19th French-German-Swiss conference on Optimization

17-20 September 2019, Nice (France)

ABSTRACTS

Dear Conference Participants,

Welcome to the 19th French-German-Swiss Conference on Optimization taking place at Université Côte d'Azur in Nice with the support of Laboratoire J. A. Dieudonné (CNRS), Laboratoire d'Informatique, Signaux et Systmes de Sophia Antipolis (CNRS), and Inria Sophia Antipolis. We hope that the conference will provide a platform for interchanging ideas, research results and experiences for an international community, actively interested in optimization.

The optimization conference is one of a series with a long and distinguished history which started in Oberwolfach in 1980. Since 1998 the conference has been organized with the participation of a third European country, and this year the conference takes place in France for the 8th time. The aim of the conference is to provide a forum for theoreticians and practitioners from academia and industry to exchange knowledge, ideas and results in a broad range of topics relevant to the theory and practice of optimization methods, models, software and applications in engineering, finance and management. This year, a selection of peer reviewed papers will be published in full open access by *ESAIM: Proceedings and Surveys*. Further details are available on the conference website.

We would like to thank all persons who helped to organize this conference. We are indebted to the organizers of the invited sessions, to the members of the Scientific Committee, to the reviewers as well as to Jean-Baptiste Hiriart-Urruty and Helmut Maurer, both founding members of the series. We would also like to thank our sponsors: Université Côte d'Azur, CNRS, Inria, SMAI-MODE, PGMO, GdR MOA, GdR Jeux, ED SFA, Ville de Nice, Région Sud Provence-Alpes-Côte d'Azur.

We hope you enjoy the conference and wish you a pleasant stay in Nice.

With our compliments,

Didier Auroux (chair)

Jean-Baptiste Caillau (chair)

Régis Duvigneau

Abderrahmane Habbal

Christine Malot

Olivier Pantz

Luc Pronzato

Ludovic Rifford

Roland Ruelle

Chiara Soresi

FGS'2019

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09:30		CS3	CS6	CS9
10:00				
10:30		Coffee break	Coffee break	Coffee break
11:00				
11:30		P3, P4	P7, P8	P11, P12
12:00				
12:30				
13:00	Opening	Lunch	Lunch	Lunch & closing
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14:00				
14:30	P1, P2	P5, P6	P9, P10	
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16:00				
16:30	MS1 / MS2	MS6 / MS7	MS11 / MS12	
17:00	CS1 / CS2	CS4 / CS5	CS7 / CS8	
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P3	Global Optimization methods for Mixed Integer Non Linear Programs with Separable Non Convexities	d'Ambrosio Claudia
P4	Analyzing Network Robustness via Interdiction Problems	Zenklusen Rico
P5	Representability of Optimization Models	Basu Amitabh
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P7	Multilevel Optimization and Non-linear Preconditioning	Krause Rolf
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P9	Optimal Control of Regularized Fracture Propagation Problems	Neitzel Ira
P10	Resilient and Efficient Layout of Water Distribution Networks	Pfetsch Marc
P11	Conditional Gradient Algorithms for Constraint Smooth Convex Minimization	Pokutta Sebastian
P12	Generalized Nash Games with PDEs and Applications in Energy Markets	Hintermüller Michael

	Title	Organizers
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MS2	Singular perturbations and turnpike in optimal control problems	Gergaud Joseph
MS3	Recent trends in nonlinear optimization 2	Goettlich Simone, Walther Andrea
MS4	Optimization and optimal control for biological models	Gouzé Jean-Luc
MS5	Nonlinear optimization methods and their global rates of convergence	Grapiglia Geovani
MS6	Game theory approaches in inverse problems and control	Habbal Abderrahmane, Borzi Alfio
MS7	Mean field games: new trends and applications	Tonon Daniela, Silva Francisco
MS8	Discrete optimization and game theory	Meunier Frédéric
MS9	Kernel methods in Bayesian optimisation and integration	Pronzato Luc, Da Veiga Sébastien
MS10	Non-smooth optimization: theory and applications 1	Noll Dominikus, Walther Andrea
MS11	Continuous optimization techniques for image processing applications	Rebegoldi Simone, Morotti Elena
MS12	Optimal control methods and applications 1	Maurer Helmut, Pickenhain Sabine
MS13	Optimization with PDE constraints	Ulbrich Michael
MS14	Optimal control methods and applications 2	Maurer Helmut, Pickenhain Sabine
MS15	Non-smooth optimization: theory and applications 2	Noll Dominikus, Walther Andrea

	Title
CS1	Optimization 1
CS2	Control 1
CS3	Optimization 2
CS4	Optimization 3
CS5	Learning
CS6	Optimization 4
CS7	Optimization 5
CS8	Games
CS9	Control 2

Venue

The conference venue is in the Parc Valrose in North-central Nice. Plenary talks, coffee breaks, lunches and the conference dinner will take place in the Grand Chateau that host the Theater. Parallel sessions will be splitted between three neighbouring builidings: LJAD (Laboratoire Jean-Alexandre Dieudonné, either in the conference room or in room LJAD II), Fizeau building, and IBV (Institut of Biology of Valrose). The cocktail will take place at LJAD.

A: Grand château (Theater), K: Fizeau, W: LJAD (and LJAD II), N: IBV

Accommodation

There are many hotels and rooms for rent in Nice. It is advise to book your hotel as soon as possible. We recommend a choice of accommodation near the Parc Valrose or near the TRAM LINE 1. You can find a list of nearby hotels often used by the local academic community here. However, the list is far from being complete, feel free to explore the available options by yourself.

Contact fgs-2019@sciencesconf.org

Previous conferences in this series

18th French-German-Italian Conference on Optimization, 2017, Paderborn, Germany

17th British-French-German Conference on Optimization, 2015, London, UK

16th French-German-Polish Conference on Optimization, 2013, Kraków, Poland

15th Austrian-French-German Conference on Optimization, 2011, Toulouse, France

14th Belgian-French-German Conference on Optimization, 2009, Leuven, Belgium

13th Czech-French-German Conference on Optimization, 2007, Heidelberg, Germany

12th French-German-Spanish Conference on Optimization, 2004, Avignon, France

11th French-German-Polish Conference on Optimization, 2002, Cottbus, Germany

10th French-German-Italian Conference on Optimization, 2000, Montpellier, France

9th Belgian-French-German Conference on Optimization, 1998, Namur, Belgium

8th French-German Conference on Optimization, 1996, Trier, Germany

7th French-German Conference on Optimization, 1994, Dijon, France

6th French-German Conference on Optimization, 1991, Lambrecht, Germany

5th French-German Conference on Optimization, 1988, Varetz, France

4th French-German Conference on Optimization, 1986, Irsee, Germany

3rd French-German Conference on Optimization, 1984, Luminy, France

Optimization: Theory and Algorithms, 1981, Confolant, France

Optimization and Optimal Control, 1980, Oberwolfach, Germany

Organizing Committee

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Plenary Talks

Tuesday, Sept. 17, 14:00-14:45 (Theater)

Second Order Variational Analysis in Optimal Control

H. Frankowska[1]

Optimal control framework is a convenient setting arising in various models of applied sciences. Though the theory started in late forties with a notable progress made in late fifties and sixties, followed by various developments and applications both by engineers and mathematicians, the natural presence of nonsmoothness and set-valued character of data and/or solutions creates continuously new mathematically challenging problems and approaches.

In this talk I will discuss the recent advances in optimality conditions of second order. This topic, beside being of interest *per se*, is important even for getting the first order necessary conditions in stochastic optimal control. Our approach relies strongly on tools of convex analysis and differential inclusions, rather than mathematical programming. This allows to avoid structural assumptions on optimal controls and control constraints and leads to a unified approach to both deterministic and stochastic control systems and also to some controlled PDEs.

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[1]CNRS and Sorbonne Université, Institut de Mathématiques de Jussieu - Paris Rive Gauche

Tuesday, Sept. 17, 14:45-15:30 (Theater)

Waveform Inversion from Ultrasound to Global Scale

C. Boehm[1]

The propagation of waves is the physical phenomenon used most widely to study the internal structure of media that are not accessible to direct observation. Most of our knowledge about the Earth's interior is based on seismic waves that are excited by earthquakes or explosions, and which provide illumination down to thousands of kilometers depth. Similarly, in medical imaging ultrasonic waves emitted by piezoelectric transducers can be used to illuminate human tissue and to reconstruct high-resolution images.

Despite the vastly different scale, seismic and medical imaging share remarkable similarities from a mathematical perspective. Both applications yield to PDE-constrained optimization problems governed by a time-dependent wave equation that infer unknown material properties or external forces from sparse observations.

In this presentation, we will review the underlying theoretical framework and address several computational challenges, such as (1) waveform modeling using the spectral-element method, (2) stochastic quasi-Newton methods that process datasets in batches, (3) smoothing operators based on an anisotropic diffusion equation, and (4) anisotropic refinement techniques to generate unstructured conforming hexahedral meshes that adapt to the local wavelengths and azimuthal complexity of the wavefield.

This is illustrated with several numerical examples and real data applications ranging from breast cancer detection with ultrasound to planetary seismic tomography.

[1]Department of Earth Sciences, ETH Zurich

Wednesday, Sept. 18, 11:00-11:45 (Theater)

Global Optimization methods for Mixed Integer Non Linear Programs with Separable Non Convexities

C. D'Ambrosio[1]

In this talk, we focus on mixed integer non linear programming (MINLP) problems with non convexities that can be formulated as sums of univariate functions. D'Ambrosio et al. [1, 2] proposed a method called Sequential Convex MINLP (SC-MINLP), an iterative algorithm based on lower and upper bounds obtained by solving a convex MINLP and a non convex non linear program, respectively. The method aims at finding a global solution of the tackled MINLP and exploits the fact that the convex or concave parts of univariate functions can be identified numerically.

The weaknesses of the original version of the SC-MINLP method are mainly two: on the one hand, solving several (one per iteration) convex MINLPs is time-consuming; on the other hand, at each iteration, the convex MINLP is modified to improve the lower bound and no information about the previous convex MINLP and its optimal solution is exploited. These two weaknesses are addressed in the recent works [3] and [4]. In the former, a strengthening of the convex MINLP relaxation is proposed based on perspective reformulation. In the latter, a disjunctive programming approach was explored to better approximate the concave parts of each univariate function. Extensive computational experiments show a significant speedup of the original SC-MINLP method.

References

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[1] LIX, CNRS & École Polytechnique

Wednesday, Sept. 18, 11:45-12:30 (Theater)

Analyzing Network Robustness via Interdiction Problems

R. Zenklusen[1]

How susceptible is a network to failures of some of its components? What are the weakest spots of a networked system? These questions lie at the heart of interdiction problems, which seek to determine the maximum impact that the failure/removal of a limited number of edges/vertices can have on the performability of a network. Interdiction problems are a natural way to measure robustness. Furthermore, they give valuable insights in how to best improve the failure resilience of a system, and sometimes, how to best attack it.

In this talk, I will first provide a general introduction to interdiction problems, showing some of their varied, and sometimes surprising, applications. I will then discuss, on specific examples, optimization techniques that allow for approaching a variety of interdiction problems.

[1]ETH Zurich

Wednesday, Sept. 18, 14:00-14:45 (Theater)

Representability of Optimization Models

A. Basu[1]

The use of any optimization model (such as mixed-integer linear programming or complementarity problems) to solve a real world problem makes the implicit assumption that the salient features of the problem can be modeled using feasible regions of the optimization paradigm used. Thus, for any optimization framework, it is important to understand precisely what kind of sets can be expressed as feasible regions of this optimization paradigm. This is known as the *representability question* in the optimization literature. We will survey classical results on mixed-integer optimization representability and then present some recent results obtained by us on bilevel optimization. The second part of the talk is based on joint work with S. Sriram and C. T. Ryan.

[1]Department of Applied Mathematics and Statistics, Johns Hopkins University, USA

Wednesday, Sept. 18, 14:45-15:30 (Theater)

A Survey of Generalized Gauss Newton and Sequential Convex Programming Methods

M. Diehl[1]

This overview talk regards a large class of Newton-type algorithms for nonlinear optimization that exploit convex-over-nonlinear substructures. All of the considered algorithms are generalizations of the Gauss-Newton method, and all of them sequentially solve convex optimization problems that are based on linearizations of the nonlinear problem functions. Though nearly all of them show linear local convergence – an unavoidable property, cf. [3] – they are widely used. Because they are popular in different communities, no generally established terminology exists to date. We attempt to classify them into two major classes, one of which might be denoted by "Generalized Gauss-Newton (GGN)", and the other by "Sequential Convex Programming (SCP)" (dating back to as early as 1961 [5] in its "Sequential Linear Programming" variant). Aim of this survey talk is an attempt to present and classify all algorithms from this class, investigate and compare their local convergence properties [7, 4], and to report on some applications in estimation [1], learning [6], and control [2].

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[1]Systems Control and Optimization Laboratory, Department of Microsystems Engineering and Department of Mathematics, University of Freiburg, Georges-Koehler-Allee 102, 79110 Freiburg, Germany

Thursday, Sept. 19, 11:00-11:45 (Theater)

Multilevel Optimization and Non-linear Preconditioning

R. Krause[1], A. Kopaničáková[2]

Multilevel decompositions are the basic ingredient of the most efficient class of solution methods for linear systems - multigrid methods, which allow to solve certain classes of linear systems with optimal complexity. Originally developed for the iterative solution of symmetric positive definite linear system, multigrid methods have been applied also to constrained and unconstrained convex minimization problems. Here, the key idea is to exploit the underlying multilevel decomposition for multilevel minimization.

In this talk, we will discuss the main ideas of multilevel optimization techniques and their relation to classical multigrid theory. We will discuss how multilevel optimization methods for convex and non-convex minimization problems can be constructed and analyzed. We will study the sometimes significant gain in performance, which can be achieved by multilevel minimization techniques. Numerical examples from contact mechanics and non-linear elasticity will illustrate our findings.

As it turns out, multilevel optimization techniques are also intimately linked to non-linear preconditioning, a relation which we will discuss at the end of the talk.

References

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Thursday, Sept. 19, 11:45-12:30 (Theater)

Nonsmoothness Can Help: Sensitivity Analysis and Acceleration of Proximal Algorithms

J. Malick[1]

Nonsmoothness pervades optimization, but the way it typically arises is highly structured. In this talk, we discuss why this structure brings special properties to optimal solutions and how it can be leveraged in practice. We first observe that, for many nonsmooth optimization problems in machine learning and signal processing, optimal solutions are trapped in low-dimensional smooth "active" manifolds: solutions are located on this manifold and do not move out of it, under small perturbations of the objective function. We show that this stability can be leveraged to obtain desirable properties, including (i) model consistency results in machine learning, and (ii) automatic dimension reduction for proximal-gradient algorithms. This situation is a nice illustration of the interplay between the notions of optimality, identifiability, and sensitivity.

