 24(323–341), 1990.
[8] Y. Matsuno. Parametric solutions of the generalized short pulse equations. *Journal of Physics A: Mathematical and Theoretical*, 53, 2020.
[9] M.A. Manna and A. Neveu. Short-wave dynamics in the Euler equations. *Inverse Problems*, 17(855–861), 2001.

Vanishing Hessian and Wild Polynomials
H. Huang, M. Michalek, E. Ventura

Abstract. Notions of ranks and border rank abounds in the literature. Polynomials with vanishing hessian and their classification is also a classical problem. Motivated by an observation of Ottaviani, we will discuss why when looking at concise polynomials of minimal border rank, being wild, i.e. their smoothable rank is strictly larger than their border rank, are the same as having vanishing Hessian. The main tool we are using here is the recent work of Buczynska and Buczynski relating the border rank of polynomials and tensors to multigraded Hilbert scheme. From here, we found two infinite series of wild polynomials and we will try to describe their border varieties of sums of powers, which is an analogue of the variety of sums of powers.

Time-domain Wavefield Reconstruction Inversion in Tilted Transverse Isostropic media

M. Louboutin, G. Rizzuti, R. Wang, F. Herrman

Abstract. We introduce a generalization of time-domain wavefield reconstruction inversion to anisotropic acoustic modeling. Wavefield reconstruction inversion has been extensively researched in recent years for its ability to mitigate cycle skipping. The original method was formulated in the frequency domain with acoustic isotropic physics. However, frequency-domain modeling requires sophisticated iterative solvers that are difficult to scale to industrial-size problems and more realistic physical assumptions, such as tilted transverse isotropy, object of this study. The work presented here is based on a recently proposed dual formulation of wavefield reconstruction inversion, which allows time-domain propagator that are suitable to both large scales and more accurate physics.

An unconditionally stable space-time FE method for the Shallow Water Equations

E. Valseth, C. Dawson

Abstract. We introduce the automatic variationally stable finite element (AVS-FE) method [1],[3] for the shallow water equations (SWE). The AVS-FE method uses a first order system integral formulation of the underlying partial differential equations (PDEs) and, in the spirit of the discontinuous Petrov-Galerkin (DPG) method by Demkowicz and Gopalakrishnan [2], employs the concept of optimal test functions to ensure discrete stability. The AVS-FE method distinguishes itself by using globally conforming FE trial spaces, e.g., $H^1(\Omega)$ and $H(\text{div}, \Omega)$ and their broken counterparts for the test spaces. The broken topology of the test spaces allows us to compute numerical approximations of the local restrictions of the optimal test functions in a completely decoupled fashion, i.e. element-by-element. The test functions can be computed with sufficient numerical accuracy by using the same local p-level as applied for the trial space.

The unconditional discrete stability of the method allows for straightforward implementation of transient problems in existing FE solvers without the need for additional stability constraints commonly encountered for traditional time-stepping schemes. Furthermore, a built-in *a posteriori* error estimate as well as element-wise error indicators allows us to perform mesh adaptive refinements in both space and time. The global trial spaces we consider leads to FE pproximations using classical polynomial FE bases such as Lagrangian interpolants and Raviart-Thomas basis functions. Hence, from a user point-of-view the AVS-FE approximations are standard FE solutions.

We present numerical verifications including numerical asymptotic convergence studies as well as utilization of the bulit-in error indicators to drive adaptive space-time mesh refinements.

References

[1] Calo, V.M., Romkes, A., and Valseth, E., Variationally Stable Analysis for Finite Element Computations: An Introduction, in: Barrenechea G., Mackenzie J. (eds) Boundary and Interior Layers, Computational and Asymptotic Methods BAIL 2018, Springer, 2020, pp. 19–43.

[2] L. Demkowicz and J. Gopalakrishnan. A Class of Discontinuous Petrov-Galerkin Methods. II. Optimal Test Functions. Numerical Methods for Partial Differential Equations, 27(1):70–105, 2011.

