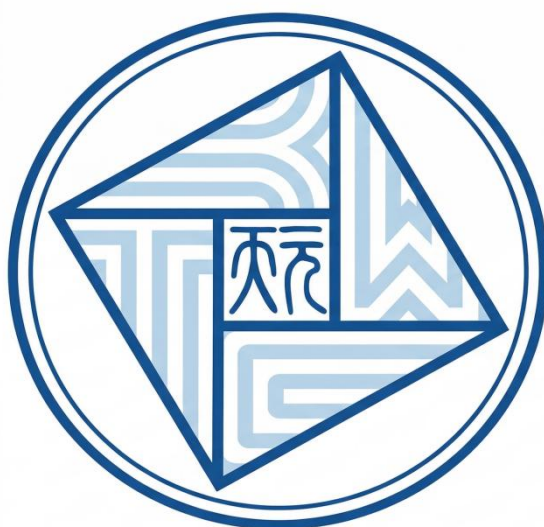




# Tianyuan Mathematics Research Center Conference on “Mathematical Control Theory and Artificial Intelligence”



April 12 - April 18, 2026

Kunming, China

Organizing Committee: Baozhu Guo (Academy of Mathematics and Systems  
Science, Chinese Academy of Sciences)

Junmin Wang (Beijing Institute of Technology)

Wen Kang (Beijing Institute of Technology)



# Table of Contents

<b>CONFERENCE PRESENTATION SCHEDULE .....</b>	<b>2</b>
<b>CONFERENCE PROGRAM ( I ).....</b>	<b>3</b>
<b>CONFERENCE PROGRAM ( II ).....</b>	<b>4</b>
<b>CONFERENCE PROGRAM ( III ).....</b>	<b>5</b>
<b>CONFERENCE PROGRAM ( IV ).....</b>	<b>6</b>
<b>ABSTRACT.....</b>	<b>7</b>



## Conference Presentation Schedule

Date Time Schedule	April 13 (Monday)	April 14 (Tuesday)	April 15 (Wednesday)	April 16 (Thursday)	April 17 (Friday)
9 : 15 - 10 : 15	Tao Li	LiGuo Zhang	BaoZhu Guo	HuanShui Zhang	Free Discussion
10 : 15 - 10 : 30	<b>Tea Break</b>				
10 : 30 - 11 : 30	ShiHua Li	ZhongJie Han	Xu Zhang	Xiang Xu	
11 : 45 - 14 : 00	<b>Lunch and Break</b>				
14 : 00 - 15 : 00	KangSheng Liu	FuKe Wu	Xue Luo	Yi Cheng	Free Discussion
15 : 00 - 16 : 00	JuanJuan Xu	HanXiao Wang	Qiang Tao	Ji Wang	
16 : 00 - 16 : 30	<b>Tea Break</b>				
16 : 30 - 17 : 30	ChuanHou Gao	Qiong Zhang	Wen Kang	ShengQuan Xiang	
17:45	<b>Dinner</b>				

**Contact Information of the Organizing Committee:**

**Lei Feng (Head of Tianyuan Mathematical Center Office): 13683660139**

**Wen Kang (Organizing Committee): 18210520481**

**Erxin Pang (Organizing Committee): 18456540352**

**Qi Wang (Organizing Committee): 18811096998**



# Conference Program ( I )

April 12 (Sunday, full day): Registration				
April 13 (Monday)				
9:00 - 9:15		Opening Ceremony, Group Photo		
Time		Speaker	Title	Chair
Morning	9:15 - 10:15	Tao Li Academy of Mathematics and Systems Science, Chinese Academy of Sciences	Distributed Online Learning and Optimization Based on Non-Stationary Data Streams	BaoZhu Guo
	10:15 - 10:30	Tea Break		
	10:30 - 11:30	ShiHua Li Southeast University	Research Progress on Safety and Anti-Disturbance Control of Electromechanical Systems	
	11:45	Lunch		
Afternoon	14:00-15:00	KangSheng Liu Zhejiang University	Uniform observability and uniformly exponential stabilization for a sequence of elastic systems under the modal approximation	ZhongJie Han
	15:00-16:00	JuanJuan Xu Shandong University	Distributed Solution of Optimal Controllers and Applications	
	16:00-16:30	Tea Break		
	16:30-17:30	ChuanHou Gao Zhejiang University	Implementation of Neural Network Algorithms via Biochemical Reaction Networks: Convergence and Error Analysis	
	17:45	Dinner		