[1]CNRS, Lab. Jean Kuntzmann, Grenoble

Thursday, Sept. 19, 14:00-14:45 (Theater)

Optimal Control of Regularized Fracture Propagation Problems

I. Neitzel[1], T. Wick[2], W. Wollner[3]

We consider an optimal control problem governed by a phase-field fracture model. One challenge of this model problem is a non-differentiable irreversibility condition on the fracture growth, which we relax using a penalization approach. While the penalization ensures sufficient differentiability properties, we need to discuss boundedness of the solutions in order to ensure well-definedness of the problem formulation. Thisis not a priori clear after removing pointwise bounds. Once this has been established, we discuss existence of solutions and first order optimality conditions. Finally, we are interested in the convergence behavior when sending the regularization parameter to the limit, and also the constraint violation for a given regularization parameter. More details can be found in [1, 2] and the references therein.

References

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[1]Rheinische Friedrich-Wilhelms-Universität Bonn
[2]Leibniz Universität Hannover
[3]Technische Universität Darmstadt

Thursday, Sept. 19, 14:45-15:30 (Theater)

Resilient and Efficient Layout of Water Distribution Networks

M. Pfetsch[1], A. Schmitt[2]

This talks considers the optimal design of resilient distribution networks on the example of water distribution networks, e.g., for water supply in high-rise buildings. These systems should be efficient both in terms of fixed cost as well as operation cost. We consider cost optimal decentralized and tree-shaped water distribution networks, where placements of pumps at different locations are allowed. A specialized branch-and-bound algorithm for solving the corresponding mixed-integer nonlinear program is presented, which exploits problem specific structure and outperforms state-of-the-art solvers.

Moreover, we try to make the systems resilient. In our case, they should still able to operate under K pump failures during the use phase. Using a characterization of resilient solutions via a system of inequalities, the branch-and-bound scheme is extended by a separation algorithm to produce cost optimal resilient solutions. This implicitly solves a multilevel optimization problem which contains the computation of worst-case failures. Moreover, using a large set of test instances, the increased energy-efficiency of decentralized networks for the supply of building is shown and properties of resilient layouts are discussed.

The details can be found in [1].

References

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[1]Department of Mathematics, TU Darmstadt
[2]Department of Mathematics, TU Darmstadt

Friday, Sept. 20, 11:00-11:45 (Theater)

Conditional Gradient Algorithms for Constraint Smooth Convex Minimization

S. Pokutta[1]

Conditional Gradients (aka *Frank-Wolfe* Methods) are an important class of algorithms for smooth constraint convex minimization, solving problems of the form:

$$\min_{x \in \mathcal{C}} f(x),$$

where f is a smooth function satisfying potentially additional properties and $\mathcal{C}$ is a compact convex set, often a polytope. These methods only require access to a first-order oracle for f (i.e., gradient and function evaluations) and a linear programming oracle for $\mathcal{C}$ (i.e., optimizing a linear objective over $\mathcal{C}$) and they are often called *projection-free* methods as they do not require projection back into the feasible region. Conditional Gradients are in particular useful, when projection onto the feasible region would be non-trivial or a sparse representation of iterates via extreme points is desired. Due to their simplicity, conditional gradient methods have become the methods of choice for many applications and often the empirically observed rates are significantly better than theoretical worst-case rates. Research in this area has been very active in recent years and refinements of the basic conditional gradients methods achieve, e.g., linear convergence in the strongly convex case or allow for variance-reduced stochastic variants.

In this talk I will discuss some of these recent developments and discuss further extensions as well as open problems.

[1]Georgia Institute of Technology

Friday, Sept. 20, 11:45-12:30 (Theater)

Generalized Nash Games with PDEs and Applications in Energy Markets

M. Hintermüller[1]

The envisaged turn around in our energy portfolio from fossil to mainly renewable energy is one of the major challenges which our society is going to face in the coming years. It turns out that increasingly more comprehensive and sometimes highly detailed models are needed in order to address this challenge properly. One particular example of this is the integration of the physical transport of energy carriers into market models in order to facilitate an optimal and robust distribution of energy. The physical transport can be described on different scales, with the finest scale leading to partial differential equation models. For instance, in the case of gas transport this would be regime dependent variants of the compressible Euler equations. Such a spatially distributed model, while perhaps too complex for large scale pipeline networks, allows for simulating and understanding important aspects such as line filling / packing. The latter is a phenomenon that utilizes pipes as some kind of (anticipative) storage devise, and helps to improve and robustify distribution. On the markets side, the strategic behavior of (selfish) agents that trade such energy related commodities on spot markets leads to equilibrium considerations in the context of game theory. Clearly, a comprehensive strategy requires agents to take the network behavior into acccount, leading to a PDE constraint common to all agents' utility optimization.

Motivated by the aforementioned context, this talk presents latest research results on generalized Nash equilibrium problems with partial differential equations. For prototypical model problems, besides modeling aspects, existence of solutions, characterizations of equilibria and numerical solution techniques are addressed. Also, current limitations and an outlook on possible future research questions in this field will be presented.

[1]Weierstrass Institute for Applied Analysis and Stochastics, Berlin, Germany

Minisymposia

Tuesday, Sept. 17, 16:00-16:30 (LJAD)

Nonsingularity and Stationarity Results for Quasi-Variational Inequalities

A. Dreves[1], S. Sagratella[2]

In a finite-dimensional quasi-variational inequality one aims to find a vector $\bar{x} \in K(\bar{x})$ such that

$$F(\bar{x})^\top (y - x) \geq 0 \qquad \forall y \in K(\bar{x}).$$

Under suitable constraint qualifications, one can find Lagrange multipliers and slack variables, such that the corresponding optimality system can be reformulated as a smooth constrained equation of the form

$$H(x, \lambda, w) = 0, \quad (x, \lambda, w) \in \Omega.$$

Further, through a complementarity function, like the Fischer-Burmeister function, one can obtain a nonsmooth equation of the form

$$\Psi(x, \lambda) = 0.$$

Exploiting these reformulations numerically, usually leads to two major issues:

1) Can we guarantee that (constrained) stationary points of the merit functions $\|H(x, \lambda, w)\|^2$ or $\|\Psi(x, \lambda)\|^2$ are solutions?
2) Can we guarantee that the Jacobian $JH(x, \lambda, w)$, or the elements of the generalized Jacobian $\partial\Psi(x, \lambda)$, are nonsingular at the iterates of the algorithm?

In this talk we present new sufficient conditions for the absence of non-optimal stationary points, and we will see that both reformulations require different conditions. This is in contrast to the nonsingularity conditions that are shown to be equivalent for both reformulations on the set of interior points. Furthermore, we present new nonsingularity conditions that are not only sufficient but also necessary.

[1]Universität der Bundeswehr Munich, Germany
[2]Sapienza University of Rome, Italy

Direct Methods for Mixed-Integer Optimization with Differential Equations

F. M. Hante[1], M. Schmidt[2]

We consider mixed-integer nonlinear optimization problems with constraints depending on initial and terminal conditions of an ordinary differential equation. A direct method is to replace the dynamics with a discrete approximation and to solve the corresponding finite-dimensional mixed-integer nonlinear optimization problem. The talk discusses the convergence of this solution approach when the approximation is refined. We provide critical examples and a set of conditions ensuring convergence in the sense of the corresponding optimal values. The results are obtained by considering the discretized problem as a parametric mixed-integer nonlinear optimization problem in finite dimensions. The necessity of the conditions is discussed on the example of pipe sizing problems for gas networks.

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Tuesday, Sept. 17, 17:00-17:30 (LJAD)

Low-Rank Surrogates in Bayesian Inverse Problems

M. Eigel[1], M. Marschall[2], R. Schneider[3]

Statistical Bayesian methods alleviate the inherent ill-posedness of inverse problems by assigning probability densities to the considered calibration parameters. Nevertheless, this informative regularization method based on statistics renders the numerical treatment of inverse problems governed by non-linear models a challenging task since it lifts the deterministic parameters up to continuous variables. To overcome this issue, low-rank representations can be employed. In particular, we propose to use hierarchical tensor formats to construct surrogate models of the quantities involved in the inversion process. We discuss the advantages of tensor decompositions and multi-level approaches, which are employed for the adaptive evaluation of the random model and the subsequent high-dimensional quadrature of the log-likelihood. In order to make the representation of the posterior better tractable in the case of highly informative data with low-noise, a "preconditioning" of the problem can be achieved by the computation of suitable transformations. These for instance can be Gaussian approximations or more general transport. Numerical experiments involving diffusion and scattering problems illustrate the performance and confirm theoretical results.

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Tuesday, Sept. 17, 17:30-18:00 (LJAD)

Interacting Particle Systems & Optimization

R. Pinnau[1], M. Burger[2], C. Totzeck[3], O. Tse[4]

In this talk we try to shed some light on the connection of dogs herding sheep and a new consensus-based global optimization algorithm. Both have in common that they can be modelled by a large system of interacting individuals. While the former leads to a constrained optimization problem, the latter will solve an optimization problem. And since there are many individuals involved we can study the corresponding mean-field limits to gain some insight in the respective asymptotic behaviour.

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Tuesday, Sept. 17, 16:00-18:00 (LJAD II)

MS2: Singular Perturbations and Turnpike in Optimal Control Problems (Joseph Gergaud, Univ. Toulouse, IRIT-ENSEEIHT)

Tuesday, Sept. 17, 16:00-16:30 (LJAD II)

Dispersion Points of ODE

C. Lobry[1]

Non-standard analysis (ANS) is increasingly used in mathematics (T. Tao works), mathematical physics (Gromov) and engineering sciences (Benveniste, Fliess). We present simulations of an easily observable phenomenon concerning the solutions of an ordinary differential equations (ODE): ≪ Dispersion points ≫ of the trajectories. These are points where the theorem of continuous dependance of solutions with respect to the initial condition seems to be in default. If this phenomenon is difficult to describe (and thus little studied) in the framework of traditional mathematics - it is necessary to make an asymptotic study of families of EDO depending on a parameter - it is on the other hand very simple to define within the framework of non-standard analysis (NSA). After giving a definition, we will present examples in classical questions of systems theory: optimal control syntheses and differential equations with discontinuous right hands.

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Tuesday, Sept. 17, 16:30-17:00 (LJAD II)

Turnpike in Shape Design

G. Lance[1], E. Trélat[2], E. Zuazua[3]

This talk will adress ways to describe the turnpike phenomenon which occurs in optimal control and more precisely in the context of optimal shape design. We consider a final time $T > 0$, fixed and large enough, and the problem to find an optimal shape evolving with the time $t \to \omega(t)$ solution of

$$\min_{\omega(\cdot)} J_T(\omega) = \frac{1}{T}\int_0^T f^0\big(y(t),\omega(t)\big)\,dt + g\big(y(T),\omega(T)\big), \quad \dot{y} = f\big(y,\omega\big), \quad R\big(y(0),y(T)\big) = 0 \tag{1}$$

Moreover we consider a static problem associated to the previous one

$$\min_{\omega} f^0(y,\omega), \quad f(y,\omega) = 0 \tag{2}$$

In line of previous works on turnpike in optimal control [1, 2, 3], we expect that an optimal solution of (1) shoud stay, most of the time, near a stationnary state which is solution of (2). Let us take $\Omega \subset \mathbf{R}^N$, y_0 and $y_d \in L^2(\Omega)$. We are interested in the heat equation and to find the optimal shape of a source term evolving with the time minimizing the distance to a target y_d

$$\min_{|\omega(\cdot)|\leq L|\Omega|} \frac{1}{T}\int_0^T \|y(t)-y_d\|^2_{L^2(\Omega)}\,dt, \qquad \frac{\partial y}{\partial t} - \triangle y = \chi_{\omega(\cdot)}, \quad y_{|\partial\Omega} = 0, \quad y(0) = y_0 \tag{3}$$

Under some hypothesis, we can show existence and uniqueness of an optimal shape for both (3) and static one associated. Then, either with strict dissipitavity arguments as in [2] or with an explicit calculus inspired of [1], we get similar turnpike properties. We finally propose several numerical simulations of (3) which enlight the turnpike phenomenon.

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Tuesday, Sept. 17, 17:00-17:30 (LJAD II)

Bacterial Growth Strategies as Optimal Control Problems: Maximizing Metabolite Production

A.G. Yabo[1], J.-B. Caillau[2], J.-L. Gouzé[3]

In nature, microorganisms are continuously facing nutrient availability changes in the environment, and thus they have evolved to dynamically adapt their physiology to cope with this phenomena. This is achieved through reorganization of the gene expression machinery, by dynamically allocating resources to different cellular functions. Among all possible allocation strategies, only few will guarantee the survival of the fittest when competing for nutrient, leading to complex and highly optimized organisms.

In contrast to previous steady-state growth studies, this line of research seeks to study the bacterial resource allocation problem in dynamical environments through self-replicator models. The fitness of the microorganism is represented as a dynamical growth maximization strategy, which is formulated as an optimal control problem. By means of the Pontryagin Maximum Principle, this theoretical approach allows us to obtain gold standard strategies, that can be then compared to feasible growth control implementations in bacterial cells.

These results provide a baseline understanding upon which it is possible to re-engineer the underlying behaviors of the cell in order to improve certain productivity measures. In the framework of the ANR Project Maximic[4], we aim at maximizing the production of a metabolite of interest in *E. coli* by means of both analytical and computational techniques. First results show that optimal solutions for the biomass and product maximization problems are similar in scenarios with unlimited nutrient supply, but differ when the latter is scarce.

Ultimately, we will explore the metabolite production scheme in the most relevant condition in biotechnological processes: the chemostat, a type of bioreactor highly conducive to industrial fermentation, but also a powerful tool in biological research.

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The Singular Perturbations Phenomenon and the Turnpike Property in Optimal Control

B. Wembe[1], O. Cots[2], J. Gergaud[3]

In nineties, several authors have studied links between optimal control problems and singular perturbations. For example, Kokotovic et al [3] explains, concerning optimal control problems on "sufficiently long intervals", the link between singular arc and singular perturbations.

We focus here on optimal control problems with turnpike properties. Such problems have been studied since the sixties, for example in econometry [1]. We say that an optimal control problem has the turnpike properties if the optimal trajectory consists in three phases: the first and the third one are transient short-time arcs and the second one is a long time arc closed to the steady-state solution of an associated static optimal control problem. The idea is here to formulate such a problem as an optimal control problem with singular perturbations with only fast variables. Then, known results in singular perturbations furnish us convergence theorems. We extend for example the theorem 2 of [3] in order to have a uniform approximation of the solution over the whole domain. Some numerical examples illustrate the result.

In conclusion, we give some others observations about links between optimal control and singular perturbations.

