2024 Conference on Control, Inversion and Numerics for PDEs

October 7-10, 2024

Fudan Univerisity, Shanghai, China

GUIDE

Welcome to the second meeting of the Sino-German mobility project M-0548 (2022-2025) on Control, Inverse Problems, and Numerical Theory of Partial Differential Equations (CIN-PDE). We are pleased to announce the 2024 Conference on Control, Inversion, and Numerics for PDEs, taking place on October 7-10th, 2024, at Fudan University in Shanghai, China. This event is jointly organized by the School of Mathematical Sciences and Center for Applied Mathematics at Fudan University and the Chair for Dynamics, Control, Machine Learning and Numerics – Alexander von Humboldt Professorship and the Center for Mathematics of Data at Friedrich-Alexander-Universität Erlangen-Nürnberg.

Scientific committee:

- Zhen Lei, Fudan University,
- Günter Leugering, Friedrich-Alexander-Universität Erlangen-Nürnberg,
- Tatsien Li, Fudan University,
- Enrique Zuazua, Friedrich-Alexander-Universität Erlangen-Nürnberg.

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Sponsors:

- School of Mathematical Sciences, Fudan University
- Center for Applied Mathematics, Fudan University
- The Chair for Dynamics, Control, Machine Learning and Numerics — Alexander von Humboldt Professorship (DCN), FAU Erlangen-Nürnberg
- The Center for Mathematics of Data (CMoD) FAU Erlangen-Nürnberg,
- Chinesisch-Deutsches Zentrum für Wissenschaftsförderung.

Invited Speakers

Jin Cheng	Fudan University
Weinan E	Peking University
Shi Jin	Shanghai Jiaotong University
Günter Leugering	Friedrich-Alexander-University of Erlangen-Nuremberg
Qianxiao Li	National University of Singapore
Yuehong Qian	Soochow University
Shanjian Tang	Fudan University
Gunther Uhlmann	University of Washington
Zhiqiang Wang	Fudan University
Pengfei Yao	Institute of Mathematics and Systems Science, CAS
Xiaoming Yuan	University of Hong Kong
Jian Zhai	Fudan University
Qiong Zhang	Beijing Institute of Technology
Shuangjian Zhang	Fudan University
Xu Zhang	Sichuan University
Enrique Zuazua	Friedrich-Alexander-University of Erlangen-Nuremberg

Poster Presentation

Albert Alcalde	Friedrich-Alexander-University of Erlangen-Nuremberg
Antonio Álvarez-López	Autonomous University of Madrid
Alberto Domínguez Corella	Friedrich-Alexander-University of Erlangen-Nuremberg
Ilias Ftouhi	Friedrich-Alexander-University of Erlangen-Nuremberg
Martín Hernández	Friedrich-Alexander-University of Erlangen-Nuremberg
Shunkai Mao	Fudan University
Michael Schuster	Friedrich-Alexander-University of Erlangen-Nuremberg
Jiaxin Tong	Fudan University
Jiahui Wang	Fudan University
Ziqi Wang	Friedrich-Alexander-University of Erlangen-Nuremberg
Yubiao Zhang	Friedrich-Alexander-University of Erlangen-Nuremberg
Yan Zhou	Fudan University

