深圳北理莫斯科大学
УНИВЕРСИТЕТ МГУ-ППИ В ШЭНЬЧЖЭНЕ
SHENZHEN MSU-BIT UNIVERSITY

2025 SMBU Sino-Russian Workshop on Applied Mathematics

主办：莫大-北理工-深北莫应用数学联合研究中心

协办：中国运筹学会数学与智能分会、中国工业与应用数学学会反问题与成像专委会、粤港澳应用数学中心深圳分中心

2025 年 01 月 12-15 日 • 深圳

会议日程(Program Schedule)

第一天(Day 1):Sino-Russian Math forum for doctoral students. Jan 12, 2025 Venue：Conference Room 336, Main Building	
Chair: Zhenyue Zhang	
14:00-14:05	Opening remark：Zhenyue Zhang
14:05-14:25	Qin Huang A CCBM-based generalized GKB iterative regularization algorithm for inverse Cauchy problems
14:25-14:35	Comment Zhenyue Zhang
14:35-14:55	Wenda Kang A General Approach for Unsupervised Domain Adaptation Using Support Points
14:55-15:05	Comment Zhenyue Zhang
15:05-15:20	**Tea break**
Chair: Zhenyue Zhang	
15:20-15:40	Tianxiang Tang Unification Algorithm for Control Systems Modeled by Parametrized Finite State Machines
15:40-15:50	Comment Zhenyue Zhang
15:50-16:10	Dong Xu Reliability analysis for a dynamic k-out-of-n system with thermal balance control
16:10-16:20	Comment Zhenyue Zhang
16:20-16:40	You Sun A concentration-preserving discontinuous Galerkin method for nonlinear time-dependent advection-diffusion equations and an accelerated inversion algorithm
16:40-16:50	Comment Zhenyue Zhang

第二天(Day 2): Sino-Russian Math forum for teachers. Jan 13, 2025 Venue：Conference Room 336, Main Building	
9:00-9:05	Opening remark：BUDAK BORIS
09:05-09:25	CHAIKOVSKII DMITRII DNA-Based Phylogenetic Analysis: A Hybrid Optimization Approach to Distance Matrix Recovery and Tree Construction
09:25-9:45	KAMZOLKIN DMITRII Solution to the Time-Optimal Control Problem of a Mathematical Pendulum
09:45-10:05	Tea break
10:05-10:25	ABRAMYAN MIKHAIL A program study of semilattices connected with the Waterloo automaton and Waterloo-like automata
10:25-10:45	DEMIN ALEKSEI Analysis of Neural Network Optimization Methods Using Tic-Tac-Toe as an Example
10:45-10:50	Mingkang Ni TBA
10:50-10:55	Ye Zhang Some questions on modern statistical regression
11:50-14:00	**Lunch（1st canteen 3nd floor）**
15:00-15:20	SHAROV ALEKSANDR Solution of the inverse elastography problem by the small parameter method
15:20-15:40	SHCHEGLOV ALEXEY The inverse problem for a hyperbolic equation with a boundary condition containing a second-order derivative
15:40-16:00	ATAMAS EVGENY Linear interval systems and their realizations
16:00-16:20	LIUBAVIN ALEKSEI Asymptotic analysis for wave-like solutions in the case of three-dimensional reaction-diffusion-advection equation
17:40- 19:40	**Banquet**

第三天(Day 3):Sino-Russian Math forum for teachers. Jan 14, 2025 Venue：Conference Room 336, Main Building	
Chair: Ye Zhang	
09:00-09:20	KRAINIUKOV NIKOLAI The solutions of systems of word equations for automata
09:20-09:40	LYSAK TATIANA Numerical realization of approximate two-color soliton solution for the problem of laser radiation propagation in the medium with combined nonlinear response
09:40-10:00	Yuping Li On the convergence of Galerkin methods for auto-convolution Volterra integro-differential equations
10:00-10:20	Chun Li Uncertainty Quantification for Incomplete Multi-View Data Using Divergence Measures
10:20-10:40	Lele Yuan A Scaling Fractional Asymptotical Regularization Method for Linear Inverse Problems

第三、四天(Day 3-4):winter school. Jan 14-15, 2025 Venue：Conference Room 336, Main Building	
Chair: Ye Zhang	
15:00-15:05	Opening remark：Ye Zhang
15:00-17:00 （Jan 14） 9:00-11:00+ 15:00-17:00 （Jan 15）	Mini-course on inverse Problems，Hongyu Liu, Chair Professor of City University of Hong Kong

报告摘要(Abstracts)

A CCBM-based generalized GKB iterative regularization algorithm for inverse Cauchy problems