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Wednesday, Sept. 18, 08:30-09:00 (LJAD)

A Sequential Homotopy Method for Mathematical Programming Problems

A. Potschka[1]

We consider nonconvex and highly nonlinear mathematical programming problems, whose solutions minimize an objective function over a closed convex subset of a Hilbert space subject to nonlinear equality constraints that map into another Hilbert space. The objective function and constraint function are assumed to be continuously Fréchet-differentiable. This class of problems includes finite dimensional nonlinear programming problems as well as optimization problems with partial differential equations and state/control constraints. We present a novel numerical solution method, which is based on a projected gradient/anti-gradient flow for an augmented Lagrangian on the primal/dual variables. We show that under reasonable assumptions, the nonsmooth flow equations possess uniquely determined global solutions, whose limit points (provided that they exist) are critical, i.e., they satisfy a first-order necessary optimality condition. Under additional mild conditions, a critical point cannot be asymptotically stable if it has an emanating feasible curve along which the objective function decreases. This implies that small perturbations will make the flow escape critical points that are maxima or saddle points. If we apply a projected backward Euler method to the flow, we obtain a semismooth algebraic equation, whose solution can be traced for growing step sizes, e.g., by a continuation method with a local (inexact) semismooth Newton method as a corrector, until a singularity is encountered and the homotopy cannot be extended further. Moreover, the projected backward Euler equations admit an interpretation as necessary optimality conditions of a proximal-type regularization of the original problem. The prox-problems have favorable properties, which guarantee that the prox-problems have uniquely determined primal/dual solutions if the Euler step size is sufficiently small and the augmented Lagrangian parameter is sufficiently large. The prox-problems morph into the original problem when taking the step size to infinity, which allows the following active-set-type sequential homotopy method: From the current iterate, compute a projected backward Euler step by applying either local (inexact) semismooth Newton iterations on the step equations or local (inexact) SQP-type (sequential quadratic programming) methods on the prox-problems. If the homotopy cannot be continued much further, take the current result as a starting point for the next projected backward Euler step. If we can drive the step size all the way to infinity, we can transition to fast local convergence. We can interpret this sequential homotopy method as extensions to several well-known but seemingly unrelated optimization methods: A general globalization method for local inexact semismooth Newton methods and local inexact SQP-type methods, a proximal point algorithm for problems with explicit constraints, and an implicit version of the Arrow–Hurwicz gradient method for convex problems dating back to the 1950s extended to nonconvex problems. We close the talk with numerical results on large-scale highly nonlinear and badly conditioned mathematical programming problems and an outlook on future directions of research.

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Wednesday, Sept. 18, 09:00-09:30 (LJAD)

A Composite Step Method for Equality Constrained Optimization on Manifolds

A. Schiela[1], J. Ortiz[2]

We present a composite step method, designed for equality constrained optimization on differentiable manifolds. The use of retractions allows us to pullback the involved mappings to linear spaces and use tools such as cubic regularization of the objective function and affine covariant damped Newton method for feasibility. We show fast local convergence when different chart retractions are considered. We test our method on equilibrium problems in finite elasticity where the stable equilibrium position of an inextensible transversely isotropic elastic rod under dead load is searched.

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Extensions of Standard Nash-Games in Finite and Infinite Dimensions

S. Steffensen[1], A. Thuenen[2], M. Gugat[3]

In this talk we present finite and infinite dimensional extensions of standard Nash games.

Nash equilibrium problems for finite-dimensional, noncooperative games, have been used since their introduction in the 1950s to mathematically describe and analyse the strategic behaviour of a (finite) number of decision makers in various fields of applications such as economics, computer science, engineering sciences, sociology and others. The standard Nash game models the situation where a finite number $N \in \mathbb{N}$ of decision makers, so-called players, each of which possesses their own set of strategies u_i aims to minimize his/her own cost function J_i which in general depends on all players' strategies.

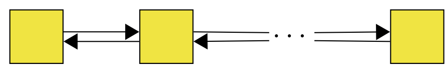
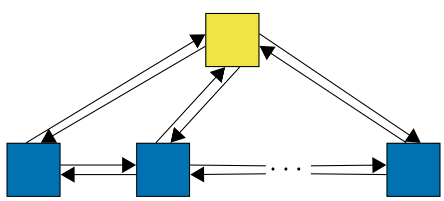
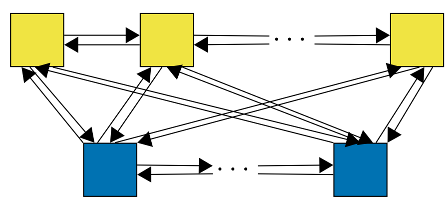


Figure 1: Classical Nash Game

In the talk, we will discuss three different extensions of this standard setting. The first extension concerns the case when the game includes a hierarchical structure. Here, the players are divided into two groups, namely the leaders and the followers, according to their position in the game. Mathematically, this yields a hierarchical Nash game (so-called Multi-Leader-Follower Game), where further minimization problems (defining a Nash game of the so-called followers) appear in the participants' (e.g. the leading companies') optimization problems as constraints. Another extension considers the case, where we have only one



(a) Stackelberg game



(b) multi-leader-follower game

Figure 2: Illustration of Extensions of Nash Games

leader, however, the number of followers becomes very large. Moreover, the considered extension of a standard Stackelberg game is dynamic i.e. time-dependent. Finally, we present a Nash equilibrium for a dynamic boundary control game with a star-shaped network of strings, where each string is governed by the wave equation.

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Wednesday, Sept. 18, 10:00-10:30 (LJAD)

Multilevel Augmented-Lagrangian Methods for Overconstrained Contact Discretizations

M. Weiser[1], R. Krause[2]

The talk will address overconstrained formulations for multi-body contact and adapted multilevel solvers of augmented Lagrange type for the resulting QPs.

We consider stationary hyperelasticity and a symmetric, pointwise sampling of the linearized nonpenetration condition essentially independent of the displacement discretization. This allows for a simple implementation, which is particularly convenient in the case of multi-body and self-contact where the a priori definition of master and slave sides is cumbersome. The drawback is, that the multiplier discretization is not of the special structure provided by dual mortar spaces. This prevents the use of efficient nonlinear Gauss-Seidel smoothers in two-body contact as it is exploited in monotone multigrid methods.

Instead, we use an augmented Lagrangian on the fine grid, and combine this with a primal multigrid hierarchy for the displacements. As a smoother, we employ an overlapping nonlinear Jacobi method, and exploit the high arithmetic intensity of local QPs to be solved for effective parallelization. In order to have effective coarse grid corrections even in the case of sliding contact along rounded contact surfaces, we propose a level-dependent penalty factor.

The properties of the resulting contact solver are illustrated at several numerical examples.

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Wednesday, Sept. 18, 08:30-10:30 (LJAD II)

MS4: Optimization and Optimal Control for Biological Models (Jean-Luc Gouzé, Inria Sophia Antipolis - Méditerranée)

Wednesday, Sept. 18, 08:30-09:00 (LJAD II)

Dynamic Optimality in Cellular Metabolism

D. A. Oyarzún[1]

Cellular metabolism is a large and complex network of biochemical reactions. It is the chemical workhorse of a cell that converts nutrients into energy needed for survival. It has been long argued that metabolic function may be explained by means of optimality principles. The hypothesis is that through evolution, metabolic dynamics have converged to an optimal state that trades off different cellular objectives [1].

In this talk I will discuss our work on dynamic optimization of metabolic networks. Motivated by experimental data [6], we used the Minimum Principle to show that temporal patterns in metabolism can be explained as a solution of a time-resource optimal control problem [4]. We have extended these results with numerical approaches suitable for larger metabolic networks [3, 5]. Motivated by challenges encountered in biotechnology, I will conclude with our recent approach that uses multiobjective optimization to compute Pareto-optimal feedback systems for metabolic networks [2].

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Over-Yielding Phenomenon in Optimal Control and Applications to the Chemostat Model

T. Bayen[1], F. Tani[2], A. Rapaport[3]

In this talk, we consider a controlled dynamics (linear w.r.t. the input) in dimension 1 or 2:

$$\dot{x} = f(x) + u(t)g(x) \quad |u(t)| \leq 1,$$

and a cost function

$$J_T(u) := \frac{1}{T}\int_0^T \ell(x(t))\,dt,$$

where $T > 0$ is fixed. Given a steady state x^* of the system with associated control u^*, the objective is to synthesize admissible controls u for which the associated solution of the dynamics is T-periodic and such that

$$J_T(u) < J_T(u^*) \quad \text{and} \quad \frac{1}{T}\int_0^T u(t)\,dt = u^*.$$

This question is related with the notion of *over-yielding* met in several applications such as in resource-consumer models (see *e.g.*, [1,2,3]). In dimension 1, we provide a full synthesis of this problem showing applications on the chemostat model with one species (see [1]). In dimension 2, we shall introduce the notion of *weak resilience* in the context of the chemostat model with two species to answer to tackle this question (see [2]).

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Wednesday, Sept. 18, 09:30-10:00 (LJAD II)

Optimisation of a Chemotherapy to prevent the emergence of Resistance in a Heterogeneous Tumour

C. Carrère[1], H. Zidani[2]

Resistance to treatments is a major cause of failuer for cancer chemotherapies. To study the effects of different treatment schedules, the team of M.Carré (biologist in CRO2, Aix-Marseille University) did in vitro experiments on cancer cells cocultures, with a mix of sensitive and resistant cells. These experiments showed the importance of metronomic schedules, ie lower doses of drugs given more frequently, compared to classical MTD (maximal tolerated dose) schedules, to prevent resistance emergence.

In order to understand and enhance these results, a mathematical model of the experiments has been designed by G.Chapuisat (mathematician at I2M, Aix-Marseille University), and an optimization of the treatment has been determined through different technics. First of all, an adaptive treatment schedule is designed by phase plane analysis. Then, optimal control theory is used to define a different schedule, which has been tested back in vitro[1]. Finally, the dynamical programmation and Hamilton-Jacobi method are presented[2], in a collaboration with H.Zidani, to address a problem formulation more adapted to medical applications.

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Wednesday, Sept. 18, 10:00-10:30 (LJAD II)

Optimization of Darwinian Selection of Microalgae

W. Djema[3], L. Giraldi[4], O. Bernard[5]

This talk addresses a Darwinian pressure of selection to make one microalgae species of interest emerging in a chemostat continuous photobioreactor.

We study a model derived from the classical Droop's model that takes into account internal quota storage for two distinct microalgae populations. We derive from Droop's model a simplified dynamical system, by considering the external substrate as a control function. The problem of strains/species selection is formulated as an optimal control problem (OCP) over a fixed time horizon. Using Pontryagin's maximum principle, we develop and fully characterize the substrate-based control strategy that steers the model trajectories and achieves species separation through a turnpike property over the fixed time window. In fact, we establish a turnpike-type behavior in the optimal control, trajectories and co-states, for sufficiently large time windows. A numerical optimal-synthesis, based on direct optimal control tools, is performed and it confirms the optimality of the provided feedback-control law.

More details can be found in [1, 2, 3].

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Wednesday, Sept. 18, 08:30-10:30 (IBV)

MS5: Nonlinear Optimization Methods and Their Global Rates of Convergence (Geovani Grapiglia, Departamento de Matemeatica, Universidade Federal do Parana, Centro Politecnico)

Wednesday, Sept. 18, 08:30-09:00 (IBV)

Greedy Quasi-Newton Method with Explicit Superlinear Convergence

A. Rodomanov[1], Yu. Nesterov[2]

We propose a new quasi-Newton method for unconstrained minimization of smooth functions. Our method is based on the famous BFGS scheme but it uses a greedily selected coordinate vector for updating the Hessian approximation at each iteration instead of the previous search direction. We prove that the proposed method has local superlinear convergence and establish a precise bound for its rate.

First, we consider the problem of approximating the inverse of a given real symmetric positive definite matrix, where the quality of a solution is measured in the relative scale. For this, we develop a new method which iteratively performs BFGS updates along the coordinate directions. The coordinates in this approach are selected in a greedy manner in order to maximize the reduction in a certain potential function. We establish that, for any initial approximation, the proposed method has linear convergence rate with the constant which equals the coordinate condition number of the matrix (the trace divided by the minimal eigenvalue).

We then show how the algorithm for inverting symmetric positive definite matrices in the relative scale can be transformed into a method for nonlinear optimization. The difficulty here is that now the matrix is non-constant and changes from one iteration to another. We provide a detailed complexity analysis of the resulting method and show that the linear convergence of the algorithm for inverting matrices transforms into the local superlinear convergence of the optimization method, where the rate of superlinear convergence depends on the square of the iteration counter.

To our knowledge, this result is the first explicit non-asymptotic rate of superlinear convergence for quasi-Newton methods.

Finally, we consider several applications in which the Hessian of the objective function has a specific structure that allows for an efficient implemention of the method. All our conclusions are confirmed by numerical experiments.

The research results of this paper were obtained with support of ERC Advanced Grant 788368.

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Wednesday, Sept. 18, 09:00-09:30 (IBV)

Minimizing Uniformly Convex Functions by Cubic Regularization of Newton Method

N. Doikov[1], Yu. Nesterov[2]

In this talk we discuss iteration complexity of Cubic Regularization of Newton method for solving composite minimization problems with uniformly convex objective.

We introduce the notion of second-order condition number of a certain degree and present the linear rate of convergence in a nondegenerate case. The algorithm automatically achieves the best possible global complexity bound among different problem classes of functions with Holder continuous Hessian of the smooth part.

As a byproduct of our developments, we justify an intuitively plausible result that the global iteration complexity of the Newton method is always better than that of the Gradient Method on the class of strongly convex functions with uniformly bounded second derivative.

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Wednesday, Sept. 18, 09:30-10:00 (IBV)

Tensor Methods for Minimizing Functions with Hölder Continuous Higher-Order Derivatives

G. Grapiglia[1], Yu. Nesterov[2]

In this work, we study p-order methods for unconstrained minimization of convex functions that are p-times differentiable with ν-Hölder continuous pth derivatives. We propose tensor schemes with and without acceleration. For the schemes without acceleration, we establish iteration complexity bounds of $\mathcal{O}\left(\epsilon^{-1/(p+\nu-1)}\right)$ for reducing the functional residual below a given $\epsilon \in (0,1)$. Assuming that ν is know, we obtain an improved complexity bound of $\mathcal{O}\left(\epsilon^{-1/(p+\nu)}\right)$ for the corresponding accelerated scheme. For the case in which ν is unknown, we present a universal accelerated tensor scheme with iteration complexity of $\mathcal{O}\left(\epsilon^{-p/[(p+1)(p+\nu-1)]}\right)$. A lower complexity bound of $\mathcal{O}\left(\epsilon^{-2/[3(p+\nu)-2]}\right)$ is also obtained for this problem class.

This work was supported by the European Research Council Advanced Grant 788368.

