UM6P University Mohammed VI Polytechnic

THE UM6P VANGUARD CENTER

INTERNATIONAL CONFERENCE

Mathematics and Decision

DECEMBER 17-20, 2024
THE UM6P VANGUARD CENTER
MOHAMMED VI POLYTECHNIC UNIVERSITY (UM6P)
RABAT, MOROCCO

LIST OF INVITED SPEAKERS

ENRIQUE FERNÁNDEZ CARA (*SPAIN*)
LUC GIRAUD (*FRANCE*)
PATRICK PERRÉ (*FRANCE*)
MARCOS RAYDAN (*PORTUGAL*)
PIERRE AUGER (*FRANCE*)
ALESSANDRO REALI (*ITALY*)
STEFANO SERRA CAPIZZANO (*ITALY*)
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Contents

Preface

This book contains selected abstracts presented at the second edition of the *international conference Mathematics and Decision*, organized by the UM6P Vangurad Center and hosted at Mohammed VI Polytechnic University, Rabat in Morocco, on 17–20 December 2024.
The conference serves as a forum to showcase significant recent advances in several important areas of applied mathematics, including but not limited to operations research, optimization, game theory, partial differential equations, numerical linear, multilinear, and nonlinear algebra and statistics. These fields are instrumental in addressing complex real-world problems. Applications highlighted at the conference span a diverse range of domains, such as machine learning, deep learning, biology, finance, and other emerging areas of scientific and industrial relevance. A special emphasis is placed on the creation and refinement of robust computational methodologies that are specifically designed to tackle practical challenges across these disciplines.

We express our deepest gratitude to the authors for their contributions, which have enriched the scientific program. Special thanks are extended to the distinguished invited speakers, from various countries who accepted to share their expertise and perspectives, thereby elevating the conference to an international standard. We also wish to acknowledge the colleagues who proposed and organized high-quality mini-symposia, as well as the international and local organizing committees from the Vanguard Center, whose tireless efforts and commitment ensured the event's success.

We would like to extend our heartfelt appreciation to Mr. Hicham El Habti, President of Mohammed VI Polytechnic University, for his unwavering support, encouragement, and financial support, which made this international conference possible.

Chairs of the conference,
Khalide Jbilou : Vanguard Center, Mohammed VI Polytechnic University, Morocco
Ahmed Ratnani : Vanguard Center, Mohammed VI Polytechnic University, Morocco

Invited Speakers

- **Marcos Raydan**, NOVA School of Science and Technology, Portugal.
- **Ricardo Vinuesa**, Universidad Politécnica de Madrid, Spain.
- **Patrick Perré**, Universite paris-saclay, France.
- **Luc Giraud**,Inria, Concace joint team with Airbus CR & T and Cerfacs.
- **Alessandro Reali**, Università degli Studi di Pavia, Italy.
- **Enrique Zuazua**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany.
- **Enrique Fernández Cara**, University of Sevilla, Spain.
- **Stefano Serra Capizzano**, Department of Science and High Technology, Insubria University, Italy.
- **Pierre Auger**, UMI IRD 209 UMMISCO & Sorbonne Université, France.

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Plenary talks

Optimization on manifolds for structured matrix problems with fixed eigenvalues

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Abstract

The talk will consider several manifold optimization schemes to solve inverse structured symmetric matrix problems with prescribed spectrum. Some entries in the desired matrix are assigned in advance and cannot be altered, and some others should be nonzero. The rest of the entries are free. The reconstructed matrix must satisfy these requirements and its eigenvalues must be the given ones. This inverse eigenvalue problem is related to the problem of determining the graph, with weights on the undirected edges, of the matrix associated with its sparse pattern. Our optimization schemes are based on considering the eigenvector matrix as the only unknown and moving iteratively on the manifold of orthogonal matrices, forcing the additional structural requirements through a change of variables and a convenient differentiable objective function in the space of square matrices. We propose and analyze Riemannian gradient-type methods combined with either a penalization or an augmented Lagrangian strategy. We also present a block alternating technique that takes advantage of a proper separation of variables. We present some numerical results to demonstrate the effectiveness of our proposals.

This is a joint work with Jean-Paul Chehab and Harry Oviedo.

Keywords: Riemannian optimization, Stiefel manifold, inverse eigenvalue problems, spectral graph theory, augmented Lagrangian.

Hybrid modeling of coupled transfer in porous media: possible options for a mechanistic model ”augmented” by machine learning

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Abstract Mechanistic modelling of coupled transfer in porous media is well-established since several decades [1]. The physical formulation at the macroscopic level includes fundamental balance equations supplied by relevant material parameters. At the macroscopic level, a system of three coupled non-linear equation has a high prediction potential. Provided suitable applied mathematics methods are implemented, computational simulations can predict real configurations, including configurations that were not observed before. On the opposite, thanks to their ability to tackle non-linear and dynamics problems, Machine Learning (ML) based model are capable of coping with complex situations even better than mechanistic modelling [2,3]. The main drawback of mechanistic models is their complexity as operational tools, namely in providing the whole set of product characteristics, while the main drawback of ML tools is its restriction to the domain paved by the database. Different pathways can be proposed to merge the best of the two worlds:

- A full coupled method (hybrid model)
- A fully decoupled method (data base populated by mechanistic modeling used for ML)
- A cascade coupling (ML to complete mechanistic outcomes)

This conference will summarize the physics of the mechanistic formulation and then will present the different possibilities of coupling the mechanistic and ML approaches to obtain an ”augmented” mechanistic model, suitable for process optimization or process control. Finally, the extension of this approach to different configurations, such as biotechnological processes, will be drafted.

Keywords: building energy, drying, machine learning, non-linear equations, on-line tuning, processes.

References

[1] S. Whitaker, Simultaneous heat, mass and momentum transfer in porous media: a theory of drying, Advances in Heat Transfer, 13: 119–203. Elsevier, 1977

[2] A. Martynenko and N. Misra, Machine learning in drying. Drying Technology, 38: 596–609, 2020

[3] M. I. H. Khan, S. S. Sablani, R. Nayak, and Y. Gu, Machine learning-based modeling in food processing applications: State of the art, Comprehensive Reviews in Food Science and Food Safety, 21: 1409–1438, 2022

A Journey on Subspace Methods for the Solution of Sequences of Linear Systems

Luc Giraud[1], Emmanuel Agullo[1], Olivier Coulaud[1], Martina Iannacito[2], Gilles Marait[1], Yanfei Xiang[1]

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Abstract In various scientific and industrial applications, solving sequences of linear systems for multiple left and right-hand sides provided either simultaneously or sequentially is a common and challenging task. This talk delves into subspace methods designed to address these challenges, presenting advances that facilitate the efficient solution of such systems in high-dimensional settings.

The first part of the presentation will focus on a class of block methods that allow simultaneous handling of multiple right-hand sides. These techniques face unique challenges, such as managing varying convergence rates across different right-hand sides, necessitating dynamic strategies for adapting the solution subspaces.

In the second part, we will explore tensor-based methods, an essential approach for mitigating the curse of dimensionality. By adapting inexact GMRES with low-rank tensor approximations, we show how these methods make high-dimensional problem-solving feasible. We will also discuss theoretical bounds that evaluate solution accuracy in variable precision settings, particularly when low-rank approximations are employed.

Keywords: block subspace emthods, spectral recycling, subspace extension policies, low rank tensors.

References

[1] Emmanuel Agullo, Luc Giraud, Yan-Fei Jing, Block GMRES method with inexact breakdowns and deflated restarting SIAM Journal on Matrix Analysis and Applications, 2014, 35 (4), pp.1625-1651.

[2] Emmanuel Agullo, Olivier Coulaud, Luc Giraud, Martina Iannacito, Gilles Marait, Nick Schenkels The backward stable variants of GMRES in variable accuracy RR-9483, Inria. 2022, pp.1-77

[3] Luc Giraud, Yan-Fei Jing, Yanfei Xiang A block minimum residual norm subspace solver with partial convergence management for sequences of linear systems SIAM Journal on Matrix Analysis and Applications, 2022, 43 (2), pp.710-739.

[4] Olivier Coulaud, Luc Giraud, Martina Iannacito A robust GMRES algorithm in Tensor Train format RR-9484, Inria. 2022, pp.1-48

[5] Mickael Robbé and Miloud Sadkane, Exact and inexact breakdowns in the block GMRES method, Linear Algebra Appl., 419 (2006), pp. 265–285.

Tracking control

Enrique Zuazua[1]

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Abstract

In this lecture, we introduce and investigate the concept of tracking controllability, where the goal is to ensure that the state of a control system, or a specified projection of it, follows a predetermined trajectory within a given time horizon. Through the use of duality principles, we characterize tracking controllability via a novel observability inequality for the adjoint system. This characterization enables the systematic construction of minimal-norm control inputs. However, establishing this observability inequality presents significant challenges. We first address the problem for the wave equation and then extend the approach to the heat equation using transmutation techniques. Additionally, we examine the implications of tracking controllability within finite-dimensional control systems, highlighting both theoretical insights and practical considerations.

Keywords: tracking controllability, duality principle, observability inequality, transmutation technique, minimal-norm control.

References

[1] Jon Asier Bárcena-Petisco, Enrique Zuazua, Tracking controllability for the heat equation, arXiv: 2310.00314 (2024).

[2] Sebastián Zamorano and Enrique Zuazua, Tracking controllability for finite-dimensional linear systems, arXiv: 2407.18641 (2024).

Theoretical and Numerical Contributions to the Control of PDEs

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Abstract In this talk, I will try to present some recent advances in the control of PDEs. Specifically, I will refer to:

- Control and domain identification for heat and Burgers PDEs and associated free-boundary systems.
- Null control of two-phase Stefan free-boundary problems.
- Nash and Pareto equilibria for Navier-Stokes PDEs and other similar systems.
- Minimal time control problems and applications, etc.

The results have been obtained in collaboration with A. Doubova, I. Marín-Gayte, M. González-Burgos and D.A. Souza, among others; see [1] and the references therein.

I will also present with detail several related open questions that may motivate the work in the next future. To this regard, I will try to explain the results we need, what is expected and what is not and how numerical experiments can help to understand and catch the ideas.

Keywords: Control theory, null controllability, bi-objective optimal control, parabolic PDEs and systems, Stefan free-boundary problems, Navier-Stokes equations.

References

[1] E. Fernández-Cara, *Remarks on control and inverse problems for PDEs,* SeMA Journal (to appear).

Updating the GLT analysis, new tools, and beyond

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Abstract The class of Generalized Locally Toeplitz (GLT) sequences has been introduced as a generalization both of classical Toeplitz sequences and of variable coefficient differential operators and, for every sequence of the class, it has been demonstrated that it is possible to give a rigorous description of the asymptotic spectrum in terms of a function (the symbol) that can be easily identified.

This generalizes the notion of a symbol for differential operators (discrete and continuous) or for Toeplitz sequences, where for the latter it is identified through the Fourier coefficients and is related to the classical Fourier Analysis.

The GLT class has nice algebraic properties and indeed it has been proven that it is stable under linear combinations, products, and inversion when the sequence which is inverted shows a sparsely vanishing symbol (sparsely vanishing symbol = a symbol which vanishes at most in a set of zero Lebesgue measure). Furthermore, the GLT class virtually includes any approximation of partial differential equations (PDEs), fractional differential equations (FDEs), integro-differential equations (IDEs) by local methods (Finite Difference, Finite Element, Isogeometric Analysis etc) and, based on this, we demonstrate that our results on GLT sequences can be used in a PDE/FDE/IDE setting in various directions, including multi-iterative solvers (combining preconditioned Krylov, multigrid, etc), spectral detection of branches, fast 'matrix-less' computation of eigenvalues, stability issues. We will discuss also the impact and the further potential of the theory with special attention to new tools and to new directions as those based on symmetrization tricks, on the extra-dimensional approach, and on blocking structures/operations.

Keywords:GLT, (g)acs, blocking, flipping, extra-dimensional, approximated PDEs, FDEs, IDEs, eigenvalues, singular values, Weyl distributions, Krylov methods, multigrid, multi-iterative solvers

References

[1] G. Barbarino, C. Garoni, S. Serra-Capizzano. Block generalized locally Toeplitz sequences: theory and applications in the unidimensional case. *Electron. Trans. Numer. Anal.* **53** (2020), 28–112.

[2] G. Barbarino, C. Garoni, S. Serra-Capizzano. Block generalized locally Toeplitz sequences: theory and applications in the multidimensional case. *Electron. Trans. Numer. Anal.* **53** (2020), 113–216.

[3] P. Ferrari, I. Furci, S. Hon, M. Mursaleen, S. Serra-Capizzano. The eigenvalue distribution of special 2-by-2 block matrix-sequences with applications to the case of symmetrized Toeplitz structures. *SIAM J. Matrix Anal. Appl.* **40-3** (2019), 1066-–1086.

[4] S. Serra-Capizzano. Multi-iterative methods. 26 (1993), no. 4, 65–87. *Comput. Math. Appl.* **26-4** (1993), 65-–87.

Effect of environmental heterogeneity on the increase in Maximum Sustainable Yield (MSY) in a multi-site fishery

Pierre Auger[1]

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Abstract

We consider a fishery consisting of two fishing sites connected by fish migrations. At each site we assume the classic fishery model with a logistically growing fish population and a Schaefer catch. We assume that migrations between the two sites are fast relative to local growth and fishing. Taking advantage of the time scales, we use methods of aggregation of variables to obtain a reduced model governing the total biomass of the fish population at a slow time scale. Then, we are looking for the maximum sustainable yield (MSY) for the system of the two connected patches. We show that although the total equilibrium population may be greater than the sum of the carrying capacities on each isolated site, the total catch is always less than or equal to the sum of the catches on the isolated fishing sites. We then consider a Lotka-Volterra prey-predator fish community in the same environment. We assume that only the predator is caught and not its prey, still growing logistically on each site. We show that in this case due to connectivity the total catch at MSY can be greater than the sum of the captures on each isolated site. This last result is held when the two sites are heterogeneous. Two heterogeneity parameters are important, the growth rate of the prey and a parameter characterizing the viability of the predator. It appears that the prey growth rate has to be large at one site while the predator viability has to be high at the other site in order to promote excess MSY. Furthermore, an emergence phenomenon can also be observed: even if none of the sites is viable for fishing, the entire system can be viable. Our study is extended to the prey-predator model with a type II Holling functional response

Some advances and applications in isogeometric analysis of coupled and complex problems

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Abstract Isogeometric Analysis (IGA) is a successful simulation framework originally proposed by T.J.R. Hughes et al., in 2005, with the aim of bridging Computational Mechanics and Computer Aided Design. In addition to this, thanks to the high-regularity properties of its basis functions, IGA has shown a better accuracy per degree-of-freedom and an enhanced robustness with respect to standard finite elements in many applications - ranging from solids and structures to fluids, as well as to different kinds of coupled problems - opening also the door for the approximation in primal form of higher-order partial differential equations. After a concise introduction of the basic isogeometric concepts, this lecture aims at presenting an overview of some recent advances in IGA with a special focus on coupled and complex problems where the characteristics of IGA seem to be of great advantage. In particular, applications that will be discussed include the simulation of fluid-structure interaction in different contexts, studies on the effect of mechanically-induced stresses on cancer growth, thermomechanical simulations of additive manufacturing processes, electro-mechanical simulations for biological tissues, and the use of phase-field modeling for fracture and topology optimization problems or for predicting the polarization evolution in elastic ferroelectric materials.

Keywords: Isogeometric analysis, immersed methods, coupled problems, phase-field modeling.

Contributed talks and posters

Generalized dictionary learnin using t-product

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Abstract

Dictionary learning is a technique in signal processing and machine learning that represents data using a set of basic elements, called atoms, from an overcomplete dictionary. Its main goal is to find a dictionary that efficiently represents data while promoting sparsity. This method is applied in various areas, such as image denoising, completion, classification, and more. In this work, we present a generalization of the dictionary learning problem using the t-product, and we employ both batch and online methods to solve it. We provide various numerical results to demonstrate the efficiency of our approach.

Keywords: dictionary learning, Tensors, t-product, completion.

References

[1] Kilmer, M.E., Martin, C.D.: Factorization strategies for third-order tensors. Linear Algebra and its Applications 435(3), 641–658 (2011).

[2] Liu, J., Garcia-Cardona, C., Wohlberg, B., Yin, W.: First- and Second-Order Methods for Online Convolutional Dictionary Learning. SIAM Journal on Imaging Sciences 11(2), 1589–1628 (2018)

[3] Zhang, Z., Aeron, S.: Denoising and Completion of 3D Data via Multidimensional Dictionary Learning

Modeling the mechanisms of antibody mixtures in viral infections: the cases of sequential homologous and heterologous dengue infections

Mostafa Adimy[1], Charlotte Dugourd-Camus[1], Claudia Pio Ferreira[3]

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Abstract

Antibodies play an essential role in the immune response to viral infections, vaccination, or antibody therapy. Nevertheless, they can be either protective or harmful during the immune response. Moreover, competition or cooperation between mixed antibodies can enhance or reduce this protective or harmful effect. Using the laws of chemical reactions, we propose (see [1]) a new approach to modeling the antigen-antibody complex activity. The resulting expression covers not only purely competitive or purely independent binding but also synergistic binding which, depending on the antibodies, can promote either neutralization or enhancement of viral activity. We then integrate this expression of viral activity in a within-host model and investigate the existence of steady-states and their asymptotic stability. We complete our study with numerical simulations to illustrate different scenarios: firstly, where both antibodies are neutralizing, and secondly, where one antibody is neutralizing and the other enhancing. The results indicate that efficient viral neutralization is associated with purely independent antibody binding, whereas strong viral activity enhancement is expected in the case of purely competitive antibody binding. Finally, data collected during a secondary dengue infection were used to validate the model. The data set includes sequential measurements of virus and antibody titers during viremia in patients. Data fitting shows that the two antibodies are in strong competition, as the synergistic binding is low. This contributes to the high levels of virus titers and may explain the Antibody-Dependent Enhancement phenomenon. Besides, the mortality of infected cells is almost twice as high as that of susceptible cells, and the heterogeneity of viral kinetics in patients is associated with variability in antibody responses between individuals. Other applications of the model may be considered, such as the efficacy of vaccines and antibody-based therapies.

Keywords: Humoral immunity response, Infectious diseases, Chemical reactions, Ordinary differential equations, Basic reproduction number, Local and global asymptotic stability.
34C60, 34D05, 37N25, 92C40, 92C45.

References

[1] C. Dugourd-Camus, C.P. Ferreira, M. Adimy, Modelling the mechanisms of antibody mixtures in viral infections: the cases of sequential homologous and heterologous dengue infections. Journal of the Royal Society Interface, 21(219), (2024).

Mean Field Games (MFGs) with a Major Player

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Abstract

This study explores Mean Field Games (MFG) with a major player, where a dominant agent significantly influences the dynamics of a large population of interacting minor agents. The minor players interact symmetrically and are influenced by the major player's actions, while the major player accounts for the collective behavior of the population. The framework combines stochastic differential equations, optimal control theory, and Nash equilibrium concepts, stochastic Hamilton Jacobi bellman equation and Stochastic maximum principle.
This study aims to understand the influence of the major player on the dynamics of the minor players and to derive analytical or numerical solutions to achieve equilibrium

Keywords:MFG With major player, SHJB, stochastic maximum principle, MFG, Nash equilibrium, control theory

References

[1] MOJTABA NOURIAN AND PETER E. CAINES, ϵ-NASH MEAN FIELD GAME THEORY FOR NONLINEAR STOCHASTIC DYNAMICAL SYSTEMS WITH MAJOR AND MINOR AGENTS

[2] RENÉ CARMONA AND XIUNENG ZHU, A PROBABILISTIC APPROACH TO MEAN FIELD GAMES WITH MAJOR AND MINOR PLAYERS

[3] RENÉ CARMONA , Lectures on BSDEs, Stochastic Control, and Stochastic Differential Games with Financial Applications

[4] RENÉ CARMONA AND FRANÇOIS DELARUE , Probabilistic Theory of Mean Field Games with Applications

Fleet Replacement Decision Optimization: Models and Approaches

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Abstract

Recently, the use of more sustainable forms of transportation such as electric vehicles (EVs) for delivering goods and parcels to customers in urban areas has received more attention from urban planners and private stakeholders. The urban freight transportation sector is examining such a shift toward using electric vehicles, besides current combustion engine vehicles, to deliver goods and services to customers. To contribute toward sustainable transportation in urban logistics, we consider the important factor of decision replacement management and study how to shift toward sustainable modes of transportation, specifically EVs, in an urban area. In this research, we will try to address the fleet composition problem of a transport operator over some planning time period in the presence of uncertainties.

