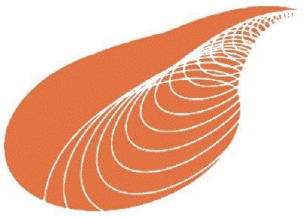
IAP VII/19 DYSCO

Dynamical systems control and optimization

Study Day

May 19th, 2016
Ibis Styles Conference Center
Louvain-la-Neuve



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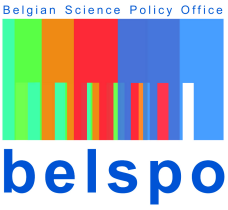


Belgian
Science Policy

Université catholique
de Louvain

Time Schedule, Thursday 19 May 2016

08:30 Registration and welcome coffee

09:50 Opening remarks

10:00 Plenary lecture 1

Reciprocity, Passivity and Optimal Control
Prof. Malcolm SMITH, University of Cambridge, UK

11:00 Speed dating session

12:00 - 14:00 Lunch with dessert and coffee

14:00 Parallel sessions

Optimization

1. Annick Sartenaer (UNamur), Getting some insight on the interaction between the blocks (Hessian vs constraints) in KKT systems arising in constrained optimization
2. François Glineur (UCL), Performance estimation of first-order methods for (composite) convex optimization
3. Quentin Louveaux (ULiège), Load flexibility in electrical networks: a game-theoretic approach

Identification and Machine Learning

1. Michel Verhaegen (TUDelft), Machine Learning and Identification for Smart Optics Systems
2. Francesco Ferranti and Yves Rolain (VUB), Who needs to identify a flexible, adaptive, multi-purpose parameter-varying model?
3. Pierre Geurts (ULiège), Random forests variable importances: application to gene regulatory network inference

Modeling and Control

1. Erik Ydstie (Carnegie Mellon University), Reinforcement learning from the perspective of dual control: the value of exploration.
2. Ilse Smets (KULeuven), From experiments to models ... and back: a case-study in wastewater treatment processes
3. Frédéric Crèvecoeur (UCL), Neural mechanisms underlying fast feedback control during postural control and reaching

15:30 Coffee

16:00 Plenary lecture 2

Network Inference : from Theory to Applications in Biology
Prof. Jorge GONCALVES, University of Luxemburg

17:00 Drink

Practical Information

Ibis Styles Meeting Center Louvain la Neuve

The 3-star ibis Styles Hotel and Meeting Center Louvain-la-Neuve is situated in a peaceful oasis of greenery on the edge of the Lauzelle woods, barely 0.6 miles (1 km) from the town center and the Catholic University of Louvain. The hotel has 80 fully-renovated rooms, a restaurant-bar with à la carte menu, and 18 meeting rooms which can accommodate up to 250 people for your professional and private events.

The address is : 61 Boulevard de Lauzelle, 1348 Louvain-la-Neuve.