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Wednesday, Sept. 18, 10:00-10:30 (IBV)

Multilevel Optimization Methods for the Training of Artificial Neural Networks

H. Calandra[1], S. Gratton[2], E. Riccietti[3], X. Vasseur[4]

In this talk we present a family of high-order multilevel optimization methods for unconstrained minimization that generalizes the methods in [1, 2]. These methods are recursive procedures that exploit the knowledge of a sequence of approximations to the original objective function, defined on spaces of reduced dimension, to build alternative models to the standard Taylor one, cheaper to minimize. These are used to define the step, reducing the major cost per iteration of the classical methods and making them scalable. We investigate the use of such methods to solve problems that do not have an underlying geometrical structure, that could be used to build the coarse problems. Specifically, we focus on an important class of such problems, those arising in the training of artificial neural networks. We propose a strategy based on algebraic multigrid techniques to build the sequence of coarse problems and we show some promising numerical results.

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Wednesday, Sept. 18, 16:00-18:00 (LJAD)

MS6: Game Theory Approaches in Inverse Problems and Control (Abderrahmane Habbal, LJAD, University of Nice, Inria Sophia Antipolis - Méditerranée)

Wednesday, Sept. 18, 16:00-16:30 (LJAD)

On the Theory and Numerics of Quantum Dynamics Nash Games

A. Borzì[1], F. Calà Campana[2], G. Ciaramella[3]

Since their formulation by John F. Nash [6], Nash games have been considered a convenient mathematical framework to investigate problems of competition and cooperation. In this framework, non-cooperative differential Nash games were introduced in [4].

This talk is devoted to a theoretical and numerical investigation of Nash equilibria (NE) and Nash bargaining (NB) problems governed by finite-dimensional quantum models. These models arise in, e.g., spin systems and as approximations of the Schrödinger equation, and in both cases the control mechanism is via external potentials that result in a bilinear control structure; see, e.g., [1]. In this framework, the building blocks of differential Nash games are different potentials associated to different players that pursue different non-cooperative objectives. This talk addresses the proof of existence of NEs and their computation with a semi-smooth Newton scheme [2] combined with a relaxation method [5]. Further, a related Nash bargaining problem is discussed in the framework given in [3]. This aims at determining an improvement of all players' objectives with respect to the Nash equilibria. Results of numerical experiments successfully demonstrate the effectiveness of the proposed NE and NB computational framework.

References

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Wednesday, Sept. 18, 16:30-17:00 (LJAD)

Examples of Games in Hyperbolic Models

R.M. Colombo[1]

Hyperbolic equations constitutes the core in modeling the behavior of *"particles"*, the most classical example being that of fluid dynamics. In various cases, however, these particles are individuals whose will affects the evolution of the system: think for instance at vehicular traffic or crowd dynamics. Whenever these individuals have competing goals, control problems or games naturally arise posing a variety of new questions to the qualitative study of hyperbolic equations.

This talk overviews recent results in this direction.

References

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Wednesday, Sept. 18, 17:00-17:30 (LJAD)

Game Strategies to Solve Inverse Obstacle Cauchy-Stokes Problems

A. Habbal[1], M. Kallel[2], M. Ouni[3]

We address in the present work the problem of detecting unknown cavities immersed in a stationary Stokes flow. The cavities are inclusions and the boundary measurements are a single compatible pair of Dirichlet and Neumann data, available only on a partial accessible part of the whole boundary. This inverse inclusion Cauchy-Stokes problem is ill-posed for both the cavities and missing data reconstructions, and designing stable and efficient algorithms, which is our main goal, is not straightforward.

The ill-posedness is tackled by decentralization : we reformulate it as a three players Nash game, following the ideas introduced earlier in [1] to solve the Cauchy-Laplace (completion) problem. Thanks to a simple yet strong identifiability result for the Cauchy-Stokes system, it is enough to set up two Stokes BVP, then use them as state equations. The Nash game is then set between 3 players, the two first targeting the data completion while the third one targets the inclusion detection. The latter problem is formulated using a level-set approach, and we provided the third player with the level-set function as strategy, while its cost functional is of Kohn-Vogelius type.

The class of algorithms we propose apply to a broad range of ill-posed inverse problems, the involved computational apparatus being rather classical : use of descent algorithms for the different minimizations, use of adjoint state method to compute the sensitivities, and use of Finite Element methods to solve the state and adjoint state equations, as well as to update the level-sets. We used Freefem++ to implement these routines for our problem.

We present 2D numerical experiments for three different test-cases. For noise free, as well as for noisy -Cauchy data- Dirichlet measurements, we obtained satisfactory results, exhibiting very stable behavior with respect to the noise level (1%, 3%, 5%). The obtained results favor our 3-player Nash game approach to solve parameter or shape identification for Cauchy problems. Finally, our approach rises difficult theoretical questions, such as the existence, uniqueness and convergence issues for the level-set solution to an implicit necessary optimality condition and, related to the game-theoretic approach, the existence and convergence issues for the 3-player Nash equilibrium.

Keywords: Data completion, Cauchy-Stokes problem, shape identification, Nash games.

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Wednesday, Sept. 18, 17:30-18:00 (LJAD)

A Nash Games Framework to Control Pedestrian Behavior

S. Roy[1], A. Borzi[2], A. Habbal[3]

This talk presents a new approach to modeling pedestrian's avoidance dynamics based on a Fokker-Planck Nash game framework. In this framework, two interacting pedestrian are considered, whose motion variability is modeled through the corresponding probability density functions (PDFs) governed by Fokker-Planck equations. Based on these equations, a Nash differential game is formulated where the game strategies represent controls aiming at avoidance by minimizing appropriate collision cost functionals. Existence of Nash equilibria solutions is proved and characterized as solution to an optimal control problem that is solved numerically. Results of numerical experiments are presented that successfully compare the computed Nash equilibria to output of real experiments (conducted with humans). The detail of this talk can be found in the paper [1].

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Wednesday, Sept. 18, 16:00-17:30 (LJAD II)

MS7: Mean Field Games: New Trends and Applications (Daniela Tonon, CEntre de REcherches en MAthématiques de la DÉcision)

Wednesday, Sept. 18, 16:00-16:30 (LJAD II)

Mean Field Games of Controls: Theory and Numerical Simulations

Z. Kobeissi[1]

We consider a class of mean field games in which the optimal strategy of a representative agent depends on the statistical distribution of the states and controls. The existence and uniqueness results presented in this talk can be found in [1]. The numerical simulations shown are part of a joint work in progress with Y. Achdou.

References

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Wednesday, Sept. 18, 16:30-17:00 (LJAD II)

From Schrödinger to Lasry-Lions via Brenier

L. Nenna[1], J-D. Benamou[2], G. Carlier[3], S. Di Marino[4]

The minimization of a relative entropy (with respect to the Wiener measure) is a very old problem which dates back to Schrd̈inger. C. Léonard [2] has established strong connections and analogies between this problem and the Monge-Kantorovich problem with quadratic cost (namely the standard Optimal Transport problem). In particular, the entropic interpolation leads to a system of PDEs which present strong analogies with the Mean Field Game system with a quadratic Hamiltonian. In this talk, we will explain how such systems can indeed be obtained by minimization of a relative entropy at the level of measures on paths with an additional term involving the marginal in time. Connection with generalised solutions (à la Brenier) for incompressible fluids will also be discussed.

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An Existence Result for a Class of Potential Mean Field Games of Controls

L. Pfeiffer[1], J.F. Bonnans[2], S. Hadikhanloo[3]

The mean field game theory aims at describing Nash equilibria between a very large number of players, each of them solving an optimal control problem. I will present an existence result for a model where the cost function to be minimized by each agent contains a price variable, depending on the average control (with respect to all agents). This situation is typical for models "à la Cournot", where the price of some raw material is an increasing function of the total demand. An important aspect of our proof is a potential formulation of the game, that is, we show that the coupled mean field game system of interest is equivalent to the optimality conditions associated with an optimal control problem of the Fokker-Planck equation.

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Thursday, Sept. 19, 08:30-09:00 (LJAD)

On Approximate Pure Nash Equilibria in Weighted Congestion Games

A. Fanelli[1], I. Caragiannis[2]

Among other solution concepts, the notion of pure Nash equilibrium plays a central role in Game Theory. Pure Nash equilibria in a game characterize situations in which no player has an incentive to unilaterally deviate from the current situation in order to achieve a higher payoff. Unfortunately, it is well known that there are games that do not have pure Nash equilibria. Furthermore, even in games where the existence of pure Nash equilibria is guaranteed, these equilibria could be very inefficient compared to solutions dictated by a central authority. Such negative results significantly question the importance of pure Nash equilibria as solution concepts that characterize the behavior of rational players.

One way to overcome the limitations of the non-existence and inefficiency of pure Nash equilibria is to consider a relaxation of the stability constraints. This relaxation leads to the concept of *approximate* pure Nash equilibrium. This concept characterizes situations where no player can *significantly improve* her payoff by unilaterally deviating from her current strategy. Approximate pure Nash equilibria can accommodate small modeling inaccuracies due to uncertainty, therefore they may be more desirable as solution concepts in practical decision-making settings. Beside mere existence and efficiency, approximate pure Nash equilibria are also an appealing alternative solution concept from a computational point of view.

In this talk we overview the results presented in [1]. In [1] we address the problem of the existence of natural improvement dynamics leading to approximate pure Nash equilibria, with a reasonable small approximation, and the problem of bounding the efficiency of such equilibria in the fundamental framework of weighted congestion game with polynomial latencies of degree at most $d \geq 1$. This is a general framework which models situations in which a group of agents compete for the use of a set of shared resources. We firstly show that, by exploiting a simple technique, the game always admits a d-approximate potential function. This implies that every sequence of d-approximate improvement moves by the players always leads the game to a d-approximate pure Nash equilibrium. As a corollary, we also obtain that, under mild assumptions on the structure of the players' strategies, the game always admits a constant approximate potential function. Secondly, by using a simple potential function argument, we are able to show that in the game there always exists a $(d + \delta)$-approximate pure Nash equilibrium, with $\delta \in [0, 1]$, whose cost is $2/(1 + \delta)$ times the cost of an optimal state.

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On a Simple Hedonic Game with Graph-Restricted Communication

V. Bilò[1], L. Gourvès[2], J. Monnot[3]

We study a hedonic game for which the feasible coalitions are prescribed by a graph representing the agents' social relations. A group of agents can form a feasible coalition if and only if their corresponding vertices can be spanned with a star. This requirement guarantees that agents are connected, close to each other, and one central agent can coordinate the actions of the group. In our game everyone strives to join the largest feasible coalition. We study the existence and computational complexity of either Nash stable and core stable partitions. Then, we provide tight or asymptotically tight bounds on their quality, with respect to both the price of anarchy and stability, under two natural social functions, namely, the number of agents who are not in a singleton coalition, and the number of coalitions. We also derive refined bounds for games in which the social graph is restricted to be claw-free. Finally, we investigate the complexity of computing socially optimal partitions as well as extreme Nash stable ones.

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Thursday, Sept. 19, 09:30-10:00 (LJAD)

Game Efficiency through Linear Programming Duality

K.-T. Nguyen[1]

The efficiency of a game is typically quantified by the price of anarchy (PoA), defined as the worst ratio of the value of an equilibrium — solution of the game — and that of an optimal outcome. Given the tremendous impact of tools from mathematical programming in the design of algorithms and the similarity of the price of anarchy and different measures such as the approximation and competitive ratios, it is intriguing to develop a duality-based method to characterize the efficiency of games.

In the talk, we present an approach based on linear programming duality to study the efficiency of games. We show that the approach provides a general recipe to analyze the efficiency of games and also to derive concepts leading to improvements. We show the applicability of the approach to the wide variety of games and environments, from congestion games to Bayesian welfare, from full-information settings to incomplete-information ones. We also mention some open directions.

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Thursday, Sept. 19, 10:00-10:30 (LJAD)

Computing all Wardrop Equilibria Parametrized by the Flow Demand

P. Warode[1], M. Klimm[2]

We develop an algorithm that computes for a given undirected or directed network with flow-dependent piece-wise linear edge cost functions *all* Wardrop equilibria as a function of the flow demand. For more details see [1]. Our algorithm is based on Katzenelson's homotopy method for electrical networks. The algorithm uses a bijection between vertex potentials and flow excess vectors that is piecewise linear in the potential space and where each linear segment can be interpreted as an augmenting flow in a residual network. The algorithm iteratively increases the excess of one or more vertex pairs until the bijection reaches a point of non-differentiability. Then, the next linear region is chosen in a simplex-like pivot step and the algorithm proceeds. We first show that this algorithm correctly computes all Wardrop equilibria in undirected single-commodity networks along the chosen path of excess vectors. We then adapt our algorithm to also work for discontinuous cost functions which allows to model directed edges and/or edge capacities. Our algorithm is output-polynomial in non-degenerate instances where the solution curve never hits a point where the cost function of more than one edge becomes non-differentiable. For degenerate instances we still obtain an output-polynomial algorithm computing the linear segments of the bijection by a convex program. The latter technique also allows to handle multiple commodities.

References

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Thursday, Sept. 19, 08:30-10:30 (LJAD II)

MS9: Kernel Methods in Bayesian Optimisation and Integration (Luc Pronzato, Laboratoire I3S, CNRS, UCA & Sébastien Da Veiga, Safran Group)

Thursday, Sept. 19, 08:30-09:00 (LJAD II)

Faster Multi-Objective Optimization: Cumulating Gaussian Processes, Preference Point and Parallelism

D. Gaudrie[1], R. Le Riche[2], V. Picheny[3]

Bayesian optimization algorithms, i.e., algorithms using Gaussian Processes, are often resorted to when the number of calls to the objective function is strongly limited. In the last decade, these algorithms have been extended to multi-objective optimization and parallelized versions have appeared [1].

In this talk, we show how a faster multi-objective optimization is possible by complementing Bayesian approaches with a preference point. The gain comes from a first phase of the search, where only one point of the Pareto front, deducted from the preference point and the Gaussian processes, it targeted. Once convergence to this point is detected, the part of the Pareto front that can be attained within the remaining budget is estimated and targeted. The method involves a new analytically tractable Bayesian criterion, the mEI. It requires preference point updatings and Pareto front simulations [2].

We will also present how, at the two stages of the algorithm, new search points can be produced in batches, making the method parallel while keeping the choice of the points optimal in a Bayesian sense. Further details about the resulting R/C-mEI algorithm can be found in [3, 4].