Keywords: Fleet replacement problem, Optimization framework, Electric vehicle

Stability and bifurcation for delay model of cancer-immune system interaction

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Abstract

The present study builds upon the classical cancer-immune model, which includes three compartments representing the populations of cancer cells, resting immune cells, and active (hunting) immune cells. We introduce an additional compartment to account for the transitional phase between resting and hunting cells, referred to as naive cells. Specifically, we identify a post-stimulation period during which naive cells convert into hunting cells, characterized by a delay that defines the maximum duration of this differentiation process. Furthermore, the dynamics of naive cells are described by an age-structured partial differential equation. We then simplify the model using the method of characteristics, resulting in a delay differential equation. The objective of this work is to investigate the influence of delay on the stability and dynamics of the cancer-immune interaction model. By treating the delay as a bifurcation parameter, we establish the conditions for the stability of steady states and explore the existence of Hopf bifurcation. Finally, we conduct numerical simulations to illustrate the theoretical findings.

Keywords: Cancer cells, immune cells, age-structured, naive cells, time delay, Hopf bifurcation.

References

[1] Helen Moore and Natasha K. Li. A mathematical model for chronic myelogenous leukemia (CML) and T cell interaction. *Journal of Theoretical Biology* 227 (2004), 513-523.

[2] Ping Bi and Shigui Ruan. Bifurcation in Delay Differential Equations and Applications to Tumor and Immune System Interaction Models. *SIAM Journal Applied Dynamical Systems* 12, 4 (2013), 1847–1888.

[3] Yueping Dong, Gang Huang, Rinko Miyazaki, Yasuhiro Takeuchi. Dynamics in a tumor immune system with time delays. *Applied Mathematics and Computation* 252 (2015), 99–113.

[4] Kaushik Dehingia, Parthasakha Das, Ranjit Kumar Upadhyay, Arvind Kumar Misra, Fathalla A. Rihan, Kamyar Hosseini. Modelling and analysis of delayed tumour–immune system with hunting T-cells.*Mathematics and Computers in Simulation* 203 (2023), 669–684.

[5] Huo Zhaoxuan and Huang Jicai and Kuang Yang and Ruan Shigui and Zhang Yuyue. Oscillations in a tumor–immune system interaction model with immune response delay.*Mathematical Medicine and Biology: A Journal of the IMA* (2024)

Generalization error estimates for Physics-Informed Neural Networks in the approximation of PDEs

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Abstract

Physics-Informed Neural Networks (PINNs) have emerged as a promising tool for solving Partial Differential Equations (PDEs) by embedding physical laws directly into the neural network training process. However, despite their growing popularity, rigorous error analysis of PINNs remains a crucial area of study. This work provides a detailed investigation of the error bounds of PINNs when applied to solve PDEs, particularly focusing on semi-linear problems. We derive theoretical error estimates that account for both the training error of the neural network and the residual error arising from the PDE constraint. Numerical experiments, validating our results, are also presented.

Keywords: PINNs, Partial differential equations (PDEs), Generalization error.

References

[1] T. De Ryck, A. D. Jagtap, S. Mishra, Error estimates for physics-informed neural networks approximating the Navier–Stokes equations, IMA J. Numer. Anal. 44 (1) (2023) 83–119.

[2] Siddhartha Mishra and Roberto Molinaro, Estimates on the generalization error of physics-informed neural networks for approximating a class of inverse problems for PDEs. IMA Journal of Numerical Analysis, 42(2):981– 1022, 2022.

[3] Tim De Ryck and Siddhartha Mishra, Error analysis for physics-informed neural networks (pinns) approximating kolmogorov pdes. Advances in Computational Mathematics, 48(6):79, 2022.

[4] G., Koley, U., Mishra, S. Molinaro, R., (2021), Physics informed neural networks (PINNs) for approximating nonlinear dispersive PDEs, arXiv preprint arXiv:2104.05584 .

[5] Kovachki, N., Lanthaler, S. Mishra, S. (2021),, On universal approximation and error bounds for Fourier Neural Operators, Journal of Machine Learning Re search 22, 176.

Mathematical Models for Task Scheduling and Resource Management in Edge and Fog Computing

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Abstract

Within the context of the rapidly advancing field of modern technology, the efficiency of communication and computing infrastructures is paramount for the success of various applications, from healthcare to industrial automation. The proliferation of the Internet of Things (IoT) has further heightened the demand for robust, low-latency, and energy-efficient networks capable of managing the vast amounts of data generated by billions of connected devices. This work compiles a series of technical studies that delve into advanced scheduling algorithms and resource management strategies within edge and fog computing environments. The study explores two primary concepts: minimizing task offloading latency in IoT systems to enhance healthcare monitoring through fog computing and machine learning, and optimizing resource allocation in 5G networks. It addresses the integration of IoT-based healthcare monitoring systems with fog computing to reduce latency issues, introducing a machine learning-based medical data segmentation technique that significantly improves classification accuracy and reduces latency. This work also examines the task offloading challenges faced by COVID-19 IoT devices in time-sensitive applications, proposing an optimization model to minimize latency and manage energy consumption in an edge computing scenario. Furthermore, it presents the Factory Resource Optimization (FRO) framework, which leverages Mobile Edge Computing, Network Slicing, and a modified Non-Orthogonal Multiple Access strategy to optimize resource allocation in 5G smart factory environments, achieving substantial energy savings and ensuring reliable low-latency communication for safety-critical equipment.

Keywords: IoT, Fog Computing, Edge Computing, Task Scheduling, Resource Optimization, 5G Networks, Machine Learning, Task Offloading, Low Latency, Energy Efficiency

1 Significant Contributions and Research Outcomes

This work significantly contributes to advancing scalable, reliable, and efficient IoT networks by addressing critical challenges in task offloading optimization. The proposed solutions enhance network performance and offer practical frameworks for real-world implementations, particularly in critical sectors such as healthcare and industrial automation. These contributions go beyond theoretical advancements, laying a foundation for next-generation IoT systems capable of handling increasingly complex and data-intensive applications. The research outcomes provide valuable insights into the development of more resilient communication infrastructures, ensuring the scalability and efficiency of IoT networks to meet future demands.

The study presents an innovative patient monitoring system designed for e-health, leveraging a hybrid IoT-fog-cloud architecture. This system integrates private and public clouds with fog nodes to enhance performance, particularly in reducing latency. The private cloud, located near the hospital, complements the public cloud, while the fog nodes handle data processing locally, minimizing delays from body sensor devices. Analytical models and mathematical formulas are developed to estimate key performance metrics and determine optimal computing resources for cloud and fog nodes. This immediate, scalable approach differs from simulation-based methods, providing dynamic solutions to meet specific performance targets. The key contributions in this area include the development of a novel IoT-fog-cloud architecture for patient health monitoring, the use of a random forest algorithm to prevent overfitting, and an analytical queuing model to assess the reliability of remote patient monitoring systems. Numerical examples further demonstrate the model's effectiveness in optimizing healthcare system performance under varying IoMT workloads [1].

This study also focuses on minimizing task offloading latency for COVID-19 IoT devices, particularly those with low energy and latency requirements. An optimization model is proposed using the Orthogonal Multiple Access (OMA) scheme to reduce delay for COVID-19 IoT devices while meeting the demands of low-energy sensor devices. The Dynamic Bandwidth and Computing Power Resource Allocation (DBCP-RA) algorithm is introduced, outperforming traditional network allocation methods. The contributions include a focus on low-latency requirements for COVID-19 IoT devices, efficient energy management for sensor devices, and a convex optimization problem to minimize latency thresholds. Simulations reveal that the proposed orthogonal slicing approach significantly improves performance compared to conventional benchmarks [2].

Additionally, this study introduces the Factory Resource Optimization (FRO) framework for optimizing resource allocation in 5G-enabled smart factories. This framework integrates Mobile Edge Computing (MEC), Network Slicing, and a modified Non-Orthogonal Multiple Access (NOMA) strategy to meet the diverse needs of Factory Safety Detectors (FSDs) requiring ultra-low latency (URLLC) and Equipment Monitoring Units (EMUs) focused on minimal energy consumption (mMTC). The study formulates a non-convex optimization problem and proposes an iterative algorithm for subchannel allocation and power control, optimizing both energy consumption and latency. The Hungarian Algorithm is employed for computational efficiency, and simulation results demonstrate significant improvements in both energy consumption and latency, confirming the framework's applicability in real-world industrial environments [3].

References

[1] A. Amzil, M. Abid, M. Hanini, A. Zaaloul, and S. El Kafhali, *Stochastic analysis of fog computing and machine learning for scalable low-latency healthcare monitoring,* Cluster Computing, vol. 27, no. 5, pp. 6097–6117, Feb. 2024.

[2] A. Amzil, M. Hanini, A. Zaaloul, M. Abid, and S. El Kafhali, *Minimization of Task Offloading Latency for COVID-19 IoT Devices,* Advances in Intelligent System and Smart Technologies, pp. 189–198, 2024.

[3] A. Amzil, M. Hanini, A. Zaaloul, *Optimizing Resource Allocation in 5G Networks: An Integrated Approach With Mobile Edge Computing, and Network Slicing.* In press.

Low-rank Tensor Completion via Einstein product

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Abstract

Low-rank matrix completion is one of the most studied problems which consist of generating a completed matrix from partially observed entries. In this work, we aim to solve the tensorial completion problem using the method of Stochastic Gradient Descent (SGD) in the framework of the Einstein product, while using the Burer-Monteiro factorization.

Keywords: Tensor completion, Burer-Monteiro factorization, Einstein product, SGD . . .

References

[1] D. Bertsimas, M. Lingzhi Li, Fast Exact Matrix Completion: A Unified Optimization Framework for Matrix Completion; Journal of Machine Learning Research; 21(231):1-43, 2020.

Deep Learning for Mean Field Games

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Abstract

Mean Field Games (MFGs) have emerged as a powerful framework to model complex systems involving many interacting agents. These games find applications in various domains such as autonomous vehicles, finance, economics, and industry. These dynamic, symmetric games describe interactions among rational, indistinguishable agents whose actions influence the population mean. The goal is often to compute a Nash equilibrium, where no agent can unilaterally improve their objective. We focus on the Partial Differential Equations (PDEs) approach to MFGs, which uses coupled forward-backwards PDEs to model the system. However, solving these equations in high dimensions is computationally challenging due to the curse of dimensionality. To address this, we propose novel deep learning-based methods for solving high-dimensional MFGs. Our approach combines neural networks with the theoretical structure of MFGs, offering a scalable and efficient alternative to standard numerical methods. Numerical experiments highlight its effectiveness in overcoming computational barriers, paving the way for broader applications.

Fractional Laplacian and ADMM for glyph extraction

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Abstract

In archaeology it is a common task to extract incisions or glyphs from a surface. This procedure is usually done manually and, therefore, it is prone to errors and it can be extremely time consuming. In this talk we present a variational model to automatically extract these incisions from a smooth surface.

We model this problem in the following way. Let $\mathbf{x} \in \mathbb{R}^n$ be a vector containing a sampling of the archaeological surface, we wish to find two vectors $\mathbf{x}_s^*$ and $\mathbf{x}_g^*$ such that $\mathbf{x} = \mathbf{x}_s^* + \mathbf{x}_g^*$, where $\mathbf{x}_s^*$ is smooth and contains the background and $\mathbf{x}_g^*$ is sparse and contains the glyph. To this aim we consider the model

$$\left(\mathbf{x}_s^*, \mathbf{x}_g^*\right) = \arg \min_{\mathbf{x}_s, \mathbf{x}_g \in \mathbb{R}^{n \times n}} \frac{1}{2} \left\| L^\alpha \mathbf{x}_s \right\|_2^2 + \mu \left\| \mathbf{x}_g \right\|_1 ,$$

$$\text{s.t. } \mathbf{x}_s + \mathbf{x}_g = \mathbf{x},$$

where $\mu > 0$, $\alpha \in [1, 2]$, $\|\mathbf{x}\|_p^p = \sum_{i=1}^n |\mathbf{x}_i|^p$, and $L \in \mathbb{R}^{n \times n}$ denotes the Laplacian operator. To perform the minimization, we employ the Alternating Direction Multiplier Method (ADMM). We provide a procedure to generate realistic synthetic data and we show the performances of the proposed method on this kind of data.

Keywords: Glyph extraction, Variational models, Fractional Laplacian, Alternating Direction Multiplier Method

References

[1] S. BOYD, N. PARIKH, E.CHU, B. PELEATO, J. ECKSTEIN,, et al, Distributed optimization and statistical learning via the alternating direction method of multipliers, Foundations and Trends® in Machine learning 3 (2011) 1–122.

[2] E. DI NEZZA, G. PALATUCCI, E. VALDINOCI, Hitchhiker's guide to the fractional Sobolev spaces, Bulletin des sciences mathématiques 136 (2012) 521–573.

[3] A. GHOLAMI, S. GAZZOLA, Automatic balancing parameter selection for Tikhonov-TV regularization, BIT Numerical Mathematics 62 (2022) 1873–1898.

New approach for solving the discrete Navier-Stokes problems:Application to Sequences of Saddle-Point Linear Systems from Incompressible Flow

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Abstract

Many practical applications of Navier-Stokes problems require solving sequences of saddle-point systems. These systems often arise from the mixed-finite element discretization of the Navier-Stokes equations. A popular strategy to solve them is by combining preconditioning techniques with Krylov subspace methods, which has proven effective in achieving computational efficiency. Since global Krylov subspace methods are specifically designed for solving saddle-point problems with multiple right-hand sides, they cannot be utilized for solving sequences of these problems. We propose an alter- native approach applicable to matrices with a saddle-point structure. In this new approach, projection into the null-space of the block-(2,1) of the saddle-point matrix leads to a linear system with several right-hand sides. Due to the large scale and ill-conditioned nature of these linear systems, effective solvers must be implemented. Instead of applying a standard iterative method to solve each linear system independently, it is often more effective to apply a global method. Here, we develop and assess various methods for solving linear systems with several right-hand sides, with a special focus on the preconditioned global conjugate gradient (PGCG) method. We show that our suggested approach is highly effective for sequences of saddle-point systems with varying matrices. The efficiency of our new approach is evaluated by measuring computational time.

Keywords: Sequences of saddle-point systems, preconditioner, Krylov subspace method, global Krylov subspace method

References

[1] M. Benzi, G. H. Golub and J. Liesen, Numerical solution of saddle point problems, Acta Numerica, 14 (2005), pp. 1-137.

[2] M. Bellalij, K. Jbilou, H. Sadok, New convergence results on the global GMRES method for diagonalizable matrices, J. Comput. Appl. Math., 219 (2008), pp. 350-358.

[3] A. Badahmane, Regularized preconditioned gmres and the regularized iteration method, Appl. Numer. Math., 152 (2020), pp. 159–168.

Utilizing Monte Carlo Simulations and Kinetic Theory to Understand Pedestrian Social Groups

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Abstract

This research investigates the application of kinetic theory to model the behavior of pedestrian social groups in confined spaces. Social groups are defined as individuals connected through social ties who intentionally move together, such as friends or family members. The model incorporates the varied behaviors of these groups through an activity variable. We developed numerical simulations using the Monte Carlo particle method. The model effectively captures key aspects of social group dynamics, including avoidance behavior, evacuation strategies, and the inclination to maintain consistent activity levels. To illustrate its applicability, several scenarios were examined, focusing on the evacuation of a room featuring one or two exits and either a bar-shaped or rectangular obstacle.

Keywords: Kinetic theory, pedestrian social groups, Monte Carlo method, evacuation scenarios.

References

[1] N. Bakhdil, A. El Mousaoui and A. Hakim, A kinetic theory approach to model pedestrian social groups behavior in bounded domain, Kinet. Relat. Models, vol. 17, pp. 88—106, 2024.

[2] N. Bellomo and L. Gibelli, Toward a mathematical theory of behavioral-social dynamics for pedestrian crowds, Math. Models Methods Appl. Sci., vol. 25, pp. 2417-2437, 2015.

[3] A. El Moussaoui, P. Argoul, M. El Rhabi and A. Hakim, Discrete kinetic theory for 2D modeling of a moving crowd: Application to the evacuation of a non-connected bounded domain, Comput. Math. Appl., vol. 75, pp. 1159—1180, 2018.

Optimal control of molecular coherent states

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Abstract: We address the optimal control problem in molecular systems, focusing on transitions within coherent states characterised by complex coefficients. Employing Hölder's inequality, we establish a mathematical relationship between the energy requirement and the distance separating the initial and the target coherent states. A key part of our study is the application of this framework to the H_2O molecule, specifically examining the local OH bond. Here, we demonstrate how energy requirements for the state transitions are influenced by the distance between these states. Furthermore, we investigate the effects of a heat bath coupled to the system, by analysing its impact on transferring the molecular system to different final coherent states. These coherent states are defined as almost eigenvectors of the Generalised Heisenberg Algebra (GHA) annihilation operator. By using the Perelomov approach, another type of coherent state for the Morse potential associated with the GHA can be constructed. By leveraging the GHA structure, we revisit and analyse Morse coherent states previously established for certain diatomic molecules, offering a deeper insight into the dynamics of state transitions under various conditions.

Keywords:Optimal control; Molecular systems.

Analysis of stability in a Predator-Prey eco-epidemic model with cooperative hunting and fear factors

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Abstract

We propose a system of delay differential equations to represent predator-prey eco-epidemic dynamics. The model incorporates the effects of predation risk-induced fear on prey and collaborative hunting strategies of predators. The crucial aim of the study is to analyze the system's dynamics under the influence of predator-hunting cooperation, discrete-time delay, and fear effect. We examine key mathematical characteristics of the proposed model, including boundedness, persistence, local stability, and Hopf bifurcation near the system's positive steady state. Additionally, we conduct numerous numerical simulations with different parameter sets to validate our analytical results.

Keywords: eco-epidemiological model, discrete-time delay, hunting cooperation, Hopf-bifurcation, fear effect.

References

[1] Hale JK, Lunel SMV (2013) Introduction to functional differential equations, vol 99. Springer

[2] Alves MT, Hilker FM (2017) Hunting cooperation and Allee effects in predators. J Theor Biol 419:13 22.

[3] Panday P, Samanta S, Pal N, Chattopadhyay J (2020) Delay induced multiple stability switch and chaos in a predator –prey model with fear effect. Math Comput Simul 172:134

"Modeling and Decision Making in Public Health: Issues, Structures, and Perspectives"

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Abstract:
Modeling in public health has emerged as a crucial tool for decision-making, particularly highlighted during the COVID-19 pandemic. This presentation explores the necessity and challenges of modeling in this field, drawing on the experience of this global health crisis.
Firstly, we will discuss the types of issues that modeling addresses in times of crisis, such as predicting epidemic dynamics or evaluating intervention measures, as well as in non-crisis periods, particularly for planning and optimizing health systems in the long term. We will then address the question of the adequacy between models and available data, examining how the quality and accessibility of data influence the relevance and robustness of models, while also proposing solutions to improve this adequacy.
The last two parts of the presentation will focus on the role of modeling within the decision-making ecosystem, highlighting the interactions between experts, policymakers, and data, as well as the structures necessary for effective modeling. In this last point, we will review concrete examples of modeling structures in Africa, offering perspectives on the specific challenges and opportunities in this context.
This presentation thus aims to provide a reflection on the foundations and applications of modeling as a strategic lever to improve public health policies.

