Invited Session Proposal for the ICONIP 2017

**Title:**

**Active Learning Control of Infinite-Dimensional Systems and its Applications**

**Abstract:**

Infinite-dimensional systems (IFDS) have a wide range of application areas, such as flexible structures, fluid flows, quantum mechanics, ocean rigs, chemical processes and so on. Different from finite-dimensional systems (FDS), IFDS is generally used to describe the spatial-temporal evolutionary systems in which the state spaces are infinite dimensional functional spaces. Mathematically, the model of IFDS described by partial dimensional equations (PDEs) makes the control design and stability analysis more challenging. Recently, promoted by practical applications demands, IFDS research has attracted more and more attention from researchers.

The proposed session shows expertise in the IFDS area to the audience of ICONIP’2017 and particularly emphasizes research work related to IFDS arising in practical applications. This session includes 6 papers and presents the most recent progress on both theoretical and applied work of IFDS.

**Keywords:**

infinite-dimensional systems, partial differential equations, boundary control, learning control, stability analysis, numerical simulation, applications

**Organizers:**

1. **Yu Liu**, Associate Professor, School of Automation Science and Engineering, South China University of Technology, auylau@scut.edu.cn

2. **Wei He**, Professor, School of Automation & Electrical Engineering, University of Science and Technology Beijing, hewei.ac@gmail.com

**Invited papers:**

**1.** **Yu Liu** and **Fang Guo** (South China University of Technology, China), Adaptive iterative learning boundary control of an Euler-Bernoulli beam system

In this article, through combining boundary control, adaptive technique with iterative learning control, an adaptive iterative learning boundary control strategy is developed for improving the tracing accurate and suppressing the vibration of an Euler-Bernoulli beam system. The dynamic model of the Euler-Bernoulli beam system can be represented by partial-ordinary differential equations in the presence of unknown disturbance. With the designed control strategy, the spillover instability problem is avoided and the learning convergence of iterative learning control is also mathematically achieved without any simplification or discretization of the PDE dynamics. Finally, simulation results are displayed to illustrate that the proposed adaptive iterative learning boundary control strategy is effective to minimize the vibration displacement and realize the bounded error in tracking the expectations orbit in the tracking Euler-Bernoulli beam system.

**2.** **Xuefang Li** (National University of Singapore, Singapore) and **Wei He** (University of Science and Technology Beijing, China), P-type iterative learning control for a class of nonlinear wave equations

This paper aims at the design and analysis of iterative learning control (ILC) for a class of nonlinear wave equations. Different from the most existing works that focus on ILC for parabolic partial differential equations (PDEs), we consider the boundary control problem of a class of hyperbolic PDE systems via ILC. Without any simplification or discretization of the 3D dynamics in the time, space as well as iteration domain, the learning convergence of ILC is analyzed by virtue of the contraction mapping methodology. It is shown that the proposed ILC algorithm works well for systems with state-independent or state-dependent uncertainties and makes full use of the process repetition. In addition, the robustness of the adopted ILC scheme is addressed for iteration-varying boundary conditions. In the end, an illustrative example is presented to demonstrate the efficacy of the proposed ILC scheme.

**3. Yun Fu** and **Qing Hui** (University of Nebraska-Lincoln, USA), Modeling and stability analysis of an axially moving belt via an iterative learning boundary control

In order to achieve the vibration suppression and the tracing accurate improvement of an axially moving accelerated/decelerated belt system, this study discusses the design of an adaptive iterative learning boundary control scheme. The dynamical model of the belt system including the dynamics of high accelerated/decelerated is described by the partial-ordinary differential equations. By utilizing adaptive technique, boundary control and iterative learning control, an adaptive iterative learning boundary control scheme is designed for minimizing the vibration displacement of the belt system, where the adaptive law is developed to handle parametric uncertainties and the S-curve acceleration/deceleration method is also adopted to plan the speed of the belt system. Besides, the proposed control scheme can also effectively avoid the control spillover problem. Lastly, numerical simulations are given for validating the effectiveness of the proposed control scheme.

**4.** **Deqing Huang** (Southwest Jiaotong University, China) and **Sergei Chernyshenko** (Imperial College London, UK), Nonlinear global stability analysis of rotating couette flow with no-slip boundary conditions using sum-of-squares optimization

By virtue of sum-of-squares (SOS) optimization, this paper focuses on the global stability analysis of a real physical version of rotating Couette flow that depends on the Reynolds number and a parameter characterizing the magnitude of the Coriolis force. Preliminary analysis on the linear and energy stabilities of the flow is first conducted. Then, in order to investigate the nonlinear global stability of the fluid flow for the value of a Reynolds number greater than what has been achieved via the energy stability approach, the original Navier-Stockes equations are converted to a finite-dimensional dynamical system under truncated and partial Galerkin expansions, respectively. The optimization techniques of SOS of polynomials are adopted to search for high-degree polynomial Lyapunov functions, which in turn prove the global stability of the flow. As a result, a lower bound of the global stability limit that is greater than the energy stability limit is obtained. In particular, when the Galerkin expansion is truncated, the global stability limit is numerically proven to be coincided with the linear stability limit of the flow for a large range of the values of the parameter characterizing the Coriolis force. Compared with other available methods that were used to address the global stability of no-slip rotating Couette flow, the adopted method shows certain conservativeness but more generality in the sense that it can be easily applied for an arbitrary flow.

**5. Zhijie Liu** and **Jinkun Liu** (Beihang University, China), Active vibration control of a flexible aerial refueling hose

The boundary control problem of a flexible aerial refueling hose with input disturbance is considered in this article. For making sure that there is an accurate representation about the behavior of aerial refueling hose, the flexible hose is modeled as a distributed parameter system and it can be described by a set of partial differential equations (PDEs). Boundary control is proposed based on the original PDE model to suppress the vibration of the flexible hose. In addition, a disturbance observer is designed to estimate the input disturbance. Finally, numerical simulations are presented to verify the control performance.

6. **Xiuyu He** and **Wei He** (University of Science and Technology Beijing, China), Vibration control of a flexible crane system

In this paper, a flexible cable with a payload attached at the bottom is considered to be the model of a crane system used for positioning the payload. The dynamics of the flexible cable coupled with the tip payload contribute to a hybrid system represented by partial-ordinary differential equations. An integralbarrier Lyapunov function (IBLF)-based control is proposed to suppress the undesirable vibrations of the flexible crane system with the boundary output constraint. Adaption laws are developed for handling parametric uncertainties. A novel IBLF is adopted to guarantee the uniform stability of the closed-loop systems without the violation of the boundary constraint. All closed-loop signals are ensured to be bounded. Extensive simulations are demonstrated to illustrate the performance of the control system.

**7. Many more from other organizers and colleagues !!**