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Workshop on Control, Inversion and Numerics for PDEs

BOOK OF ABSTRACTS

PROGRAM

CIN-PDE 2023

ERLANGEN-SHANGHAI

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#CINPDE2023

Workshop on Control, Inversion and Numerics for PDEs

CIN-PDE 2023

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TUE. AUGUST 1, 2023

09:00 - 09:20H Opening
Enrique Zuazua, Zhen Lei

09:20 - 09:30H Photo shoot

09:30 - 10:15H Exact controllability for a refined stochastic wave equation
Qi Lü, SCU

10:20 - 10:35H Coffee/Tea break

10:35 - 11:20H Domain decomposition in optimal control problems for PDEs
Günter Leugering, FAU

11:25 - 12:10H Linearized inverse Schrödinger potential problems at a large wavenumber
Shuai Lu, Fudan

WED. AUGUST 2, 2023

09:00 - 09:40H Long time dynamics of two dimensional Euler and Navier Stokes in high Reynolds number regime
Hao Jia, University of Minnesota

09:45 - 10:25H Optimal control of critical wave equations
Hannes Meinlschmidt, FAU

10:30 - 10:45H Coffee/Tea break

10:45 - 11:25H On the construction of exact control for the wave equation
Yi Zhou, Fudan

11:30 - 12:10H Inverse design for some systems of conservation laws
Nicola De Nitti, FAU DCN-AvH

THU. AUGUST 3, 2023

09:00 - 09:40H Feedback stabilization and inverse problem for a nonlocal transport equation
Zhiqiang Wang, Fudan

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Jan Sokolowski, Université de Lorraine

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Long Hu, SDU

11:30 - 12:10H Control and Machine Learning
Enrique Zuazua, FAU

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09:00 - 09:40H An inverse boundary value problem for a nonlinear elastic wave equation
Jian Zhai, Fudan

09:45 - 10:25H Physics-informed neural networks for non-smooth PDE-constrained optimization problems
Yongcun Song, FAU

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10:45 - 11:25H The inverse problem of the wave equation
Xi Chen, Fudan

11:30 - 12:10H Exact boundary controllability of nodal profile with nonuniform steady states for quasilinear hyperbolic systems
Ke Wang, Donghua University

12:15 - 12:30H Closing
Yue Wang, **Peng Qu**

WHEN

Tuesday **August 01 -** Friday **August 04, 2023**

WHERE

On-site / Online

Germany

09:00 - 12:15H
Room **H13**. Johann-Radon-Hörsaal.
FAU, Friedrich-Alexander-Universität Erlangen-Nürnberg
Cauerstraße 11, 91058 Erlangen

China

15:00 - 18:15H
Room **1801**. Guanghua East Main Building.
光华楼东主楼 Fudan University
Handan Road 220. 200433 Shanghai

Online

Zoom meeting link: **shorturl.at/hmDQU**

Meeting ID: **640 7719 0955**
PIN: **858411**

Scientific Committee

FAU, Friedrich-Alexander-Universität Erlangen-Nürnberg (Germany)
• Enrique Zuazua
• Günter Leugering

Fudan University (Shanghai, China)
• Tatsien Li
• Zhen Lei

Organizers

FAU, Friedrich-Alexander-Universität Erlangen-Nürnberg (Germany)
• Yue Wang

Fudan University (Shanghai, China)
• Peng Qu

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TUE. AUGUST 1, 2023

09:00 - 09:20H. Opening. Prof. **Enrique Zuazua** • Prof. **Zhen Lei**


09:20 - 09:30H. Photo shoot

09:30 - 10:15H. **Prof. Qi Lü** • Sichuan University, Chengdu

Exact controllability for a refined stochastic wave equation

A widely used stochastic wave equation is the classical wave equation perturbed by a term of It^o's integral. We show that this equation is not exactly controllable even if the controls are effective everywhere in both the drift and the diffusion terms and also on the boundary. In some sense this means that some key feature has been ignored in this model. Then, based on a stochastic Newton's law, we propose a refined stochastic wave equation. By means of a new global Carleman estimate, we establish the exact controllability of our stochastic wave equation with three controls. Moreover, we give a result about the lack of exact controllability, which shows that the action of three controls is necessary. Our analysis indicates that, at least from the point of view of control theory, the new stochastic wave equation introduced in this paper is a more reasonable model than that in the existing literatures.