[3] Valseth, E., Dawson, C., An Unconditionally Stable Space-Time FE Method for the Korteweg-de Vries Equation. Computer Methods in Applied Mechanics and Engineering 371 (2020) 113297.

Resonance of periodic combination antiviral therapy and intracellular delays in virus model

X.-S. Wang

Abstract. We study within-viral dynamics under general intracellular distributed delays and periodic combination antiviral therapy. The basic reproduction number R_0 is established as a global threshold determining extinction versus persistence, and spectral methods are utilized for analytical and numerical computations of R_0. We derive the critical maturation delay for virus and optimal phase difference between sinusoidally varying drug efficacies under various intracellular delays. Our results demonstrate that the relative timing of the key viral replication cycle steps and periodic antiviral treatment schedule involving distinct drugs all can interact to critically affect the overall viral dynamics. This talk is based on a joint work [1] with Cameron J. Browne (University of Louisiana at Lafayette), Xuejun Pan (Tongji Zhejiang College), and Hongying Shu (Shaanxi Normal University).

References

[1] C. J. Browne, X. Pan, H. Shu and X.-S. Wang, Resonance of periodic combination antiviral therapy and intracellular delays in virus model, *Bulletin of Mathematical Biology*, 82 (2020), 29.

Delay-induced uncertainty in physiological systems

B. Karamched, G. Hripcsak, D. Albers, W. Ott

Abstract. We introduce a novel route through which delay causes dynamical systems to lose reliability. We precisely explain the nature of the resulting delay-induced uncertainty (DIU). Importantly, the chaos induced by the delay is both sustained in time and observable. Our work poses new mathematical questions at the interface of ergodic theory and (infinite-dimensional) delay dynamical systems. We show that DIU occurs in an archetypal physiological model, the Ultradian glucose-insulin model. This observation suggests that DIU may profoundly affect clinical medical care, including glycemic management in the intensive care unit. DIU may be relevant throughout biomedicine because delay is ubiquitous in physiological systems. Developing DIU detection methods and assessing the impact of DIU on data assimilation techniques will be important future research directions.

Elastic full-waveform inversion with petrophysical Information in a probabilistic approach

O. Aragao, P. Sava

Abstract. Elastic full waveform inversion (EFWI) augmented with petrophysical information defines a high standard for velocity model building, as it delivers high-resolution, accurate and lithologically feasible subsurface models. The technique enhances the benefits of using an elastic wave equation over the acoustic implementation while constraining the inverted models to geologically plausible solutions. We derive elastic models of subsurface properties using EFWI and explicitly incorporate petrophysical penalties to guide models toward realistic lithology, i.e., to models consistent with the seismic data as well as with the petrophysical context in the area of study. This methodology mitigates several issues related to EFWI, as it reduces the high non-linearity of the inverse problem, mitigates the artifacts created by inter-parameter crosstalk, and prevents geologically implausible earth models [1],[2]. We define this penalty using multiple probability density functions (PDFs) derived from petrophysical information, such as well logs, where each PDF represents a different lithology. We demonstrate that the combined FWI objective function establishes a more robust foundation for EFWI by explicitly guiding models toward plausible solutions in the specific geological context of the exploration problem, while at the same time reducing the misfit between the observed and modelled data.

References

[1] O. Aragao and P. Sava. Elastic full-waveform inversion with probabilistic petrophysical model constraints. *Geophysics*, 85(2), R101-R111, 2020.

[2] O. Aragao and P. Sava. Elastic full waveform inversion with probabilistic petrophysical clustering. *Geophysical Prospecting*, 68(4), R1341-R1355, 2020.

On R0 in heterogeneous environment

Y. Lou

Abstract. We will discuss some reaction-diffusion models for the spread of disease in spatially heterogeneous and time-periodic environment. Our aim is to understand the effect of frequency and dispersal rate on the basic reproduction number R0, with connections to the eigenvalue theory for linear parabolic operators. This talk is based on a joint work with Shuang Liu.