Riemannian optimization applied to low-rank matrix and tensor completion

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Abstract

In some constrained optimization problems, the feasible set possesses a natural smooth manifold structure, which can be sometimes endowed with a Riemannian metric that is relevant to the problem. Setting the feasible set as the domain of the objective function makes the problem into an unconstrained one.

We present how the differential and geometric structure of manifolds was exploited to generalize some classical unconstrained optimization algorithms to the optimization problems on manifolds [1, 4]. We then mention how these and other special-purpose optimization algorithms were used to solve low-rank matrix and tensor completion problems [3, 5, 2], which are related to some decision-making problems like the *Netflix problem*.

Keywords: Riemannian optimization, matrix completion, tensor completion.

References

[1] N. BOUMAL, *An Introduction to Optimization on Smooth Manifolds*, Cambridge University Press, 2023.

[2] D. KRESSNER, M. STEINLECHNER, AND B. VANDEREYCKEN, "Low-rank tensor completion by Riemannian optimization". In: *BIT Numerical Mathematics* 54.2 (2014), pp. 447-468.

[3] L. T. NGUYEN, J. KIM, AND B. SHIM, "Low-Rank Matrix Completion: A Contemporary Survey". In: *IEEE Access* 7 (2019), pp. 94215-94237.

[4] H. SATO, *Riemannian Optimization and Its Applications*, SpringerBriefs in Electrical and Computer Engineering · Control, Automation and Robotics, Springer Cham, 2021.

[5] B. VANDEREYCKEN, "Low-Rank Matrix Completion by Riemannian Optimization" In: *SIAM Journal on Optimization* 23.2 (2013), pp. 1214-1236.

Adaptive Replication Strategies in Trust Region-Based Bayesian Optimization for Stochastic Functions

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Abstract Stochastic simulators may exhibit low signal-to-noise ratios, hence requiring larger budgets of evaluations to find accurate solutions. For deterministic and high signal-to-noise ratio problems, Bayesian optimization is a sample efficient technique [4]. In particular, recent works have shown the interest of combining it with trust region methods to help convergence, see e.g., [2, 3]. Here we revisit this combination for noisier problems, when the number of evaluations may become much larger. We build upon local heteroscedastic Gaussian process modeling with the `hetGP R` package [1] to adapt to both noise and nonstationarity, while adapting the degree of replication at each design to scale with respect to the number of observations. We illustrate our method on several synthetic test cases, as well as some more realistic ones.

Keywords: Gaussian processes, input-varying noise variance, cost awareness

References

[1] Binois, M., Gramacy, R.B.: hetGP: Heteroskedastic Gaussian process modeling and sequential design in R. Journal of Statistical Software **98**(13), 1–44 (2021)

[2] Diouane, Y., Picheny, V., Riche, R.L., Perrotolo, A.S.D.: TREGO: A trust-region framework for efficient global optimization. Journal of Global Optimization pp. 1–23 (2022)

[3] Eriksson, D., Pearce, M., Gardner, J., Turner, R.D., Poloczek, M.: Scalable global optimization via local Bayesian optimization. In: Advances in Neural Information Processing Systems, pp. 5497–5508 (2019)

[4] Garnett, R.: Bayesian optimization. Cambridge University Press (2023)

Basic offspring number and robust feedback design for the biological control of vectors by sterile insect release technique

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Abstract

Controlling mosquitoes that transmit established or potentially (re)emerging diseases, and pests that threaten agriculture is likely to become even more necessary in the future, including in the temperate zones of the world, due to global climate changes. Sterile Insect Technique (SIT) is a promising control method against these scourges. It consists in releasing males previously sterilized in laboratory, in order to reduce or eliminate a specific wild population. We study here the implementation by feedback control of SIT-based elimination campaign of *Aedes* mosquitoes. We use a model borrowed from [4], itself inspired by [5, 8], and extend results from [3, 1].

From a control theory perspective, population elimination amounts to stabilize the extinction equilibrium. We provide state-feedback and output-feedback control laws and establish their convergence, as well as their robustness properties. In this design procedure, a pivotal role is played by the average number of secondary female insects produced by a single female insect, called the *basic offspring number*, and by the use of properties of monotone systems [6, 7]. Illustrative simulations are provided. See [2] for more details.

Keywords: Population Dynamics, Sterile Insect Technique, Output Feedback, Interval Observers

References

[1] P.-A. Bliman, *A feedback control perspective on biological control of dengue vectors by Wolbachia infection*, European Journal of Control, 59 (2021), pp. 188–206.

[2] ——, *Basic offspring number and robust feedback design for the biological control of vectors by sterile insect release technique*, October 2024. (hal-04757871).

[3] P.-A. Bliman, D. Cardona-Salgado, Y. Dumont, and O. Vasilieva, *Implementation of control strategies for sterile insect techniques*, Mathematical biosciences, 314 (2019), pp. 43–60.

[4] H. Bossin, Y. Dumont, and M. Strugarek, *On the use of the sterile insect release technique to reduce or eliminate mosquito populations*, Appl. Math. Model, 68 (2019), pp. 443–470.

[5] L. Esteva and H. M. Yang, *Mathematical model to assess the control of Aedes aegypti mosquitoes by the sterile insect technique*, Mathematical biosciences, 198 (2005), pp. 132–147.

[6] H. L. Smith, *Monotone dynamical systems: an introduction to the theory of competitive and cooperative systems*, vol. 41 of Mathematical surveys and monographs, AMS, 1995.

[7] H. L. Smith, *Monotone dynamical systems: Reflections on new advances & applications*, Discrete & Continuous Dynamical Systems-A, 37 (2017), pp. 485–504.

[8] R. C. Thomé, H. M. Yang, and L. Esteva, *Optimal control of Aedes aegypti mosquitoes by the sterile insect technique and insecticide*, Mathematical biosciences, 223 (2010), pp. 12–23.

Accelerated Non-linear Krylov Methods for Multilinear PageRank

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Abstract

Multilinear PageRank extends the traditional Google PageRank algorithm by incorporating higher-order relationships between web pages. While offering increased accuracy and ranking power, its computation is significantly more expensive.

In this talk, we present some methods to accelerate the computation of the multilinear PageRank vector using non-linear Krylov methods, particularly suited for addressing its inherent non-linearity. We integrate extrapolation techniques (Anderson, MPE, and RRE) within the Newton framework for efficient computation. Additionally, we investigate the application of Krylov methods within the Newton framework, which is advantageous for solving large-scale systems.

We evaluate our approach on benchmark tests and in various real-world networks, demonstrating significant performance improvements compared to existing methods.

Keywords: Tensor, Google PageRank, Extrapolation Methods, Non-linear Krylov method, Newton.

References

[1] D. Gleich, L. Lim, Y. Yu, *Multilinear pagerank;* SIAM Journal on Matrix Analysis and Applications, 36.4, pp. 51507–1541, 2015.

[2] K. Jbilou, H. Sadok, *Vector extrapolation methods. Applications and numerical comparison;* Journal of computational and applied mathematics, 122.1-2, pp. 149–165, 2000.

[3] Anderson, D. G. *Iterative procedures for nonlinear integral equations;* Journal of the ACM (JACM), 12.4,pp. 547-560, 1965.

[4] Brown, P. N., Saad, Y. *Hybrid Krylov methods for nonlinear systems of equations;* SIAM Journal on Scientific and Statistical Computing, 11(3), 450-481, 1990.

Enhancing Solid-State Batteries through Machine-Learning and Mathematical Modeling

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Abstract

Solid-state lithium-ion batteries play a crucial role in energy research. Particularly, They are recognized for their potential to advance safer and sustainable energy storage systems. This work introduces a machine learning model that predicts the ionic conductivity of Solid State Electrolytes (SSEs). Moreover, we show that a system of partial differential equations can be used to describe the overall behavior of the complete battery—encompassing anode, solid electrolyte, and cathode—across diverse charge and discharge conditions. The solution of these equations provides a cost-effective and time-efficient methodology for comprehending battery performance, thereby contributing significantly to the progress of solid-state battery (SSB) technology.

Keywords: Solid-state batteries; Solid-state electrolyte; Machine learning; Mathematical modeling.

References

[1] Becker-Steinberger, K., Funken, S., Landstorfer, M., & Urban, K. (2010). A mathematical model for all solid-state lithium-ion batteries. ECS Transactions, 25(36), 285.

[2] Verduzco, J. C., Marinero, E. E., & Strachan, A. (2021). An active learning approach for the design of doped LLZO ceramic garnets for battery applications. Integrating Materials and Manufacturing Innovation, 10(2), 299-310.

[3] D. Danilov, R. A.H. Niessen, and P. H.L. Notten, Modeling All-Solid-State Li-Ion Batteries, *Journal of The Electrochemical Society*, vol. 158, no. 3, pp. A215, 2010. doi: 10.1149/1.3521414.

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Molecular Modeling and Multiscale Simulation for Coated Fertilizers

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Abstract

The study of mass transport in porous media is vital for many fields, including civil and petroleum engineering, hydrogeology, and the nuclear industry.

Driven by the global push for sustainable agriculture, this research focuses on controlled-release fertilizers (CRF) as an alternative to conventional fertilizers, which often underperform. CRFs offer a promising solution to enhance crop yields and ensure food security. Fertilizer diffusion in soil involves intricate interactions between fluids, solid particles, and chemical reactions. A review of current models highlights significant gaps in their ability to capture this complex behavior.

Traditional fluid dynamics models, though rigorous for fluid flow, fail to effectively incorporate the non-linear interactions present in porous media. Additionally, the variability in pore size, shape, and connectivity complicates flow predictions, while interactions between different phases introduce further challenges, leading to errors when applying these models in real-world scenarios.

Our research focuses on modeling the transport dynamics of fertilizers within soil, using a coupled system to capture the characteristics of porous media. This approach utilizes two macroscopic differential equations to describe the behavior of nutrients as they move from fertilizers to plants.

We also aims to explore direct numerical simulations of representative porous media. This method seeks to extract parameters for macroscopic laws, validate theoretical and experimental correlations, and compute values relevant to our specific pore geometries. Our goal is to enhance predictive capabilities regarding nutrient release patterns from controlled-release fertilizers under varying environmental conditions, ultimately improving agricultural outcomes.

Keywords: Transport equation, Diffusion models, Mesoscale modeling, Porous media Simulation, Macroscale behavior.

References

[1] Irfan SA, Razali R, KuShaari K, Mansor N, Azeem B, Ford Versypt AN. A review of mathematical modeling and simulation of controlled-release fertilizers. J Control Release. Feb 2018 10;271:45-54.

[2] Vi Nguyen and Dimitrios V. Papavassiliou. Hydrodynamic Dispersion in Porous Media and the Significance of Lagrangian Time and Space Scales. Fluids 5(2):79 May 2020 DOI: 10.3390/fluids5020079

The Impact of Delay on Second Order Evolution Equations

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Abstract

Second-order evolution equations arise in many engineering fields, modeling systems such as vibrating structures in civil engineering (e.g., bridges and buildings), wave propagation in telecommunications, and mechanical systems in aerospace engineering. These equations describe how these systems evolve over time under forces and feedback mechanisms [1, 2].
When the current system state depends on past states due to time lags, we invoke systems with delays [2, 3].
In this presentation, we aim to present new instability results highlighting the effect of arbitrary delays whether finite, large, or small on a class of second-order evolution equations within a Hilbert space. Specifically, we demonstrate that even small delays can destabilize an otherwise well-behaved (stable) system, leading to various types of unstable behaviors: periodic solutions with constant energy, solutions that exhibit exponential growth, and blow-up phenomena where the system energy becomes unbounded. Moreover, we establish a constructive result showing how large delays can lead to unexpected new effects. Our study is complemented by practical applications and numerical simulations, illustrating the disruptive role of delays in real-world systems.

Keywords: Second order evolution equations, Delay effects, Feedback stabilization.

References

[1] Ammari, K., & Nicaise, S. (2014). Stabilization of elastic systems by collocated feedback (Vol. 2124). Springer

[2] Tucsnak, M., & Weiss, G. (2009). Observation and control for operator semigroups.

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2020 Mathematics Subject Classification: 37L15, 37L05, 93B52, 93B05, 37N35.

[3] Hale, J. K., & Lunel, S. M. V. (2001). Effects of small delays on stability and control. In Operator theory and analysis (pp. 275-301). Birkhäuser, Basel.

[4] Datko, R. (1988). Not all feedback stabilized hyperbolic systems are robust with respect to small time delays in their feedbacks. SIAM Journal on Control and Optimization, 26(3), 697-713.

Software for $\ell^p - \ell^q$ minimization methods using generalized Krylov subspaces

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Abstract

This talk describes software for the solution of finite-dimensional minimization problems with two terms, a fidelity term and a regularization term. The sum of the p-norm of the former and the q-norm of the latter is minimized, where $0 < p, q \leq 2$. We note that the "p-norm" is not a norm when $0 < p < 1$, and similarly for the "q-norm." This kind of minimization problems arise when solving linear discrete ill-posed problems, such as certain problems in image restoration. They also find applications in statistics. Recently, limited-memory restarted numerical methods, that are well suited for the solution of large-scale minimization problems of this kind, were described in [1]. These methods are based on the application of restarted generalized Krylov subspaces. This talk presents software for these solution methods and is based on the paper [2].

Keywords: ℓ^p-ℓ^q minimization, inverse problem, regression, iterative method

References

[1] A. BUCCINI AND L. REICHEL, *Limited memory restarted ℓ^p-ℓ^q minimization methods using generalized Krylov subspaces*, Adv. Comput. Math., 49 (2023), Art. 26 (26 pages).

[2] ——, *Software for limited memory restarted $\ell^p - \ell^q$ minimization methods using generalized Krylov subspaces*, Electron. Trans. Numer. Anal., 61 (2024), pp. 66–91.

Bernstein Finite Elements for Maxwell Equations

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Abstract

The efficient preconditioning of linear systems arising from high-order finite element discretizations of Maxwell's equations is a crucial challenge in computational electromagnetics. This work addresses this challenge by employing advanced preconditioning techniques to enhance the robustness and efficiency of solving these systems. The primary method utilized is the auxiliary space preconditioning technique, which is grounded in a suitable regular decomposition derived from finite element exterior calculus. This approach leverages the mathematical framework of exterior calculus to ensure that the preconditioner maintains stability and effectiveness across varying mesh sizes.

In particular, we combine this technique with Bernstein-Bézier finite elements applied on unstructured triangular mesh grids. Bernstein-Bézier elements are chosen for their nice proprieties that reduce the computational cost. By integrating these elements with the auxiliary space preconditioning method, we develop a preconditioner that is robust with respect to mesh size, thus improving computational performance and convergence rates.

Keywords: Bernstein polynomials, Finite elements, auxiliary space preconditioning, Maxwell's equations.

References

[1] A. El Akri, K. Jbilou, A.Ratnani, Auxiliary Splines Space Preconditioning for B-Splines Finite Elements: The case of H(curl, Ω) and H(div, Ω) elliptic problems, http://dx.doi.org/10.2139/ssrn.4573555.

[2] Ralf Hiptmair, Jinchao Xu, Nodal auxiliary space preconditioning in h (curl) and h (div) spaces , SIAM Journal on Numerical Analysis 45 (2007), no. 6, 2483–2509.

[3] M. G. Andriamaro, Bernstein–Bézier techniques and optimal algorithms in finite element analysis. PhD thesis, University of Strathclyde, 2013.

[4] M. Bonazzoli, F. Rapetti, High-order finite elements in numerical electromagnetism: degrees of freedom and generators in duality, Numer Algorithms, 74(1):111–136, 2017.

The wave equation with dynamic boundary conditions: inverse problems and controllability

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Abstract

In this talk, we present a refined approach to establish a global Lipschitz stability for an inverse source problem concerning the determination of forcing terms in the wave equation with mixed boundary conditions. It consists of boundary conditions incorporating a dynamic boundary condition and Dirichlet boundary condition on disjoint subsets of the boundary. We discuss Carleman estimates associated with the wave system subject to a dynamic boundary condition. In particular, our findings complete and drastically improve some previous results. This is achieved by using a different weight function to overcome some relevant difficulties. As for the stability proof, we extend to dynamic boundary conditions a recent argument avoiding cut-off functions. Finally, we also show that our developed Carleman estimate yields a sharp boundary controllability result.

Keywords: Inverse problem, wave equation, dynamic boundary condition, stability estimate, Carleman estimate.

References

[1] S.E. Chorfi, G. El Guermai, L. Maniar, W. Zouhair, Lipschitz stability for an inverse source problem of the wave equation with kinetic boundary conditions, arXiv: 2402.12902 (2024).

[2] C.G. Gal and L. Tebou, Carleman inequalities for wave equations with oscillatory boundary conditions and application, *SIAM J. Control Optim.*, **55** (2017), 324–364.

[3] E. Vitillaro, On the wave equation with hyperbolic dynamical boundary conditions, interior and boundary damping and source, *Arch Ration Mech Anal.*, **223** (2017), 1183–1237.

Multi-Patch Space-Time Isogeometric Discontinuous Galerkin Method for Hamilton–Jacobi Equations

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Abstract

This work presents a multi-patch space-time isogeometric discontinuous Galerkin (DG) method designed to solve Hamilton–Jacobi equations on complex geometries. The proposed framework decomposes the computational domain into multiple patches, each with tailored isogeometric basis functions, enabling enhanced flexibility and accuracy in capturing domain-specific features. By incorporating a numerical flux at patch interfaces, the method ensures weak continuity of the solution across patches, maintaining stability and consistency of the DG formulation. This multi-patch approach is particularly well-suited for problems involving complex boundaries or regions requiring adaptive refinement. Numerical experiments validate the method's robustness and efficiency, demonstrating its effectiveness in accurately capturing the solution behavior for a variety of Hamilton–Jacobi problems. This approach offers a powerful tool for high-dimensional and nonlinear Hamiltonian systems, providing both precision and computational scalability.

References

[1] Klaij, Christiaan M., Jaap JW van der Vegt, and Harmen van der Ven. "Space–time discontinuous Galerkin method for the compressible Navier–Stokes equations." Journal of Computational Physics 217.2 (2006): 589-611.

[2] Smears, Iain, and Endre Süli. "Discontinuous Galerkin finite element methods for time-dependent Hamilton–Jacobi–Bellman equations with Cordes coefficients." Numerische Mathematik 133.1 (2016): 141-176.

[3] Nicolas Adam, Patrick Le Tallec, Malek Zarroug. Multipatch isogeometric mortar methods for thick shells. Computer Methods in Applied Mechanics and Engineering, 2020, 372, pp.113403. ff10.1016/j.cma.2020.113403ff. ffhal-03088221f

Two-sided matching for college admission

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Abstract

In many countries, students apply to higher education programs through centralized platforms, that collect each student's preferences and each college's ranking of students. A matching, i.e., an allocation of students in each program, is then computed with the goal of satisfying students and colleges' preferences as much as possible. This presentation will introduce the mathematical theory of matching, and how to find matchings that satisfy agents' preferences, then present some recent research results regarding the effects of correlation of colleges' rankings (or lack thereof) on students' satisfaction and demographic inequalities.