Schedule

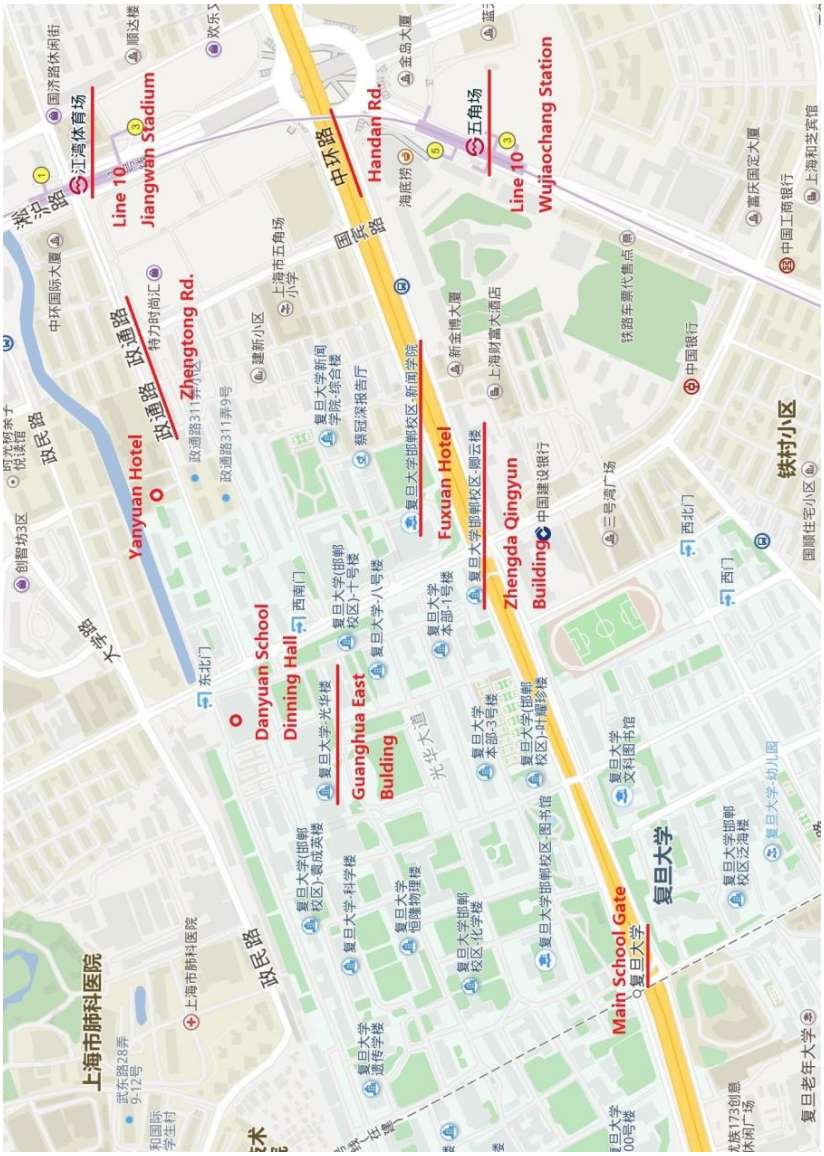
Monday Oct. 7		
10:00—18:00	Registration at Shanghai Pagoda Jun Ting Hotel（上海君亭设计酒店）	

Tuesday Oct. 8	Main-venue: Room 2201, 22nd floor, Guanghua East Main Building（光华楼东主楼 2201 室） Sub-venue: Room 2001, 20th floor, Guanghua East Main Building（光华楼东主楼 2001 室）	
8:50-9:10	Opening ceremony	
9:10-9:15	Group photo	
9:15-10:00	Speaker: Weinan E Title: Towards an Understanding of the Principles behind Deep Learning	Chairman: Enrique Zuazua
10:00-10:45	Speaker: Gunther Uhlmann Title: Inverse Problems in Anisotropic Media	
10:45-11:00	Tea break and poster exhibition	
11:00-11:45	Speaker: Enrique Zuazua Title: Data Representation by Neural Networks: A Control Perspective	Chairman: Zhen Lei
12:00-14:30	Lunch at Shanghai Pagoda Jun Ting Hotel（上海君亭设计酒店）	
14:30-15:15	Speaker: Shanjian Tang Title: Viscosity Solution of Second-Order Path-dependent HJB Equation in Hilbert Spaces	Chairman: Pengfei Yao
15:15-16:00	Speaker: Yuehong Qian Title: Alternative Approach to Solving some Special PDEs	
16:00-16:15	Tea break and poster exhibition	
16:15-17:00	Speaker: Pengfei Yao Title: Geometrical Rigidity of Elastic Shells	Chairman: Shanjian Tang
17:00-17:45	Speaker: Qiong Zhang Title: Stability Analysis of an Abstract System with Local Damping	
18:00	Dinner at Zhengda Restaurant（正大餐厅）, Fudan University	

Wednesday Oct. 9	Room 2201, 22nd floor, Guanghua East Main Building（光华楼东主楼 2201 室）	
9:15-10:00	Speaker: Shi Jin Title: Dimension Liftings for Quantum Computation of Partial Differential Equations and Related Problems	Chairman: Jin Cheng
10:00-10:45	Speaker: Xiaoming Yuan Title: Revisiting First-order Algorithms for Optimization Problems in Industry	
10:45-11:00	Tea break and poster exhibition	
11:00-11:45	Speaker: Jin Cheng Title: Runge Approximation and Learning based Numerical Methods for Lame Equations	Chairman: Shi Jin
12:00-14:30	Lunch at Shanghai Pagoda Jun Ting Hotel（上海君亭设计酒店）	
14:30-15:15	Speaker: Qianxiao Li Title: Learning, Approximation and Control	Chairman: Shuangjian Zhang
15:15-16:00	Speaker: Zhiqiang Wang Title: Stabilization of 1-D Wave Equation with Rational Time Delays	
16:00-16:15	Tea break and poster exhibition	
16:15-17:00	Speaker: Shuangjian Zhang Title: Characterization of the Monopolist's Profit-Maximization Problem as a Free-Boundary Problem	Chairman: Zhiqiang Wang
17:30	Dinner at Danyuan Restaurant（旦苑餐厅）, Fudan University	