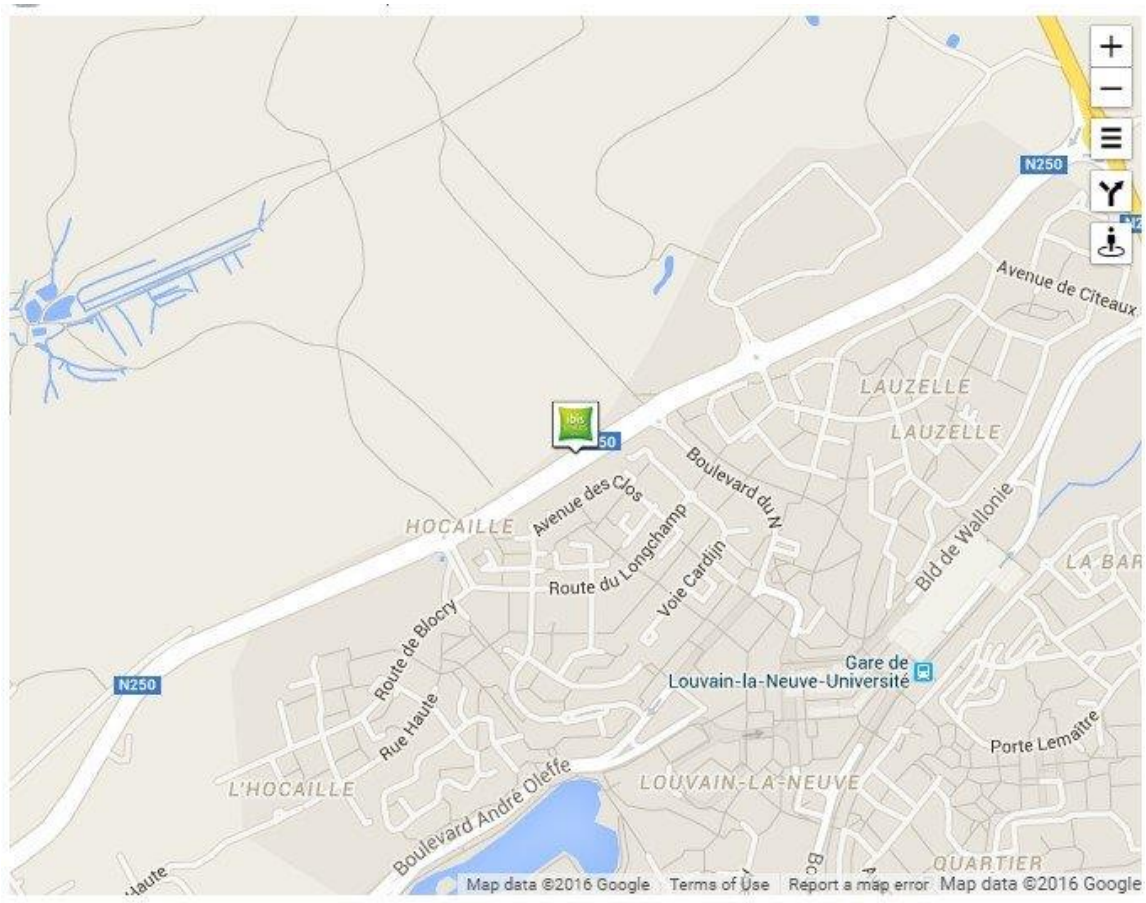
Access to the hotel and center by car

IBIS STYLES LOUVAIN LA NEUVE : Arriving from Brussels, take the E411 toward Namur, take exit 7, turn right onto the N4, go straight over the 1st roundabout, go right at the 2nd roundabout and the hotel is 219 yds (200 m) after the next roundabout. Arriving from Luxembourg, Namur, take the E411, take exit 8a, go right at the roundabout, at the next roundabout turn left and the hotel is 219 yds (200 m) after the next roundabout.

and by public transport

Bus line 1 and 20, station LAUZELLE.

The railway station of Louvain-la-Neuve is at 1 km walking (0.62 miles).



Plenary Lectures

Reciprocity, Passivity and Optimal Control

Malcolm SMITH, University of Cambridge, United Kingdom

Abstract

The talk will explore the classical notion of reciprocity in physics and network theory. Standard proofs of the reciprocity property in electrical circuits will be explained. The recent treatment of Jan Willems will be highlighted. The analogous property for mechanical networks will be described. The consequences of reciprocity in the ride-handling compromise for passive vehicle suspensions will be outlined. The talk then considers a nonlinear optimal control problem arising in semi-active vehicle suspensions in which the ride-handling compromise is modelled with stochastic disturbance inputs for ride performance and deterministic disturbances for handling inputs. Experimental results implemented on a high-performance sports car using the proposed approach will be presented. The talk will conclude with some remarks on reciprocity in relation to this application.

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Network Inference : from Theory to Applications in Biology

Jorge GONCALVES, University of Luxemburg

Abstract

A major goal of biological sciences is the identification of regions in genetic networks that underpin responses to stimuli, with the potential to identify drug targets or differences between cell types. This talk will describe recent developments, both from theoretical and application point of view, for the identification of dynamical biological networks. Theoretically, it gives conditions for network identifiability of networks with deterministic or stochastic inputs. For identification, it considers recent developments of efficient algorithms that impose sparsity constraints on the network and model complexity. Then, the talk describes the application of control systems tools, such as system identification and the gap metric, to improve our understanding of circadian clocks in Arabidopsis thaliana. In particular, this work is interested in explaining alterations in circadian clock period in the toc1-1 mutant and in response to the drug nicotinamide. Finally, the talk discusses the gap between theory and application and some of the theoretical challenges in biology.

