Control and decision at Paris-Saclay: iCODE

Overview

All IFAC World Congress participants are welcome to participate to this scientific event organized by the Institute for Control and Decision of Paris Saclay University (iCODE). The aim of this event is to briefly present the iCODE initiative and to get an overview of recent advances and perspectives in the four core iCODE topics:

- Challenge Eco: *Bounded rationality in behavioral economics*
- Challenge Energy: *Decision support for energetic transition*
- Challenge Exo: *Lightweight exoskeleton for teenagers*
- Challenge Neuro: *Control theory approach for neuroscience.*

To find out more about iCODE: http://www.icode-institute.fr/en

Organizers

This workshop is co-organized by:

- Luca Greco, associate professor at Univ. Paris Sud – L2S, luca.greco@l2s.centralesupelec.fr
- Yacine Chitour, professor at Univ. Paris Sud – L2S, yacine.chitour@l2s.centralesupelec.fr
- Antoine Chaillet, professor at CentraleSupélec – L2S, antoine.chaillet@centralesupelec.fr

Please contact them for any inquiry about this workshop.

Registration

The registration to this workshop can be done while registering to the IFAC World Congress. The attendance price is 30€, including a coffee break.

Schedule

1:45 - 2:00PM: Overview of the iCODE initiative
Yacine Chitour, professor at Univ. Paris Sud – L2S, head of iCODE

2:00 - 2:50PM: Mean field games and applications – *Challenge Energy*
Guilherme Mazanti, post-doc at Univ. Paris Sud, Hadamard Lecturer at FMJH

2:50 - 3:40PM: An overview of contract theory and application to moral hazard problems with mean field type interactions – *Challenge Eco*
Thibaut Mastrolia, associate professor at Ecole polytechnique – CMAP

3:40 – 4:00PM: Coffee break

4:00 – 4:50PM: HYDROïD - Integrated hydraulic actuation technology for humanoid robotic applications – *Challenge Exo*
Samer Al Fayad, associate professor at UVSQ – LISV

4:50 – 5:40PM: Control of spatio-temporal brain oscillations: recent results and perspectives – *Challenge Neuro*
Antoine Chaillet, professor at CentraleSupélec – L2S, junior member of IUF

Abstracts

Mean field games and applications – *Challenge Energy*

Guilherme Mazanti, post-doc at Univ. Paris Sud, Hadamard Lecturer at FMJH
https://www.math.u-psud.fr/~mazanti/

Mean field games are differential games with a continuum of agents, assumed to be rational, indistinguishable, and influenced only by the average behavior of other agents. Such models were introduced around 2006 by J.-M. Lasry and P.-L. Lions, motivated by questions in game theory and economics, and independently at about the same time by P. E. Caines, M. Huang, and R. P. Malhamé, motivated by engineering problems.

This talk will begin by a general introduction to mean field games, exposing their mathematical framework and the main questions one typically considers in their analysis, in particular the characterization of Nash equilibria as a system of PDEs. We will then present some recent developments on mean field game models motivated by population dynamics and crowd motion, where congestion phenomena are avoided through constraints in the density or in the maximal speed of agents in congested zones.

An overview of contract theory and application to moral hazard problems with mean field type interactions – *Challenge Eco*

Thibaut Mastrolia, associate professor at Ecole polytechnique – CMAP
http://www.cmap.polytechnique.fr/~thibaut.mastrolia/ThibautMastrolia.html

In this talk, we investigate a model in contract theory in which two entities interact to maximize their own payoff with asymmetry of information. One of these entities is called the Principal and it proposes to the other, called the Agent, some incentives to impact the value of its firm through its effort. Basically, an employer (the Principal) aims at hiring an employee (the Agent) by giving him a salary (the incentive) to manage a risky project. The main difficulty for the Principal comes from the fact that it only observes the value of its firm managed by its Agent and does not control its effort. This kind of situation coincides exactly with a moral hazard problem in which the Principal has to design a hiring contract given to the Agent in order to maximize its utility without observing directly its work. We can identify this paradigm with a Stackelberg equilibrium that can be solved in two steps. First we solve the problem of the Agent who provides a best reaction effort given a contract provided by the Principal. This utility maximization problem, seen as an optimization problem, can be reduced to solve a particular class of stochastic differential equations such that solutions fully characterize the optimal effort and the value of the problem of the Agent. Then, taking into account the best reaction of the Agent, the Principal solves its problem, which coincides with a stochastic control problem. We then extend this model to N-interacting Agents hired by one Principal and we finally focus on a model dealing with mean-field interactions between many Agents by solving explicit examples.