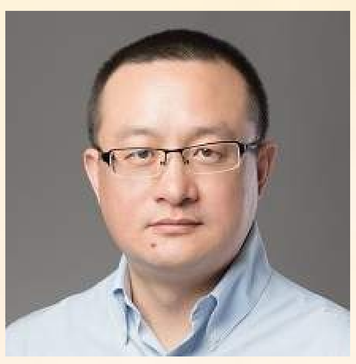
10:20 - 10:35H. Coffee/Tea break

10:35 - 11:20H. **Prof. Günter Leugering** • FAU. Friedrich-Alexander-Universität Erlangen-Nürnberg

Domain decomposition in optimal control problems for PDEs

The focus of this lecture is on space and time domain decomposition of hyperbolic and p-parabolic PDEs on metric graphs and in particular on optimal control problems for such systems. The work is motivated by applications in gas networks. See www.trr154.fau.de for the general context. The methods to be discussed concentrate on non-overlapping domain decomposition at multiple nodes of the network and are inspired by the classical approach due to P.L. Lions 1989. The lecture covers modelling, analysis of the governing optimal control problems on the entire network and the corresponding decomposed sub-problems. As for optimal control problems, the main idea is to decompose the overall optimality system in such a way that the decomposed system is itself an optimality system for a corresponding virtual control problem related to the system on a sub-graph. Algorithms are developed and numerical experiments are reported.

11:25 - 12:10H. **Prof. Shuai Lu** • Fudan University



Linearized inverse Schrödinger potential problems at a large wavenumber

Inverse Schrodinger potential problem concerns about the recovery of a potential function in the Schrodinger equation in a bounded domain throught the DtN map. In this talk, we introduce the linearized DtN map, and prove a stability estimate with explicit dependence on wavenumbers. This is an increasing stability result, in the sense that the logarithmic stable term decays when wavenumber increases. The talk is based on joint works with Victor Isakov (Wichita), Mikko Salo (Jyvaskyla), Boxi Xu (SUFE) and Sen Zou (Fudan).

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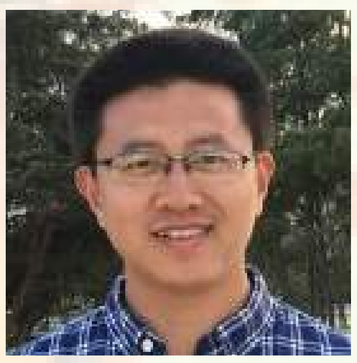
09:00 - 09:40H. **Prof. Hao Jia** • University of Minnesota



Long time dynamics of two dimensional Euler and Navier Stokes in high Reynolds number regime

In this talk, we will present some recent progress in the study of long time dynamics of solutions to 2d Euler and NSE with small viscosity, near physically important coherent structures. After general introductions we will focus on recent results on Orr-Sommerfeld equations and its applications to uniform-in-viscosity linear inviscid damping and vorticity depletion phenomena for NSE in high Reynolds number regime.

09:45 - 10:25H. **Prof. Hannes Meinlschmidt** • FAU. Friedrich-Alexander-Universität Erlangen-Nürnberg

Optimal control of critical wave equations

In this talk we consider optimal control problems which are subject to a semilinear critical wave equation. Here, critical means first-order Sobolev critical which amounts to a power nonlinearity of degree 5 in 3D. This is precisely the borderline case between unconditional global existence of solutions and blow-up. We show how to handle the case of distributed control, that is, the control enters the right-hand side of the equation. But ultimately we would be interested in boundary control, so having the control as the boundary datum for the problem. We outline a possible route how to handle this setting.

10:30 - 10:45H. Coffee/Tea break

10:45 - 11:25H. **Prof. Yi Zhou** • Fudan University

On the construction of exact control for the wave equation

We consider the problem of global exact null internal controllability for defocusing semilinear wave equations with certain power nonlinearity in up to three space dimensions, which has been open for decades. By applying the sharp observability inequality of T.Duyckaerts, X.Zhang, and E. Zuazua [Ann. Inst. H. Poincare Anal. Non Lineaire, 2008, 25:1-41], We are able to construct feedback controls to make the energy of the system very small in a very short time, then we reduce the problem to the local exact null controllability which is well known. We will also consider the corresponding problem for the focusing nonlinearity.

11:30 - 12:10H. **Dr. Nicola De Nitti** • FAU. Friedrich-Alexander-Universität Erlangen-Nürnberg

Inverse design for some systems of conservation laws

We consider the prototypical example of the 2×2 liquid chromatography system and characterize the set of initial data leading to a given attainable profile at t=T. For profiles that are not attainable at time T, we study a non-smooth optimization problem: recovering the initial data that lead as close as possible to the target in the L^2-norm. We then study the system on a bounded domain and use a boundary control to steer its dynamics to a given trajectory. We illustrate these results with a suitable finite volumes scheme. Minor modifications of our arguments apply to other types of triangular systems of conservation laws. This talk is based on a joint work with G. M. Coclite, C. Donadello, and F. Peru.