Linear FDEM subsoil data inversion in Banach spaces

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Abstract

The applicative motivation of this work is the reconstruction of some electromagnetic features of the earth superficial layer by measurements taken above the ground. We resort to frequency domain electromagnetic data inversion through a well-known linear integral model, by considering three different collocation methods to approximate the solution of the continuous problem as a linear combination of linearly independent functions. The discretization leads to a strongly ill-conditioned linear system. To overcome this difficulty, an iterative regularization method based on Landweber iterations in Banach spaces is applied to reconstruct solutions which present discontinuities or have a low degree of smoothness since this kind of solutions are common in many imaging applications.

Several numerical experiments show the good performance of the algorithm in comparison to other regularization techniques.

Keywords: First-kind Fredholm integral equations; electromagnetic induction; inverse problems in geophysics; collocation methods; iterative regularization; Landweber method; Banach spaces.

References

[1] P. Díaz de Alba, C. Estatico, M. Lazzaretti, G. Rodriguez, Linear FDEM subsoil data inversion in Banach spaces. Submitted to Electronic Transactions on Numerical Analysis, 2024.

Identification of Degeneracy in Parabolic Equations

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Abstract We address an inverse problem involving the reconstruction of a degeneracy point in the diffusion coefficient of a one-dimensional parabolic equation using measurements of the normal derivative on one side of the boundary. Our study focuses on the sensitivity of this inverse problem to the initial data. We establish sufficient conditions on the initial data to ensure uniqueness and stability with a single-point measure, and provide examples of both positive and negative results. These theoretical conclusions are supported by numerical evidence. We also present more general uniqueness results for the identification of both degeneracy and initial data by boundary measurements distributed over time. The method of proof is based on the representation of the solution by means of Bessel functions of the first kind. The details can be found in [1].

Keywords: inverse problems, degenerate parabolic equations, numerical reconstruction

References

[1] P. CANNARSA1, A. DOUBOVA, M. YAMAMOTO, Reconstruction of degenerate conductivity region for parabolic equations, Inverse Problems, Volume 40, Number 4.

Auxiliary Splines Space Preconditioning for B-Splines Finite Elements: The case of $\boldsymbol{H}(\boldsymbol{curl}, \Omega)$ and $\boldsymbol{H}(div, \Omega)$ elliptic problems

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Abstract

This talk presents a study of large linear systems resulting from the regular B-splines finite element discretization of the $\boldsymbol{curl} - \boldsymbol{curl}$ and $\boldsymbol{grad} - div$ elliptic problems on unit square/cube domains. We consider systems subject to both homogeneous essential and natural boundary conditions. Our objective is to develop a preconditioning strategy that is optimal and robust, based on the Auxiliary Space Preconditioning method proposed by Hiptmair et al. [2]. Our approach is demonstrated to be robust with respect to mesh size, and we also show how it can be combined with the Generalized Locally Toeplitz (GLT) sequences analysis presented in [3] to derive an algorithm that is optimal and stable with respect to spline degree. Numerical tests are conducted to illustrate the effectiveness of our approach.

Keywords: Auxiliary splines space preconditioning Isogeometric Analysis (IgA), Preconditioning methods, B-splines, $\boldsymbol{H}(\boldsymbol{curl}, \Omega)$ and $\boldsymbol{H}(div, \Omega)$ problems.

References

[1] A. El Akri, K.Jbilou and A. Ratnani, Auxiliary Splines Space Preconditioning for B-Splines Finite Elements: The case of $\boldsymbol{H}(\boldsymbol{curl}, \Omega)$ and $\boldsymbol{H}(div, \Omega)$ elliptic problems, CAMWA **159**, 102–121, (2024).

[2] R. Hiptmair and J. Xu, Nodal auxiliary space preconditioning in h (curl) and h (div) spaces, SIAM Journal on Numerical Analysis **45**, 2483–2509, (2007).

[3] M. Mazza, C. Manni, A. Ratnani, S. Serra-Capizzano, and H. Speleers, Isogeometric analysis for 2d and 3d curl–div problems: Spectral symbols and fast iterative solvers, Computer Methods in Applied Mechanics and Engineering **344**, 970–997, (2019).

Heat Kernel for heat equation with inverse square potential and dynamic boundary conditions

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Abstract

Let $T > 0$ be a fixed final time and let $\Omega \subset \mathbb{R}^n$ $(n \geq 3)$ be a bounded domain such that $0 \in \Omega$ with smooth boundary $\Gamma = \partial\Omega$ of class C^2. We denote by $\Omega_T = (0,T) \times \Omega$ and $\Gamma_T = (0,T) \times \Gamma$. Let $0 \leq \mu < \mu^*(n) := \frac{(n-2)^2}{4}$. We consider the following heat equation with a singular potential subject to dynamic boundary conditions we establish the parabolic Harnack inequality for a coupled system of partial differential equations featuring a singular heat equation; $\partial_t y - \Delta y - \frac{\mu}{|x|^2} y = 0, \quad \text{in } \Omega_T$, with dynamic boundary conditions; $\partial_t y_\Gamma - \Delta_\Gamma y_\Gamma + \partial_\nu y = 0, \quad \text{on } \Gamma_T$.

The problem involves the heat equation with an inverse square potential $\frac{\mu}{|x|^2}$ in the domain Ω and a boundary equation that couples the solution y with its boundary component y_Γ. We derive heat kernel estimates for this system by carefully addressing the singular nature of the potential and the dynamic coupling at the boundary. Utilizing the Hardy inequality and techniques from weighted Sobolev spaces, we prove the parabolic Harnack inequality, which provides valuable insights into the regularity and long-term behavior of the solution. These results enhance the understanding of Harnack-type estimates in the presence of singularities and dynamic boundary conditions.

Keywords: Singular heat equation, dynamic boundary conditions, heat kernel estimates, Hardy inequality

References

[1] Adimurthi, Hardy-Sobolev inequality in $H^1(B(0,1))$ and its applications, *Comm. Contem. Math.*, **4** (2002), 409–434.

[2] L. Moschini and A. Tesei , Parabolic Harnack inequality for the heat equation with inverse-square potential, Forum Mathematicum, **19**(3) (2007), 407-427.

A Discrete-Time Model for Viral Epidemics with Distributed Delays and Multiple Transmission Modes

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Abstract :

The aim of this work is to propose and analyse a discrete virus dynamics model with distributed delays and both modes of transmission, one by virus-to-cell infection and the other by cell-to-cell transfer. In the proposed model, the first distributed delays describes the time needed for infected cells to produce new virions, and the second portrays the time necessary for the newly produced virions to become mature and infectious. In addition, the infection transmission process is modelled by general incidence functions for both modes. Furthermore, we prove that the proposed discrete model has the same dynamics as the corresponding continuous model, such as positivity, boundedness and global behaviours of solutions with no restriction on the time step size. Moreover, numerical simulations are given to illustrate and confirm our main analytical results.

Accelerating Large-Scale Linear Solvers: A Mixed Precision Approach for Modern GPU Architectures

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Abstract

Solving massive linear systems is a fundamental challenge in scientific computing and engineering applications. Our research explores the use of mixed precision techniques to accelerate both iterative and direct linear solvers. By strategically employing a combination of half precision (fp16), single precision (fp32), and double precision (fp64) arithmetic, we aim to strike an optimal balance between computational efficiency and numerical accuracy.

The key focus of our work is on optimizing performance-sensitive operations such as sparse matrix-vector multiplication (SpMV) and inner product calculations. We develop algorithms that are cache-friendly and incorporate modified versions of pairwise summation and Kahan summation techniques. These modified algorithms are designed to minimize the impact of rounding errors when working with lower precision formats while maintaining cache efficiency, unlike their original counterparts.

To fully harness the potential of modern GPU architectures, our methodology leverages the IEEE 754-2008 half-precision format for computationally intensive but less numerically sensitive tasks. This allows us to maximize throughput, especially on GPUs equipped with specialized half-precision hardware.

In the context of direct solvers, we perform LU factorizations using fp16 arithmetic, taking advantage of tensor core acceleration on contemporary GPUs. Iterative refinement in higher precision is then applied to improve the accuracy of the computed solution.

Our algorithms are optimized to leverage hardware-specific capabilities such as fused multiply-add (FMA) instructions and efficient memory access patterns, ensuring optimal performance on state-of-the-art high-performance computing systems.

Non-negative Einstein tensor factorization for unmixing hyperspectral images

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Abstract

In this work, we introduce a tensor-based approach to Non-Negative Tensor Factorization (NTF). The method entails tensor dimension reduction through the utilization of the Einstein product. To maintain the regularity and sparsity of the data, certain constraints are imposed. Additionally, we present an optimization algorithm in the form of a tensor multiplicative updates method, which relies on the Einstein product. To guarantee a minimum number of iterations for the convergence of the proposed algorithm, we employ the Reduced Rank Extrapolation (RRE) and the Topological Extrapolation Transformation Algorithm (TEA). The efficacy of the proposed model is demonstrated through tests conducted on Hyperspectral Images (HI) for denoising, as well as for Hyperspectral Image Linear Unmixing. Numerical experiments are provided to substantiate the effectiveness of the proposed model for both synthetic and real data.

Keywords: Tensor, non-negative tensor factorization, hyperspectral images, the Einstein tensor product, the reduced rank extrapolation, the topological extrapolation transformation algorithm, linear unmixing, denoising

Sufficient Conditions for the Exponential Stability of a Thermoporoelastic System with Thermal Dissipation and Distributed Time Delay

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Abstract

The aim of the present work is to establish sufficient conditions for the well-posedness and exponential stability of a thermoporoelastic system with distributed time delay, which is the following

$$\begin{cases} \rho u_{tt} = a u_{xx} + b\phi_x \\ J\phi_{tt} = \alpha\phi_{xx} - b u_x - \zeta\phi - \beta\theta_x \\ c\theta_t = a_0\theta_{xx} + a_1 \displaystyle\int_{r_1}^{r_2} \mu(s)\theta_{xx}(x, t-s)ds - \beta\phi_{xt} \\ u(x,0) = u_0(x), \quad u_t(x,0) = u_1(x) \\ \phi(x,0) = \phi_0(x), \quad \phi_t(x,0) = \phi_1(x) \\ \theta(x,0) = \theta_0(x) \\ \theta(x,-t) = f_0(x,-t) \qquad for \ (x,t) \in (0,\pi) \times (0,r_2) \\ u(0,t) = u(\pi,x) = \phi_x(0,t) = \phi_x(\pi,t) = \theta(0,t) = \theta(\pi,t) = 0. \end{cases} \tag{1}$$

We prove that when one of the sufficient conditions fails to hold, the exponential stability can be lost.

References

[1] Racke, R., & Jiang, S. (2000). Evolution equations in thermoelasticity. Chapman and Hall/CRC.

[2] Nicaise, S., & Pignotti, C. (2008). Stabilization of the wave equation with boundary or internal distributed delay.

[3] Ahmima, A., Fareh, A., & Messaoudi, S. A. (2024). On the decay of a porous thermoelastic system with thermal dissipation and delay term. Evolution Equations and Control Theory, 13(2), 458-477.

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Balancing Returns and Responsibility: Markowitz Optimization for ESG Portfolios and Networked Asset Allocation Strategies in Morocco

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Abstract

Portfolio selection and allocation are complex issues, and integrating environmental, social, and governance (ESG) criteria further complicates investment decisions. In our study, we aim first to assess the impact of incorporating ESG criteria into portfolio optimization in Morocco, and then to analyze the dynamic evolution of correlations. We developed two models using a sample of the top-performing Moroccan companies for our study period. The first model, based on Markowitz's mean-variance (MV) theory, is used to determine optimal allocations. The second model imposes a constraint on a minimum acceptable ESG score (MV-ESG). Using the same sample, we constructed correlation networks employing the minimal spanning tree (MST). We selected two portfolios: the central portfolio P^c and the peripheral portfolio P^p, which were also evaluated according to the two developed models. These portfolios were compared with portfolio P, which includes the original eight companies and was also evaluated according to these models during both the health crisis and post-crisis periods. The results indicate that responsible portfolios do not outperform conventional portfolios in terms of performance but offer opportunities to balance returns and risks while maintaining significant ESG scores. Stricter ESG score requirements lead to higher risk levels for higher returns or lower returns to reduce risk. Correlation network analysis reveals variations in the topological structure of MST_s. Peripheral portfolios P^p outperformed central portfolios P^c during both periods in terms of higher returns and less severe losses. However, portfolios P^c and P had higher ESG scores during the crisis and post-crisis periods. After imposing the ESG score requirements during the post-crisis period, P^p portfolios showed improvements in returns, while other portfolios became less attractive. This suggests that peripheral assets are better suited for responsible investing in stable periods, highlighting the importance of network topology in constructing high-performance portfolios. These results indicate that SR portfolio optimization in Morocco is a relatively new area of exploration, requiring further research on different asset types and alternative optimization models. Additionally, correlation network analysis provides valuable insights into understanding the dynamic evolution

of correlations. However, our study period does not include a prolonged crisis affecting all sectors, which may mitigate the results.

Keywords: ESG criteria; Moroccan Portfolio optimization; Markowitz's mean- variance theory; Multi-criteria approach; Socially Responsible (SR) Investing; Returns; Risk; Graph Theory; correlation network; Minimum Spanning Tree (MST)

References

[1] C. A. ZAPATA QUIMBAYO, Modelo Media-Varianza y criterios ASG: de Markowitz al portafolio socialmente responsable (Mean-Variance Model and ESG criteria: From Markowitz to the socially responsible portfolio), *ODEON*, 2021.

[2] S. M. GASSER, M. RAMMERSTORFER, ET K. WEINMAYER, Markowitz revisited: Social portfolio engineering, *European Journal of Operational Research*, vol. 258, no. 3, pp. 1181–1190, 2017.

[3] F. CESARONE, M. L. MARTINO, ET A. CARLEO, Does ESG impact really enhance portfolio profitability?, *Sustainability*, vol. 14, no. 4, p. 2050, 2022.

[4] F. REN, Y.-N. LU, S.-P. LI, X.-F. JIANG, L.-X. ZHONG, ET T. QIU, Dynamic portfolio strategy using clustering approach, *PloS one*, vol. 12, no. 1, p. e0169299, 2017.

[5] T. MILLINGTON ET M. NIRANJAN, Construction of minimum spanning trees from financial returns using rank correlation, *Physica A: Statistical Mechanics and its Applications*, vol. 566, p. 125605, 2021.

[6] X. YAN, H. YANG, Z. YU, ET S. ZHANG, A network view of portfolio optimization using fundamental information, *Frontiers in Physics*, vol. 9, p. 721007, 2021.

Two-sided matching for college admission

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Abstract

For several years, network formation theory is gaining importance in economic theory. Briefly, considering some agents (e.g. firms, researchers, friends, ...), a network formation process is generally modelled as a mapping which associates to each link (i.e. each pair of distinct agents) a weight in 0, 1 – in the case of unweighted networks – or in [0, 1] – in the case of weighted networks – which measures the strength of the relationship between the two agents who compose this link. Moreover, one attributes to each agent a payoff function which depends on this mapping (each payoff function represents the agent's preferences in terms of linking). The main tool for analysing stability of a given unweighted network was introduced by Matthew O. Jackson and Asher Wolinsky (1996), and is called pairwise stability. This notion has been extended recently by Philippe Bich and Lisa Morhaim (2020) to weighted networks. The idea is simple: at equilibrium, for each link (i,j) (composed by agent i and agent j), neither i, nor j, have an incentive to decrease their common weight, and both i and j together do not have the incentive to increase their common weight. This presentation provides a gentle introduction to network formation theory and to some recent results concerning pairwise stability.

The iterated Arnoldi-Tikhonov method

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Abstract

The Arnoldi-Tikhonov method is a well-established regularization technique for solving large-scale ill-posed linear inverse problems. This method leverages the Arnoldi decomposition to reduce computational complexity by projecting the discretized problem into a lower-dimensional Krylov subspace, in which it is solved.

We studied the iterated Arnoldi-Tikhonov method, conducting a comprehensive analysis that addresses all approximation errors. Additionally, we introduce a novel strategy for choosing the regularization parameter, leading to more accurate approximate solutions compared to the standard Arnoldi-Tikhonov method. Moreover, the proposed method demonstrates robustness with respect to the regularization parameter, as confirmed by the numerical results.

Keywords: Inverse problems, Arnoldi decomposition, iterated Arnoldi-Tikhonov method

References

[1] D. Bianchi, M. Donatelli, D. Furchì, L. Reichel, Convergence analysis and parameter estimation for the iterated Arnoldi-Tikhonov method, arXiv:2311.11823v1

Modeling Digital Twins: Application to healthcare

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Abstract

In this talk, we will present some mathematical models and their applications in medical Industry 4.0. More precisely, it involves investing in the mathematical models of Digital Twins (DT), to study, experiment, adapt and improve medical interventions for dynamical medical system from structural health monitoring to power neural network dynamics. The work clarifies the importance of Digital Twins DT in healthcare services and describes the technical process used in DT for industry 4.0. In addition, basing on the mathematical models, we point out the supportive features of DT that create a virtual model which is a virtual copy of the physical model in order to identify some related applications in healthcare. We, then, discuss the advantages and challenges related to DT as a technical solution.
On this basis, some possible activities for further research works will be discussed and we will also present some challenging open problems.

Keywords: Digital twin, Industry 4.0, Deep learning, IoT, Optimization, Inverse problem.

References

[1] S.Chakraborty, S.Adhikari,and R.Ganguli, *The role of surrogate models in the development of digital twins of dynamic systems*, Applied Mathematical Modelling , 90(2021): 662–681.

[2] E. Nikolaos, A. Angelos, P. Markopoulos, A.J Paulo Davimi, *Computational Methods for Application in Industry4.0*, Springer, Berlin, 2018.

[3] S.Y. Barykin, A.A. Bochkarev, O.V. Kalinina, V.K. Yadykin, *Concept for a supply chain digital twin*, International Journal of Mathematical, Engineering and Management Sciences 5(6), 2020, 43-61.

[4] S. Cai, Z. Wang, L. Lu, T. A. Zaki, and G. E. Karniadakis, DeepM&Mnet: Inferring the Electroconvection Multiphysics Fields Based on Operator Approximation by Neural Networks, preprint, https://arxiv.org/abs/2009.12935, 2020.

GPU-Accelerated Approaches in Tensor Singular Triplet Approximation

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Keywords: Tensor, T-product, T-svd, Tensor Lanczos Bidiagonalization, GPU.

Abstract

In this study, we explore the application of GPU technology to advance the performance of algorithms designed for calculating singular triplets in third-order tensors under t-product. The central focus is on the development and optimization of these algorithms, with a particular emphasis on effective memory management techniques. These techniques are pivotal in managing the high data throughput and fulfilling the intensive parallel processing demands inherent in these iterative methods. Through this approach, we aim to significantly enhance the computational efficiency of the algorithms, making full use of the GPU's capabilities for efficient data handling and processing. This integration of GPU technology in tensor computations is further validated through a series of numerical tests, demonstrating the improvements in computational speed and scalability. These tests provide valuable insights into the potential benefits and applications of GPU-accelerated tensor calculations in various computational fields.

References

[1] A. EL HACHIMI, K. JBILOU, A. RATNANI, L. REICHEL, A tensor bidiagonalisation method for higher-order singular value decomposition with applications, NLA, (2023).

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Worst-Case Complexity of Trust-Region Methods for Multiobjective Optimization

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Abstract

In this talk, we explore worst-case complexity in continuous optimization, defined as the computational cost an algorithm incurs, in the worst-case scenario, to drive a stationarity measure below a specified positive threshold. We begin with a foundational discussion of worst-case complexity, reviewing key results from single-objective optimization to establish a baseline for comparison.

Next, we turn to the more intricate domain of multiobjective optimization, examining its unique challenges and recent advances in the field [1]. Finally, we analyze a trust-region algorithm [3], evaluating its worst-case complexity under convexity and strong convexity assumptions [2].