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Thursday, Sept. 19, 09:00-09:30 (LJAD II)

Stepwise Entropy Reduction : Review of Theoretical Results in the Finite/Deterministic Case

J. Bect[1]

The stepwise entropy reduction idea was introduced in the field of Bayesian optimization by Villemonteix, Vazquez and Walter [1]. In short, given a prior model on the "unknown" function to be minimized, evaluation points are selected sequentially in order to greedily minimize the expected conditional entropy of the minimizer. The same idea can be found under various forms and names in many different fields, such as sequential testing [2], active learning [3], search [4], image processing [5], etc. This communication will review some theoretical results about the performance of stepwise entropy reduction strategies in simple settings where the probability space is finite and the responses are deterministic [6, 7].

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Thursday, Sept. 19, 09:30-10:00 (LJAD II)

Goal-Oriented Adaptive Sampling under Random Field Modeling of Response Distributions

A. Gautier[1], D. Ginsbourger[2], G. Pirot[3]

In the study of complex systems, it is common that responses of interest are not completely determined by decision variables x but can rather be modelled as random variables which distributions depend on x. Here we consider cases when this dependence on x does not only concern the mean and/or the variance of such distributions, but other features of response distributions can evolve, including for instance their shape, their unimodal versus multi-modal nature, etc. Our contributions build upon a non-parametric Bayesian approach to modeling the thereby induced fields of probability distributions, and in particular to a spatial extension of the logistic Gaussian model [1]. We demonstrate the applicability of this class of models in the context of complex systems with stochastic outputs. The considered models deliver probabilistic predictions of response distributions at candidate points, allowing for instance to perform (approximate) posterior simulations of probability density functions, to jointly predict multiple moments and other functionals of target distributions, as well as to quantify the impact of collecting new samples on the state of knowledge of the distribution field of interest. In particular, we introduce adaptive sampling strategies leveraging the potential of the considered random distribution field models to guide system evaluations in a goal-oriented way, with a view towards parsimoniously addressing calibration and related problems from non-linear (stochastic) inversion and global optimization.

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Thursday, Sept. 19, 10:00-10:30 (LJAD II)

Stein Point Markov Chain Monte Carlo

W.Y. Chen[1], A. Barp[2], F.X. Briol[3], J. Gorham[4], M. Girolami[5], L. Mackey[6], C.J. Oates[7]

An important task in machine learning and statistics is the approximation of a probability measure by an empirical measure supported on a discrete point set. Stein Points [1] are a class of algorithms for this task, with the property that only an un-normalised representation of the probability measure is required to generate the point set. As such, Stein Points can be widely applied in the Bayesian statistical context, where one typically does not have access to the normalisation constant. These algorithms proceed by sequentially minimising a Stein discrepancy between the empirical measure and the target and, hence, require the solution of a non-convex optimisation problem to obtain each new point.

In this talk we provide a succinct introduction to Stein Point algorithms. In addition, we will present recent work [2] that removes the need to solve the optimisation problem at each step by, instead, selecting each new point based on a Markov chain sample path. This significantly reduces the computational cost of Stein Points and leads to a suite of algorithms that are straightforward to implement. The new algorithms are illustrated on a set of challenging Bayesian inference problems, and rigorous theoretical guarantees of consistency are established.

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Thursday, Sept. 19, 08:30-10:30 (IBV)

MS10: Non-Smooth Optimization: Theory and Applications 1 (Andrea Walther, Paderborn University)

Thursday, Sept. 19, 08:30-09:00 (IBV)

Variable Metric Forward-Backward Method for Minimizing Nonsmooth Functionals in Banach Spaces

L. Blank[1], Chr. Rupprecht[2]

We consider the minimization of the sum of a smooth possibly nonconvex and a nonsmooth but convex functional in a Banach space. The Banach space shall be given by the intersection of a reflexive space and a dual space of a separable space like e.g. $H^1 \cap L^\infty$ or L^∞. These arise often in the context of pde constrained optimization. Motivated by the gradient projection method we extend the variable metric forward-backward algorithm given in finite dimensions to Banach spaces and to the use of a Armijo type backtracking. In addition, due to the intersection of two spaces we can relax the requirement of the uniformly norm equivalency of the variable metric to the underlying norm. Hence there is more flexibility to include second order information and speed up the method. We deduce a type of gradient related descent property and provide global convergence results. Moreover, we give examples which fulfill the required assumptions on the involved spaces and on the variable metric. Finally, we present numerical results. In particular, we demonstrate the efficency on a convexly constrained nonconvex problem in structural topology optimization. Here one can clearly see that choosing the wrong inner product leads to mesh dependency and including second order information appropriately can speed up the method drastically.

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On Second-Order Optimality Conditions for Optimal Control Problems Governed by the Obstacle Problem

C. Christof[1], G. Wachsmuth[2]

This talk is concerned with second-order optimality conditions for optimal control problems of the type

$$\begin{aligned} \text{Minimize} \quad & j(y) + \frac{\alpha}{2}\|u\|_{L^2}^2 \\ \text{w.r.t.} \quad & (y,u) \in H_0^1(\Omega) \times L^2(\Omega) \\ \text{s.t.} \quad & y \in K, \quad \langle -\Delta y, v-y\rangle \geq \langle u, v-y\rangle \quad \forall v \in K \\ \text{and} \quad & u_a \leq u \leq u_b. \end{aligned} \tag{P}$$

Here, Ω is assumed to be a domain with a sufficiently smooth boundary, $\alpha > 0$ is an arbitrary but fixed Tikhonov parameter, $j : H_0^1(\Omega) \to [0,\infty)$ is a given C^2-function, $u_a, u_b : \Omega \to [-\infty,\infty]$ are two measurable functions satisfying $u_a \leq 0 \leq u_b$ a.e. in Ω, and the set K is supposed to be of the form $K := \{v \in H_0^1(\Omega) \mid v \geq \psi \text{ a.e. in } \Omega\}$ with some arbitrary but fixed $\psi \in H^2(\Omega)$ satisfying $\operatorname{tr}(\psi) \leq 0$ a.e. on $\partial\Omega$. Using a simple observation that allows to identify precisely the structure of optimal controls of (P) on those parts of the domain Ω where the constraint $v \geq \psi$ in K is active, we derive various conditions that guarantee the local/global optimality of first-order stationary points of (P) and/or the local/global quadratic growth of the reduced objective function. Our analysis extends and refines existing results from the literature (cf. [1, 3]) and can also be applied in those situations where the problem at hand involves additional constraints on the state y. As a byproduct, our approach shows in particular that optimal control problems of the type (P) can be reformulated as state-constrained optimal control problems for the Poisson equation and that (P) possesses a unique local/global solution when the obstacle ψ is subharmonic and the function j is convex.

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Thursday, Sept. 19, 09:30-10:00 (IBV)

Dealing with Nonsmooth Optimization Problems in Function Spaces by Exploiting the Nonsmoothness

O. Weiß[1], S. Schmidt[2], A. Walther[3]

Nonsmooth functions and operators can arise intrinsically in numerous applications.

We consider nonsmooth optimization problems where all non-differentiabilities are assumed to be given by the Lipschitz-continuous operators abs(), min() and max().

The corresponding optimization problems can not be solved with ordinary methods and therefore require new concepts. Hence, very often regularization techniques are applied in order to avoid facing the intrinsic nonsmoothness.

In this talk, we will apply the techniques of Abs-Linearization to function spaces, where the Frechet-differentiability plays an important role. This technique does not require any regularization for the nonsmoothness but instead allows for exploitation of the nonsmoothness and in addition, yields promising convergence results.

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Thursday, Sept. 19, 10:00-10:30 (IBV)

Optimal Control of Elliptic Variational Inequalities Using Bundle Methods in Hilbert Space

L. Hertlein[1], M. Ulbrich[2]

Motivated by optimal control problems for elliptic variational inequalities we develop an inexact bundle method for nonsmooth nonconvex optimization subject to general convex constraints. The proposed method requires only approximate (i.e., inexact) evaluations of the cost function and of an element of Clarke's subdifferential. The algorithm allows for incorporating curvature information while aggregation techniques ensure that an approximate solution of the piecewise quadratic subproblem can be obtained efficiently. A global convergence theory in a suitable infinite-dimensional Hilbert space setting is presented. We discuss the application of our framework to optimal control of the (stochastic) obstacle problem and present numerical results.

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Thursday, Sept. 19, 16:00-18:00 (LJAD)

MS11: Continuous Optimization Techniques for Image Processing Applications (Simone Rebegoldi, Università degli Studi di Modena e Reggio Emilia & Elena Morotti, Università degli Studi di Bologna)

Thursday, Sept. 19, 16:00-16:30 (LJAD)

Linear Convergence of a Forward-Backward Splitting Algorithm for Strongly Convex Optimisation with Adaptive Backtracking

L. Calatroni[1], A. Chambolle[2]

We propose an extension of the Fast Iterative Shrinkage/Thresholding Algorithm (FISTA) algorithm [3, 1] for non-smooth strongly convex composite optimisation problems combined with an adaptive backtracking strategy. Differently from classical monotone line searching rules, the proposed strategy allows for local increasing and decreasing of the descent step size (i.e. proximal parameter) along the iterations and enjoys linear convergence rates defined in terms of quantities averaging both Lipschitz constant estimates and local condition numbers. We report some numerical experiments showing the outperformance of the algorithm compared to standard ones and we discuss the use of standard restarting strategies [4], in the case when the strong convexity parameters are unknown. This is joint work with A. Chambolle.

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Thursday, Sept. 19, 16:30-17:00 (LJAD)

Computational Approaches for Parametric Imaging of Dynamic PET Data

S. Crisci[1], M. Piana[2], V. Ruggiero[3], M. Scussolini[4]

Compartmental analysis [2] is an effective method to quantitatively assess the metabolic process of a radioactive tracer, used in dynamic Positron Emission Tomography (PET) studies. In this context, we consider the indirect parametric imaging problem of determining the kinetic parameters (i.e. the exchange rates between the model compartments) of the glucose-like-tracer ^{18}F-fluorodeoxyglucose (FDG) for every pixel of the PET images [3]. The FDG metabolization can be well described by a two-compartment model, accounting for tracer in free and bound status, and four kinetic parameters. The dynamic PET images of the tracer distribution are first pre-processed by applying a deblurring technique consisting in minimizing a Kullback-Leibler divergence penalized by a smooth approximation of the total variation by means, e.g., of a scaled gradient projection method [1]. Then, for each pixel of the PET images we solve an ill-posed nonlinear least-squares problem subject to non-negative constraints, by means of a trust-region-based method [4] properly adapted to handle the non-negativity constraints and combined with regularization techniques. In this talk, we describe our approach and the convergence results. Further, we report the numerical results obtained on a set of synthetic data created mimicking a real FDG–PET acquisition of the human brain, and we compare the effectiveness of our method with state-of-the-art techniques.

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Structural Priors in Low Dose Multi-Energy CT Reconstruction

A. Meaney[1], J. Toivanen[2], V. Kolehmainen[3], S. Siltanen[4], M. Juntunen[5]

Identification and classification of materials in computed tomography (CT) can be drastically improved by using multi-energy imaging [1]. By taking advantage of the nonlinear energy dependencies of the attenuation coefficients, qualitative and quantitative material characterization can be performed on the imaged object. Simultaneous dose reduction and improved image quality in the multi-energy reconstructions can be obtained by using structure-based priors in the objective function: although the attenuation values will differ at each energy, it is reasonable to assume that the underlying structural properties of the imaged object, i.e., its boundaries and interfaces, will remain in the same locations at each energy.

We present an imaging scheme for low dose multi-energy CT using sparse, non-overlapping projection angles. The reconstructions are computed using a joint reconstruction technique, where all of the data is combined into one inverse problem that is solved simultaneously for all of the X-ray energies, and the priors promote structural similarities the reconstructions [2]. The multi-energy reconstructions can then be used to compute a material decomposition into basis materials.

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Convex-Concave Backtracking for Inertial Bregman Proximal Gradient Algorithms in Non-Convex Optimization

M.C. Mukkamala[1], P. Ochs[2], T. Pock[3], S. Sabach[4]

Backtracking line-search is an old yet powerful strategy for finding better step size to be used in proximal gradient algorithms. The main principle is to locally find a simple convex upper bound of the objective function, which in turn controls the step size that is used. In case of inertial proximal gradient algorithms, the situation becomes much more difficult and usually leads to very restrictive rules on the extrapolation parameter. In this talk, we show that the extrapolation parameter can be controlled by locally finding also a simple concave lower bound of the objective function. This gives rise to a double convex-concave backtracking procedure which allows for an adaptive and optimal choice of both the step size and extrapolation parameters. We apply this procedure to the class of inertial Bregman proximal gradient methods, and prove that any sequence generated converges globally to a critical point of the function at hand. Numerical experiments on a number of challenging non-convex problems in image processing and machine learning were conducted and show the power of combining inertial step and double backtracking strategy in achieving improved performances.

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Thursday, Sept. 19, 16:00-18:30 (LJAD II)

MS12: Optimal Control Methods and Applications 1 (Helmut Maurer, Institute of Computational and Applied Mathematics & Sabine Pickenhain, Mathematical Institute, Brandenburg University of Technology at Cottbus)

Thursday, Sept. 19, 16:00-16:30 (LJAD II)

Multi-Objective Optimal Control Problems and Optimization over the Pareto Front

H. Maurer[1], Y. Kaya[2]

We consider multi-objective optimal control problems which are not assumed to be convex as in [2]. The standard scalarization method for solving multi-objective problems consists in scalarizing the problem via a convex combination of the objectives through a vector of parameters (weights). Then the set of all parametric solutions obtained by solving the scalarized problem is equal to the efficient set (Pareto front). We have shown in [1] that the Tschebycheff scalarization method is better suited for finding also the non-convex parts of the Pareto front. From a practical point of view, it is often compulsory to choose a solution with an additional objective (master function) in mind. To optimize the master function over the Pareto front we need differentiability properties of this function. Here, we can use existing solution differentiability results for parametric optimal control problems which are based on second-order sufficient conditions. Then the optimization of the master function can be achieved by gradient-type methods. Our numerical approach uses discretization and nonlinear programming methods. We give two examples illustrating our approach. The first example concerns the Rayleigh problem where the solution differentiabilty can be checked via a Riccati equation [3]. The second example presents a model of optimal vaccination and treatment in an epidemiological SEIR model [4].

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Asymptotic Controllability and Infinite Horizon Optimal Control - Theory and Application of Laguerre - Fourier Approximation Methods

S. Pickenhain[1], A. Burtchen[2]

We consider an optimal control problem with a priori given infinite horizon. The objective is of regulator type and all integrals are of Lebesgue type. The dynamics is linear with respect to state and control. The problem statement includes state variables in the intersection of uniformly and non-uniformly weighted Sobolev spaces. Based on a Pontryagin type maximum principle including transversality conditions for the adjoints we are able to transform the infinite horizon control problem into a boundary problem. Using a spectral approximation scheme we are looking for polynomial solutions using generalized Laguerre polynomials as basis functions. Therefore finally we are left with solving a linear equation system, where the unknowns are the coefficients of the ansatz functions. Examples demonstrate the application of this method and advantages of our approach comparing to a direct approximation scheme.