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Parallel sessions

Optimization

Room A, 14:00 to 15:30

Getting some insight on the interaction between the blocks (Hessian vs constraints) in KKT systems arising in constrained optimization

Annick Sartenaer, University of Namur

Abstract

We consider (possibly large and sparse) saddle-point linear systems of the form

$$\mathcal{A}x = b \equiv \begin{bmatrix} A & B \\ B^T & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} f \\ g \end{bmatrix},$$

where $A \in \mathbb{R}^{n\times n}$ and $B \in \mathbb{R}^{n\times m}$, with $n \geq m$. We assume that A is symmetric and positive definite and that B has full column rank. Such kind of systems typically arise in constrained nonlinear continuous optimization, as the result for first-order optimality conditions, where $\mathcal{A}$ is known as the Karush-Kuhn-Tucker (KKT) matrix. The assumption of positive-definiteness of A is met, in particular, when solving strictly convex quadratic optimization problems.

Efficiently solving systems $\mathcal{A}x = b$ using iterative solvers is thus a crucial task for many algorithms in constrained optimization. Such systems can be very ill-conditioned, in particular when the (1,1) block A has few very small eigenvalues, see [1]. However, it is commonly observed that despite this possible ill-conditioning, some sort of interaction between the Hessian block A and the constraints block B^T actually occurs, that can either spoil the convergence of Krylov subspace methods like MINRES, or not at all. In this talk, we highlight some aspects of this interaction and give deeper insights on how and in which circumstances the bad conditioning contained in these few very small eigenvalues of the (1,1) block A effectively spoils the convergence of MINRES. Our study is based on theoretical arguments and supported by numerical illustrations.

This is joint work with Daniel Ruiz and Charlotte Tannier from the Université de Namur.

Reference [1] T. Rusten and R. Winther, *A preconditioned iterative method for saddle-point problems*, SIAM Journal on Matrix Analysis and Applications, 13(3) (1992), pp. 887–904.

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Performance estimation of first-order methods for (composite) convex optimization

François Glineur, Université catholique de Louvain

Abstract

Composite convex optimization consists in the minimization over a given convex feasible region of a convex objective function equal to the sum of a smooth term and a nonsmooth term. We show that the exact worst-case performance of fixed-step first-order methods solving composite convex optimization can be computed by solving a semidefinite optimization problem. We consider a relatively large class of black-box methods designed to solve such problems (in general or for particular cases), for which the computation of the next step can combine the output of several oracles, such as:

- computation of the gradient (for the smooth part of the objective)
- computation of a projection on the feasible region

- computation of a proximal step (for the nonsmooth part of the objective)
- computation of a Frank-Wolfe-type step (linear minimization oracle)

This class of fixed-steps methods includes a large number of classical first-order methods found in the literature.

Finding the worst-case performance of such a black-box first-order method is formulated as an optimization problem over a set of smooth and/or nonsmooth convex functions (possibly with an additional strong convexity property). Using a recently derived set of closed-form necessary and sufficient interpolation conditions, we reformulate the worst-case performance estimation problem as a finite dimension-independent semidefinite optimization problem, whose exact solution can be recovered up to numerical precision. Optimal solutions to this performance estimation problem provide both worst-case performance bounds and explicit functions matching them.

We apply our approach to different fixed-step first-order methods with several performance criteria, including objective function accuracy and residual gradient norm. We test our approach to compute the worst-case performance of the gradient method, fast gradient method, optimized gradient method, subgradient method, proximal point algorithm, fast proximal gradient, conditional gradient and alternate projection methods. We also conjecture several numerically supported worst-case bounds.

This is joint work with Adrien B. Taylor and Julien M. Hendrickx, Université catholique de Louvain

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Load Flexibility in Electrical Networks: a Game-theoretic Approach

Quentin Louveaux, Université de Liège

Abstract

This talk studies the impact of load flexibility on the day-ahead energy market. Electricity retailers are assumed to control their flexible consumption in order to minimize their own energy costs. Shifting their consumption from one hour of the day to another influences the corresponding market prices and consequently their costs. The total cost for all retailers may be far from the system optimum that would be obtained if only one actor would control the whole flexible demand. The purpose of the talk is to evaluate the implications of having multiple retailers gaming on the market to optimize their own costs. To this end, the previous problem is assimilated to an atomic splittable flow congestion game with players sending flow in arcs linking a unique source and destination. Some concepts of the game theory literature are therefore directly applicable to this case. We also provide new contributions for games with affine cost functions. We focus on laminar Nash equilibria where the constraints on the minimum and maximal flow that a player must send in a given arc are not binding. We show that the flow sent by a player at a laminar Nash equilibrium does not depend on the demand of other players. In laminar flow, we bound the price of anarchy and the ratio between the maximum and the minimum arc cost. Finally, we propose a simple method based on the property of a laminar Nash equilibrium to compute the price of flexibility, i.e. the price at which energy flexibility should be remunerated in electrical power systems.