Keywords: Continuous optimization, Trust-region methods, Multiobjective optimization, Worst-case complexity

References

[1] A. L. CUSTÓDIO, Y. DIOUANE, R. GARMANJANI, AND E. RICCIETTI, Worst-case complexity bounds of directional direct-search methods for multiobjective optimization, *Journal of Optimization Theory and Applications 188(1):73-93, 2021.*

[2] R. GARMANJANI, Complexity bound of trust-region methods for convex smooth unconstrained multiobjective optimization, *Optimization Letters 17:1161–1179, 2023.*

[3] K. D. V. VILLACORTA, P. R. OLIVEIRA, A. SOUBEYRAN, A trust-region method for unconstrained multiobjective problems with applications in satisficing processes, *Journal of Optimization Theory and Applications 160:865-889, 2014.*

Data assimilation for gas flows via observers using distributed measurements

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Abstract

We begin by explaining the basic ideas of data assimilation using Luenberger observers. Then, we construct and investigate Luenberger type observers for data assimilation in the context of gas flows modeled by barotropic Euler equations. We are interested in the case in which one field (e.g. velocity) is measured everywhere and we aim to reconstruct the other field (e.g. density). What we will prove is that in one space dimension over long times the state of the observer system converges exponentially fast to the state of the observed system if there are no measurement errors and if the observer system is based on the exact dynamics of the observed system. Our results are based on a combination of the relative entropy method and hypocoercivity.

We will also discuss the effects of measurement errors and of discrepancies between the model used in the observer system and the exact dynamics.

Keywords: Data Assimilation, Luenberger Observers, Barotropic Euler Equations, Hypocoercivity, Relative Entropy Method.

References

[1] JAN GIESSELMANN, MARTIN GUGAT, TERESA KUNKEL, Observer-based data assimilation for barotropic gas transport using distributed measurements, arXiv: 2303.04045 (2024).

Optimal control problems with probabilistic constraints

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Abstract

We study problems of optimal control for a boundary control system that is governed by the wave equation, where the control acts through Neumann boundary control. We consider uncertain initial data that occur in numerous applications and that can be represented by a Karhunen-Loeve expansion. In this situation, equality terminal constraints have to be relaxed to inequality constraints that are required in the sense of probabilistic constraints, that is the inequality constraint has to hold with a sufficiently large probability. A lower bound for the probability is included in the optimal control problem as an additional parameter. The probabilistic constraints allow that the inequality constraints do not hold with a certain small probability, which greatly reduces the optimal control cost. We present theoretical and numerical results that illustrate the structure of the problem.

Keywords: Optimal control, wave equation, Neumann boundary control, probabilistic constraints, Karhunen-Loeve expansion.

Stabilization of PDE systems and applications

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Abstract

One of the central challenges within control theory is the stabilization problem. In this talk, we will highlight recent progresses on this problem, in particular for partial differential equations (PDEs).

We will begin by introducing a novel approach known as F-equivalence (or Fredholm backstepping). Instead of directly attempting to solve the problem, this method involves selecting a feedback control that allows the PDE system to be invertibly transformed into a simpler PDE system whose stability is already established. Significant advancements in the past two years have demonstrated the surprisingly remarkable efficacy of this technique.

Next, we will discuss a practical application: stabilizing hyperbolic PDEs to control traffic flow. We will show how abstract mathematical concepts, like entropic solutions, can have tangible impacts in real-world scenarios and we will discuss the application to the regulation of traffic flow and the dampening of traffic jams' waves. Lastly, if time allows, we will discuss recent advances in AI for mathematics: how to teach mathematical intuition to an AI to solve mathematical problems, in particular in stabilization.

Keywords: Stabilization, F-equivalence (Fredholm backstepping), Partial Differential Equations (PDEs), Traffic flow control, AI in mathematics.

References

[1] AMAURY HAYAT AND EPIPHANE LOKO, Fredholm backstepping and rapid stabilization of general linear systems, hal-04597173 (2024).

A fully implicit non linear finite volume scheme for single flow reactive transport in porous media

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Abstract

This work deals with the development of a monotone Nonlinear Two-Point Flux Approximation (NTPFA) see, e.g., [1] for a nonlinear degenerate model arising from the mathematical modeling of reactive transport in porous media, including equilibrium sorption [2]. Our method is based on a new corrected upwind scheme with second-order accuracy, which makes the scheme fully implicit, in an attempt to avoid the restrictive CFL condition, while preserving positivity and stability. The discrete nonlinear system is solved using the Picard method, which preserves the positivity of the solution at each iteration. Our aim is, on the one hand, to introduce a regularization step to handle the degenerate sorption model (of the Freundlich type). On the other hand, we employ the Anderson Acceleration (AA) method to accelerate the convergence of the Picard iteration, while still satisfying the monotonicity of the scheme [3]. These results are illustrated by numerical tests showing the performance of the AA method in terms of computation time.

Keywords: Reactive transport, monotonicity, heterogeneity, anisotropy, Picard method, Anderson acceleration, regularization.

References

[1] G. Yuan, and Z. Sheng, *Monotone finite volume schemes for diffusion equations on polygonal meshes*; Journal of computational physics 227.12 (2008) : 6288-6312.

[2] Radu, F. A., Pop, I. S. (2010), *Newton method for reactive solute transport with equilibrium sorption in porous media.*; Journal of computational and applied mathematics, 234(7), 2118-2127.

[3] Hamidi, S., El Ossmani, M., & Taakili, A. (2024), *A monotone finite volume scheme for single phase flow with reactive transport in anisotropic porous media.*; Journal of Computational and Applied Mathematics, 440, 115626.

An improved Newton approach for solving non-linear systems arising in porous media flows

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Abstract This study tackles the difficulties in solving nonlinear systems that arise from spatially discretization of the Richards equation, which describes water flow in partially saturated porous media. The equation's nonlinearity is originating from how hydraulic properties change with soil moisture. The classic Newton method, used to solve such nonlinear systems, may converge poorly or even fail to converge. To address this problem, we suggest in this study an enhanced Newton method to solve effectively these non-linear systems. We incorporate the assembly of the Jacobian matrix, computed once for all iterations, unlike the classical Newton method where Jacobian is recalculated at each step. Together with inexpensive iterative solver, this modification significantly reduces CPU time and the number of iterations, leading to an interesting reduction comparably to the classic Newton method in computational coast while maintaining stability and convergence rates. Several examples are provided to demonstrate the efficiency of our approach.

Keywords: Richards equation, Newton method, Finite volume method.

References

[1] M. W. Farthing and F. Ogden. Numerical solution of Richards' equation: A review of advances and challenges. Soil Science Society of America J., 81, 2017.

[2] K. Brenner and C. Cancès. Improving Newton's method performance by parametrization: the case of Richards equation. SIAM J. Numerical Analysis, 2017, 55 (4), pp.1760–1785.

[3] R. Helmig. Multiphase flow and transport processes in the subsurface: a contribution to the modeling of hydro-systems. Springer Book Archive, 1997.

[4] EL-H. Quenjel. Nonlinear finite volume discretization for transient diffusion problems on general meshes. J. Applied Numerical Mathematics, 161, pp. 148-168, 2021.

Cognitive behaviors modeled with Nash games: the case of pedestrian avoidance

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Abstract Multiple pedestrian motion is a complex social and biological process, involving psychological and nondeterministic behavioural decisions. It includes features like pattern formation, e.g., groups and lanes, and non-rational dynamics like as in a panic situation. A good knowledge of pedestrian and, more generally, crowd flow scenarii is of utmost importance for urban management and safe evacuation, hence the importance of realistic modelling and simulation, notably with the help of mathematical and computational tools.

One of the most critical process in crowd motion is the avoidance dynamics, where two or more pedestrian adapt their trajectories in order to avoid collision.

An original approach to modelling pedestrian's avoidance dynamics based on a Fokker-Planck Nash game framework is presented. In this framework, two interacting pedestrian are considered, whose motion variability is modelled through the corresponding probability density functions (PDFs) governed by Fokker-Planck equations. Based on these equations, a Nash differential game is formulated where the game strategies represent controls aiming at avoidance by minimizing appropriate collision cost functionals, while taking into consideration specific departure-arrival requests. Existence of Nash equilibria solutions is proved and characterized as solution to an optimal control problem that is solved numerically. Results of numerical experiments are presented that successfully compare the computed Nash equilibria to output of real experiments (conducted with humans) for four selected test cases.

Keywords:Pedestrian motion, avoidance, Fokker-Planck equation, differential games, Nash equilibrium, optimal control.

References

[1] S. Roy, A. Borzì and A. Habbal, *Pedestrian motion modeled by Fokker-Planck Nash games* Royal Society open science 4.9 (2017): 170648.

TITLE: REAL WORD EVIDENCE OF THE EFFICACY OF MECHANICAL THROMBECTOMY: A CASE-CONTROL, PROPENSITY SCORE-MATCHED ANALYSIS OF A NATIONWIDE STROKE REGISTRY

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Abstract:

Background and Aims

The efficacy and safety of mechanical thrombectomy (MT) has been demonstrated in Randomized clinical Trials (RCTs), but there is less real world data on its effects on survival and functional outcome.

Methods

Clinical data were extracted from the Sentinel Stroke National Audit Programme (SSNAP) for the 26 UK centres providing MT for patients admitted between 2016-04-01 and 2024-01-21. SSNAP is the national stroke registry for England, Wales and Northern Ireland with a case ascertainment of >95%. Propensity score was used to match MT cases and controls in a 1:1 ratio by age, gender and clinical covariates (pre-stroke disability, stroke severity, Atrial Fibrillation (AF), diabetes, thrombolysis and onset-arrival time). Logistic regression was used to assess independent recovery outcome (mRS 0-2) at discharge. Inverse probability of treatment weighted (IPTW) Kaplan-Meier was used to assess the impact of MT on survival outcomes over 90-day.

Results

Out of 605,467 cases of ischemic strokes, 10,312 pairs of treatment-control were successfully matched. In the 90-day survival analysis, The MT group is associated with a

23.6% reduction in risk of Death compared to the control group indicating the efficacy of MT in improving survival outcomes.

Patients who underwent MT also showed a higher probability of achieving independent recovery at discharge 1.17 (95% confidence interval (CI): 1.10-1.24; $p<0.001$). Notably, there were no significant complications observed after MT intervention, with only 91 cases (0.88%) of symptomatic Intracerebral haemorrhage (sICH). 8,741 cases (85%), had a modified Thrombolysis in Cerebral Infarction (mTICI) score of 2b, 2C and 3.

Conclusions

In real-world UK practice MT is associated with improved survival at 90 days after ischemic stroke, and better functional recovery at discharge. The safety and efficacy for MT shown in RCTs is replicated in stroke patients treated in UK neuroscience centres, but the proportion of patients receiving the treatment under present conditions remains low.

Alternating Direction Multiplier method to estimate the initial condition in the time-fractional diffusion equation

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Abstract

In this paper, we study the inverse problem of identifying the initial condition in a linear subdiffusion model from measurement data by the alternating direction method of multipliers (ADMM). The linear subdiffusion model involves a Caputo fractional derivative of order $\alpha \in (0, 1)$ in time. To address our model, we first examine the regularity of the solution for the direct problem. Then, we establish the existence of the optimal solution and prove the convexity of the considered cost function by using its first derivative. Finally, the efficiency and accuracy of the present method are illustrated by some numerical examples.

Keywords: Inverse problem, Optimal control, Alternating direction method of multipliers, Time-fractional diffusion, Stability, Optimization techniques.

References

[1] TUAN, VU, Inverse problem for fractional diffusion equation.

[2] LIU, JJ AND YAMAMOTO, M, A backward problem for the time-fractional diffusion equation.

[3] LIU, WANG, LIYAN AND LIU, JIJUN, Data regularization for a backward time-fractional diffusion problem.

STABILITY OF BACKWARD PROBLEMS FOR DEGENERATE MEAN FIELD GAME EQUATIONS

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Abstract

For solution $(u(x,t), m(x,t))$ to second-order Mean-Field Game (MFG) system in $(0,1) \times (0,T)$ with a degenerate diffusion coefficient, we consider inverse backward-in-time problems : determine $(u(.,t_0), m(.,t_0))$ in $(0,1)$ by $(u(.,T), m(.,T))$, where t is the time variable and $0 \leqslant t_0 \leqslant T$. We prove a conditional stability under boundedness assumptions on $(u(.,0), m(.,0))$. The proofs are based on Carleman's estimates with a simple weight function. We first prove a Carleman estimate for the Hamilton-Jacobi-Bellman (HJB) equation. A second Carleman estimate will be derived for the Fokker-Planck (FP) equation. Then, by combining the two estimates, we obtain a Carleman estimate for the mean-field game system, leading to the stability of the backward problems.

Keywords: Degenerate parabolic equation, backward problem, Carleman estimate, stability, Mean field game system

References

[1] O.Y. Imanuvilov, H. Liu and M. Yamamoto, Lipschitz stability for determination of states and inverse source problem for the mean-field game equations, Inverse Probl. Imaging, **18** (2024), 824–859.

[2] O.Y. Imanuvilov, H. Liu and M. Yamamoto, Unique continuation for a mean-field game system, Applied Mathematics Letters, **145** (2023), 108757.

[3] O.Y. Imanuvilov and M. Yamamoto, Global Lipschitz stability for an inverse coefficient problem for a mean-field game system, (2023), arXiv: 2307.04025.

[4] P. CANNARSA, G. FRAGNELLI, D. ROCCHETTI, Controllability results for a class of one-dimensional degenerate parabolic problems in nondivergence form., J. Evol. Equ., 8 (2008), 583-616.

[5] K.J. ENGEL, R. NAGEL, One-Parameter Semigroups for Linear Evolution Equations, Springer-Verlag, New York, (2000).

Optimal-control obesity

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Keywords: Adipose tissue, Adipocytes, fiber network, IBM, White adipose tissue, Brown adipose tissue

Abstract

Worldwide, more than 700 million people suffer from obesity, a health problem taken as seriously as cancer, rendering it one of the deadliest diseases. Adipose tissue (AT) serves as an energy storage organ, constituting 20 to 50% of the body weight. Recent studies have identified a crucial type of adipose tissue that can play a role in combating this disease. Consequently, we are interested in comprehending the structure of this organ, which comprises lobular clusters of adipocytes surrounded by an organized collagen fiber network. According to a 2-D Individual-Based Model (IBM), we explain the morphology of adipose tissue as simple mechanical interactions between cells and fibers, with the objective of minimizing this mechanical interaction energy.

References

[1] Diane Peurichard, Fanny Delebecque, Anne Lorsignol, Corinne Barreau, Jacques Rouquette, Xavier Descombes, Louis Casteilla, and Pierre Degond, *Simple mechanical cues could explain adipose tissue morphology*, *Journal of theoretical biology*, **429**, 61–81, Elsevier, 2017.

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Multiplex network completion via similarity learning using Einstein-product

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Abstract

In this work, we focus on advancing the multiplex network completion method using tensor structures through the Einstein product. We introduce a novel approach based on similarity tensors. Furthermore, we have developed a strategy to simultaneously factorize the adjacency tensor of the observed nodes. Additionally, we propose an optimization technique that employs alternating minimization to tackle the multiplex network completion challenge. Our method is demonstrated with applications on both synthetic and real-world datasets.

Keywords: Einstein Product, Multiplex network, Tensor network completion

References

[1] F. Masrour, I. Barjesteh, R. Forsati, A. H. Esfahanian, H. Radha. (2015, August). Network completion with node similarity: A matrix completion approach with provable guarantees. In Proceedings of the 2015 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining 2015 (pp. 302-307).

[2] D. Rafailidis, F. Crestani: Network completion via joint node clustering and similarity learning. In: 2016 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM), pp. 63–68 (2016). IEEE

[3] T.G. Kolda, B.W. Bader: Tensor decompositions and applications. SIAM review 51(3), 455–500 (2009)

[4] R. Behera, D. Mishra: Further results on generalized inverses of tensors via the einstein product. Linear and Multilinear Algebra 65(8), 1662–1682 (2017)

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PEFT-HSIC: Parameter-Efficient Fine-Tuning for Hyperspectral Image Classification with Remote Sensing Foundation Models

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Abstract

In recent years, foundation models have transformed various domains, including remote sensing (RS), by enabling efficient transfer learning through large-scale pre-trained models. However, adapting these models to specific tasks like hyperspectral image classification (HSIC) presents challenges due to the high computational and storage demands of fine-tuning. In this work, we explore Parameter-Efficient Fine-Tuning (PEFT) techniques, focusing on both Low-Rank Adaptation (LoRA) and Kronecker Adaptation (KronA), to adapt a multispectral remote sensing foundation model for HSIC. LoRA introduces low-rank matrices to minimize the number of trainable parameters, while KronA utilizes a Kronecker product to increase expressiveness without excessive computational overhead. Through extensive experiments on multiple hyperspectral image datasets, we demonstrate that PEFT-HSIC, using LoRA and KronA, achieves comparable or superior accuracy to fully fine-tuned models, with a substantial reduction in trainable parameters and memory requirements. This approach highlights the effectiveness of PEFT methods for hyperspectral tasks, making them viable solutions for resource-constrained environments.

Keywords: Hyperspectral Image Classification, Finetuning, PEFT, LoRA, KronA,

References

[1] M. Ahmad et al. , Hyperspectral Image Classification—Traditional to Deep Models: A Survey for Future Prospects

[2] D. Hong et al. , SpectralGPT: Spectral Remote Sensing Foundation Model

[3] Edward Hu et al., LoRA : Low-Rank Adaptation of Large Language Models

[4] Ali Edalati et al., KronA: Parameter Efficient Tuning with Kronecker Adapter

VEM–Nitsche fully discrete polytopal scheme for mixed-dimensional poromechanical models with Coulomb frictional contact at matrix-fracture interfaces

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Abstract

This work deals with the discretisation of processes coupling a Darcy flow in a fractured/faulted porous medium, the mechanical deformation of the matrix domain surrounding the fractures, and the mechanical behavior of the fractures. Such coupled models are of paramount importance in a broad range of subsurface processes like geothermal systems or geological storage. Fractures or faults will be represented as a network of planar surfaces leading to the so-called mixed-dimensional models. Small displacements and a linear elastic behavior are considered in the matrix domain. Our objective is to design a discretisation adapted to polyhedral meshes in order to cope with the geometrical complexity of faulted/fractured geological systems. The discretisation of the flow model is based on an Hybrid Finite Volume scheme using cell, face and fracture edge unknowns and accounting for the discontinuity of the pressure at matrix-fracture interfaces. The discretisation of the mechanics is based on a first order Virtual Element Method (VEM) for the displacement field combined with a Nitsche's formulation for the Coulomb frictional contact at matrix-fracture interfaces. Nitsche's method introduced for contact-mechanics by F. Chouly and co- authors in [1] in the Finite Element framework aims at treating interface conditions in a weak sense with appropriate consistent terms that involve only the displacement field, not requiring the use of Lagrange multipliers. To the best of our knowledge, our work is the first extension of the Nitsche's contact formulation to the polytopal VEM framework. We first establish the well-posedness and provide an optimal error estimate for the VEM-Nitsche discretisation using a frictionless contact model. Then, our polytopal method is investigated numerically both for stand-alone contact-mechanics test cases and for fully coupled mixed-dimensional poromechanical test cases.

Keywords: Contact mechanics, Darcy flow, Fractured/faulted porous medium, Mixed-dimensional models, Virtual Element Method (VEM), Nitsche's formulation.