## Conference Program ( II )

April 14 (Tuesday)				
Time		Speaker	Title	Chair
Morning	9:15 - 10:15	LiGuo Zhang Beijing University of Technology	Boundary Control Theory and Methods for ARZ Traffic Flow Model	Qiong Zhang
	10:15 - 10:30	Tea Break		
	10:30 - 11:30	ZhongJie Han Tianjin University	Optimal Decay Rate for Degenerate Hyperbolic-Parabolic Coupled System	
	11:45	Lunch		
Afternoon	14:00-15:00	FuKe Wu Huazhong University of Science and Technology	Analyzing Systems of Coupled Forward-Backward Stochastic Differential Equations: Fast and Slow Motions, Associated Quasi-Linear Partial Differential Equations, and Applications	LiGuo Zhang
	15:00-16:00	HanXiao Wang Shenzhen University	BSDEs and BSVIEs with anticipating generators	
	16:00-16:30	Tea Break		
	16:30-17:30	Qiong Zhang Beijing Institute of Technology	Stability for Weakly Coupled System with Partial Controls	
	17:45	Dinner		



## Conference Program ( III )

April 15 (Wednesday)				
Time		Speaker	Title	Chair
Morning	9:15 - 10:15	BaoZhu Guo Academy of Mathematics and Systems Science, Chinese Academy of Sciences	Zero Point Problem and Output Tracking for Partial Differential Systems	Bing Sun
	10:15 - 10:30	Tea Break		
	10:30 - 11:30	Xu Zhang Sichuan University	Controllability of Deterministic and Stochastic Wave Equations	
	11:45	Lunch		
Afternoon	14:00-15:00	Xue Luo Beihang University	The Gaussian Mixture Optimal Transport Ensemble Kalman Filter and Its Applications to Partially Linear Systems	Wen Kang
	15:00-16:00	Qiang Tao Shenzhen University	Controllability of the viscous micropolar fluids	
	16:00-16:30	Tea Break		
	16:30-17:30	Wen Kang Beijing Institute of Technology	Stabilization of PDE systems and its application in Multi-agent systems	
	17:45	Dinner		



## Conference Program (IV)

April 16 (Thursday)				
Time		Speaker	Title	Chair
Morning	9:15 - 10:15	HuanShui Zhang Shandong University of Science and Technology	OCP Optimization Methods and Applications	ShengQuan Xiang
	10:15 - 10:30	Tea Break		
	10:30 - 11:30	Xiang Xu Southern University of Science and Technology	Boundary Control of Parabolic PDE-ODE Systems with Distributed Interconnections	
	11:45	Lunch		
Afternoon	14:00-15:00	Yi Cheng Bohai University	Boundary Stabilization for a Class of Nonlinear Axially Moving Systems with Coupling Transverse and Longitudinal Vibrations	Xiang Xu
	15:00-16:00	Ji Wang Xiamen University	Secure Boundary Control for Distributed Parameter Systems	
	16:00-16:30	Tea Break		
	16:30-17:30	ShengQuan Xiang Peking University	Symmetry and observability for wave equations on the torus	
	17:45	Dinner		
April 17 (Friday)				
Free Discussion				



## Abstract

### **Distributed Online Learning and Optimization Based on Non-Stationary Data Streams**

**Tao Li**

**Academy of Mathematics and Systems Science, Chinese Academy of Sciences**

**Abstract:** The convergence of several classes of distributed learning and optimization algorithms based on non-stationary data streams is investigated. This includes: establishing "stochastic spatio-temporal excitation conditions" that guarantee mean-square strong consistency for distributed linear regression; for the case with an L2 regularization term, deriving "sample-path stochastic spatio-temporal excitation conditions" that ensure strong consistency; establishing convergence conditions for stochastic gradient descent algorithms without requiring the boundedness of subgradient functions; and for a class of stochastic inverse problems, deriving "infinite-dimensional stochastic spatio-temporal persistent excitation conditions" that guarantee both mean-square and almost sure strong consistency.