Qin Huang

In this talk, we consider inverse Cauchy problems that are governed by a kind of elliptic partial differential equation. The inverse problems involve recovering the missing data on an inaccessible boundary from the measured data on an accessible boundary, which is severely ill-posed. By using the coupled complex boundary method (CCBM), which integrates both Dirichlet and Neumann data into a single Robin boundary condition, we reformulate the underlying problem into an operator equation. Based on this new formulation, we study the solution existence issue of the reduced problem with noisy data. A Golub–Kahan bidiagonalization (GKB) process together with Givens rotation is employed for iteratively solving the proposed operator equation. The regularizing property of the developed method, called CCBM-GKB, and its convergence rate results are proved under a posteriori stopping rule. Finally, a linear finite element method is used for the numerical realization of CCBM-GKB. Various numerical experiments demonstrate that CCBM-GKB is a kind of accelerated iterative regularization method, as it is much faster than the classic Landweber method.

A General Approach for Unsupervised Domain Adaptation Using Support Points

Wenda Kang

Unsupervised domain adaptation (DA) for regression tasks has garnered significant attention in industrial engineering, such as predicting remaining useful life and engine thrust. Most existing algorithms rely on maximum mean discrepancy (MMD) to measure differences in the marginal distributions between source and target domains. However, MMD primarily captures mean differences, which limits its ability to fully represent the overall discrepancies in these distributions.

In this paper, we propose an enhanced metric that integrates support points with MMD to more comprehensively capture marginal distribution differences between domains. Building on this metric, we develop a novel framework for unsupervised DA, leveraging transfer component analysis to improve performance in regression tasks. Additionally, we explore the theoretical properties of the proposed metric and provide an analysis of its generalization bounds.

Simulation studies are conducted to validate the effectiveness of the proposed framework in unsupervised DA. Two important applications, one focused on aero-engine thrust prediction and the other on battery remaining useful life prediction using early-cycle data, highlight that the proposed framework significantly outperforms traditional MMD-based approaches.

Unification Algorithm for Control Systems Modeled by Parametrized Finite State Machines

Tianxiang Tang

In mathematics, the unification problem is that of computing the parameters of two models (formulas, automata, programs, etc.) in such a way that these models have the same behavior. We study the unification problem for parameterized finite state machines that are used as discrete models of control and information processing systems, such as controllers, drivers, converters, routers, and many other reactive systems. We present an efficient unification algorithm for parameterized finite state machines, prove its correctness and estimate its time complexity. This algorithm can be used to verify control systems, check the compatibility of alternative designs of such systems, and also to refine the values of their parameters.

Reliability analysis for a dynamic k-out-of-n system with thermal balance control

Dong Xu

Temperature is a non-negligible source of failure in common electronic systems. In this article, we present a new dynamic k-out-of-n model for power distribution units, considering thermal coupling and thermal balance. Thermal imbalance refers to localized overheating within a system, which can cause component failure. The system fails when there are insufficient undamaged components to meet the dynamic power supply demand. Additionally, a new balance measure is developed based on the minimum energy criterion to assess the level of balance. With its help, a thermal balance control technique is proposed to prevent localized overheating during system operation, thereby enhancing overall system reliability. System reliability can be evaluated through the Monte Carlo simulation, and it can be used to demonstrate the effectiveness of the proposed thermal balance control method for system reliability enhancement. Moreover, a novel redundancy allocation problem is solved to minimize the system volume with a given constraint of reliability. we present several numerical experiments to illustrate the effectiveness of the proposed methods.

A concentration-preserving discontinuous Galerkin method for nonlinear time-dependent advection-diffusion equations and an accelerated inversion algorithm

You Sun

In this talk, we design, analyze, and numerically validate a concentration-preserving discontinuous Galerkin method for solving forward and inverse problems in nonlinear time-dependent advection-diffusion equations. Moreover, we prove the semi-discrete formulation preserves the concentration, ensures the existence of unique Galerkin approximations, and demonstrates optimal rates of convergence. Based on this forward model, we propose an efficient regularization algorithm for solving inverse problems which computes the gradients of the objective function by the adjoint method. Various numerical examples for both forward and inverse problems are given to show the efficiency of the proposed numerical approach. Numerical examples for both forward and inverse problems are given to show the proposed numerical approach, confirmed that the convergence rate is optimal, and demonstrate the efficacy of our method in capturing chromatographic processes.