References

[1] F. CHOULY, P. HILD, AND Y.RENARD., Symmetric and non-symmetric variants of Nitsche's method for contact problems in elasticity: theory and numerical experiments. Mathematics of Computation, 84(293), pages 1089-1112, 2015

Outlier-free isogeometric discretizations for Laplace eigenvalue problems: closed-form eigenvalue and eigenvector expressions

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Abstract

We derive explicit closed-form expressions for the eigenvalues and eigenvectors of the matrices resulting from isogeometric Galerkin discretizations based on outlier-free spline subspaces for the Laplace operator, under different types of homogeneous boundary conditions on bounded intervals. For optimal spline subspaces and specific reduced spline spaces, represented in terms of B-spline-like bases, we show that the corresponding mass and stiffness matrices exhibit a Toeplitz-minus-Hankel or Toeplitz-plus-Hankel structure. Such matrix structure holds for any degree p and implies that the eigenvalues are an explicitly known sampling of the spectral symbol of the Toeplitz part. Moreover, by employing tensor-product arguments, we extend the closed-form property of the eigenvalues and eigenvectors to a d-dimensional box. As a side result, we have an algebraic confirmation that the considered optimal and reduced spline spaces are indeed outlier-free.

Keywords: Laplace eigenvalue problem, Isogeometric analysis, Optimal spline subspace, Cardinal B-spline, Mass matrix, Stiffness matrix, Toeplitz matrix, Hankel matrix

References

[1] C. Manni, E. Sande, and H. Speleers, Application of optimal spline subspaces for the removal of spurious outliers in isogeometric discretizations; Computer Methods in Applied Mechanics and Engineering, 389:114260, 2022

An Insensitizing control problem involving tangential gradient terms for a reaction-diffusion equation with dynamic boundary conditions

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Abstract

In this talk, an insensitizing control problem for a nonlinear reaction-diffusion equation with dynamic boundary conditions is considered. The associated functional depends on the norm of the state in a subset of the bulk together with the norm of the tangential gradient of the state on the boundary. We prove a local existence result using the equivalence between this problem and a (relaxed) null controllability problem for the optimality system of cascade type, with a zeroth-order coupling term in the bulk and a second-order coupling term on the boundary. To achieve this result, we linearize the system around the origin and analyze it by duality and using a new Carleman estimate for the corresponding adjoint system. Then, applying an inverse function theorem we deduce a local null controllability result for the nonlinear system.

Keywords: Insensitizing control, Reaction-diffusion equation, Dynamic boundary conditions, Null controllability, Carleman estimate.

References

[1] Mauricio C. Santos, Nicolás Carreño, Roberto Morales, An Insensitizing control problem involving tangential gradient terms for a reaction-diffusion equation with dynamic boundary conditions, arXiv: 2407.09882 (2024).

Thermo-Hydro-Mechanical Model for a Single-Phase Compressible Gas Flow

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Abstract

This study explores the feasibility of underwater hydrogen storage in a cemented cavity within a porous medium, using hydrogen produced from water electrolysis. The aim is to provide a solution to the overproduction of electricity from offshore wind farms by storing excess energy. However, after infiltrating the hydrogen into the materials, some complications arise like chemical degradation, structural damage and reduced resistance, all of which increase the risk of leaks. Our goal is to prevent these issues and ensure a safe and efficient storage.

Starting from [1] and [2] , we consider a Thermo-Hydro-Mechanical (THM) model describing a non-isothermal monophasic compressible gas-phase flow in a porous medium characterized by small strains, displacements and variations of the porous rocks. Linear isotropic thermo-poro-elastic constitutive laws are considered for the skeleton assuming small variations of temperature around the reference temperature T_0 and thermal equilibrium is assumed between the fluid and the skeleton. The THM model consists of a system of nonlinear parabolic partial differential equations. These equations incorporate the mass conservation of hydrogen in the gas phase, fluid entropy conservation under reversible mechanical deformation, and the momentum balance equation for the skeleton where the main unknowns are the fluid pressure, the fluid temperature and the displacement of the skeleton.

The study is divided into two parts. First, we prove the energy estimates for the solutions of the continuous model by multiplying our system of equations with appropriate functions depending on our main unknowns and by applying Gronwall's lemma, which assures that our solution is bounded under appropriate assumptions. In the second part, we devote our work to the numerical analysis of the THM model. We discretize our system of equations preserving energy estimates using the cell-centered finite volume method for space discretization and backward Euler scheme for time discretization. We are also in the work of a numerical implementation of this model in 1D and 2D using the Newton-Raphson algorithm.

Keywords: Thermo-hydro-mechanical model, finite volume method, energy estimates, porous medium.

References

[1] O. COUSSY, Poromechanics, Wiley, 2004

[2] J. DRONIOU ET AL, Thermodynamically Consistent discretisation of a Thermo-Hydro-Mechanical model. FVCA 2023 - 10th International Symposium on Finite Volumes for Complex Applications, Oct 2023, Strasbourg, France.

A New Combination of Polynomial Extrapolation Methods and Multigrid Solvers for IGA Applied to Linear and Nonlinear Elliptic PDEs

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Abstract

In this work, we introduce a novel approach for efficiently solving large, sparse linear systems arising from the discretization of elliptic partial differential equations (PDEs) using isogeometric analysis (IGA). Our method integrates polynomial extrapolation techniques with geometric multigrid solvers (GMG), significantly enhancing the performance of standard multigrid iterations with classical smoothers. We further extend this approach to nonlinear problems by employing polynomial-type extrapolation to accelerate the Picard iterative method. This work provides quadratic convergence results for polynomial extrapolation methods. Specifically, a new theoretical result on the correlation between the residual norm and the error norm, as well as a new estimation for the generalized residual norm of some extrapolation methods, are given. Through various numerical experiments, we demonstrate that the proposed combination of multigrid solvers with polynomial extrapolation methods significantly accelerates convergence and provides a robust alternative to existing techniques, such as Anderson acceleration.

Keywords: Multigrid methods, Isogeometric analysis, Picard method, MPE method, RRE method, Anderson acceleration, Restarted extrapolation methods, Bratu problem, Monge–Ampère equation

References

[1] M. Donatelli, C. Garoni, C. Manni, S. Serra-Capizzano, and H. Speleers, Robust and optimal multi-iterative techniques for IgA Galerkin linear systems, Comput. Methods Appl. Mech. Engrg (2015), no. 284, 230–264.

[2] M. Bahari, A. Habbal, A. Ratnani, E. Sonnendrücker, Adaptive Isogeometric Analysis using optimal transport and their fast solvers, Comput. Methods Appl. Mech. Engrg (2024), no. 418, 116570.

[3] K. Jbilou, H. Sadok, Analysis of some vector extrapolation methods for linear systems, Numer. Math (1995), no. 70, 73–89.

Switching Problem and Reflected Backward Stochastic Differential Equations

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Abstract

Keywords: Switching problem; Real options; Starting and stopping problem; Backward SDEs; Reflected BSDEs; Snell envelope; Optimal stopping problem

This is an abstract for a literature review around the topic of switching problem and backward stochastic differentiel equations. The switching problem or stopping and strating problem occurs where systems are subject to sudden changes in regime or state.In conciseness, such a problem consists in finding an optimal management strategy for a production facility/company that can operate in several different modes.

Our study begins with a presentation of the theoretical foundations of BSDEs, including the necessary conditions for existence and uniqueness of solutions. We then introduce the concept of regime switching, characterized by a finite-state Markov process that governs the transitions between different regimes. By coupling BSDEs with thes optimal strategy, we develop a comprehensive model that control the systems under regime switching.

A conceptual example is the management of an electricity producing company which can produce electricity through different means, e.g., solar cells, wind power stations and oil power plants. Due to fluctuations in the spot price of electricity, spot price of oil, solar radiation and wind strength, the optimal way (in terms of revenue) to produce electricity varies. Changing the production mode will in many cases incur costs for the company as investements/disinvestments in technology and/or staff may be necessary.

All in all, the manager of the company must decide, based on her beliefs of unknown parameters such as weather, electricity spot price, etc..., which mode of production to use and when to switch to a new mode. An optimal management stragtegy is needed to manage the production and maximize the expected optimal profit.

Mathematically speaking, consider a production facility which can run the production in $d, d \geq 2$, different production modes. Denote the set of available modes by $\mathcal{D} = \{1, \ldots, d\}$ and let $\mathcal{D}^{-i} = \{1, \ldots, i-1, i+1, \ldots, d\}$. Let $X = \{X_t\}_{t \geq 0}$ be a vector-valued Markovian stochastic process representing random factors that influence the profitability of the production, e.g., the market price of the underlying commodities, weather, and market demand of the produced goods.

The process X may be a Brownian motion or some other more general stochastic process, possibly with jumps. Let the running payoff in production mode i, at time t, be $\psi_i(X_t, t)$ and let $c_{i,j}(X_t, t)$ denote the cost of switching from mode i to mode j at time t.

A management strategy is a combination of a non-decreasing sequence of stopping times $\{\tau_k\}_{k \geq 0}$, where at time τ_k, the manager decides to switch the production from its current mode to another, and a sequence of indicators $\{\xi_k\}_{k \geq 0}$, taking values in $\mathcal{D}$, indicating the mode to which the production is switched.

For a strategy starting in mode i at time t, we have $\tau_0 = t$ and $\xi_0 = i$. At τ_k the production is switched from mode ξ_{k-1} to ξ_k. A strategy $\left(\{\tau_k\}_{k \geq 0}, \{\xi_k\}_{k \geq 0}\right)$ can be represented by the function $\mu : [0, T] \rightarrow \mathcal{D}$ defined as

When the production is run using a strategy μ, defined by $\left(\{\tau_k\}_{k\geq 0}, \{\xi_k\}_{k\geq 0}\right)$,the total expected profit is

$$\mathbb{E}\left[\int_0^T \psi_{\mu_s}(X_s, s)\, ds - \sum_{\substack{k\geq 1\\ \tau_k\leq T}} c_{\xi_{k-1},\xi_k}(X_{\tau_k}, \tau_k)\right].$$

Similarly, given that the stochastic process X starts from x at time t, the profit made using strategy μ, over the time horizon $[t, T]$, is

$$J(x,t,\mu) := \mathbb{E}\left[\int_t^T \psi_{\mu_s}(X_s, s)\, ds - \sum_{\substack{k\geq 1\\ \tau_k\leq T}} c_{\xi_{k-1},\xi_k}(X_{\tau_k}, \tau_k) \mid X_t = x\right].$$

The optimal switching problem now consists in finding the value function

$$v(x,t) = \sup_{\mu} J(x,t,\mu),$$

and an optimal management strategy μ^*, defined by $\left(\{\tau_k^*\}_{k\geq 0}, \{\xi_k^*\}_{k\geq 0}\right)$, such that

$$J(x,t,\mu^*) \geq J(x,t,\mu)$$

There are today basically three different approaches available to tackle the optimal switching problem.Two of them are based on stochastic techniques, in particular Snell envelopes and backward stochastic differential equations, and one is of deterministic type, making use of variational inequalities/obstacle problems.
The purpose of this presentation is to give a summary of the stochastic techniques used in the otimal switching control.
This abstract is given within the framework of a litterature review as I'm a first year PHD student aiming to establish a solid theoretical foundation for my research in the topic of Switching problem and related system of RBSDEs.

References

[1] S. Hamadène and M. Jeanblanc, ***On the starting and stopping problem: Application in reversible investments*** ; Journal, Math. Oper. Res. 32 (1) (2007) 182,192.

[2] Said. Hamadène and Jianfeng.Zhangb,, ***Switching problem and related system of reflected backward SDEs*** ; Stochastic Processes and their Applications.

[3] Ying.Hu,Shanjian.Tang, ***Multi-dimensional BSDE with oblique reflection and optimal switching*** ; Probab. Theory Relat. Fields (2010) 147:89.121.

[4] S. Hamadène,M. Hassani, Y. Ouknine , ***Backward SDEs with two rcll reflecting barriers without Mokobodskis hypothesis*** ; Probab. Theory Relat. Fields (2010) 147:89.121.

[5] N. El Karoui, C. Kapoudjian, E. Pardoux, S. Peng and M. C. Quenez , ***REFLECTED SOLUTIONS OF BACKWARD SDEs, AND RELATED OBSTACLE PROBLEMS FOR PDEs*** ; The Annals of Probability 1997, Vol. 25, No. 2, 702,737.

[6] E. Pardoux and S. Peng , ***Backward SDEs and quasilinear PDEs, in Stochastic Partial Differential Equations and Their Applications*** ; B. L. Rozovskii and R. B. Sowers, eds., Lecture Notes in Control and Inform. Sci. 176, Springer,Verlag, Berlin, 1992.

[7] B. Djehiche, S. Hamadène , ***On a finite horizon starting and stopping problem with risk of abandonment*** ; Int. J. Theor. Appl. Finance 12 (4) (2009) 523;543.

Mixed Precision Iterative Refinement for Linear Inverse Problems

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Abstract

We investigate the iterative refinement method applied to the solution of linear discrete inverse problems by considering its application to the Tikhonov problem in mixed precision. Previous works on mixed precision iterative refinement methods for the solution of symmetric positive definite linear systems and least-squares problems have shown regularization to be a key requirement when computing low precision factorizations [1, 2]. For problems that are naturally severely ill-posed, we formulate the iterates of iterative refinement in mixed precision as a filtered solution using the preconditioned Landweber method with a Tikhonov-type preconditioner. Through numerical examples simulating various mixed precision choices, we showcase the filtering properties of the method and the achievement of comparable or superior accuracy compared to results computed in double precision as well as another approximate method.

Keywords: mixed precision, iterative refinement, Tikhonov regularization, preconditioned iterative methods, Landweber

References

[1] N. Higham and S. Pranesh. "Exploiting lower precision arithmetic in solving symmetric positive definite linear systems and least squares problems." SIAM Journal on Scientific Computing 43.1 (2021): A258-A277.

[2] E. Carson and N. J. Higham, "Accelerating the solution of linear systems by iterative refinement in three precisions." SIAM Journal on Scientific Computing, 40 (2018), pp. A817– A847.

Impulse controllability for degenerate parabolic equation in non-divergence form with drift

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Abstract

The main goal is to investigate the null approximate impulse controllability of a one-dimensional degenerate heat equation in non-divergence form with a drift term. To achieve this result, we derive a logarithmic convexity estimate for the solution of the corresponding homogeneous system, utilizing the Carleman commutator technique with a tailored weight function.

Keywords: Impulsive approximate controllability, impulse control problems, Carleman commutator, logarithmic convexity, degenerate equation.

Let ω be a non-empty open subset of $(0,1)$ and $T > 0$ the time-horizon. We consider the following impulsive degenerate system:

$$\begin{cases} \partial_t y - x^\alpha y_{xx} - x^\gamma y_x = 0, & \text{in } (0,1)\times(0,T)\backslash\{\tau\}, \\ y(\cdot,\tau) = y(\cdot,\tau^-) + \mathbb{1}_\omega h(\cdot,\tau), & \text{in } (0,1), \\ y(1,t) = y(0,t) = 0, & \text{on } (0,T), \\ y(x,0) = y_0(x), & \text{on } (0,1), \end{cases} \tag{1}$$

where $\tau \in (0,T)$ is an impulse time, y_0 is the initial data, $y(.,\tau^-)$ represents the left limit of the function y at time τ, $\mathbb{1}_\omega$ is the characteristic function of ω and $h(\cdot,\tau) \in L^2(\omega)$ is the impulse control.

References

[1] P. Cannarsa, G. Fragnelli, D. Rocchetti, *Controllability results for a class of one-dimensional degenerate parabolic problems in nondivergence form.* J. Evol. Equ. **8**, 583–616 (2008).

[2] H. Maarouf, L. Maniar, I. Ouelddris, J. Salhi, *Impulse controllability for degenerate singular parabolic equations via logarithmic convexity method.* IMA J. Math Control Info. **40**(4), 593–617

Modeling Demography's Influence on Malaria Treatment Using Transmission-Blocking Drugs

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Abstract

In this talk, we present and analyze a novel mathematical model for malaria transmission, incorporating treatment with transmission-blocking drugs (TBDs) and varying demographic growth terms. The aim is to examine how different demographic factors affect disease spread and TBD treatment outcomes. We calculate the control reproduction number, identify equilibria, and perform a global stability analysis of the disease-free state. The analysis shows that, depending on the demographic structure, the model may exhibit forward, backward, or non-traditional bifurcations, where disease elimination may occur at both low and high reproduction numbers. Numerical results indicate that one of the three demographic scenarios experienced a significantly higher disease burden, and under high levels of TBD treatment, malaria was successfully eliminated within a reasonable timeframe only in this scenario.

Keywords: demography, malaria, mathematical modeling, simulation, transmission-blocking drugs

Preconditioned $\ell^p - \ell^q$

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Abstract

In this talk I will present a work on an extension of the Maximization-Minimization Generalized Krylov Subspace (MM-GKS) method for solving $\ell_p - \ell_q$ minimization problems, as proposed in [1], by introducing a right preconditioner aimed at accelerating convergence without compromising the quality of the computed solution. The original MM-GKS approach relies on iterative reweighting and projection onto subspaces of increasing dimensions, enabling efficient resolution of minimization problems. Our enhanced method leverages a carefully designed regularizing preconditioner, inspired by Iterated Tikhonov regularization, to address the inherent ill-conditioning of the problem. We demonstrate that our preconditioned MM-GKS method preserves the stability and accuracy of the original MM-GKS method, as validated by numerical results in image deblurring, showing significant reductions in CPU time.

Keywords: $\ell_p - \ell_q$ minimization, inverse problems, image deblurring, iterative method

References

[1] A. LANZA, S. MORIGI, L. REICHEL, F. SGALLARI, A generalized Krylov subspace method for $\ell_p - \ell_q$ minimization. SIAM Journal on Scientific Computing, (2015), 37(5), S30-S50.

Control and stabilization of degenerate/singular hyperbolic systems

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Abstract

In this talk, we consider a system of two degenerate and singular wave equations coupled through the velocities, where only one of the equations is controlled or damped. Under some technical assumptions on the coefficients of the system, we prove new controllability and stability results. Firstly, we derive the explicit time for the indirect controllability of the corresponding control problem. Secondly, we prove that the total energy of the associated stabilization problem is exponentially decaying to zero, providing an explicit formula for the decay rate. The proofs of our results are mainly based on careful energy estimates and suitable Hardy-Poincaré type inequalities.

Keywords: Degenerate hyperbolic systems, singular hyperbolic systems, controllability, observability, stabilization, multiplier method

References

[1] F. Alabau-Boussouira, P, Cannarsa and G. Leugering, Control and stabilization of degenerate wave equation, SIAM J. Control Optim., **6** (2016), 161-204.

[2] B. Allal, A. Moumni and J. Salhi, Boundary controllability for a degenerate and singular wave equation, Math Methods in the App Sci., **45** (2022), 11526-11544.

[3] J. Vancostenoble and E. Zuazua, Hardy Inequalities, observability, and control for the wave and Schrödinger equations with singular potentials, SIAM J. Math. Anal., **41** (2009), 1508-1532.

Some new results on the controllability of parabolic and hyperbolic problems

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Abstract

We will explore recent control problems associated with a class of degenerate and singular equations. We will discuss a heat equation in the parabolic context [1], and extend our discussion to the hyperbolic case, presenting some results related to the wave equation [2, 3].

Keywords: Boundary controllability, degenerate equations, singular potentials, heat equation, wave equation.

References

[1] S. EDDARGANI, A. SBAI, Minimal time of the pointwise controllability for degenerate singular operators and related numerical results via B-splines, https://arxiv.org/abs/2405.04930.

[2] G. FRAGNELLI, D.MUGNAI, A. SBAI, Boundary controllability for degenerate/singular hyperbolic equations in nondivergence form with drift, https://arxiv.org/abs/2402.18247.

[3] G. FRAGNELLI, D. MUGNAI, A. SBAI, Stabilization for degenerate equations with drift and small singular term, https://arxiv.org/abs/2403.17802.