### **Research Progress on Safety and Anti-Disturbance Control of Electromechanical Systems**

**ShiHua Li**

**Southeast University**

**Abstract:** Electromechanical systems inherently contain various nonlinearities—such as friction, backlash, hysteresis, dead zones, and pneumatic/hydraulic nonlinearities—as well as unavoidable parameter uncertainties, perturbations, noise, measurement delays, and external disturbances. These factors significantly affect the performance, usability, and reliability of electromechanical systems. This talk discusses how to enhance the anti-disturbance capability and precision of closed-loop systems from the perspectives of model predictive control, constrained safety control, disturbance observation, and preview compensation. Recent theoretical advances and their validation results in electromechanical systems are presented.

### **Uniform observability and uniformly exponential stabilization for a sequence of elastic systems under the modal approximation**



**KangSheng Liu**

**Zhejiang University**

**Abstract:** This paper is devoted to the investigation of modal approximation for elastic systems with damping or control. The so-called modal approximation projects the system into a finite-dimensional space spanned by the modal vectors of free vibration without damping or control. First, we consider a complete second-order variational evolution equation in a Hilbert space, which can model elastic systems with unbounded damping. By adapting the Trotter-Kato Theorem concerning the convergence of a sequence of  $C_0$ -semigroups on a fixed space, we establish the convergence of a family of  $C_0$ -semigroups on the different spaces associated with approximation systems. Second, we discuss an elastic system, a second-order differential equation in a Hilbert space, with bounded control and dual observation. It is proved that the equivalence between the uniform observability, the uniformly exponential stabilization under the modal approximation and the eigenfunctions test.

## **Distributed Solution of Optimal Controllers and Applications**

**JuanJuan Xu**

**Shandong University**

**Abstract:** In practical scenarios such as large-scale networks and swarm systems, the global information of the system cannot be acquired by a single agent; instead, it is collected in a distributed manner by a group of agents, each holding private information. In such settings, the design and solution of global optimal controllers are constrained by the absence of global information, making the development of distributed solution methods a core issue demanding urgent attention. This talk first introduces the distributed approach to solving linear quadratic optimal controllers, and then applies the method to representative problems such as consensus control of heterogeneous multi-agent systems, distributed load frequency control in smart grids, and cooperative formation control of unmanned aerial and ground vehicles.

## **Implementation of Neural Network Algorithms via Biochemical**

### **Reaction Networks: Convergence and Error Analysis**

**ChuanHou Gao**

**Zhejiang University**



**Abstract:** We report on how to realize the various functional modules and steps of fully connected neural networks—including assignment, forward propagation, conditional judgment, loops, backpropagation learning, and termination—using biochemical reaction networks. Convergence proofs for the designed biochemical reaction networks are provided, along with the derivation of upper bounds for the compilation errors of each functional module.

## **Boundary Control Theory and Methods for the ARZ Traffic Flow Model**

**LiGuo Zhang**

**Beijing University of Technology**

**Abstract:** Can autonomous driving and intelligent connected vehicle technologies completely resolve traffic congestion? How can next-generation information technologies be utilized to suppress stop-and-go waves? How can a closed-loop feedback system for traffic control be established? To address these questions, this talk primarily presents research on traffic shockwave modeling, well-posedness analysis, and boundary feedback stabilization based on the Aw–Rascle–Zhang macroscopic traffic flow model. In contrast to traditional traffic control approaches that rely on model discretization or linearization, this study explores boundary feedback control theory and methods grounded in hyperbolic PDE traffic flow models within the framework of systems theory and control theory.