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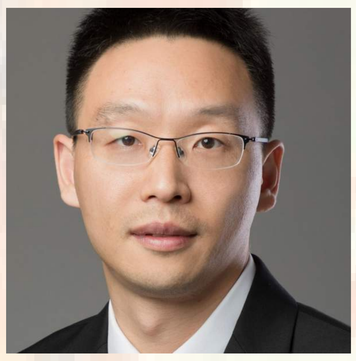
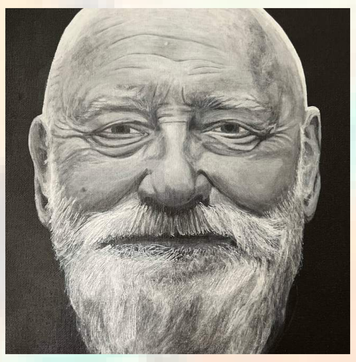
09:00 - 09:40H. **Prof. Zhiqiang Wang** • Fudan University



Feedback stabilization and inverse problem for a nonlocal transport equation

In this talk, we will show some results on feedback stabilization and inverse problems for a transport equation with nonlocal velocity. This model arises in the control of semiconductor manufacturing systems which have a highly re-entrant character. Firstly we obtain a semi-global stabilization result by using a time-varying feedback control. Secondly with the help of certain feedback control, we recover the velocity function from the measurements.

09:45 - 10:25H. **Prof. Jan Sokolowski** • Université de Lorraine



Topological derivative method for control and design on networks.

The dynamical optimal control problems on networks are considered. The model includes a graph and Linear Partial Differential Equations on the edges of the graph. The continuity conditions for the solutions and the fluxes are prescribed at the vertices of the graph. The domain of definition for the distributed parameter system is a tree. The cost function for control problem is optimized with respect to the shape and topology of the graph. The singular geometrical perturbations of the graph are considered for topology optimization using the topological derivative method. Namely, the nucleation of a small cycle at a central vertex is considered and the topological derivative of the cost with respect to the size of the cycle is determined. The topological derivative method in shape and topology optimization is a new tool which can be used to minimize the shape functionals under the PDEs constraints. The topological derivative is used for optimum design of graphs. In optimal control problems the topological derivative is used for optimum design of the domain of integration of the state equation. An example is the optimal control problem on a cross with a small cycle. The state equation is the wave equation on the graph. The Neumann boundary control problem at a boundary vertex is solved with a tracking cost function. The shape functional is given by the optimal value of the cost. The topological derivative of the shape functional is determined for the size of the cycle $\varepsilon \to 0$. Numerical results are presented.

10:30 - 10:45H. Coffee/Tea break

10:45 - 11:25H. **Prof. Long Hu** • Shandong University

Minimal time for null-controllability of 1-D linear hyperbolic systems of balance laws

In this talk, we are concerned with the minimal time for null-controllability of 1-D linear hyperbolic systems of balance laws by means of boundary control on one side. It is known in some previous works that this critical quantity can be sensitive to both internal and boundary coupling terms, especially when null and exact controllability are not equivalent. We will propose necessary and sufficient conditions for this minimal control time to be invariant with respect to all the possible internal coupling terms. We will also show some new results on how to characterize minimal time for some special systems (e.g. 2x2 system, analytical system, etc) if aforementioned conditions are not satisfied.

11:30 - 12:10H. **Prof. Enrique Zuazua** • FAU. Friedrich-Alexander-Universität Erlangen-Nürnberg

Control and Machine Learning

In this lecture we shall present some recent results on the interplay between control and Machine Learning, and more precisely, Supervised Learning and Universal Approximation.We adopt the perspective of the simultaneous or ensemble control of systems of Residual Neural Networks (ResNets). Roughly, each item to be classified corresponds to a different initial datum for the Cauchy problem of the ResNets, leading to an ensemble of solutions to be driven to the corresponding targets, associated to the labels, by means of the same control. We present a genuinely nonlinear and constructive method, allowing to show that such an ambitious goal can be achieved, estimating the complexity of the control strategies. This property is rarely fulfilled by the classical dynamical systems in Mechanics and the very nonlinear nature of the activation function governing the ResNet dynamics plays a determinant role. It allows deforming half of the phase space while the other half remains invariant, a property that classical models in mechanics do not fulfill. The turnpike property is also analyzed in this context, showing that a suitable choice of the cost functional used to train the ResNet leads to more stable and robust dynamics. This lecture is inspired in joint work, among others, with Borjan Geshkovski (MIT), Carlos Esteve (Cambridge), Domenec Ruiz-Balet (IC, London) and Dario Pighin (Sherpa.ai)