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Thursday, Sept. 19, 17:00-17:30 (LJAD II)

A Quest for Necessary Conditions for Nonregular Mixed Constrained Optimal Control Problems

J. Becerril[1], M.d.R. de Pinho[2]

Necessary conditions for optimal control problems with regular mixed constraints are well-known. However, problems with nonregular mixed constraints have received little attention apart from some work developed following Dubovitskii and Milyutin ; see [1] and [2] and references within. Also worth mentioning is the work of Ito and Shimizu in [3] where they derive necessary conditions for the nonregular mixed constraint case using a nonlinear programming approach.

In the last decades one has witnessed an increase of applications of optimal control approach to real life problems. Such an increase has made clear that many problems of interest, in particular problems involving sweeping processes, may be reformulated as nonregular mixed constrained problems.

Here, and following the vein of [3], we present necessary conditions for problems involving nonregular mixed constraints derived via infinite dimensional optimization. Our work differs from [3] since we consider the control functions to be essentially bounded functions instead of continuous functions. We also show how our set of necessary conditions leads to the usual first order necessary conditions for regular mixed constraints. Finally we discuss some possible approaches to nonregular mixed constrained problems with some nonsmooth data.

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Thursday, Sept. 19, 17:30-18:00 (LJAD II)

Optimal Control of a Delayed HIV Model with State Constraints

C. Silva[1], H. Maurer[2]

This talk will address a delayed HIV model proposed in [3] and analyze the local stability of the co-existence equilibrium point, for any positive time delay, extending the results in [3]. An optimal control problem is proposed and analyzed, where HIV treatment and immunotherapy are described by two control functions, subject to time-delays. In addition the process is subject to a state constraint on the number of effector cells. The main goal is to find the optimal combination of HIV treatment and immunotherapy that maximizes the concentration of uninfected $CD4^{+}T$ cells and immune response cells (CTL) and keep the side effects as low as possible. The necessary optimality conditions of the Maximum Principle for time-delayed optimal control problems with state constraints [2], is discussed. In particular, we obtain an explicit formula of the multiplier associated with the state constraint. Solutions for the non-delayed and delayed control problem are computed numerically, applying the discretization and nonlinear programming methods developed in [1].

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Thursday, Sept. 19, 18:00-18:30 (LJAD II)

Modified Pascoletti-Serafini Scalarization Method for Multi-Objective Optimal Control Problems

Z. Forouzandeh[1], M.d.R. de Pinho[2], M. Shamsi[3]

Scalarization methods are conventional approaches to analyze and solve Multi-Objective Optimization Problems (MOOPs). These methods mainly reformulate the MOOP as a parameter dependent single-objective optimization problem. Here we propose a new scalarization method to solve Multi-Objective Optimal Control Problems(MOOCPs). Our method is a modification of the well known Pascoletti-Serafini scalarization approach. Indeed, we show that by restricting the parameter sets of Pascoletti-Serafini scalarization method, we overcome some difficulties associated with this scalarization. A remarkable feature of the approach we propose is that it can handle problems with nonconvex Pareto front [1] and we get impressive results for three objective optimal control problems. We illustrate our method by applying it to some MOOCPs, including an epidemiology problem involving SEIR model (based on [3]), a fed-batch bio-reactor problem and a three-objective tubular reactor problem (based on [2]).

Acknowledgment: In this research, we acknowledge the support of FEDER/ COMPETE2020/ NORTE2020/POC/ PIDDAC/MCTES/FCT funds through the projects UID/IEEA/00147/006933 (SYSTEC), PTDC-EEI-AUT-2933-2014—16858 (TOCCATA), and POCI-01-0145-FEDER031447—FCT (UPWIND).

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Friday, Sept. 20, 08:30-10:30 (LJAD)

MS13: Optimization with PDE Constraints (Michael Ulbrich, Technical University of Munich)

Friday, Sept. 20, 08:30-09:00 (LJAD)

Optimal Boundary Control of Entropy Solutions for Conservation Laws with State Constraints

S. Ulbrich[1], J.M. Schmitt[2]

This talk deals with the treatment of pointwise state constraints in the context of optimal boundary control of nonlinear hyperbolic scalar balance laws [3].

We study an optimal control problem governed by balance laws with initial and boundary conditions, where we suppose that the boundary data switch between smooth functions at certain switching points. The smooth functions and the switching points are hereby considered as the control. The results can also be used to consider controlled networks of conservation laws with appropriate node conditions.

The appearance of state constraints presents a special challenge, since solutions of nonlinear hyperbolic balance laws may develop discontinuities after finite time, which prohibits the use of standard methods. In this talk, we will build upon the recently developed sensitivity- and adjoint calculus by Pfaff and Ulbrich [1, 2] to derive necessary optimality conditions. In addition, we will use Moreau-Yosida regularization for the algorithmic treatment of the pointwise state constraints. Hereby, we will prove convergence of the optimal controls and weak convergence of the corresponding Lagrange multiplier estimates of the regularized problems.

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Friday, Sept. 20, 09:00-09:30 (LJAD)

Optimal Control of the Principal Coefficient in a Scalar Wave Equation

C. Clason[1], K. Kunisch[2], P. Trautmann[3]

We consider optimal control of the scalar wave equation where the control enters as a coefficient in the principal part. Adding a total variation penalty allows showing existence of optimal controls, which requires continuity results for the coefficient-to-solution mapping for discontinuous coefficients. Under additional assumptions on the data, we also derive a "maximal hyperbolic regularity" result that yields hidden regularity of the state, leading to optimality conditions that can be interpreted in an appropriate pointwise fashion. The numerical solution makes use of a nonlinear primal-dual proximal splitting algorithm.

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[2]Karl-Franzens-University of Graz and RICAM, Linz
[3]Karl-Franzens-University of Graz

Friday, Sept. 20, 09:30-10:00 (LJAD)

Computing a Bouligand Generalized Derivative for the Solution Operator of the Obstacle Problem

A.-T. Rauls[1], S. Ulbrich[2]

Various problems in physics, finance and other areas can be expressed in terms of variational inequalities of obstacle type. The presence of such obstacle problems in the constraint set of an optimal control problem results in nonsmoothness of the optimization problem, since the solution operator of the obstacle problem is only directionally differentiable.

In this talk, we discuss the differentiability properties of a general class of obstacle problems with control operator on the right hand side and characterize generalized derivatives from the Bouligand generalized differential of the solution operator for the obstacle problem. The generalized derivatives we obtain are determined by solution operators of Dirichlet problems on quasi-open domains [1]. A subgradient for a cost functional can now be computed easily by an appropriate adjoint equation. To use the derived subgradients in practice within nonsmooth optimization methods, a discretization of the ob- stacle problem is necessary. We investigate how the respective subgradients can be approximated in this case.

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Friday, Sept. 20, 10:00-10:30 (LJAD)

A Hybrid Semismooth Quasi-Newton Method and its Application to PDE-Constrained Optimal Control

F. Mannel[1], A. Rund[2]

We present an algorithm for the efficient solution of structured nonsmooth operator equations in Banach spaces. Here, the term *structured* indicates that we consider equations which are composed of a smooth and a semismooth mapping. Equations of this type occur, for instance, as optimality conditions of structured nonsmooth optimization problems. In particular, the algorithm can be applied to nonconvex PDE-constrained optimal control problems with sparsity.

The novel algorithm combines a semismooth Newton method with a quasi-Newton method and exhibits local superlinear convergence under standard assumptions. Because of their inherent smoothing properties, PDE-constrained optimal control problems are particularly well-suited for the application of the new method.

On nonsmooth PDE-constrained optimal control problems the hybrid method has a significantly lower runtime than semismooth Newton methods, and this speedup persists when globalization techniques are added. Most notably, the hybrid approach can be embedded in a matrix-free limited-memory truncated trust-region framework to efficiently solve nonconvex and nonsmooth large-scale real-world optimization problems, as we will demonstrate by means of an example from magnetic resonance imaging. In this challenging environment it consistently outperforms semismooth Newton methods, sometimes by a factor of fifty and more.

All of these topics are addressed in the talk.

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Friday, Sept. 20, 08:30-10:30 (LJAD II)

MS14: Optimal Control Methods and Applications 2 (Helmut Maurer, Institute of Computational and Applied Mathematics & Sabine Pickenhain, Mathematical Institute, Brandenburg University of Technology at Cottbus)

Friday, Sept. 20, 08:30-09:00 (LJAD II)

Optimal Control Problem of Metronomic Chemotherapy under Assumption of a Growing Mortality Force

V. Lykina[1], D. Grass[2]

In this talk we consider a dynamic model of metronomic chemotherapy which is optimally controlled over the expected future lifetime of the particular patient. The word "metronomic" stands for the modelling approach which assumes that nearly continuous giving small doses of a chemotherapeutic agent to a patient has not only tumor-killing effect, but also has both anti-angiogenic effect preventing the growth of tumor vasculature and an immuno-stimulating effect. Under certain assumptions concerning the distribution of random variable T denoting the future lifetime of the patient, the original stochastic optimal control problem can be easily transformed to a purely deterministic optimal control problem with infinite horizon. In the present talk, we concentrate ourselves on investigating the case of a growing mortality force, e.g. its linear growth in dependence on the age of the patient. In this case, the mentioned random variable T is particularly Weibull distributed. To solve the resulting infinite horizon optimal control problem the open source software package OCMat was used which has been designed for numerical solving discounted nonlinear in control infinite horizon optimal control problems. Solutions to optimal control problems with L_2- and L_1-objective functionals are structurally compared. Outlook about further possible distributions is given.

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Friday, Sept. 20, 09:00-09:30 (LJAD II)

An Infinite Horizon Optimal Control Problem with Control Constraints – A Dual Based Approach with Application to an Epidemic Model

K. Kolo[1], S. Pickenhain[2]

We consider a class of infinite horizon optimal control problems with vector-valued states and controls involving the Lebesgue integral in the objective, a dynamics linear with respect to the control and control constraints.

This special class of problems arises in epidemic models and in the theory of economic growth.

We consider an epidemic model in the form of a SEIR-model. The aim is to find an exponentially stable vaccination strategy that prevents the spreading of the epidemic. We construct a control, which stabilizes the dynamical system asymptotically by solving an infinite horizon optimal control problem with a quadratic objective and a nonlinear dynamic with respect to the states.

The problem is formulated as an optimization problem in Hilbert Spaces. The remarkable on this statement is the choice of Weighted Sobolev- and Weighted Lebesgue spaces as state and control spaces respectively.

These considerations give us the possibility to extend the admissible set and simultaneously to be sure that the adjoint variable belongs to a Hilbert space.

For the class of problems proposed, we are able to derive a related dual program in form of an infinite horizon optimal control problem in Hilbert Spaces. Based on this formulation we use Fourier-Laguerre analysis and approximations introduced in [1], to solve the problem numerically.

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Friday, Sept. 20, 09:30-10:00 (LJAD II)

Optimal Control of an Optical System for Material Testing

C. Schneider[1], W. Alt[2], M. Seydenschwanz[3]

In this talk, we consider the process of automatic optical material testing in the manufacturing of glass panels. To model this problem, we use an optimal control approach with a discontinuous cost functional and box constraints for both, the control and the state variables. We implement a prototype for this application which aims for computing the optimal control at run time. The algorithm will be demonstrated and tested with the help of an illustrative example where it turns out that the optimal control is of bang-bang or bang-zero-bang type, depending on the state constraints.

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Computation of Wind-Perturbed Ship Trajectories through Parametric Sensitivity Analysis

C. Meerpohl[1], S. Roy[2], C. Büskens[3]

Commercial ships are often large and heavy vessels with very slow system dynamics. Their maneuverability is so limited that safety-critical areas (such as ports) cannot be entered or left without external assistance. For this reason, tugboats are used to move these large vessels by pushing or pulling them either by direct contact or by means of a tow line. Coordinating these boats is the task of experienced ship pilots and involves various aspects like respecting obstacle restrictions or considering changing environmental factors such as wind and current conditions. In this talk we will show how optimal control theory can be utilized in order to develop a powerful assistance system for a specific scenario.

We consider a model of a surface ship maneuvering in the horizontal plane with three degrees of freedom (namely surge, sway and yaw) [1]. The dynamics of the tugboats are not taken into account. Instead, the effects of the tugboats on the ship are modeled as force vectors, each with a fixed point of attachment. The vessel is constrained to remain within the limits of a harbor and its motion is affected by the wind.

In this presentation we consider a scenario where a pilot has to perform a docking maneuver. Given the estimated wind speed and direction, an optimal trajectory can be computed which includes the forces to be exerted by the tugboats. However, in situations where changes in wind intensity or direction can become problematic, parametric sensitivity analysis is used to determine the influence of these changes on a specific optimal trajectory. Perturbed trajectories can be computed in a few milliseconds by using feasibility self-correction techniques. As a result, safety-critical situations can be recognized before taking action and this gives the pilot the opportunity to look for alternative solutions.

The assistance system is being developed within the project GALILEOnautic [2]. For computing optimal trajectories, we use the nonlinear optimization library WORHP [3].

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Friday, Sept. 20, 08:00-10:00 (IBV)

MS15: Non-Smooth Optimization: Theory and Applications 2 (Andrea Walther, Paderborn University)

Friday, Sept. 20, 08:00-08:30 (IBV)

Nonconvex Bundle Method with Applications to PDE Boundary Control

Dominikus Noll[1]

We use a non-convex bundle or bundle trust region method to design feedback control laws for infinite dimensional systems. This includes boundary and distributed control of PDEs, delay ODEs, fractional order systems, and much else. The challenge is that despite the infinite dimension we have to enable stabilization and control with practically implementable controllers.

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Friday, Sept. 20, 08:30-09:00 (IBV)

Lipschitz Properties of Neural Networks

J.-C. Pesquet[1], P.L. Combettes[2]

Deriving sharp Lipschitz constants for feed-forward neural networks is essential to assess their robustness in the face of adversarial inputs. To derive such constants, we propose a model in which the activation operators are nonexpansive averaged operators, an assumption which is shown to cover most practical instances. By exploiting the averagedness of each activation operator, our analysis finely captures the interactions between the layers, yielding tighter Lipschitz constants than those resulting from the product of individual bounds for groups of layers. These constants are further improved in the case of separable structures. The proposed framework draws on tools from nonlinear operator theory, convex analysis, and monotone operator theory.

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Friday, Sept. 20, 09:00-09:30 (IBV)

The Total Variation of the Normal as a Prior for Geometrically Inverse Problems

S. Schmidt[1], M. Herrmann[2], R. Herzog[3], J. Vidal-Núñez[4], R. Bergmann[5]

The focus of this talk are regularization techniques for geometrically inverse problems and 3D scanning, which foster the detection of non-smooth objects. To this end, we propose to use the total variation (TV) of the outer normal as prior. Due to the typical sparsity behavior of L_1 or TV-regularization terms, we expect the creation of piecewise flat objects. It turns out that this prior behaves quite differently in a continuous and discrete setting and we study critical shapes, i.e., those shapes, which have zero directional derivatives, in each case.