## **Optimal Decay Rate for Degenerate Hyperbolic-Parabolic Coupled System**

**ZhongJie Han**

**Tianjin University**

**Abstract:** This talk is concerned with the explicit decay rates of a coupled PDE system composed of a wave equation and a degenerate heat equation posed on two adjoining domains. We first consider the one-dimensional setting and derive an explicit decay rate for the solutions, depending solely on the degree of degeneracy of the heat equation’s diffusion coefficient near the interface. Moreover, we show that this rate is optimal. We then investigate the system on a rectangular domain where the Geometric Control Condition (GCC) fails, and establish an explicit polynomial decay rate. Remarkably, this rate coincides with the optimal one obtained by Batty et al. [SIAM J. Math. Anal., 2018] for the corresponding systems with constant diffusion coefficients. In this sense, the decay rate derived here may also be regarded as sharp for this class of degenerate systems.



# Analyzing Systems of Coupled Forward-Backward Stochastic Differential Equations: Fast and Slow Motions, Associated Quasi-Linear Partial Differential Equations, and Applications

FuKe Wu

Huazhong University of Science and Technology

**Abstract:** This work analyzes systems of coupled forward-backward stochastic differential equations with fast and slow motions. First, well-posedness and a number of estimates of the systems are established. Then the paper is focused on obtaining averaging principles in the sense of mean-square convergence uniform in finite time interval for solutions of both forward and backward stochastic differential equations. The averaging principle enables us to further analyze certain associated quasi-linear PDEs. In addition, as an application, the convergence of a class of associated singularly perturbed stochastic control problems is established.

## BSDEs and BSVIEs with anticipating generators

HanXiao Wang

Shenzhen University

**Abstract:** For a backward stochastic differential equation (BSDE, for short), when the generator is not progressively measurable, it might not admit adapted solutions, shown by an example. However, for backward stochastic Volterra integral equations (BSVIEs, for short), the generators are allowed to be anticipating. This gives, among other things, an essential difference between BSDEs and BSVIEs. Under some proper conditions, the well-posedness of such BSVIEs is established. Further, the results are extended to path-dependent BSVIEs, in which the generators can depend on the future paths of unknown processes. An additional finding is that for path-dependent BSVIEs, in general, the situation of anticipating generators is not avoidable, and the adaptedness condition similar to that imposed for anticipated BSDEs by Peng and Yang [Ann. Probab., 37 (2009), pp. 877--902] is not necessary. Joint work with Jiongmin Yong and Chao Zhou.

## Stability for Weakly Coupled System with Partial Controls

Qiong Zhang

Beijing Institute of Technology



**Abstract:** We study the stability of general weakly coupled systems subject to a reduced number of local or boundary controls. We show that, under Kalman's rank condition, the exponential stability of the underlying scalar equation implies polynomial stability of the full coupled system. Moreover, the decay rate remains unchanged regardless of the number of equations in the system.

## **Zero Point Problem and Output Tracking for Partial Differential Systems**

**BaoZhu Guo**

**Academy of Mathematics and Systems Science, Chinese Academy of Sciences**

**Abstract:** Control systems process the feedback of input and output signals to achieve output tracking. There are two extreme cases: one occurs when certain input signals produce infinitely large output signals—these correspond to poles; the other occurs when certain input signals yield no observable output—these correspond to zeros. Poles can be eliminated through feedback, whereas zeros cannot. Consequently, zero-related problems pose substantial difficulties. The zero problem for infinite-dimensional systems is particularly intricate. Non-collocated configurations, where control and observation act at different locations, often give rise to non-minimum phase behavior, even though the transfer function may possess no zeros whatsoever. Even if the system is controllable and observable, non-minimum phase systems cannot track arbitrary  $L^2$  signals. This issue has been rarely studied for partial differential systems, especially those subject to disturbances—specifically, which total disturbances can be estimated from the output and which cannot. This talk discusses some fundamental results we have recently obtained in this direction.

## **Controllability of Deterministic and Stochastic Wave Equations**

**Xu Zhang**

**Sichuan University**

**Abstract:** This talk reviews the principal methods and results concerning the controllability of deterministic and stochastic wave equations. It analyzes the fundamental importance of the pseudoconvexity condition introduced by Fields Medalist L. Hörmander in the 1960s for establishing observability estimates for wave equations with variable coefficients, and presents several open problems.