An asymptotically compatible treatment of traction loads in peridynamics

Y. Yu, H. You, N. Trask

Abstract. Meshfree discretizations of state-based peridynamic models are attractive due to their ability to naturally describe fracture of general materials. However, two factors conspire to prevent meshfree discretizations of state-based peridynamics from converging to corresponding local solutions as resolution is increased: quadrature error prevents an accurate prediction of bulk mechanics, and the lack of an explicit boundary representation presents challenges when applying traction loads. In this work, we develop a reformulation of the linear peridynamic solid (LPS) model to address these shortcomings, using improved meshfree quadrature, a reformulation of the nonlocal dilitation, and a consistent handling of the nonlocal traction condition to construct a model with rigorous accuracy guarantees. In particular, these improvements are designed to enforce discrete consistency in the presence of evolving fractures, whose a priori unknown location render consistent treatment difficult. These improvements provide asymptotically compatible convergence to corresponding local solutions, eliminating surface effects and issues with traction loads which have historically plagued peridynamic discretizations. We provide rigorous error analysis and demonstrate convergence for a number of benchmarks, including manufactured solutions, free-surface, nonhomogeneous traction loads, and composite material problems. Finally, we validate simulations of brittle fracture against a recent experiment of dynamic crack branching in soda-lime glass, providing evidence that the scheme yields accurate predictions for practical engineering problems.

On the Dynamics of solitons for the 'good' Boussinesq equation

V. Vatchev

Abstract. It is well known that multi-soliton solutions of the 'good' Boussinesq equation in one spatial variable exhibit intriguing fission and fusion type of interactions. In the talk we discuss in detail these type of interactions for solutions obtained by Wronskian determinants. We provide complete characterization of the parameters as well as plausible physics interpretation. We also introduce Boussinesq type potentials for which fusion and fission can be observed for different sets of parameters.

Fast multiscale contrast independent preconditioner for linear elastic topology optimization problems
V. Vatchev

Abstract. In this work we study efficient algorithms for the solution of the elasticity equation posed in a domain that represents a material with properties that may variate several orders of magnitude over different scales. Here we focus on the application of the domain decomposition and multiscale approximations to topology optimization problems. Topology optimization consists in finding the efficient use of materials in different settings. In particular we consider the density formulation of the minimum compliance design. In the optimization procedure, an elasticity equation where the material properties are scaled by E_0 outside stiff regions; where E_0 is a positive regularization parameter with $E_0 << 1$. In order to solve this problem we can run an optimizer that requires, in each iteration, the solution of an finite element elasticity equation with high-contrast properties after a few iterations. Most of the computation time is spent in the solution of the linear system needed to compute the next density iterate. The time spent in computing an instance of this elasticity equation may depend on the contrast $1/E_0 >> 1$. In this work we design robust solvers for this elasticity equation. We use the recently introduced Generalized Multiscale Finite Element methods framework in order to construct robust methods (but adapted to the elasticity equation).

Multiagent Reinforcement Learning Accelerated MCMC on Multiscale Inversion Problem
Z. Zhang

Abstract. In this work, we proposed a multi-agent actor-critic reinforcement learning (RL) algorithm to accelerate the multi-level Monte Carlo Markov Chain (MCMC) sampling. The policies (actors) of the agents are used to generate the proposal in the MCMC steps; and the critic which is centralized is in charge of estimating the reward to go. We apply our algorithm to solve an inverse problem with multiscales. We use generalized multiscale finite element methods (GMsFEM) as the forward solvers in evaluating posterior distribution in the multi-level rejection procedure. Our experiments show that the proposed method is a good alternative to the classical sampling process.