Finally, we discuss optimization algorithms to numerically solve the resulting non-smooth optimization problems. To this end, we introduce ADMM-type methods on surfaces and manifolds, with the Split-Bregman approach being our method of choice. The talk concludes with numerically reconstruction schemes in geoelectrial impedance.

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Friday, Sept. 20, 09:30-10:00 (IBV)

Analytical and Numerical Investigations of Shape Optimization Problems Constrained by VIs of the First Kind

K. Welker[1], D. Luft[2], V. Schulz[3]

In this talk, shape optimization problems constrained by variational inequalities (VI) are treated from an analytical and numerical point of view in order to formulate approaches on shape spaces. In contrast to classical VIs, where no explicit dependence on the domain is given, VI constrained shape optimization problems are in particular highly challenging because of the two main reasons: Firstly, one needs to operate in inherently non-linear, non-convex and infinite-dimensional shape spaces. Secondly, one cannot expect for an arbitrary shape functional depending on solutions to VIs the existence of the shape derivative or to obtain the shape derivative as a linear mapping, which imply that the adjoint state cannot be introduced and, thus, the problem cannot be solved directly without any regularization techniques. In this talk, we investigate analytically a VI constrained shape optimization problem with respect to its state, adjoint and design equation. The analytical insight in this problem enables its computational treatment which is also presented in this talk.

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Contributed Talks

Tuesday, Sept. 17, 16:00-16:20 (IBV)

Time Adaptivity in POD Based Model Predictive Control

A. Alla[1], C. Gräßle[2], M. Hinze[3]

Model predictive control (MPC) is a method to synthesize time infinite horizon approximately optimal feedback laws from the iterative solution of open-loop finite horizon optimal control problems by shifting the horizon at each iteration, see e.g. [3]. A major advantage of the approach is the possibility to react to changes of the problem data due to external influences.

A crucial challenge within the MPC idea is the choice of the prediction horizon, i.e. the time horizon length of each suboptimal open-loop problem. Since the length of the prediction horizon strongly influences the quality of the solution and the computational times of the method, a suitable (i.e problem-specific) choice is advantageous. We propose a residual-based time-adaptive approach which uses a reformulation of the optimality system of the open-loop control problem into a biharmonic equation [1, 2]. In an adaptive cycle, the biharmonic equation is solved iteratively and the time discretization is adapted according to an a-posteriori error indicator. In this way, dominant temporal structures are recognized, which is used to determine the selection of appropriate time grid points and time horizon lengths. Since the resulting solution to the biharmonic system is related to the optimal solution, it can be used as a warm start in order initialize the actual MPC iteration. In order to gain a further speedup, POD reduced-order modeling is applied to solve open-loop problems for each MPC step. Numerical experiments will show the effectiveness of the proposed approach.

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Tuesday, Sept. 17, 16:20-16:40 (IBV)

Certified Reduced Basis Methods for Variational Data Assimilation

N. Aretz[1], M.A. Grepl[2], K. Veroy-Grepl[3], F. Silva[4]

In order to approximate the state of a physical system, data from physical measurements can be incorporated into a mathematical model to improve the state prediction. Discrepancies between data and models arise, since on the one hand, measurements are subject to errors and, on the other hand, a model can only approximate the actual physical phenomenon.

In this talk, we present a model order reduction method for (an interpretation of) the 3D- and 4D-VAR methods of variational data assimilation for parametrized partial differential equations. The classical 3D- and 4D-VAR methods make informed perturbations in order to find a state closer to the observations while main physical laws described by the model are maintained.

For the 3D-VAR method, we take inspiration from recent developments in state and parameter estimation and analyse the influence of the measurement space on the amplification of noise. Here, we prove a necessary and sufficient condition for the identification of a good measurement space which can, in turn, be used for a stability-based selection of measurement functionals. For both 3D- and 4D-VAR we propose a certified reduced basis (RB) method for the estimation of the model correction, the state prediction, the adjoint solution, and the observable misfit. Finally, we introduce different approaches for the generation of the RB spaces suited for different applications, and present numerical results testing their performance.

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Tuesday, Sept. 17, 16:40-17:00 (IBV)

Adaptive Localized Reduced Basis Methods in PDE-Constrained Optimization

M. Ohlberger[1], F. Schindler[2]

The computational demand of PDE constrained optimal control in the context of large-scale or multi-scale applications easily exceeds existing resources, if standard approximation methods are employed for the underlying forward problem. Model order reduction (MOR) methods for parameterized partial differential equation (pPDEs), such as the Reduced Basis (RB) method, allow to quickly explore the solution space by a decomposition of the computation into an expensive offline and a cheap online part. If employed as a surrogate for the forward problem, MOR methods have the potential to significantly speed up outer-loop algorithms (such as those arising in optimal control). However, standard global (in a spatial as well as parametric sense) MOR methods that construct a single reduced space for the whole parameter range of the underlying pPDE may still induce a tremendous offline computational burden for multi-scale or large scale problems.

A possible remedy is to consider localized methods, both in parameter- as well as physical space. In the context of the latter, localized RB methods combine ideas from domain decomposition and RB methods to obtain a (parameter) global surrogate model spanned by spatially localized reduced spaces. As a particular example, the localized RB multi-scale method equipped with localized error control allows to adaptively enrich these local reduced spaces [2]. In the context of optimization problems, such adaptive localized MOR methods have the potential to evolve the reduced model during the outer-loop algorithm (see also [3, 1]).

We will demonstrate recent advances of localized RB methods in the context of PDE constrained optimization, in particular regarding error control and adaptivity.

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Tuesday, Sept. 17, 17:00-17:20 (IBV)

Reduced Basis Method for Parameter Functions with Application in Quantum Mechanics

S. Hain[1], K. Urban[2]

We want to consider the time-dependent linear Schrödinger equation (SE)

$$\begin{aligned} \mathrm{i}\partial_t\psi(t,x) &= -\Delta\psi(t,x)+\mu(t,x)\psi(t,x)+f(t,x) && (t,x)\in(0,T)\times\Omega,\\ \psi(t,x) &= 0 && (t,x)\in(0,T)\times\partial\Omega,\\ \psi(0,x) &= \psi(x) && x\in\Omega, \end{aligned}$$

with a variable reaction coefficient μ, which is interpreted as a parameter function within the Reduced Basis Method (RBM), see e.g. [4, 5, 6]. Typically, the parameter space $\mathcal{P}$ is given by a finite-dimensional subset of $\mathbb{R}^P$, $P \in \mathbb{N}$. However, the parameter space consisting of all possible reaction coefficients is of infinite dimension. While finite-dimensional parameter spaces have been studied well, there has been done little work on the infinite-dimensional setting so far. First progress in this direction has been made by A. Mayerhofer and K. Urban, where the initial value of parabolic PDEs is interpreted as a parameter function, see [1]. In the end, this setting should be transferred to a PDE constrained optimal control problem, where an external potential arises in the SE as parameter function.

For this we propose an ansatz that follows [1, 2] based on a space-time variational formulation of the SE. It is well-known, see e.g. [3], that a space-time variational formulation of a time-dependent paraterized PDE leads – at least analytically – to sharper error estimates for the reduced solution, which is a crucial aspect for the construction of a reduced model within the RBM. However, the setting of a well-posed variational space-time formulation with a weakly differentiable initial value as well as its stable discretization, based on tensor formats, is – according to our knowledge – not studied, yet. Numerical examples will be presented.

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Tuesday, Sept. 17, 17:20-17:40 (IBV)

Cost-Optimal Design and Operation of Decentralized Energy Networks Including Renewable Energies

K. Janzen[1], S. Ulbrich[2]

The ongoing expansion of decentralized infrastructure including renewable energies represents a new challenge for the energy sector. In order to meet this challenge, new complex models for network design and optimal distribution of coupled energy sources have to be created to satisfy the consumers' demand for heat and electricity. Therefore, we present an optimization model based on [1, 2, 3] that minimizes the costs for the design of a network regarding different acquisition options, e.g., storage, photovoltaics and wind turbines, as well as their variable operating costs under consideration of generation and load constraints. Due to acquisition choices of different technologies and discrete sizes for distribution lines, discrete integer decision variables occur. Along with nonlinear equations for modeling the energy generation and the detailed description of the flow dynamics, this results in a mixed-integer nonconvex optimization problem (MINLP). Numerical results of representative problem instances are shown by using the spatial branch and bound method. Furthermore, we present an extension of our energy model including ordinary and partial differential equations and discuss developed estimators for appropriate discretizations.

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Tuesday, Sept. 17, 17:40-18:00 (IBV)

Numerical Solution Strategies for Finite Plasticity in the Context of Optimal Control

A. Walter[1], S. Ulbrich[2]

We consider the optimal control of the elastoplasticity problem with large deformations motivated by engineering applications such as deep drawing processes. In order to represent the occuring large deformations we use a hyperelastic material model where the deformation gradient is multiplicative decomposed into an elastic and a plastic part. We focus on the handling of the flow rule which appears in the state system of the optimal control problem. For this we analyze different solution approaches such as a semismooth reformulation [1] or the radial return method [2]. These strategies are motivated by methods applied in linear elastoplasticity and extended to the more complex case of a multiplicative split of the deformation gradient. We relate our resulting time-discrete model to the incremental problem of the energetic formulation [3]. This formulation offers the advantage that we get existence results under certain assumptions. Due to the computational complexity of the model and the associated high running time, we include reduced order models for finite plasticity and nonlinear elasticity to speed up the simulation process, where we follow the ideas in [4].

References

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Tuesday, Sept. 17, 18:00-18:20 (IBV)

Goal–Oriented A Posteriori Error Estimation For Dirichlet Boundary Control Problems

H. Yücel[1]

In this talk, we study goal–oriented a posteriori error estimates for the numerical approximation of Dirichlet boundary control problem governed by a convection diffusion equation with pointwise control constraints on a two dimensional convex polygonal domain. The local discontinuous Galerkin method is used as a discretization technique since the control variable is involved in a variational form in a natural sense. We derive primal–dual weighted error estimates for the objective functional with an error term representing the mismatch in the complementary system due to the discretization. Numerical examples are presented to illustrate the performance of the proposed estimator.

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Tuesday, Sept. 17, 16:00-18:00 (Fizeau)

CS2: Control 1

Tuesday, Sept. 17, 16:00-16:20 (Fizeau)

Some Regularity Results for Minimizers in Dynamic Optimization

P. Bettiol[1], C. Mariconda[2]

We consider the classical problem of the Calculus of Variations, and we discuss the validity of a new Weierstrass-type condition for local minimizers of the reference problem. This is a necessary condition which allows to derive important properties of minimizers for a broad class of problems involving a nonautonomous possibly extended-valued Lagrangian. A first consequence is the Erdmann Du Bois-Reymond necessary condition expressed in terms of classical tools of convex analysis (e.g., Dini derivatives or convex subdifferentials), and in terms of limiting subdifferentials. If the Lagrangian satisfies an additional growth condition (less restrictive than the classical coercivity), this Weierstrass-type condition yields also the Lipschitz regularity of the minimizers.

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Tuesday, Sept. 17, 16:20-16:40 (Fizeau)

Higher Order Problems in the Calculus of Variations: Du Bois-Reymond Condition and Regularity of Minimizers

J. Bernis[1], P. Bettiol[2], C. Mariconda[3]

This talk concerns a N-order problem in the calculus of variations of minimizing the functional

$$\int_a^b \Lambda(t, x(t), \dots, x^{(N)}(t))\mathrm{d}t$$

subject to suitable conditions, in which the Lagrangian Λ is a Borel measurable, non autonomous, and possibly extended valued function. Imposing some additional assumptions on the Lagrangian, such as an integrable boundedness of the partial proximal subgradients (up to the $(N-2)$-order variable), a growth condition (more general than superlinearity w.r.t. the last variable) and, when the Lagrangian is extended valued, the lower semicontinuity, we prove that the N-th derivative of a reference minimizer is essentially bounded. We also provide necessary optimality conditions in the Euler-Lagrange form and, for the first time for higher order problems, in the Erdmann – Du Bois-Reymond form. The latter can be also expressed in terms of a (generalized) convex subdifferential, and is valid even without requiring a particular growth condition.

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Tuesday, Sept. 17, 16:40-17:00 (Fizeau)

Optimality for Minimum Time Control-Affine Systems

M. Orieux[1], J.-B. Caillau[2]

This talk will focus on optimal control of systems whose dynamics are affine in the control. This problems have a wide range of applications, from energy minimisation in orbit transfer problems to quantum control. Necessary conditions give the optimal trajectories as projections of integral curves of an Hamiltonian system defined on the cotangent bundle of the initial phase space M. In that regard, minimum time control plays a singular role with respect to other criteria because the integral curves of the Hamiltonian do not depend on the cost, but only on the initial dynamics. Those curves are called extremal, and their projection on M are extremal trajectories. The final time minimisation induces a lack of regularity: the Hamiltonian is not smooth, and has codimension 2 singularities. In this talk we will prove sufficient conditions for optimality of these singular extremals. Let us consider a reference extremal $t \mapsto \bar{z}(t) \in T^*M$.

Theorem 1 ([1]). *Assume that*

(i) $\bar{z}$ *is a normal extremal,*

(ii) We have disconjugacy along $\bar{z}$*,*

then the reference trajectory is a $\mathcal{C}^0$*-local minimizer among all trajectories with same endpoints.*

Our method uses techniques from symplectic geometry, and consist in building a Lagrangian submanifold on which the canonical projection of the extremal flow is invertible. Then one can compare final times of neighbouring trajectories by lifting them to the cotangent bundle and evaluate the Poincaré-Cartan form along their lifts. The main difficulty is the definition of these objects, as well as the disconjugacy property in the theorem below, without the required regularity, and an extended study of the extremal flow is necessary, [2].

More is known in the case of the minimum time orbit transfer problem with two or three bodies, where the amount of singularities can be bounded.

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Necessary and Sufficient Optimality Conditions in an Optimal Control Problem with Nonlocal Conditions

A.T. Ramazanova[1]

This work is devoted to the study of the linear optimal control problem associated with the nonlocal boundary value problem for the system of hyperbolic equations of the fourth order. To study this problem, we present a modified version of the method for constructing Lagrange multipliers, which allows us to take into account the nonlocality of the problem in a more natural way. With the help of this variant, the adjoint system was introduced for the considered problem, which allowed to find the necessary and sufficient condition for optimality in the form of the Pontryagin maximum principle.