## **The Gaussian Mixture Optimal Transport Ensemble Kalman Filter and Its Applications to Partially Linear Systems**

**Xue Luo**

**Beihang University**



**Abstract:** In this talk, we revisit the Gaussian mixture optimal transport Ensemble Kalman filter (GM-OT-EnKF) to make it more efficient in some partially linear problems. We first show the equivalence between the OT-EnKF with the classical Kalman filter (KF) in the linear system with Gaussian initial distribution. Next, we compare the Gaussian sum filter (GSF) with the GM-OT-EnKF in the setting of linear system with GM initial distribution. The updating of the components' weights in GM-OT-EnKF is finer than those in the GSF, due to the flexibility induced by the particles. These observations in the linear system suggest two adaptations to the original GM-OT-EnKF corresponding to partially linear systems. The one is when the state's equation is linear, the EM algorithm is unnecessary in every cycles; the other one is when the observation is linear, the posterior mean and covariance matrix should be updated explicitly, rather than the empirical ones. The GM-OT-EnKF with either one of the two adaptations above is called the compact GM-OT-EnKF in this paper. The efficiency and accuracy of our proposed algorithm have been numerically verified in the estimation of the states in the Lorenz 63 system and the prediction of the remaining useful life of the lithium-ion batteries.

## **Controllability of the viscous micropolar fluids**

**Qiang Tao**

**Shenzhen University**

**Abstract:** In this talk, we will begin by briefly reviewing recent advances in the controllability of viscous fluid dynamics equations. We then focus specifically on the controllability of two classes of models associated with viscous micropolar fluids: the global controllability of incompressible micropolar fluids, and the local controllability of compressible micropolar fluids.

## **Stabilization of PDE systems and its application in Multi-agent systems**

**Wen Kang**

**Beijing Institute of Technology**

**Abstract:** Many important plants (e.g. flexible manipulators or chemical reactors) are governed by PDEs and are often described by models with a significant degree of uncertainty. Stabilization for infinite-dimensional PDE systems is a challenging problem. We aim to provide efficient methods for stabilization of PDEs and for PDE-based multi-agent deployment.



## OCP Optimization Methods and Applications

HuanShui Zhang

Shandong University of Science and Technology

**Abstract:** Optimization plays a pivotal role in applied mathematics and simultaneously constitutes a fundamental scientific basis for engineering and information sciences. The theory of optimization has evolved over several centuries, yielding classical algorithms such as gradient descent, improved gradient descent variants, Newton iteration, and enhanced quasi-Newton methods. Although each algorithm possesses distinct merits, they also exhibit limitations: gradient descent is stable but often converges slowly, whereas Newton iteration converges rapidly yet tends to diverge, with its modified versions suffering from similar drawbacks. This talk presents a novel optimization algorithm that combines fast convergence with stability, whose core idea originates from Optimal Control Principles (OCP). The algorithm regards the update step size in the iterative process as a control input, which is designed to minimize the sum of the objective function at future instants and the control energy. Minimizing the objective function ensures the fastest convergence, while minimizing the control energy guarantees algorithmic stability. By employing Taylor expansion for approximation, the algorithm is further transformed into an iterative form, thereby circumventing the need to solve nonlinear forward-backward difference equations. Rigorous theoretical analysis demonstrates that the algorithm achieves superlinear convergence comparable to Newton's method while retaining the stability characteristic of gradient descent. Moreover, the algorithm encompasses gradient descent, Newton's method, modified accelerated gradient descent, and regularized Newton methods, thereby providing a unified theoretical framework for these algorithms from a mathematical perspective. Finally, the talk introduces successful applications of OCP in areas such as trajectory tracking for intelligent vehicles, three-dimensional image restoration, power flow calculation in electrical power systems, and large-scale deep learning.