Thursday Oct. 10	Room 2201, 22nd floor, Guanghua East Building（光华楼东主楼 2201 室）	
9:15-10:00	Speaker: Xu Zhang Title: PDE Approach in Infinite-Dimensional Complex Analysis	Chairman: Jian Zhai
10:00-10:45	Speaker: Günter Leugering & Yue Wang Title: Exact Boundary Controllability of a Timoshenko Beam	
10:45-11:00	Tea break and poster exhibition	
11:00-11:45	Speaker: Jian Zhai Title: Inverting the Local Transverse and Mixed Ray Transforms	Chairman: Günter Leugering
12:00-14:30	Lunch at Shanghai Pagoda Jun Ting Hotel（上海君亭设计酒店）	
14:30-16:00	Free Discussion	

Map of Fudan University



复旦大学周边设施 Facilities around Fudan University

1. 银行 Bank

中国农业银行（邯郸路 220 号，复旦正门外东侧）

Agriculture Bank of China (#220 Handan Rd., outside the campus, east of the main entrance of Fudan Univ.)

中国银行（邯郸路 220 号，复旦正门内东侧）

Bank of China (#220 Handan Rd., inside the campus, east of the main entrance of Fudan Univ.)

2. 邮局 Post Office

邯郸路 220 号，复旦正门外西侧

#220 Handan Rd., outside the campus, west of the main entrance of Fudan Univ.

3. 餐饮 Restaurants

复旦大学附近拥有五角场、大学路、三号湾等多个商业中心，每个中心均有众多餐厅

Around Fudan University, there are several business centers such as Wujiaochang, Daxue Rd. and Basin 3 Plaza (#330 Guoding Rd.), in each of them there are many restaurants including Chinese restaurants of different styles, western restaurants, fast foods and restaurants of other countries and districts.

Address and Telephone Numbers of Some Consulates in Shanghai

Country	Address	Tel
Germany	#1399 West Beijing Rd.	021-34010106
USA	#1469 HuaihaiZhong Rd.	021-64336880
Singapore	#89 Wanshan Rd.	021-62785566

Reminder

1. Please take the name badge for the conference activities including the banquet.
2. Please take the tickets for lunch and supper.
3. For emergency, please call
   a) +86 13564678958 (Peng QU)
   b) +86 18817583950，+49 15207487491 (Yue WANG)

Titles and Abstracts of the Invited Talks

Speaker: Jin CHENG (Fudan University)

Title: Runge Approximation and Learning based Numerical Methods for Lame Equations

Abstract: Runge approximation is one of interesting properties for partial differential equations, which means that the solutions of a partial differential equation in a small domain can uniformly approximated by the solutions of the partial differential equation in a large domain. In this talk, we prove the quantitative Runge approximation property for Lame equations. By this result, we propose the learning based numerical methods for Lame equations. The generality of this method is proved. The error analysis and numerical experiments are presented.

Speaker: Weinan E (Peking University)

Title: Towards an Understanding of the Principles behind Deep Learning

Abstract: The field of deep learning is evolving rapidly, driven by the availability of the vast amount of data and computing resources. Deep learning techniques have also evolved in several different ways, including different formulations such GAN and the diffusion model, different architecture such as CNN and transformers, and different training protocols such as BERT and GPT. This evolution has largely been empirical. Consequently there are a lot mysteries, surprises and 'black magics' in this field. Is it possible to decipher some kind of guiding principles behind this? In this talk, we will discuss our thoughts along this line. Specifically, we will discuss how simple mathematical concepts such as symmetry and stability can be used as guiding principles for designing and understanding neural network models.

Speaker: Shi JIN (Shanghai Jiaotong University)

Title: Dimension Liftings for Quantum Computation of Partial Differential Equations and Related Problems

Abstract: Quantum computers have the potential to gain algebraic and even up to exponential speed up compared with its classical counterparts, and can lead to technology revolution in the 21st century. Since quantum computers are designed based on quantum mechanics principle, they are most suitable to solve the Schrodinger equation, and linear PDEs (and ODEs) evolved by unitary operators. The most efficient quantum PDE solver is quantum simulation based on solving the Schrodinger equation. It will be interesting to explore what other problems in scientific computing, such as ODEs, PDEs, and linear algebra that arise in both classical and quantum systems, can be handled by quantum simulation.