DNA-Based Phylogenetic Analysis: A Hybrid Optimization Approach to Distance Matrix Recovery and Tree Construction

CHAIKOVSKII DMITRII

This paper introduces a computer-implemented system for phylogenetic tree reconstruction that seamlessly integrates sequence alignment with advanced optimization techniques. By utilizing the Needleman-Wunsch algorithm for partial sequence alignment and a custom hybrid optimization approach based on the Adam optimizer, the system efficiently reconstructs incomplete DNA distance matrices by directly computing only 10-30% of the distances and estimating the remaining 70-90% through optimization. This approach preserves valuable genetic information without discarding incomplete data, significantly reduces computational complexity compared to exhaustive alignment methods, maintains essential biological constraints, and scales efficiently with larger datasets. By balancing computational efficiency with biological accuracy, this method is particularly valuable for researchers working with large or incomplete genomic datasets, effectively addressing a critical need in modern bioinformatics research.

Solution to the Time-Optimal Control Problem of a Mathematical Pendulum

KAMZOLKIN DMITRII

This report considers the problem of optimal control of an oscillatory process in a medium with viscous friction. In contrast to classical optimal control problems, the frequency of oscillations was chosen as the control parameter rather than the force of external influence. It was required to move the controlled system from a given initial state to the final state in the least time. The Pontryagin maximum principle and the Bellman optimality principle were applied to solve this problem. The existence conditions and the general form of optimal control are obtained, and some of its properties are studied.

A program study of semilattices connected with the Waterloo automaton and Waterloo-like automata

ABRAMYAN MIKHAIL

We study semilattices containing covering automata for the Waterloo automaton, which plays an important role in vertex minimization algorithms for nondeterministic finite automata. We give a complete description of the obtained semilattices in terms of the equivalence of the covering automata they contain to the Waterloo automaton. Three classes of semilattices are considered, and several representations for each class are constructed. We also consider algorithms for generating nondeterministic finite automata possessing the Waterloo automaton property (the "Waterloo-like badness" property, or walibad property), namely: among their covering automata, there exist automata which are not equivalent to the original automaton. Two algorithms are described: the first one is based on recursive analysis of covering automata for automata with the walibad property, the second one uses non-equivalent transformations of a complete automaton created on the basis of an automaton with the walibad property. Examples of application of both algorithms to the Waterloo automaton are given, and some interesting features of the resulting sets of new walibad automata are described.

Analysis of Neural Network Optimization Methods Using Tic-Tac-Toe as an Example

DEMIN ALEKSEI

This report focuses on optimizing neural network structure to improve the operation efficiency using the tic-tac-toe game as an example. In order to improve the operation efficiency of neural network in tic-tac-toe game, the research focuses on optimizing the network structure. By reducing the number of network layers and nodes, a lightweight neural network model is going to be constructed. Experiments are conducted in order to demonstrate whether optimizing the network structure can significantly reduce the computational overhead and speed up the problem solving.

Linear interval systems and their realizations

ATAMAS EVGENY

The challenges of transitioning between various representations for linear interval systems that are controlled are discussed. These systems contain parameters that are only known within a specific range, or interval. We propose constructive algorithms for performing these transitions, taking into account the features of interval arithmetic. We also provide numerical examples of how these algorithms can be applied to specific systems.

Asymptotic analysis for wave-like solutions in the case of three-dimensional reaction-diffusion-advection equation

LIUBAVIN ALEKSEI

In this topic, the dynamics of moving fronts in three-dimensional spaces is covered. This phenomenon is observed in different contexts, such as various autowave models, in-situ combustion during oil production and the propagation of acoustic waves. The core problem is a singularly perturbed reaction-diffusion-advection type initial-boundary value problem. This analysis is based on asymptotic theory with an internal layer. One of the important tasks is locating the position of the transition layer. Numerical example is provided in order to check the accuracy of this approach.

Solution of the inverse elastography problem by the small parameter method

SHAROV ALEKSANDR

The paper considers the small parameter method for solving the inverse problem of elastography, with the help of which it is possible to find an analytical solution. Using the analytical solution allows determining the distribution of elastic properties of the material in the online mode.

The inverse problem for a hyperbolic equation with a boundary condition containing a second-order derivative

SHCHEGLOV ALEXEY

The solvability of the direct problem (DP) and the uniqueness of the solution of the inverse problem (IP) are investigated for the model of small transverse vibrations of a finite string with the gravity of a body with a changing mass acts on one end of the string ([1], Sect.II, § 1.7). Additional information for solving the IP is the known solution of the direct problem for a given fixed value of the spatial argument. The model describes the vibrations of a drill in a deep well with a nonclassical boundary regime. A similar model and an IP for it have been studied in cases of classical [2] and nonclassical boundary condition [3]. Here, in the framework of the IP, two unknown functions need to be restored: a function in a nonclassical boundary condition and a functional multiplier on the right side of the oscillation equation. The uniqueness theorem of the solution of the IP is proved. For the DP, the conditions of unambiguous solvability are established in a form that simplifies the study of the IP. An algorithm for step-by-step separate reconstruction of the functions sought in the framework of the IP based on the method of successive approximations is proposed.