## Secure Boundary Control for Distributed Parameter Systems

Ji Wang

Xiamen University

**Abstract:** This talk investigates secure boundary control problems for distributed parameter systems described by partial differential equations (PDEs), with an emphasis on achieving a unified boundary control design that integrates stabilization, output regulation, and safety constraints under external disturbances and model uncertainties. First, to address the high relative degree arising when control acts on the boundary while safety constraints are imposed on the uncontrolled output, a boundary control design approach based on the backstepping method and the Control Barrier Function (CBF) framework is proposed. This approach achieves system stabilization and output regulation while ensuring that the system output always satisfies



prescribed safety requirements: if the initial output lies within the safe region, safety is maintained at all times; otherwise, the output enters and remains within the safe region within a prescribed finite time. Furthermore, to handle parameter uncertainties, a novel adaptive Control Barrier Function (aCBF) method is developed, which integrates the Batch Least-Squares Identification (BaLSI) mechanism into the CBF safety control framework. This method effectively reduces the conservatism of existing safe adaptive control approaches without relying on high adaptive gains or persistent excitation conditions. Finally, simulation examples verify the effectiveness of the proposed method in jointly achieving safety constraints and control performance.

## **Boundary Stabilization for a Class of Nonlinear Axially Moving Systems with Coupling Transverse and Longitudinal Vibrations**

**Yi Cheng**

**Bohai University**

**Abstract:** This talk discusses boundary stabilization within the framework of absolute stability for axially moving systems experiencing transverse and longitudinal coupling vibrations. These vibrations are described by a nonlinear coupled beam model derived from Hamilton's principle. A boundary feedback sector criterion is proposed, encompassing a wide array of linear and nonlinear functions, to reduce vibrations within the axially moving systems by measuring boundary transverse, longitudinal, and angular velocities. Under these control strategies, the resulting closed-loop coupled system has been proven to be well-posed using the nonlinear semigroup approach. Furthermore, the study employs a combination of a generalized Gronwall-type integral inequality and the integral multiplier method to investigate the explicit decay rate of the closed-loop coupled system. This investigation involves the construction of a novel energy functional. Numerical simulations validate the effectiveness of the proposed controls, with the explicit exponential decay rate closely mirroring the actual decay rate.

## **Boundary Control of Parabolic PDE-ODE Systems with Distributed Interconnections**

**Xiang Xu**

**Southern University of Science and Technology**

**Abstract:** Parabolic partial differential equation (PDE) – ordinary differential equation (ODE) systems find applications in industrial manufacturing, temperature control, chemical process control, and related fields. This talk primarily introduces boundary control for parabolic PDE-ODE systems with distributed interconnections. Traditional infinite-dimensional backstepping is applicable only to PDE-ODE systems in strict-feedback form, whereas the



presence of distributed interconnections breaks the strict-feedback structure. To address this, two novel boundary controller design methodologies are proposed: a backstepping-feedforward approach and a low-gain control method, which achieve boundary stabilization for various classes of parabolic PDE-ODE systems with distributed interconnections. The talk further illustrates the effectiveness of the boundary controllers through numerical simulation examples and discusses future directions for the theory and applications of boundary control for PDE systems.

## Symmetry and observability for wave equations on the torus

ShengQuan Xiang

Peking University

**Abstract:** In this talk, I will discuss observability for wave equations, with particular emphasis on symmetry. I will focus on spacetime measurable observation sets on the one-dimensional torus, where a complete characterization is available.

I will first describe a counterexample showing that the Geometric Control Condition (GCC), while sufficient in many settings, does not guarantee observability when observation is restricted to certain spacetime measurable sets. Inspired by this counterexample, we introduce a symmetry condition, referred to as the Observable Symmetry Condition (OSC), which captures an additional structural constraint underlying observability.

We show that OSC, together with GCC, provides a necessary and sufficient characterization of observability on spacetime measurable sets. Finally, motivated by OSC, we introduce a weak GCC and show that, when combined with OSC, it yields a necessary and sufficient condition for unique continuation. Based on recent joint work with Jingrui Niu and Ming Wang.



**Kunming · April 2026**