We will present a systematic way to develop quantum simulation algorithms for general differential equations. Our basic framework is dimension lifting, that transfers nonlinear PDEs to linear ones, and linear ones to Schrodinger type PDEs. For non-autonomous PDEs and ODEs, or Hamiltonian systems with time-dependent Hamiltonians, we also add an extra dimension to transform them into autonomous PDEs that have only time-independent coefficients, thus quantum simulations can be done without using the cumbersome Dyson's series and time-ordering operators. Our formulation allows both qubit and qumode (continuous-variable) formulations, and their hybridizations, and provides the foundation for analog quantum computing.

Speaker: Günter LEUGERING (Friedrich-Alexander-University of Erlangen-Nuremberg)

Title: Exact Boundary Controllability of a Timoshenko Beam

Abstract: We consider a linear planar Timoshenko beam with boundary controls at one end and degeneration at the other end. More precisely, the flexural stiffness and the shear stiffness are subject to individual degeneration at the uncontrolled end, that is to say, the corresponding coefficients vanish there. We discuss a class of such functions and describe the degree of degeneracy. Using this degree, we can discriminate between weak and strong degeneration. For strong degeneracy, Neumann boundary conditions have to be posed at the degenerate end of the beam. We discuss the well-posedness of the system, provide Poincaré inequalities and prove multiplier identities. We then utilize the HUM-principle to establish observability and exact controllability for the underlying system of equations. We also reflect on boundary stabilization. The results extend the known results for linear elastic strings.

Speaker: Qianxiao LI (National University of Singapore)

Title: Learning, Approximation and Control

Abstract: In this talk, we discuss some interesting problems and recent results on the interface of deep learning, approximation theory and control theory. Through a dynamical system viewpoint of deep residual architectures, the study of model complexity in deep learning can be formulated as approximation or interpolation problems that can be studied using control theory, but with a mean-field twist. In a similar vein, training deep architectures can be formulated as optimal control problems in the mean-field sense. We provide some basic mathematical results on these new control problems that so arise, and discuss some applications in improving efficiency, robustness and adaptability of deep learning models.

Speaker: Yuehong QIAN (Soochow University)

Title: Alternative Approach to Solving Some Special PDEs

Abstract: Lattice Boltzmann Method(LBM) is an alternative approach to traditional methods used to solve partial differential equations, e.g., finite element method and finite volume method etc. Based-on the physical conservation laws, we are able to derive the conventional hydrodynamic equations, e.i., the Navier-Stokes equation. All the applications so far simulated have shown the validity and efficiency of the this relatively new method. LBM is naturally suitable on the parallel supercomputers and we will present interesting applications

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Speaker: Shanjian TANG (Fudan University)

Title: Viscosity Solution of Second-Order Path-dependent HJB Equation in Hilbert Spaces

Abstract: Optimal control and the associated second-order path-dependent Hamilton-Jacobi-Bellman (PHJB) equation are discussed for unbounded functional stochastic evolution systems in Hilbert spaces. The notion of viscosity solution without B-continuity is introduced in the sense of Crandall and Lions, and the value functional is proved to be the unique continuous viscosity solution to the associated PHJB equation, without assuming any B-continuity on the coefficients. In particular, in the Markovian case, our result provides a new theory of viscosity solutions to the Hamilton-Jacobi-Bellman equation for optimal control of stochastic evolutionary equations—driven by a linear unbounded operator—in a Hilbert space. This work is coauthored with Jianjun Zhou (Northwest A & F University).

Speaker: Gunther UHLMANN (University of Washington)

Title: Inverse Problems in Anisotropic Media

Abstract: We will consider the Calderon problem in anisotropic media and the fractional anisotropic Calderon problem which is a non-local analog of the Calderon problem.

Speaker: Zhiqiang WANG (Fudan University)

Title: Stabilization of 1-D Wave Equation with Rational Time Delays

Abstract: In this talk, we show some results on output stabilization of one-dimensional wave equation with rational input time delays. By spectral analysis, we obtain the sufficient and necessary conditions (for the feedback gains and the time delay) that lead to the exponential stability of the closed-loop system. The stability region of the feedback gains exists if and only if the time delay is rational. In addition, we find that the small perturbation of magnitude in the time delay can only trigger the excitation of high frequency modes. That gives a mathematical explanation why numerical experiments usually do not demonstrate the non-robustness when a small perturbation is added to the time delay.