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Identification and Machine Learning

Room B, 14:00 to 15:30

Machine Learning and Identification for Smart Optics Systems

Michel Verhaegen, Technische Universiteit Delft

Abstract

The presentation introduces control engineers to two challenging research areas where the integration of sensor technology and control methodologies can make a contribution in improving the resolution of an imaging system. The first is modeling the spatial-temporal dynamics of the wavefront aberrations making use of a (linear) Shack-Hartmann pupil plane wavefront sensor. The challenges here are the identification of the linear time-varying dynamics and this in a big data context. The big data context is a consequence of the large number of sensors and the high sampling ratio planned to be used on future extreme large telescopes. The second is the modeling and the optimization of the image quality metric using focal plane imaging sensors. Here the challenge is the modeling, estimation and optimization of a time-varying static non-linearity. The societal relevance to make contributions in both areas is vast ranging from health and life sciences to astronomy and mobile communication.

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Who needs to Identify a Flexible, Adaptive, Multi-purpose Parameter-varying Model?

Francesco Ferranti and Yves Rolain, Vrije Universiteit Brussel

Abstract

Model building is often a complex and time-consuming task for someone who is not an identification expert. This is especially true if the system behavior depends on a number of system parameters, as it is the case in a design context (e.g., layout parameters). In this talk, we discuss interpolation-based parameter-varying models for design purposes. We will introduce the model class first and show that these models can be extracted relatively easily and with a reduced user interaction. We will discuss the importance of guaranteeing properties of the interpolation-based models, such as stability and passivity. We will show that it is possible to obtain such property-preserving parameter-varying-models. Next, we will illustrate the power of the modeling framework by giving some application examples. The applicability in design is first shown for microwave filters. Finally, we will discuss the application of the models for the electro-thermal design of electronic components.

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Random forests variable importances: application to gene regulatory network inference

Pierre Geurts, Université de Liège

Abstract

Random forests are among the most popular supervised machine learning methods. They provide a unique combination of competitive accuracy, reasonable computing costs, and ease of use that makes them a major data analysis tool with successful applications in various scientific areas. One of their most practically useful features is the possibility to derive from the ensemble of trees an importance score for each variable that assesses its relevance for predicting the output. Two main

importance measures have been proposed in the literature: the mean decrease of impurity (MDI) importance and the permutation importance. These measures have been successfully applied on many problems, notably in bioinformatics, but they are still not well understood from a theoretical point of view. In this talk, I will first present our ongoing effort towards a better understanding of these measures. Our main contributions in this domain include a theoretical analysis of the MDI measure in asymptotic sample and ensemble size conditions and the derivation of an efficient algorithm for identifying the most important variables in high-dimensional settings. I will then discuss the application of these measures in the context of the GENIE3 method for the inference of gene regulatory networks from both steady-state and time series expression data.

This is joint work with Vân Anh Huynh-Thu, Gilles Louppe, Antonio Sutera, and Louis Wehenkel from the Université de Liège.

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Modeling and Control

Room C, 14:00 to 15:30

Reinforcement learning from the perspective of dual control: the value of exploration

Erik Ydstie, Carnegie Mellon University, U.S.A.

Abstract

An adaptive optimal control algorithm for systems with uncertain dynamics is formulated under a Reinforcement Learning framework. An embedded exploratory component is included explicitly in the objective function of an output feedback receding horizon Model Predictive Control problem. The optimization is formulated as a Quadratically Constrained Quadratic Program and it is solved to ϵ-global optimality. The iterative interaction between the action specified by the optimal solution and the approximation of cost functions balances the exploitation of current knowledge and the need for exploration. The proposed method is shown to converge to the optimal policy for a controllable discrete time linear plant with unknown output parameters.