HYDROïD - Integrated hydraulic actuation technology for humanoid robotic applications – *Challenge Exo*

Samer Al Fayad, associate professor at UVSQ – LISV
http://www.sameralfayad.net

HYDROïD (HYDraulic andROïD) is a full-size humanoid robot, currently under development to contribute to improving our understanding of human locomotion and manipulation. Humanoids with hydraulic actuation are able to achieve hard and useful tasks and replace human in a disaster environment.

In hydraulic actuation, pistons are used to produce motion. At least one hydraulic piston is implemented for each degree of freedom (DoF). The main difficulty lies in the way to bring hydraulic energy to each piston. Hydraulic pipes are usually employed to drive hydraulic power from the control unit to pistons. Each piston needs two pipes, one to drive fluid “in” and the other to drive it "out". In robotic applications, flexible hydraulic pipes are used to drive the oil in parallel to the joints. This solution suffers from three main disadvantages: i) the hydraulic pipes connected in parallel to joints lead to a spring effect that complicates control design; ii) an increased number of pipes leads to an increased leakage probability; and iii) external pipes increase dramatically the robot size and decrease its anthropomorphic aspects.

To overpass these limitations, a new "integrated hydraulic actuation" method was proposed and implemented on HYDROïD. The goal is to eliminate all external pipes and replace them with integrated hydraulic passages. Fluid paths are integrated internally (through the mechanical structure) rather than externally (through pipes). In other words, "arteries" and "veins" were built inside the HYDROïD body to drive hydraulic fluid like blood in human body.

This presentation will focus on two research areas. First, we present two innovative hybrid mechanisms, each consisting of a rotating actuator carrying a parallel structure with two active DoF. The first type has been dedicated to the modules of the hip, shoulder, and torso. The second type, actuation of parallel structure with cables, was chosen for the ankle, wrist, and neck modules. The second part of the presentation will be dedicated to the actuation of the HYDROïD robot for which a new highly integrated actuator has been proposed. The actuation principle will be detailed and the benefits of the proposed solution will be shown. Very interesting performance of the realized prototype will be presented.

Control of spatio-temporal brain oscillations: recent results and perspectives – *Challenge Neuro*

Antoine Chaillet, professor at CentraleSupélec – L2S, junior member of IUF
https://sites.google.com/site/antoinechaillet/home

Several neurologic disorders are related to pathological brain oscillations. In the case of Parkinson's disease, sustained low-frequency oscillations (especially in the beta-band, 13–30Hz) correlate with motor symptoms. Among the hypotheses to explain the generation of such pathological oscillations, one is the possible pacemaker role played by two feedback-interconnected neuronal populations, one inhibitory and one excitatory. In this scenario, the abnormal increase of synaptic weights between these two populations, combined with the inherent transmission delays, gives rise to sustained oscillations.

In this talk, we rely on a spatiotemporal model of the neuronal populations involved to show that a simple proportional feedback on the excitatory population is enough to attenuate pathological oscillations, provided that the internal synaptic weights within the inhibitory population are sufficiently low. The model used is a delayed nonlinear integro-differential equation known as delayed neural field. Delays are allowed to be position-dependent in order to model longer transmission delays between more distant neurons.

In order to analyze such neuronal populations networks, we extend stability and robustness tools to spatiotemporal delayed dynamics. We provide conditions under which each population is input-to-state stable (ISS) with respect to the inputs coming from the other population. Extending small-gain theorems to spatio-temporal delayed dynamics, we show that proportional feedback successfully suppresses pathological oscillations in the network, provided that the internal coupling inside the inhibitory population is not too strong. The use of ISS allows in turn to evaluate the robustness of the proposed feedback with respect to imperfect actuation and control delays, and to attenuate oscillations using a spatially-uniform stimulation signal.

We finally provide possible research directions in control theory for the real-time steering of brain oscillations in health and disease, which advocate a closer interaction between control theoreticians and neuroscience practitioners.