Using infinitesimal symmetries for computing the first Maxwell time in the geometric control problem on SH(2)

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Abstract

In this work, we utilize infinitesimal symmetries to compute Maxwell points which play a crucial role in studying sub-riemannian control problems. By examining the infinitesimal symmetries of the geometric control problem on the SH(2) group, particularly through its Lie algebraic structure, we identify invariant quantities and constraints that streamline the Maxwell point computation

Keywords: Geometric control theory, Lie algebra, Maxwell time, special hyperbolic group, sub-Riemannian geometry

1 Preliminaries on Geometric Control Theory

1.1 Controllability of control affine systems

A driftless control affine system on a manifold M is any differential system of the form

$$\frac{dx}{dt} = \sum_{i=1}^{m} u_i(t) X_i(x), \tag{1}$$

where

- $x = x(t)$ is the state,
- $X_1, \ldots, X_m$ are smooth vector fields on M,
- $u_1(t), \ldots, u_m(t)$ are the control imputs.

Let $\mathcal{F}$ be a family of smooth vector fields on M, then the Lie algebra generated by $\mathcal{F}$ is the smallest Lie algebra that contains $\mathcal{F}$. It is obtained by considering all linear combinations of elements of $\mathcal{F}$, taking all Lie brackets of these, considering all linear combinations of these, and continuing so on. It will be denoted by $\mathrm{Lie}(\mathcal{F})$ and its evaluation at any point $q \in \mathrm{M}$ will be denoted by $Lie_q(\mathcal{F})$.

The following result gives a necessary and sufficient condition for a driftless control affine system to be controllable.

Proposition 1.1 *([7]). The control affine system* $\frac{dx}{dt} = \sum_{i=1}^{m} u_i X_i(x)$ *with* $u = (u_1, \ldots, u_m) \in \mathbb{R}^m$ *is controllable if and only if* $\mathrm{Lie}_q(\mathcal{F}) = T_q\mathrm{M}$, *for all* $q \in \mathrm{M}$.

1.2 Sub-Riemannian Problem and optimal solutions

A sub-Riemannian manifold is a triplet $(\mathrm{M}, \Delta, \mathrm{g})$ such that M is a manifold of dimension n, Δ is a smooth distribution of rank $k \leq n$, and g is a Riemannian metric defined on Δ. More precisely, $\forall q \in \mathrm{M}$, Δ_q is a subspace of $T_q\mathrm{M}$ of dimension k and g is a family of inner products g_q in Δ_q.
We say that a Lipschitz curve $\gamma : [0, t_1] \mapsto \mathrm{M}$ is admissible if $\dot{\gamma}(t) \in \Delta_{\gamma(t)}$ for all $t \in [0, t_1]$. Then the sub-Riemannian length of such a curve is defined by:

$$\ell(\gamma) = \int_0^{t_1} \sqrt{\mathrm{g}_{\gamma(t)}(\dot{\gamma}(t), \dot{\gamma}(t))}\, dt.$$

Given two points q_0 and q_1 of M, the sub-Riemannian distance between q_0 and q_1 is stated by

$$\mathrm{d}(q_0, q_1) = \inf\{\ell(\gamma) \mid \gamma \text{ admissible}, \gamma(0) = q_0, \gamma(t_1) = q_1\}.$$

A sub-Riemannian problem is a control problem on a sub-Riemannian manifold $(\mathrm{M}, \Delta, \mathrm{g})$ where one seek for admissible curves γ that satisfy the property $\ell(\gamma) = d(\gamma(0), \gamma(t_1))$. Suppose there exists a family of smooth vector fields $X_1, \ldots, X_k$ that forms an orthonormal frame on (Δ, g), i.e. $\forall q \in \mathrm{M}$, $\Delta_q = \mathrm{span}\{X_1(q), \ldots, X_k(q)\}$ and $\mathrm{g}_q(X_i(q), X_j(q)) = \delta_{ij}$. Thus, sub-Riemannian minimizers (or optimal solutions) are the solutions of the following optimal control problem on M:

$$\dot{x} = \sum_{i=1}^{k} u_i X_i(x), \quad u = (u_1, ..., u_k) \in \mathbb{R}^k, \tag{2}$$

$$x(0) = q_0, \quad x(t_1) = q_1, \tag{3}$$

$$\ell = \int_0^{t_1} (\sum_{i=1}^{k} u_i^2)^{1/2} dt \longrightarrow \min. \tag{4}$$

If we add the condition $\sum_{i=1}^{k} u_i^2 \leq 1$, the system given by equations (2)-(4), becomes:

$$\begin{aligned} &\dot{x} = \sum_{i=1}^{k} u_i X_i(x), \quad \sum_{i=1}^{k} u_i^2 \leq 1, \\ &x(0) = q_0, \quad x(t_1) = q_1, \\ &t_1 \rightarrow \min. \end{aligned} \tag{5}$$

By Filipov's theorem ([10]), the existence of optimal solutions for the optimal control problem (5) is guaranteed.
The Pontryagin Maximum Principle [1] provides necessary conditions for optimality of trajectories solutions of sub-Riemannian control problems. Following this principle, we first compute trajectories, called extremals, of a dynamic system in the cotangent bundle of the variety M. Then the projections of the extremals on the state space M constitute the optimal solutions and are called geodesics.

A point $\gamma(t_1)$ is called a Maxwell point along a geodesic γ if there exists another geodesic $\widetilde{\gamma} \not\equiv \gamma$ such that $\gamma(t_1) = \widetilde{\gamma}(t_1)$. This means that there exists a geodesic $\widehat{\gamma}$ coming to the point $q_1 = \gamma(t_1)$ earlier than γ.

2 Computing the infinitesimal symmetries of a sub-Riemannian problem

For more details on symmetries of differential equations, we refer to [6].

Let $(\mathrm{M}, \Delta, \mathrm{g})$ be a sub-Riemannian manifold, where M is endowed with a Lie group structure of dimension n. We assume that the distribution Δ is left-invariant which means that

$$\Delta_{ab} = L_{a*}\Delta_b, \quad \mathrm{g}_b(v, w) = g_{ab}(L_{a*}v, L_{a*}w), \quad \forall a, b \in M,$$

where L_{a*} denotes the differential of the left translation by a. We consider the sub-Riemannian system (2)-(3)-(4) on the Lie group $(\mathrm{M}, \Delta, \mathrm{g})$ and we assume it is controllable and admits optimal solutions.

Once we compute a basis (v_i) for the symmetry algebra of the system defined by equations (2)-(3)-(4), we get the following result:

Proposition 2.1 *The infinitesimal symmetries of our system can be identified by calculating the flow associated with the vector field v_i at time s, denoted by $\gamma_i(s, t) = (q_1(s, t), \ldots, q_n(s, t))$. This flow is obtained by solving the system of differential equations:*

$$\frac{\partial \gamma_i(s, t)}{\partial s} = v_i(\gamma_i(s, t)), \quad \gamma_i(0, t) = (q_1(t), \ldots, q_n(t)).$$

3 Infinitesimal symmetries on SH(2) and the first Maxwell time

The motion of a unicycle on a hyperbolic plane can be described using the following driftless control system

$$\begin{cases} \dot{x} = u_1 \cosh z, \\ \dot{y} = u_1 \sinh z, \\ \dot{z} = u_2, \end{cases} \tag{6}$$

where u_1 is the translational velocity and u_2 is the angular velocity. The configuration and state manifold M of the system is three-dimensional, where, for any point $q = (x, y, z) \in \mathrm{M}$, x and y are position variables and z is the angular orientation variable of the unicycle on the hyperbolic plane. The following proposition provides an important result concerning the symmetry algebra of our system

Proposition 3.1 *Infinitesimal symmetries of the control system (6) form a Lie algebra generated (over R) by vector fields.*

$$\begin{aligned} v_1 &= -x\partial_y - y\partial_x - \partial_z, \\ v_2 &= \partial_x, \\ v_3 &= \partial_y. \end{aligned} \tag{7}$$

Proposition 3.2 *The action of the flow of the infinitesimal transformation $v = -x\partial_y - y\partial_x - \partial_z$, at the time s maps a local extremal corresponding to a local minimizer with the initial condition $x(0) = y(0) = z(0) = 0$ to another local extremal.*

$$\begin{aligned} x &\mapsto x\cosh(s) - y\sinh(s), \\ y &\mapsto y\cosh(s) - x\sinh(s), \\ z &\mapsto z - s. \end{aligned} \tag{8}$$

Next, we focus on finding the first Maxwell time where our trajectory loses its optimality.

Proposition 3.3 *The first Maxwell time T_1^{Max} where our trajectory loses optimality corresponding to This symmetry is given as:*

$$\begin{aligned} \lambda \in C_1 &\Longrightarrow T_1^{Max} = +\infty \\ \lambda \in C_2 &\Longrightarrow T_1^{Max} = 4k_0K(k_0), \quad k_0 \in (0,1) \\ \lambda \in C_3 \cup C_4 \cup C_5 &\Longrightarrow T_1^{Max} = +\infty \end{aligned}$$

References

[1] A.A. Agrachev, D. Barilari, U. Boscain, A comprehensive introduction to sub-Riemannian geometry

[2] Andrei Agrachev, Davide Barilari, Sub-Riemannian structures on 3D Lie groups

[3] Frank W. J, Daniel W, Ronald F, Ronald F, Charles W, Nist handbook of mathematical functions

[4] Igor Moiseev, Yuri L. Sachkov, Maxwell strata in sub-Riemannian problem on the group of motions of a plane

[5] Jean Gallier, Jocelyn Quaintance, Notes on differential Geometry and Lie Groups [Lecture notes]

[6] Peter J.Olver, Application of Lie Groups to Differential Equations

[7] Velimir Jurdjevic, Optimal Control and Geometry: Integrable Systems

[8] Yu. L. Sachkov, Complete description of the Maxwell strata in the generalized Dido problem

[9] Yu. L. Sachkov, The Maxwell set in the generalized Dido problem

[10] Yuri Sachkov, Introduction to Geometric Control

[11] Yasir Awais Butt, Sub-Riemannian Problem on Lie Group of Motions of Pseudo Euclidean Plane

A space-time isogeometric analysis method for control theory

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Abstract

The controllability problem, which consists in guiding the evolution system towards a desired state in a given time frame thanks to appropriate controls, is a major challenge in the control theory of dynamic systems. In this work, we propose a method based on space-time isogeometric analysis (IgA) to numerically solve the controllability problem of the wave equation. The use of B-splines in the framework of IgA improves the smoothness and precision of these controls. Case studies demonstrate its effectiveness for control problems. This approach opens promising perspectives for the application of advanced numerical methods to systems governed by partial differential equations.

Keywords: *controllability problem; spacetime; Isogemoetric analysis.*

References

[1] E. Burman, A. Feizmohammadi, A. Munch and L. Oksanen. *Space-time Finite Element Methods for Control Problems Subject to the Wave Equation.* ESAIM: Control,Optimisation and Calculus of Variations, 29, (2023), p.41.

[2] S. Fraschini, G. Loli, A. Moiola and G. Sangalli. *An unconditionally stable space–time isogeometric method for the acoustic wave equation.* Computers and Mathematics with Applications, 169, (2024), 205–222.

Bilinear control of the Fokker-Planck equation

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Abstract Despite the importance of control systems governed by bilinear controls for the description of phenomena that cannot be realistically modeled by additive controls, the action of multiplicative controls is generally not so widely studied as it happens for boundary and locally distributed controls. The main reasons of this fact might be found in the intrinsic nonlinear nature of such problems and furthermore, for controls that are scalar functions of time, in an ineluctable obstruction for proving results of exact controllability, which is contained in the celebrated work of Ball, Marsden and Slemrod, 1982.

In this talk, I will present results on the stabilization and controllability of parabolic-type evolution equations using a scalar input bilinear control. Specifically, I will focus on steering the system toward particular target trajectories known as eigensolutions. Finally, I will present a recent extension of this work that enables us to control the Fokker-Planck equation by the drift term.

Keywords: bilinear control, controllability, stabilizability, moment method, Fokker-Planck equation

References

[1] F. Alabau-Boussouira, P. Cannarsa, C. Urbani, "Superexponential stabilizability of evolution equations of parabolic type via bilinear control", Journal of Evolution Equations, vol. 21, pages 941-967 Springer (2021)

[2] F. Alabau-Boussouira, P. Cannarsa, C. Urbani, "Exact controllability to eigensolutions for evolution equations of parabolic type via bilinear control", Nonlinear Differ. Equ. Appl., vol. 29, pages 38 (2022)

[3] F. Alabau-Boussouira, P. Cannarsa, C. Urbani, "Bilinear control of evolution equations with unbounded lower order terms. Application to the Fokker-Planck equation", Comptes Rendus Mathématiques, vol. 362, pp. 511-545 (2024)

Convergence of a CVFE finite volume scheme for a nonisothermal incompressible two-phase flow in porous media

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Abstract

Two-phase flow in porous media arise in various applications such as productioon of geothermal energy and sequestration of CO2. This talk is concerned with a numerical method for modeling an incompressible immiscible two-phase flow through heterogeneous reservoirs by incorporating temperature variations and taking into account capillary effects. The mathematical model consists of a nonlinear degenerate parabolic system of three PDEs: a mass balance equation for both fluids and the energy balance equation, where flow velocities are modeled using Darcy-Muskat's law. The model is written in terms of the fractional flow formulation [1], i.e. the saturation of one phase, the nonisothermal global pressure and the temperature are primary unknowns.

Our numerical method consists in a fully coupled fully implicit strategy. The spatial discretization is carried out applying a vertex-centered CVFE (Control Volume Finite Element) finite volume scheme [3] to accurately solve the diffusion terms, while taking into account an anisotropic permeability tensor. The time derivative is approximated by a first-order implicit Euler scheme and the convective terms by an upwind scheme. Under physically relevant assumptions on the data, we first establish some a priori estimates, then we use compactness arguments [2] to show the convergence of the numerical scheme towards a weak solution of the continuous problem.

The algorithm developed, based on the above scheme, was implemented using the open source platform DuMu$^{\mathrm{X}}$ [4]. The effectiveness and robustness of the scheme is illustated through two numerical experiments relating to the injection of CO2, into a 2D heterogeneous reservoir that is fully saturated with water.

Keywords: Nonlinear degenerate system, Finite volume, Two-phase flow, Nonisothermal, Heterogeneous porous media, DuMu^X.

References

[1] B. Amaziane, M. Jurak, L. Pankratov, and A. Piatnitski. An existence result for nonisothermal immiscible incompressible 2-phase flow in heterogeneous porous media. *Math. Meth. Appl. Sci.*, 40:7510–7539, 2017.

[2] B. Andreianov, M. Bendahmane, and R. Ruiz-Baier. Analysis of a finite volume method for a cross-diffusion model in population dynamics. *Math. Models Methods Appl. Sci.*, 21(2):307–344, 2011.

[3] M. Ghilani, M. Saad, and E. H. Quenjel. Positive control volume finite element scheme for degenerate compressible two-phase flow in anisotropic porous media. *J. Comput. Phys.*, 23(1):55–79, 2019.

[4] T. Koch, D. Gläser, K. Weishaupt, et al. DuMux 3 – an open-source simulator for solving flow and transport problems in porous media with a focus on model coupling. *Comput. Math. with Appl.*, 81:423–443, 2021.

A low-rank non-convex norm method for multiview graph clustering

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Abstract

This study addresses the challenge of multiview clustering, where the goal is to accurately cluster data points by integrating information from multiple data sources or views. We present a novel approach, the "Consensus Graph-Based Multi-View Clustering Method Using Low-Rank Non-Convex Norm" (**CGMVC-NC**), which enhances clustering accuracy by capturing correlations across views. The method leverages the structural properties of multiview data, introducing a non-convex tensor norm to improve the representation of these correlations. Unlike traditional techniques, CGMVC-NC achieves superior performance on multiple benchmark datasets. This new approach not only advances multiview clustering but also offers potential for broader applications, enhancing analysis capabilities in complex data systems.

Keywords: Clustering, Multi-view, Non-Convex Norm, Tensor, Graph.

Minisymposium

Tensor computation and Applications

Organizers: A. Bentbib[1]

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Abstract: In recent real-world applications such as in image and video analysis, graph analysis, signal processing or completion process, the involved data are multidimensional. Various tensor-based approximation techniques have been developed to solve problems for such applications. The canonical (CP) and the Tucker, tensor decompositions can be considered to be higher order generalizations of the matrix well known singular value decomposition (SVD) and principal component analysis (PCA). Image processing such as compression, face recognition or classification has been a widely explored topic in mathematics, and many algorithms have proven to be effective for 2D cases . However, for high order structures, the most accurate methods typically have significantly high storage costs, or require complicated procedures that may be computationally expensive and this needs new approaches based on tensors. We focus in this session on the use of tensor computation to treat many interesting applications. The use of tensor's interesting properties will be discussed.

Speakers:

- **Ferdaous Ait Addi** (f.aitaddi.ced@uca.ac.ma). *Genralized dictionary learning using t-product.*
- **Sanaa Khobizy** (khobizy.sanaa23@gmail.com). *Multiplex network completion via similarity learning using Einstein-product.*
- **Rachad Bentbib** (bentbibrachad@gmail.com). *Low-rank matrix and tensor completion using convex and Riemannian optimization.*
- **Maryam Boubekraoui** (boubekraoui1996maryam@gmail.com). *Multilinear PageRank.*
- **Aoulaia Andahmou** (a.andahmou.ced@uca.ac.ma). *High-order Tensor Completion via SGD based on Einstein product.*
- **Ridwane Tahiri** (tahiri0ridwane@gmail.com). *Einstien-Multidimensional Extrapolation methods.*

Regularization of ill-posed inverse problems

Organizers: Andrea Azzarelli[1], Alessandro Buccini[1]

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Abstract: Ill-posed inverse problems arise in almost any field of science and engineering. We are faced with an inverse problem whenever we wish to reconstruct an unknown signal from measured data. The first and the latter are tied by a functional relation that may be known or unknown. In either case this kind of problems may have no solution or the solution may not be unique. Moreover, they are usually extremely sensitive to the presence of perturbation of the data. In other words, they are ill-posed. Regularization methods aim to reduce this sensitivity by substituting the original problem with a well-posed nearby one whose solution well approximate the solution of the first. In this minisymposium we present several algorithms to efficiently and accurately solve ill-posed inverse problems and discuss both their theoretical and numerical properties.

Speakers:

- **Andrea Azzarelli**, University of Cagliari, Cagliari, Italy.
  Fractional Laplacian and ADMM for glyph extraction.
- **Alessandro Buccini**, University of Cagliari, Cagliari, Italy.
  Software for $\ell^p - \ell^q$ minimization methods using generalized Krylov subspaces.
- **Patricia Díaz de Alba**, University of Salerno, Salerno, Italy.
  Linear FDEM subsoil data inversion in Banach spaces.
- **Davide Furchì**, University of Insubria, Como, Italy.
  The iterated Arnoldi-Tikhonov method.
- **Lucas Onisk**, Emory University, Atlanta, USA.
  Mixed precision iterative refinement for linear inverse problems.
- **Federica Pes**, University of Cagliari, Cagliari, Italy.
  A two-dimensional integral model for LIN electromagnetic data inversion.
- **Marco Ratto**, University of Insubria, Como, Italy.
  Preconditioned $\ell^p - \ell^q$ regularization.

Recent Breakthroughs in Optimization and Identification

Organizers: A. DOUBOVA[1], A. HABBAL[2]

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Abstract

The Mini-symposium on *Recent Breakthroughs in Optimization and Identification* brings together leading researchers to discuss the latest advancements in these critical areas of mathematical and computational science. The mini-symposium focus is on original theoretical developments, innovative methods, algorithms, and applications that have reshaped optimization techniques and identification processes across various fields.