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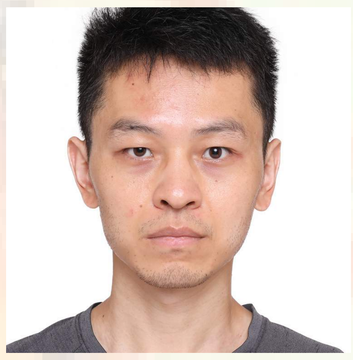
09:00 - 09:40H. **Prof. Jian Zhai** • Fudan University



An inverse boundary value problem for a nonlinear elastic wave equation

We consider an inverse boundary value problem for a nonlinear elastic wave equation. We show that all the parameters appearing in the equation can be uniquely determined from boundary measurements under certain geometric assumptions. The proof is based on second order linearization and Gaussian beams.

09:45 - 10:25H. **Prof. Yongcun Song** • FAU. Friedrich-Alexander-Universität Erlangen-Nürnberg

Physics-informed neural networks for non-smooth PDE-constrained optimization problems

We study the application of well-known physics-informed neural networks (PINNs) for solving non-smooth PDE-constrained optimization problems. First, we consider a class of PDE-constrained optimization problems where additional nonsmooth regularization is employed for constraints on the control or design variables. For solving such problems, we combine the alternating direction method of multipliers (ADMM) and PINNs and propose the ADMM-PINNs algorithmic framework, which unties the PDE constraints and the nonsmooth regularization terms for iterations. Accordingly, at each iteration, one of the resulting subproblems is a smooth PDE-constrained optimization which can be efficiently solved by PINNs, and the other is a simple nonsmooth optimization problem which usually has a closed-form solution or can be efficiently solved by various standard optimization algorithms or pre-trained neural networks. Then, we consider optimal control problems of PDEs with interfaces. We employ the recently developed discontinuity-capturing neural network to tackle the non-smoothness of the PDEs with interfaces and propose hard-constraint PINNs for solving such optimal control problems. The hard-constraint PINNs ensure both the boundary and interface conditions are satisfied strictly, and meanwhile, they are decoupled from the learning of the PDEs. All these PINNs methods are mesh-free, easy to implement, and scalable to different PDE settings. Various numerical results are reported to validate the effectiveness and efficiency of the proposed PINNs methods.

10:30 - 10:45H. Coffee/Tea break

10:45 - 11:25H. **Prof. Xi Chen** • Fudan University

The inverse problem of the wave equation

In GR and QFT, some Euler-Lagrange equations (e.g. Einstein and Yang-Mills equations) describe the dynamics of underlying fields (e.g. gravitational and electromagnetic fields). These equations usually turn out to be time-dependent nonlinear wave equations. Some physical parameters in the models are encoded in the coefficients of these equations. We shall discuss how to recover the coefficients by doing local measurements of wave phenomena.

11:30 - 12:10H. **Prof. Ke Wang** • Donghua University

Exact boundary controllability of nodal profile with nonuniform steady states for quasilinear hyperbolic systems

In this talk, we investigate the exact boundary controllability of nodal profile for quasilinear hyperbolic systems in a C1 neighborhood of a nonuniform steady state, and obtain its asymptotic stability on an infinite time interval. In order to achieve this, we first establish the existence and uniqueness of semi-global C1 solution to the one-sided mixed initial-boundary value problem for nonautonomous quasilinear hyperbolic systems and discuss the asymptotic behavior of the solution with respect to the x variable. Then, under the condition that the given nodal profile and boundary functions possess a certain exponential or polynomial decaying property with respect to the t variable, we can prove the exponential or polynomial stability of the solution toward this nonuniform steady state. The method developed here also allows us to establish the exact boundary controllability with nonuniform steady states for quasilinear hyperbolic systems. This work is jointly with Libin Wang.

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FAU, Friedrich-Alexander-Universität Erlangen-Nürnberg
Cauerstraße 11, 91058 Erlangen

CHINA

15:00 - 18:15H
Room **1801**. Guanghua East Main Building.
光华楼东主楼 Fudan University
Handan Road 220. 200433 Shanghai

ONLINE

Zoom meeting link:
https://fau.zoom.us/j/64077190955?pwd=UjRJRzFJb0orMzNsN2dmelkzVXRSUT09

Meeting ID: **640 7719 0955** | PIN: **858411**

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Chinesisch-Deutsches Zentrum für Wissenschaftsförderung
中德科学中心

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