Lax representation and Hamiltonian structure for integrable systems
S. Li

Abstract. In this talk, we simplify the Calogero equation and reduce it to one single equation only containing a function $\alpha(x)$ to be determined, and meanwhile the other two $g(x), \gamma(x)$ are able to be expressed in terms of the function $\alpha(x)$. We provide a procedure to determine what kind of function $g(x)$ is appropriate and what is inappropriate. Several examples are analyzed to show integrability and nonintegrability. In particular, some new integrable Hamiltonian systems are found and the remarkable peakon dynamical system is a reduction.

List of E-Posters Contributors

- ▷ P. Alexander, TCU, *Treatment of Viral Coinfections*;
- ▷ H. Dang, Texas Christian University, *Modeling Wound Healing Using Deep Learning*;
- ▷ H. Dobrovolny, Texas Christian University, *SARS-CoV-2 coinfections: Implications for the second wave*;
- ▷ S. Escobar, Rice University, *Effects of Convolution Dimension for Medical Image Segmentation*;
- ▷ I. Eze, university of Texas at Dallas, *Subharmonic Solutions in Second Order Reversible Non-Autonomous Differential Equations*;
- ▷ B. Fain, Texas Christian University, *Validating an agent based model of viral spread in a mono layer of cells*;
- ▷ I. Garli Hevage, Texas Tech University, *Localization property of Einstein's Model with Drift and Absorption*;
- ▷ Z. Ghanem, The University of Texas at Dallas, *The Interface of Reduced Order Modeling and Deep Learning*;
- ▷ S. Hetzel, Southern Methodist University, *Modeling the Spread of COVID-19: A University Study*;
- ▷ K. Johnson, University of California Davis, *Mathematical Modeling of Fish Density and Habitat Relations*;
- ▷ R. Juenemann, Tulane University, *A first-pass statistical dashboard for categorizing diverse particle movement patterns*;
- ▷ S. Lama, The University of Texas at Dallas, *A group formation technique and the rate of convergence for the stochastic weighted particle method*;
- ▷ C. Liao, Texas A&M University, *Learning from Non-Random Data in Hilbert Spaces: An Optimal Recovery Perspective*;
- ▷ T. Mahanama, Texas Tech University, *Tornado Property Loss Scale: Up to $8 Billion by 2025*;
- ▷ K. Mainali, University of the Incarnate Word, *Sylvester type LASSO and It's Application to EEG Inverse Problem*;
- ▷ M. Markowski, Rice University, *Newton-Based Methods for the Numerical Solution of Risk-Averse PDE-Constrained Optimization Problems*;
- ▷ A. Mohideen, North Carolina A&T State University, *Police Funding and Fatal Police Shootings in the United States*;
- ▷ F. Mostafa, Texas Tech University, *Optimization of Robust Clustering from Graphs*;
- ▷ A. Mozumder, University of Texas at Dallas, *A two way coupled model for viscous damping of a vibrating structure with visco-thermo-acoustic forcing*;
- ▷ M. Parker, North Carolina Agricultural and Technical State University, *Regression Analysis of Statewide COVID-19 Data in the U.S.*;
- ▷ W. Saad, German University in Cairo, *On Sinc Methods and Photonic Crystal Fibers*;
- ▷ V. Shinglot, University of Texas at Dallas, *Discovering periodically stationary pulses in a lumped fiber laser model via optimization of a Poincare map functional*;
- ▷ A. Stefan, Florida Institute Technology, *Extension of the Bessmertnyi Realization Theorem*;
- ▷ C. Tian, University of Texas at Austin, *A Modified Bernardi-Raugel Element using Direct Serendipity Space*;

- ▷ C. Wang, UT Austin, *Direct Serendipity and Mixed Finite Elements on Quadrilaterals*;
- ▷ P. Ward, Tarleton State University, *Transit Time Compactness*;
- ▷ G. Woollard, University of Toronto, *Seeing Living Atoms, One Electron at a Time: the expectation-maximization algorithm with Poisson statistics for analyzing counting frames of direct electron detectors in electron cryomicroscopy*;
- ▷ D. Xu, Texas Tech University, *A Distribution-Free Goodness-of-Fit Test*.