Speakers

- **Mickaël Binois** (Université Côte d'Azur, Inria).
  Adaptive Replication Strategies in Trust Region-Based Bayesian Optimization for Stochastic Function
- **Anna Doubova** (Universidad de Sevilla).
  Identification of Degeneracy in Parabolic Equations
- **Abderrahmane Habbal** (Université Côte d'Azur, Inria).
  Cognitive behaviors modeled with Nash games: the case of pedestrian avoidance
- **Cristina Urbani** (Dipartimento di Scienze Tecnologiche e dell'Innovazione, Universitas Mercatorum, Piazza Mattei 10, 00186, Roma).
  Bilinear control of the Fokker-Planck equation

Control Theory and Applications

Abdeladim Elakri[1], Lahcen Maniar[2], Enrique Zuazua[3]

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Abstract: Control theory has evolved significantly over the past few decades, addressing complex systems across diverse domains, from engineering to industry. Essentially, control theory involves designing models and algorithms that respond to inputs to drive a system to a desired state while ensuring stability. It involves developing strategies to optimize performance in the face of various complexities and environments. This mini-symposium aims to explore recent advancements in control theory and its applications across various fields. It will feature presentations on recent mathematical developments of control theory as well as modern real-world applications, including robotics, traffic control, and many others.

Speakers:

- **Jan Giesselmann**, Technical University of Darmstadt, Germany
  Data assimilation for gas flows via observers using distributed measurements

- **Martin Gugat**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
  Synchronization of Observer Systems for the Flow in Gas Networks.
- **Amaury Hayat**, Ecole des Ponts Paristech, France
  Stabilization of PDE systems and applications

- **Roberto Morales**, University of Sevilla, Spain
  An Insensitizing control problem involving tangential gradient terms for a reaction-diffusion equation with dynamic boundary conditions.
- **Salah-Eddine Chorfi**, Cadi Ayyad University, Morocco
  Controllability of wave equations with oscillatory boundary conditions.

Modeling and Mathematical Analysis of Biological Complex Systems

Organizer: Moulay Lhassan HBID [1]

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Abstract: The Mini-Symposium on Modeling Biological Complex Systems aims to bring together researchers and practitioners from various disciplines to explore and discuss innovative modeling approaches in the study of biological systems. This event will focus on key areas such as epidemiology, cellular dynamics, and mathematical ecology, highlighting the importance of interdisciplinary collaboration in advancing our understanding of complex biological phenomena.

This mini-symposium will appeal to researchers, practitioners, and students interested in modeling biological systems, as well as those engaged in related fields such as public health, computational biology, and environmental science.

Objectives

1. Interdisciplinary Exchange: To encourage interdisciplinary dialogue among researchers from diverse backgrounds, facilitating knowledge sharing and collaboration.
2. Showcasing Innovations: To highlight recent advancements and methodologies in the modeling of biological systems, particularly in the fields of epidemiology, cellular dynamics, and mathematical ecology.
3. Problem-Solving Focus: To address current problems in biological systems through robust modeling techniques, potentially leading to novel insights and applications.
4. Research Team Development: To reflect on the establishment of research teams within the framework of the PhD Program: Mathematica and Decisions. This objective will create an environment that encourages mentorship, collaboration, and the development of interdisciplinary research projects aimed at solving complex biological problems.

Format

• Keynote Presentation (30 minutes): The symposium will feature a keynote speaker who is an expert in the field of biological modeling. This presentation will provide an overview of the latest trends and explore significant challenges in modeling and anlysis of biological systems, setting the stage for subsequent discussions.

• Contributed Talks (15 minutes each): Following the keynote, the symposium will include contributed talks from participants. Each presentation will focus on specific problems or case studies related to:

o Epidemiology: Modeling disease spread, intervention strategies, and public health implications.

o Cellular Dynamics: Investigating cell behavior, interactions, and responses through dynamic models.

o Mathematical Ecology: Understanding ecosystem dynamics, species interaction, and environmental impacts using mathematical frameworks.

<u>**Speakers**</u>:

- **Gauthier Sallet** (INRIA and University of Lorraine, France).
- **Mostafa Adimy** (INRIA, Rhône Alpes, France).
- **Pierre Alexandre Bliman**(INRIA and Sorbonne University, France). (Teams)
- **Slimane Ben Miled** (Pasteur Institute Tunis, Tunisia).
- **Rachid Ouifki** (North-West University, South Africa) .
- **Abdellah Douiri**(Kings College of London, UK).
- **Jalila El Ghordaf** (CRMF, Beni Mellal, Maroc).
- **Youssef HBID** (Imperial College London, School of Public health, London, United Kingdom, UK).

Mathematics in Game Theory

Organizer: Rida Laraki[1]

[1] *UM6P, Director of the Moroccan Center for Game Theory; Rida.LARAKI@um6p.ma*

Abstract

This talk presents some fundamental results in game theory, highlighting the diverse mathematical tools employed in this field. We will provide detailed expositions of significant theorems and their proofs. Specifically:

The von Neumann-Morgenstern Min-max theorem, presented with two proofs: one using duality in linear programming and the other via follow the leader learning procedure. The Nash equilibrium existence theorem, with a proof based on Brouwer's fixed point theorem. A strategic characterisation of +1 index equilibria. This aims to showcase the richness of mathematical approaches in game theory, appealing to both novices and experts.

Speakers

- **Rida Laraki** (UM6P, Director of the Moroccan Center for Game Theory). *Fundamental results in game theory*
- **Rémi Castera** (Post-Doc at the Moroccan Center for Game Theory). *Two-sided matching for college admission*
- **Julien Fixary** (Post-Doc at the Moroccan Center for Game Theory). *An Introduction to Network Formation Theory*
- **Mouhcine ASSOULI** (PhD student at the Moroccan Center for Game Theory). *Deep Learning for Mean Field Games*

Minisymposium:
Numerical simulations of porous media flows

Organizer: Dr. El-Houssaine Quenjel [1]

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Abstract: Simulating flows in complex porous media has an increasing interest in many environmental and engineering problems such as, soil remediation, CO2 sequestration, hydrogen storage or nuclear waste management. The main objective is to understand the behavior of such a process in different scales of space and time. In such a context, repetitive experiments may be exorbitant, difficult or impossible to conduct. Modeling and numerical simulations offer a good alternative to go beyond these constraints. However, many challenges arise in the design of efficient, robust and convergent numerical methods allowing the resolution of porous media flow models. The main one comes from the coupling together with the nonlinearities of the physical laws. The second issue is related to porous medium that could be highly heterogeneous and anisotropic. Developing solvers answering these question has given rise to many scientific works in the literature depending on the choice of the model hypothesis as well as the used numerical method. In this mini-symposium, we invite contributions related to the development of advanced numerical schemes for the analysis and the efficient resolution of some versions of incompressible two-phase flows in porous media.

Speakers:

- **Mohamed Laaziri** Université Côte d'Azur, Inria, Laboratoire J.A. Dieudonné, Nice, France.
  VEM–Nitsche fully discrete polytopal scheme for mixed-dimensional poromechanical models with Coulomb frictional contactat matrix-fracture interfaces
- **Mohamed-Amine Hamadi** Université Paris-Saclay, CentraleSupélec, LGPM, CEBB, 3 rue des Rouges Terres 51110 Pomacle, France.
  An improved Newton approach for solving nonlinear systems arising in porous media flows
- **Mayssam Mohamad** Ecole Centrale de Nantes, 1 Rue de la Noë, 44300 Nantes, France.
  Energy Estimates of a Thermo-Hydro-Mechanical Model for a Single-Phase Compressible Gas Flow.
- **Youssef Zahraoui** University of Moulay Ismaïl, L2M3S-ENSAM, Meknès, Morocco
  Convergence of a CVFE fnite volume scheme for a nonisothermal incompressible two-phase flow in porous media
- **Hamidi Sadiq** University of Moulay Ismaïl, L2M3S-ENSAM, Meknès, Morocco.
  A fully implicit non linear finite volume scheme for single flow reactive transport in porous media
- **El-Houssaine Quenjel** Université Paris-Saclay, CentraleSupélec, LGPM, CEBB, 3 rue des Rouges Terres 51110 Pomacle, France.
  Efficient prediction of the macroscopic permeability matrix of 3D hygroscopic media

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Index of speakers

Scientific program

Mathematics & Decision Conference

December 17-20, 2024

Tuesday

08:00-09:15	**Registration**	
09:15-09:30	**Opening**	
09:30-10:15	**Marcos Raydan**	
10:15-10:45	**Presentation of the Vanguard Center**	
Coffee Break (10:45-11:15)		
11:15-13:00	**Vanguard Center Posters**	
LUNCH (13:00-15:00)		
15:00-15:40	**Ricardo Vinuesa**	
15:45-18:15	**Mini Symposium (M.L. Hbid)**	**Session I: Advanced Numerical Linear Algebra & Optimization**

Wednesday

09:00-09:40	**Patrick Perré**	
09:45-10:30	**Luc Giraud**	
Coffee Break (10:30-11:00)		
11:00-13:30	**Mini Symposium (A. Buccini)**	**Session II: Control & Optimization**
LUNCH (13:30-15:00)		
15:00-15:40	**Alessandro Reali**	
15:45-18:15	**Mini Symposium (A. Habbal)**	**Mini Symposium (A. Bentbib)**

Thursday

09:00-09:40	**Enrique Zuazua**	
09:45-10:30	**Enrique Fernández Cara**	
Coffee Break (10:30-11:00)		
11:00-13:30	**Mini Symposium (E. Quenjel)**	**Mini Symposium (R. Laraki)**
LUNCH (13:30-15:00)		
15:00-15:40	**Stefano Serra-Capizzano**	
15:45-18:15	**Mini Symposium (L. Maniar)**	**Session III: Numerical PDEs**

Friday

09:00-09:40	**Pierre Auger**	
Coffee Break (09:45-10:15)		
10:15-13:15	**PhD Posters**	

Session I: Advanced Numerical Linear Algebra & Optimization

Tuesday Afternoon

Time	Speaker and Title
15:45 - 16:10	**Parisa Ahani** Fleet Replacement Decision Optimization: Models and Approaches.
16:10 - 16:35	**Rohollah Garmanjani** Worst-Case Complexity of Trust-Region Methods for Multiobjective Optimization.
16:35 - 17:00	**Achraf Badahmane** New approach for solving the discrete Navier-Stokes problems: Application to Sequences of Saddle-Point Linear Systems from Incompressible Flow.
17:00 - 17:25	**Abdellatif Mohssine** A New Combination of Polynomial Extrapolation Methods and Multigrid Solvers for IGA Applied to Linear and Nonlinear Elliptic PDEs.
17:25 - 17:50	**Abdessamad Belfakir** Optimal control of molecular coherent states.
17:50 - 18:15	**Anas Elhachimi** Non-negative Einstein tensor factorization for unmixing hyperspectral images.

Session II: Control & Optimization

Wednesday Morning

Time	Speaker and Title
11:00 - 11:25	**Jawad Salhi** Control and stabilization of degenerate/singular hyperbolic systems.
11:25 - 11:50	**Soukaina Ezzeroual** Using infinitesimal symmetries for computing the first Maxwell time in the geometric control problem on SH(2).
11:50 - 12:15	**Hind Elbaggari** Heat Kernel for heat equation with inverse square potential and dynamic boundary conditions.
12:15 - 12:40	**Samia Moustaid** Switching Problem and Reflected Backward Stochastic Differential Equations.
12:40 - 13:05	**Soufiane Boumasmoud** The Impact Of Delay On Second Order Evolution Equations.
13:05 - 13:30	**Amine Sbai** Some new results on the controllability of parabolic and hyperbolic problems.

Session III: Numerical PDEs

Thursday Afternoon

Time	Speaker and Title
15:45 - 16:10	**Noureddine Lamsahel** Outlier-free isogeometric discretizations for Laplace eigenvalue problems: closed-form eigenvalue and eigenvector expressions.
16:10 - 16:35	**Abou Cisse** Multi-Patch Space-Time Isogeometric Discontinuous Galerkin Method for Hamilton–Jacobi Equations.
16:35 - 17:00	**Mohammed Amraoui** Generalization error estimates for Physics-Informed Neural Networks in the approximation of PDEs.
17:00 - 17:25	**Nohayla Alaoui** Stability and bifurcation for delay model of cancer immune system interaction.
17:25 - 17:50	**Fatima Ismague** Alternating Direction Multiplier method to estimate the initial condition in the time-fractional diffusion equation.
17:50 - 18:15	**Ibtissam Benamara** Analysis of stability in a Predator-Prey eco-epidemic model with cooperative hunting and fear factors.

Mini-symposium: Modeling and Mathematical Analysis of Biological Complex Systems

(By Moulay Lhassan Hbid)

Tuesday Afternoon

Time	Speaker and Title
15:45 - 16:10	**Gauthier Sallet** Applications of numerical analysis in biological modeling.
16:10 - 16:35	**Youssef Hbid** Real word evidence of the efficacy of mechanical thrombectomy: a case-control, propensity score-matched analysis of a nationwide stroke registry.
16:35 - 17:00	**Rachid Ouifki** Epidemiological modeling in global contexts.
17:00 - 17:25	**Mostafa Adimy** odeling the mechanisms of antibody mixtures in viral infections: the cases of sequential homologous and heterologous dengue infections.
17:25 - 17:50	**Jalila El Ghordaf** Complex systems modeling in ecology.
17:50 - 18:15	**Slimane Ben Miled** Modeling and Decision Making in Public Health: Issues, Structures, and Perspectives.
18:15 - 18:40	**Pierre Alexandre Bliman** Mathematical modeling teams and dynamics.

Mini-symposium: Regularization of Ill-posed Inverse Problems

(By Andrea Azzarelli, Alessandro Buccini)

Wendesday Morning

Time	Speaker and title
11:00 - 11:25	**Andrea Azzarelli** Fractional Laplacian and ADMM for glyph extraction.
11:25 - 11:50	**Alessandro Buccini** Software for $\ell^p-\ell^q$ minimization methods using generalized Krylov subspaces.
11:50 - 12:15	**Patricia Díaz de Alba** Linear FDEM subsoil data inversion in Banach spaces.
12:15 - 12:40	**Davide Furchì** The iterated Arnoldi-Tikhonov method.
12:40 - 13:05	**Lucas Onisk** Mixed precision iterative refinement for linear inverse problems.
13:05 - 13:30	**Federica Pes** A two-dimensional integral model for LIN electromagnetic data inversion.
13:30 - 13:55	**Marco Ratto** Preconditioned $\ell^p - \ell^q$ regularization.

Mini-symposium: Recent Breakthroughs in Optimization and Identification

(By A. Doubova, A. Habbal)
Wednesday Afternoon

Time	Speaker and title
15:45 - 16:10	**Mickaël Binois** Adaptive Replication Strategies in Trust Region-Based Bayesian Optimization for Stochastic Function.
16:10 - 16:35	**Anna Doubova** Identification of Degeneracy in Parabolic Equations.
16:35 - 17:00	**Abderrahmane Habbal** Cognitive behaviors modeled with Nash games: the case of pedestrian avoidance.
17:00 - 17:25	**Cristina Urbani** Bilinear control of the Fokker-Planck equation.

Mini-symposium: Tensor Computation and Applications

(By A. Bentbib)

Wendesday Afternoon

Time	Speaker and title
15:45 - 16:10	**Ferdaous Ait Addi** Generalized dictionary learning using t-product.
16:10 - 16:35	**Sanaa Khobizy** Multiplex network completion via similarity learning using Einstein-product.
16:35 - 17:00	**Rachad Bentbib** Low-rank matrix and tensor completion using convex and Riemannian optimization.
17:00 - 17:25	**Maryam Boubekraoui** Multilinear PageRank.
17:25 - 17:50	**Aoulaia Andahmou** High-order Tensor Completion via SGD based on Einstein product.
17:50 - 18:15	**Ridwane Tahiri** Einstein-Multidimensional Extrapolation methods.

Mini-symposium: Numerical Simulations of Porous Media Flows

(By El-Houssaine Quenjel)

Thursday Morning

Time	Speaker and title
11:00 - 11:25	**Mohamed Laaziri** VEM–Nitsche fully discrete polytopal scheme for mixed-dimensional poromechanical models with Coulomb frictional contact at matrix-fracture interfaces.
11:25 - 11:50	**Mohamed-Amine Hamadi** An improved Newton approach for solving nonlinear systems arising in porous media flows.
11:50 - 12:15	**Mayssam Mohamad** Energy Estimates of a Thermo-Hydro-Mechanical Model for a Single-Phase Compressible Gas Flow.
12:15 - 12:40	**Youssef Zahraoui** Convergence of a CVFE finite volume scheme for a non-isothermal incompressible two-phase flow in porous media.
12:40 - 13:05	**Hamidi Sadiq** A fully implicit non-linear finite volume scheme for single flow reactive transport in porous media.
13:05 - 13:30	**El-Houssaine Quenjel** Efficient prediction of the macroscopic permeability matrix of 3D hygroscopic media.

Mini-symposium: Mathematics in Game Theory

(By Rida Laraki)

Thursday Morning

Time	Speaker and title
11:00 - 12:00	**Rida Laraki** Fundamental results in game theory.
12:00 - 12:25	**Rémi Castera** Two-sided matching for college admission.
12:25 - 12:50	**Julien Fixary** An Introduction to Network Formation Theory.
12:50 - 13:15	**Mouhcine Assouli** Deep Learning for Mean Field Games.

Mini-symposium: Control Theory and Applications

(By Abdeladim Elakri, Lahcen Maniar, Enrique Zuazua)

Thursday Afternoon

Time	Speaker and title
15:45 - 16:10	**Jan Giesselmann** Data assimilation for gas flows via observers using distributed measurements.
16:10 - 16:35	**Martin Gugat** Synchronization of Observer Systems for the Flow in Gas Networks.
16:35 - 17:00	**Amaury Hayat** Stabilization of PDE systems and applications.
17:00 - 17:25	**Roberto Morales** An Insensitizing control problem involving tangential gradient terms for a reaction-diffusion equation with dynamic boundary conditions.
17:25 - 17:50	**Salah-Eddine Chorfi** Controllability of wave equations with oscillatory boundary conditions.

Poster Session

Friday Morning

Name	Title
Elhoucine Ait Bougnsa	Mean Field Games (MFGs) with a Major Player.
Abdellah Amzil	Mathematical Models for Task Scheduling and Resource Management in Edge and Fog Computing.
Nouamane Bakhdil	Utilizing Monte Carlo Simulations and Kinetic Theory to Understand Pedestrian Social Groups.
Mustapha Bouchaara	Enhancing Solid-State Batteries through Machine-Learning and Mathematical Modeling.
Fadoua Boudrari	Molecular Modeling and Multiscale Simulation for Coated Fertilizers.
Omar Chadad	Efficient Preconditioning of Linear Systems for Maxwell's Equations.
Ibrahim El Mountasser	Scalable Accelerating Large-Scale Linear Solvers on Modern GPU Architectures.
Zakaria El Hafiane	Sufficient Conditions for the Exponential Stability of a Thermoporoelastic System.
Afaf El Rhiouane	Balancing Returns and Responsibility: Markowitz Optimization for ESG Portfolios.
Hicham Maadan	Modeling Digital Twins: Application to Healthcare.
Mohamed Jalal Maaouni	GPU-Accelerated Approaches in Tensor Singular Triplet Approximation.
Meryeme Jahid	Stability of Backward Problems for Degenerate Mean Field Game Equations.
Wissal Khoudraji	Optimal-Control Obesity.
Bernardin Ligan	PEFT-HSIC: Parameter-Efficient Fine-Tuning for Hyperspectral Image Classification.
Ilham Ouelddris	Impulse Controllability for Degenerate Parabolic Equation.
Tibaut Kayo	A Space-Time Isogeometric Analysis Method for Control Theory.
Samih Khobzi & Yassine Farhane	Autonomous unmanned Surface vehicle : application for Maritime suveillance
Samih Khobzi & Yassine Farhane & Hamza Boussetta	Autonomous delivery robot
Alaeddine Zahir	High-dimensional multi-view clustering methods