Control of dynamical systems
Contrôle des systèmes dynamiques
(Org: **Ludovick Gagnon** (INRIA - Nancy) and/et **Roberto Guglielmi** (Waterloo))

ALA' ALALABI, University of Waterloo

Boundary Stabilization of a Parabolic-Elliptic System Using Backstepping Approach

We consider the boundary stabilization of a parabolic partial differential equation coupled with an elliptic partial differential equation. Even in the situation when these equations are exponentially stable when uncoupled, the coupled system may be unstable. In fact, increasing the coupling factor tends to destabilize the dynamics of the system. A backstepping approach is used to design a boundary control that will stabilize the system, or more generally, improve the decay rate in the situation when the original system is stable. The result is illustrated with simulations.

MIREILLE BROUCKE, University of Toronto

Principles and Paradoxes of Systems Neuroscience

The talk will give an overview of control theoretic problems arising in the field of systems neuroscience. We present three case studies regarding the reflex paradox, the use it or lose it principle, and the principle of optimal steady-state. We show how these principles and paradoxes give rise to new challenges for control theory, and we discuss how we are addressing them.

MICHEL DELFOUR, Université de Montréal

Control, Shape, and Topological Derivatives via Minimax Differentiability of Lagrangians

In Control Theory, the semidifferential (a one-sided directional derivative) of a state constrained objective function can be obtained by introducing a Lagrangian and an adjoint state. This problem is equivalent to the one-sided derivative of the minimax of the parametrized Lagrangian with respect to a positive parameter t as it goes to 0 (for instance, Delfour and Zolésio, Shape and Geometries, Metrics, Analysis, Differential Calculus and Optimization, SIAM Ser. Advance in Control and Design, 2011] and Sturm, SIAM J. on Control and Optim., 53, no. 4, 2017-2039]. In this talk new simpler conditions that predict the occurrence of an extra term (the polarization term in Mechanics) are given in term of the standard adjoint [Delfour, Control, shape, and topological derivatives via minimax differentiability of Lagrangians, Springer INdAM Series Vol. 29, 2018]. They are applied to the computation of semidifferentials with respect to the control and the shape and the topology of the underlying domain [Delfour, Topological Derivative of State Constrained Objective Functions: a Direct Approach, SIAM J. on Control and Optim. (1) 60 (2022), 22-47]. The shape derivative is a differential while the topological derivative usually obtained by expansion methods is not. It is a semidifferential obtained by perturbations arising from dilatations of points, curves, surfaces and, potentially, microstructures by using the notion of d-dimensional Minkowski content. Examples of such perturbations are the d-rectifiable sets and the sets of positive reach of Federer [Delfour, Topological derivatives via one-sided derivative of parametrized minima and minimax, Engineering Computations (1) 39 (2022), 34-59].

STEVAN DUBLJEVIC, University of Alberta

Observer-based model predictive control for a class of well-posed linear systems

We consider observer-based model predictive control (MPC) for well-posed linear systems that are exponentially stabilizable and detectable using distributed state feedback and output injection. The proposed MPC controller is motivated by classical output MPC designs for finite-dimensional systems and comprises of dynamic output feedback and open-loop MPC. The dynamic output feedback will be obtained as an output of a Luenberger-type observer, and the open-loop MPC will be solved based on a nominal system which is essentially a copy of the actual plant. The proposed MPC design is applicable to any well-posed system satisfying the stabilability and detectability assumptions, which includes various reaction-convection-diffusion equations with boundary controls and observations as well as all exponentially stable well-posed linear systems. A one-dimensional diffusion equation will be considered as an illustrative example. Moreover, we will comment on possible extensions to more general classes of systems, e.g., if the assumptions on distributed state feedback and output injection are lifted.

MICHEL DUPREZ, Inria
Models of mosquito population control strategies for fighting against arboviruses

In the fight against vector-borne arboviruses, an important strategy of control of epidemic consists in controlling the population of the vector, Aedes mosquitoes in this case. Among possible actions, a technique consist in releasing sterile mosquitoes to reduce the size of the population (Sterile Insect Technique). This talk is devoted to studying the issue of optimizing the dissemination protocol for each of these strategies, in order to get as close as possible to these objectives. Starting from a mathematical model describing the dynamic of a mosquitoes population, we will study the control problem and introduce the cost function standing for sterile insect technique. In a second step, we will consider a model with several patchs modeling the spatial repartition of the population. Then, we will establish some properties of these two optimal control problems. Finally, we will illustrate our results with numerical simulations.

MARTIN GUAY, Queen's University

PIERRE LISSY, Université Paris-Dauphine
Desensitizing controls for the heat equation with respect to boundary variations

In this talk, I will present some recent results obtained in collaboration with Sylvain Ervedoza and Yannick Privat concerning desensitizing controls for the heat equation posed on a bounded domain of $\mathbb{R}^d$. The desensitization problem roughly consists in finding a control function, distributed on a subdomain, such that some functional depending on the solution of the heat equation (in our case, the L^2 norm of the solution on another subdomain) is locally insensitive to some perturbation of the equation. Here, the main originalty of our work relies on the fact that the perturbation is the domain itself, in the sense that its boundary can be subject to some small variations. I will present various definitions of the desensitization problem and give some positive and negative results related to them.

JUN LIU, University of Waterloo
Neural Lyapunov Control with Stability Guarantees

Learning for control of dynamical systems with formal guarantees remains a challenging task. In this talk, we introduce a learning framework to simultaneously stabilize an unknown nonlinear system with a neural controller and learn a neural Lyapunov function to certify a region of attraction for the closed-loop system. The algorithmic structure consists of two neural networks and a satisfiability modulo theories (SMT) solver. The first neural network is responsible for learning the unknown dynamics. The second neural network aims to identify a valid Lyapunov function and a provably stabilizing nonlinear controller. The SMT solver then verifies that the candidate Lyapunov function indeed satisfies the Lyapunov conditions. We provide theoretical guarantees of the proposed learning framework in terms of the closed-loop stability for the unknown nonlinear system. We illustrate the effectiveness of the approach with a set of numerical experiments. The talk is based on a recent paper published in NeurIPS 2022 (joint work with Ruikun Zhou, Thanin Quartz, and Hans De Sterck).

IVAN MOYANO, Université de Nice

KEXUE ZHANG, Queen's University
Event-Triggered Control for Linear Time-Delay Systems

Event-triggered control offers a practical method to update the control signals at a series of discrete-time moments determined by certain execution rules, often referred to as an event. The key benefit is to improve the efficiency of control implementations while still maintaining the desired performance levels for closed-loop control systems. In this talk, we present an event-triggered control method for the stabilization of linear time-delay systems. Based on two new Halanay-type inequalities, the global asymptotic stability of the event-triggered control system can be guaranteed, and a lower bound of the inter-event times, the intervals between successive control updates, can be derived to ensure the practical implementation of the proposed event-triggering condition. Two examples are given to demonstrate the suggested control method.