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From experiments to models ... and back: a case-study in wastewater treatment processes

Ilse Smets, Katholieke Universiteit Leuven

Abstract

This presentation highlights a case-study on how an iterative loop between experimental work and modeling is required to advance the knowledge in biological conversion processes. The focus will be on membrane bioreactors in which a mix of micro-organisms (i.e., the activated sludge) degrades the polluting components in the wastewater and in which a membrane achieves the separation of that activated sludge from the purified water, which can then be discharged to the receiving water bodies. The main bottleneck of this technology remains membrane fouling. This fouling is predominantly influenced by the activated sludge characteristics which are dictated by the influent and operational characteristics. Question is then: which activated sludge characteristics are of importance and how to influence them? Through a cycle of lab- and pilot scale experiments and full scale sampling campaigns, the most significant activated sludge characteristics are inferred on the basis PCA and PLS models. On the basis of some of these characteristics, being the particle size distribution and the polymeric content of the activated sludge, a 3D model that is able to predict and visualize the membrane fouling cake layer is developed.

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Neural mechanisms underlying fast feedback control during postural control and reaching

Frédéric Crèvecoeur, Université catholique de Louvain

Abstract

Understanding how the brain controls movements is a major challenge for fundamental and clinical research. Indeed, we perform a wide range of complex motor tasks, from a mundane reaching movement to grab a tool to the skillful performance of athletes or musicians, without even thinking about the complexity of the underlying sensorimotor processes. Strikingly, we know very little about how sensory signals are transformed into purposeful motor commands. Here I

will present how principles of systems theory can provide insight into how the nervous system performs such sensorimotor transformations. Recent studies have consistently highlighted that the brain continuously monitors sensory feedback and adjust ongoing motor actions according to task demands, a process well captured in optimal feedback control models. An important question is how quickly does the information flow from sensory organs following changes in the environment to the generation of the motor response. In a series of experiments, we found that flexible motor responses to external disturbances were typically expressed within 60ms. These observations have fundamental implication, as this delay is in the same range as the temporal delay induced by conduction velocity of neural signals along the nerves. In other words, the rapid sensorimotor processing engaged following a perturbation must account for the temporal delay in the neural feedback loop. I will present data supporting the hypotheses that rapid feedback control accounts for sensorimotor delays and show how this hypothesis has shed light on the time course of flexible control, rapid decision-making, and multisensory integration.

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List of participants

UCL
Absil Pierre-Antoine
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Athanasopoulos Nikos
Barrea Allan
Chevalier Pierre-Yves
Cordova David
Crevecoeur Frédéric
Delvenne Jean-Charles
Deravet Nicolas
Dochain Denis
Genicot Matthieu
Gevers Michel
Glineur François
Gonze François
Gousenbourger Pierre-Yves
Gusev Vladimir
Gutierrez Leonardo
Hajizadeh Roghayeh
Hendrickx Julien
Huang Wen
Joveneau Marie-Christine
Kande Moctar
Lefèvre Philippe
Massart Estelle
Peel Leto
Philippe Matthew
Ponet Nathalie
Renard Emilie
Rocher Luc
Romo Hernández Aarón
Salmen Florian
Samir Chafik
Simonetto Andrea
Smpoukis Konstantinos
Stich Sebastian
Taylor Adrien
Van Dooren Paul
Vincent Benjamin
Vital Jacome Miguel Angel

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Dumon Korneel
Fanuel Michael
Fenzi Luca
Ferandez Angela
Karevan Zahra
Lauwers Oliver
Mao Xian
Meerbergen Karl
Michiels Wim
Piampongsant Supinya
Pilbauer Dan
Pipeleers Goele
Robee Pieterjan
Roose Dirk
Smets Ilse
Suykens Johan
Tong Duy Son
Van Craen Robin
Vandewalle Stefan

UGent
Apers Simon
de Cooman Gert
Farnam Arash
Sarlette Alain
Van Camp Arthur

VUB
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Ferranti Francisco
Hollander Gabriel
Ishteva Mariya
Marconato Ann
Peumans Dries
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Louveaux Quentin
Sootla Aivar
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Dewasme Laurent
Fernandes Sofia
Grimard Jonathan
Monroy Isaac
Sbarciog Mihaela
Vande Wouwer Alain

UNamur
Buhendwa Nyenyezi Justin
Crelot Anne-Sophie
Dehaye Jonathan
Lambiotte Renaud
Lamoline François
Libert Anne-Sophie
Nicolay Delphine
Salnikov Vsevolod
Sartenaer Annick
Tannier Charlotte
Themans Pauline
Winkin Joseph

Guest Speakers
Goncalves Jorge (University of Luxemburg)
Smith Malcolm (University of Cambridge)
Verhaegen Michel (TUDelft)
Ydstie Erik B. (Carnegie Mellon University)