Speaker: Pengfei YAO (Institute of Mathematics and Systems Science, Chinese Academy of Sciences)

Title: Geometrical Rigidity of Elastic Shells

Abstract: Thin elastic objects have fascinated mathematicians and engineers for centuries and more recently have also become an object of intense study in theoretical physics, biology and material design. A long time ago mankind has been recognized that the geometry shape of an elastic shell plays an important role in the rigidity of the shell.In this talk, we shall review some recent developments on the relationship between the rigidity and the geometry shape of shells when they undergo “small deformations.”

Speaker: Xiaoming YUAN (University of Hong Kong)

Title: Revisiting First-Order Algorithms for Optimization Problems in Industry

Abstract: We will revisit some classic first-order algorithms for optimization problems arising in the industries of AI and Cloud Computing, including post-training pruning for large language models, bandwidth allocation for live streaming, and digital human simulation. In particular, we will show their adaptability to GPUs and other parallel architectures for real industrial applications. We will also showcase how to save computation substantially for classic first-order algorithms by mathematically-driven heuristics.

Speaker: Jian ZHAI (Fudan University)

Title: Inverting the Local Transverse and Mixed Ray Transforms

Abstract: We consider the transverse and mixed ray transforms on a compact Riemannian manifold with smooth boundary. We show that the transverse ray transform and the mixed ray transform are invertible, up to natural obstructions, near a boundary point. When the manifold admits a strictly convex function, this local invertibility result leads to a global result by a layer stripping argument.

Speaker: Qiong ZHANG (Beijing Institute of Technology)

Title: Stability Analysis of an Abstract System with Local Damping

Abstract: We consider an abstract system of the type $u_{tt} + Lu + Bu_{t} = 0$, where L is a self-adjoint operator on a Hilbert space and operator B represents the local damping. By establishing precise estimates on the resolvent, we prove polynomial decay of the corresponding semigroup. The results reveal that the rate of decay depends strongly on the concentration of eigenvalues of operator L and non-degeneration of operator B. Finally, several examples are given as application of our abstract results.

Speaker: Shuangjian ZHANG (Fudan University)

Title: Characterization of the Monopolist's Profit-maximization Prooblem as a Free-boundary Problem

Abstract: The principal-agent problem is one of the central problems in microeconomics with many applications. Existence, uniqueness, convexity/concavity, regularity, and characterization of the solutions have been widely studied after Mirrlees and Spence in the 1970s. For multidimensional spaces of agents and products, Rochet and Choné (Econometrica, 1998) reformulated this problem to a concave maximization over the set of convex functions, by assuming agent preferences combine bilinearity in the product and agent parameters with a quasilinear sensitivity to prices. We characterize solutions to this problem by identifying a dual minimization problem. This duality allows us to reduce the solution of the square example of Rochet-Choné to a novel free boundary problem, giving the first analytical description of an overlooked market segment, where the regularity built by Caffarelli-Lions plays a crucial role — an extension of their regularity work to the quasilinear case is also recently studied.

In this talk, I will first introduce the historical work on the principal-agent framework under the context of the monopolist problem before moving to the recent progress. The results profoundly connect with the Optimal Transport theory, a powerful tool with potential applications in many areas. This talk contains my joint work with Guillaume Carlier, Robert J. McCann and Cale Rankin.

Speaker: Xu ZHANG (Sichuan University)

Title: PDE Approach in Infinite-dimensional Complex Analysis

Abstract: Abstract: The classical L^2 approach is a basic tool in complex analysis of several variables. Naturally, one expected to extend it to infinite-dimensional complex analysis, but this is a longstanding unsolved problem. The main purpose in this work is to establish L^2 estimates and existence theorems for the $\overline{\partial}$ operators in general pseudo-convex domains of infinite dimensions. For this purpose, we introduce several new techniques, which have independent interest to be adopted to study some other problems in infinite-dimensional analysis. (This is a joint work with Zhouzhe Wang and Jiayang Yu).

Speaker: Enrique ZUAZUA (Friedrich-Alexander-University of Erlangen-Nuremberg)

Title: Data Representation by Neural Networks: A Control Perspective

Abstract: In this lecture I shall present some recent work in cooperation with Dr. Kang Liu (FAU). We investigate several non-convex optimization problems involving shallow neural networks (NN), with the aim of representing data sets. The problems are convexified using a "mean-field" technique and the lack of relaxation gap is proved employing classical "representer theorems". We also derive generalization bounds providing insight into the choice of optimal parameters. We also derive efficient numerical algorithms, and analyze the analogy with classical control problems for parabolic equations.