The solutions of systems of word equations for automata

KRAINIUKOV NIKOLAI

In this discussion, we use some programing tools and algorithms for solving system of word equation for regular languages. There are many possibilities for presentation of regular languages such as grammars, finite automata, rewriting systems and so on. Some of these systems is presented by system of computational discrete algebra GAP and the possibilities of presentation now in some systems interactive theorem provers (Isabelle, Coq). This computer system can give to detailed understanding of solution of system of word equation, compared the languages and regular expressions of the languages.

Numerical realization of approximate two-color soliton solution for the problem of laser radiation propagation in the medium with combined nonlinear response

LYSAK TATIANA

A mathematical model for femtosecond laser radiation propagation in a medium with quadratic and cubic nonlinear response is considered. The model is based on two coupled Schrödinger equations with quadratic and cubic nonlinearities for the fundamental frequency wave and the second harmonic wave, and it also takes into account the third order dispersion of both waves. For the large mismatching of interacting waves, an approximate two-color soliton solution with comparable peak intensities of both waves has been derived. This soliton solution was verified in numerical simulations on basis of conservative nonlinear finite-difference scheme and its stability was studied

On the convergence of Galerkin methods for auto-convolution Volterra integro-differential equations

Yuping Li

The Galerkin method is proposed for initial value problem of auto-convolution Volterra integro-differential equation (AVIDE). The solvability of the Galerkin method is discussed, and the uniform boundedness of the numerical solution is provided by defining a discrete weighted exponential norm. In particular, it is proved that the quadrature Galerkin method obtained from the Galerkin method by approximating the inner products by suitable numerical quadrature formulas, is equivalent to the continuous piecewise polynomial collocation method. For the Galerkin approximated solution in continuous piecewise polynomial space of degree m, at first, the m global convergence order is obtained. By defining a projection operator, the convergence is improved, and the optimal $m+1$ global convergence order is gained, as well as $2m$ local convergence order at mesh points. Furthermore, all the above analysis for uniform mesh can be extended to typical quasi-uniform meshes. Some numerical experiments are given to illustrate the theoretical results.

Uncertainty Quantification for Incomplete Multi-View Data Using Divergence Measures

Chun Li

Existing multi-view classification and clustering methods typically improve task accuracy by leveraging and fusing information from different views. However, ensuring the reliability of multi-view integration and final decisions is crucial, particularly when dealing with noisy or corrupted data. Current methods often rely on Kullback-Leibler (KL) divergence to estimate uncertainty of network predictions, ignoring domain gaps between different modalities. To address this issue, KPHD-Net, based on Hölder divergence, is proposed for multi-view classification and clustering tasks. Generally, our KPHD-Net employs a variational Dirichlet distribution to represent class probability distributions, models evidences from different views, and then integrates it with Dempster-Shafer theory (DST) to improve uncertainty estimation effects. Our theoretical analysis demonstrates that Proper Hölder divergence offers a more effective measure of distribution discrepancies, ensuring enhanced performance in multi-view learning. Moreover, Dempster-Shafer evidence theory, recognized for its superior performance in multi-view fusion tasks, is introduced and combined with the Kalman filter to provide future state estimations. This integration further enhances the reliability of the final fusion results. Extensive experiments show that the proposed KPHD-Net outperforms the current state-of-the-art methods in both classification and clustering tasks regarding accuracy, robustness, and reliability, with theoretical guarantees.

A Scaling Fractional Asymptotical Regularization Method for Linear Inverse Problems

Lele Yuan

In this talk, I will present our new regularization method, called the Scaling Fractional Asymptotical Regularization (S-FAR) method, for solving linear ill-posed operator equations in Hilbert spaces, inspired by the work of (2019, Fract. Calc. Appl. Anal., 22(3), 699–721).

Our method is incorporated into the general framework of linear regularization and demonstrates that, under both H¨older and logarithmic source conditions, the S-FAR with fractional orders in the range (1, 2] offers accelerated convergence compared to comparable order optimal regularization methods. Additionally, we introduce a de-biasing strategy that significantly outperforms previous approaches, alongside a thresholding technique for achieving sparse solutions, which greatly enhances the accuracy of approximations. A variety of numerical examples, including one- and two-dimensional model problems, are provided to validate the accuracy and acceleration benefits of the FAR method.