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Sparse Grid Approximation of the Riccati Operator for Closed Loop Parabolic Control Problems with Dirichlet Boundary Control

H. Harbrecht[1], I. Kalmykov[2]

We consider the sparse grid approximation of the Riccati operator P arising from closed loop parabolic control problems. In particular, we concentrate on the linear quadratic regulator (LQR) problems, i.e. we are looking for an optimal control u_{opt} in the linear state feedback form $u_{\text{opt}}(t,\cdot) = Px(t,\cdot)$, where $x(t,\cdot)$ is the solution of the controlled partial differential equation (PDE) for a time point t. Under sufficient regularity assumptions, the Riccati operator P fulfills the algebraic Riccati equation (ARE)

$$AP + PA - PBB^{\star}P + Q = 0,$$

where A, B, and Q are linear operators associated to the LQR problem. By expressing P in terms of an integral kernel p, the weak form of the ARE leads to a non-linear partial integro-differential equation for the kernel p – the Riccati IDE. We represent the kernel function as an element of a sparse grid space, which considerably reduces the cost to solve the Riccati IDE. Numerical results are given to validate the approach.

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Tuesday, Sept. 17, 17:40-18:00 (Fizeau)

On the Solution of a Time-Dependent Inverse Shape Identification Problem for the Heat Equation

R. Brügger[1], H. Harbrecht[2], J. Tausch[3]

In the talk, we treat the solution of a time-dependent shape identification problem. We specifically consider the heat equation on a domain, which contains a star-shaped inclusion of zero temperature. We aim at detecting this time-dependent inclusion by measuring the heat flux on the exterior boundary of the domain. Reformulation by using a Neumann data tracking functional leads to a time-dependent shape optimization problem, for which a gradient based method is considered. Numerical examples will be discussed.

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Wednesday, Sept. 18, 08:30-08:50 (Fizeau)

Adding Long Edges Incident with the Root to Complete K-ary Tree

K. Sawada[1]

A pyramid organization structure can be expressed as a rooted tree, if we let nodes and edges in the rooted tree correspond to members and relations between members in the organization respectively. Then the pyramid organization structure is characterized by the number of subordinates of each member, that is, the number of children of each node and the number of levels in the organization, that is, the height of the rooted tree. We have proposed several models of adding relations between members of the same level in the pyramid organization structure which is a complete K-ary tree of height $H(H = 2, 3, \ldots)$ such that the communication of information between every member in the organization becomes the most efficient in [1] . A complete K-ary tree is the rooted tree in which all leaves have the same depth and all internal nodes have $K(K = 2, 3, \ldots)$ children.

Furthermore, we have proposed a model of adding relations between the top and members of the same level in a pyramid organization structure in [2]. This model is expressed as all relations have the same length. However, we should consider that adding relations differ from those of original organization structure in length. This study proposes a model of adding edges with long lengths between the root and all nodes with the same depth $N(N = 2, 3, \ldots, H)$ in a complete K-ary tree of height $H(H = 2, 3, \ldots)$. The lengths of adding edges are L which is more than 1 while those of edges of complete K-ary tree are 1. An optimal depth N^* is obtained by maximizing the total shortening distance which is the sum of shortened lengths of shortest paths between every pair of all nodes by adding edges.

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A Linear Programming Approach to Solve One-Versus-All Polynomial Systems

M. Boyet[1], M. Akian[2], X. Allamigeon[3], S. Gaubert[4]

In the tropical semifield $\mathbb{R}_{\max} = (\mathbb{R} \cup \{-\infty\}, \max, +)$, a polynomial in the indeterminate x corresponds to the maximum of a finite number of affine functions in x (with integer slopes). Likewise, a tropical polynomial in $x_1, \ldots, x_n$ is a maximum of finitely many affine functions of $x = (x_1, \ldots, x_n)$. For given n pairs of polynomials in n variables, (P_i, Q_i), finding the points x where P_i and Q_i are equal for all $1 \leq i \leq n$ (the "tropical zeroes") is a fundamental problem which arises in tropical geometry, especially in the study of amoebas (images by the valuation) of semialgebraic sets over a real nonarchimedean field. Here, we study the situation in which, for each $1 \leq i \leq n$, one of the two polynomials, say P_i, has only one monomial, meaning that it reduces to a single affine function. We call "one-versus-all" the polynomial systems of this kind. This is motivated by performance evaluation issues, since the computation of stationary regimes of discrete event systems with priorities reduces to the solution of one-versus-all systems [1].

We show that if the tropical polynomials (P_i, Q_i) of the system satisfy a certain condition involving colored sets of point configurations, then finding a zero reduces to a linear program. We study properties of such configurations and provide a necessary condition for the method to work, using results on common supporting hyperplanes to families of convex bodies [2].

We explore the subclass of one-versus-all systems arising from Markov decision processes and show how these can be solved using a homotopy method on the rewards. This approach corresponds to the shadow-vergtex simplex method, and we show that it is dual to the idea of tropical polyhedral homotopy, developed by Jensen for a different class of systems [4]. Using complexity results by Dadush and Hähnle [3] we prove that it provides a solution in strongly polynomial time on average. Eventually, we discuss the extension of our results to polynomial systems over the positive reals.

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A Necessary Condition For Copositive Matrices

M. Naffouti[1], A. Baccari[2]

One says that a given real symmetric matrix is copositive if its associated quadratic form takes only nonnegative values on the nonnegative orthant. In general testing the copositivity of a matrix of is an NP-complete problem, for more explanation, see [5]. A characterization of copositive matrices through spectral properties is studied by many authors, see [1, 2, 3, 1]. In this presentation, we present a new necessary condition for copositive matrices. This condition is given by the relationship between the subspace spanned by the eigenvectors of a given symmetric real matrix and the nonnegative and the positive orthant. More precisely, If a matrix is copositive we prove that the intersection between the subspace spanned by the eigenvectors corresponding to negative eigenvalues and the nonnegative orthant is equal to the singleton zero of n real.

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Most IPs With Bounded Determinants Can Be Solved in Polynomial Time

J. Paat[1], M. Schlöter[2], R. Weissmantel[3]

In 1983 Lenstra showed that an integer program (IP) is fixed parameter tractable in the number of integer variables or the number of constraints. Since then, an open question has been to identify other parameters for which IP is fixed parameter tractable. One candidate parameter is the largest full-dimensional minor Δ of the constraint matrix. If $\Delta \leq 2$, then Artmann et al. (2017)[2] showed that an IP can be solved in polynomial time. However, it is not known if an efficient algorithm exists for $\Delta > 2$. We consider the family of IPs whose minors are bounded by an arbitrary Δ and provide a fixed parameter tractable algorithm in Δ that solves most IPs in this family. Here, 'most' refers to fixing the constraint matrix and objective function and varying the right hand side.

Let $A \in \mathbb{Z}^{m\times n}$ have $\operatorname{rank}(A) = n$ and $c \in \mathbb{Z}$. We consider solving *interger programs* of the form $\mathrm{IP}_{A,c}(b) := \max\{c^\top x : Ax \leq b \text{ and } x \in \mathbb{Z}^n\}$, for $b \in \mathbb{Z}^m$.
For a fixed choice of A and c, we denote the family of problems $\mathrm{IP}_{A,c}(b)$ by $\mathcal{F}_{A,c} := \{\mathrm{IP}_{A,c}(b) : \ b \in \mathbb{Z}^m\}$. The first main contribution presented in this talk is a sufficient condition for a problem $\mathrm{IP}_{A,c}(b)$ in $\mathcal{F}_{A,c}$ to be solvable in polynomial time when Δ is fixed, where Δ is the largest absolute value of an $n \times n$ minor of A. Although this sufficient condition is not met by all problems in $\mathcal{F}_{A,c}$, it turns out that *most* problems in $\mathcal{F}_{A,c}$ do satisfy the condition. Observe that we can parameterize the problems in $\mathcal{F}_{A,c}$ by their right hand sides in $\mathbb{Z}^m$. In order to quantify 'most', we define the *proportion of right hand sides b in a set $\mathcal{A} \subseteq \mathbb{Z}^m$* to be

$$\Pr(\mathcal{A}) := \liminf_{t\to\infty} \frac{|\{-t,\dots,t\}^m \cap \mathcal{A}|}{|\{-t,\dots,t\}^m|}.$$

The value $\Pr(\mathcal{A})$ can be viewed as the probability that the family $\{\mathrm{IP}_{A,c}(b) : b \in \mathcal{A}\} \subseteq \mathcal{F}_{A,c}$ occurs. We are interested in finding a set $\mathcal{G} \subseteq \mathbb{Z}^m$ such that $\Pr(\mathcal{G}) = 1$ and for every $b \in \mathcal{G}$ the problem $\mathrm{IP}_{A,c}(b)$ can be solved in polynomial time when Δ is fixed.
Our second main contribution is a fixed parameter tractable algorithm ALG^Δ in Δ that solves every problem $\mathrm{IP}_{A,c}(b)$ in $\mathcal{G}$. An algorithm ALG for solving the problems in a family $\mathcal{F}$ is *fixed parameter tractable (FPT)* in π if ALG has a running time in $O(f(\pi)\cdot \mathrm{poly}(\phi))$, where ϕ is the input size of a problem in $\mathcal{F}$ and f is a function that does not depend on ϕ. We also say that $\mathcal{F}$ is FPT in π. Lenstra's algorithm for $\mathcal{F}_{A,c}$ is FPT in *the number of integer variables* n as well as in *the number of constraints* m [5]. We denote by $\mathrm{LEN}(\cdot)$ the fixed parameter function in this algorithm.

Theorem 2. *There exists a set $\mathcal{G} \subseteq \mathbb{Z}^m$ and an algorithm ALG^Δ that is FPT in Δ such that*

(*i*) *ALG^Δ solves $\mathrm{IP}_{A,c}(b)$ for every $b \in \mathcal{G}$,*

(*ii*) *ALG^Δ has running time $O(LEN(\Delta^{2/3}+\log_2(\Delta))\cdot \mathrm{poly}(n,\phi))$, where ϕ is the encoding size of $\mathrm{IP}_{A,c}(b)$,*

(*iii*) $\Pr(\mathcal{G}) = 1$.

The overall structure of $\mathcal{F}_{A,c}$ and its connections to discrete optimization have been studied since the 1960s [4, 6, 1, 3]. To the best of our knowledge, this is the first study to quantify the number of problems in $\mathcal{F}_{A,c}$ that are efficiently solvable.

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Variational and Convex Analysis of Mean Value Theorems: a Further Example of Cross-Fertilization of Two Mathematical Areas

J.-B. Hiriart-Urruty[1]

The classical mean value theorem (also called LAGRANGE's theorem) is one of the most popular ones in Analysis; it states the following: Given a differentiable real-valued function f, for any $a < b$, there *exists* c in the open interval (a, b) such that

$$\frac{f(b) - f(a)}{b - a} = f'(c). \tag{1}$$

In the first part of our talk, we revisit this type of result with the help of tools and results from Convex or Variational analysis, especially the LEGENDRE-FENCHEL transform (which turns out to be incredibly powerful in our context). We answer two types of questions:

- Classify functions according to the properties of the "intermediate points c";

- Study the sensitivity, especially the differentiability, of c as a function of the two variables (a, b). In particular, under appropriate convexity assumptions on f, we provide the gradient of c at points (d, d) of the critical diagonal line.

The second part of our presentation deals with vector-valued functions $X : I \to \mathbb{R}^n$. Mean value theorems for such functions are usually derived in *inequality* forms; some authors like J. DIEUDONNÉ even claimed that they are the only possible. This not true. We present a simple result, with its proof, showing how the mean value $\frac{X(b)-X(a)}{b-a}$ could be expressed as a *convex combination* of some values $X'(t_i)$ of the derivative of X at intermediate points $t_i \in (a, b)$. This result is not new, apparently not well-known, especially as no integral of any kind is called, only values of derivatives X' at points are used. Moreover, the kinematics interpretation of the result is very expressive.

The talk is based upon two recent short papers by the author.

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On Metric Regularity of Composed Multimaps

M. Meddahi[1]

This paper concerns a new result of metric regularity of composition set-valued mappings between metric spaces. The work is based on several important results (like error bound estimation and Ekeland variational principle) and on a new concept of local composition stability of multifunctions. We give some new results and we provide an application to best proximity points.

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Wednesday, Sept. 18, 16:00-16:20 (IBV)

A Constrained Bundle Trust-Region Method in the Context of Shape Optimization Governed by Frictional Contact Problems

B.M. Horn[1], S. Ulbrich[2]

We present a nonsmooth optimization approach for a shape optimization problem governed by a fractional contact problem including stress constraints. The weak formulation of the Coulomb problem is regularized to circumvent well-known difficulties, namely ill-posedness and non-differentiability [1]. As a result we get a semismooth state equation, which is solved by a semismooth Newton method. The solution operator of the full-regularized contact problem with Coulomb friction can be proofed to be locally Lipschitz continuous with respect to the design, which is a crucial property for the application of nonsmooth optimization algorithms. This property remains to be true for a non-differentiable semi-regularized formulation. Based on a damage parameter of Smith, Watson and Topper, we include stress constraints to guarantee a predefined level of fatigue strength. To ensure a consistent model representation between CAD and the finite element simulation, we choose an isogeometric approach to model the finite dimensional formulation of the contact problem [3]. The friction and contact conditions are formulated in terms of the mortar approach using dual basis functions. The resulting shape optimization problem is nonconvex, constrained and due to the contact conditions nonsmooth. We solve this optimization problem with a bundle trust region algorithm [2], which is modified to handle linear and nonlinear constraints. The linear constraints are satisfied exactly in each iteration, whereas the nonlinear constraints are handled in the sense of penalty methods. This approach is motivated by the constraint linearization method [1]. For the introduced approach, we present numerical results in the context of algorithm based product development.

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Wednesday, Sept. 18, 16:20-16:40 (IBV)

Restarting Frank-Wolfe

T. Kerdreux[1], A. d'Aspremont[2], S. Pokutta[3]

Conditional Gradients (aka Frank-Wolfe algorithms) form a classical set of methods for constrained smooth convex minimization due to their simplicity, the absence of projection step, and competitive numerical performance. While the vanilla Frank-Wolfe algorithm only ensures a worst-case rate of $O(1/\epsilon)$, various recent results have shown that for strongly convex functions, the method can be slightly modified to achieve linear convergence. However, this still leaves a huge gap between sublinear $O(1/\epsilon)$ convergence and linear $O(\log 1/\epsilon)$ convergence to reach an ϵ-approximate solution. Here, we present a new variant of Conditional Gradients, that can dynamically adapt to the function's geometric properties using restarts and thus smoothly interpolates between the sublinear and linear regimes.

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Lower Bound Convex Programs for Exact Sparse Optimization

M. De Lara[1], J.-P. Chancelier[2]

In exact sparse optimization problems, one looks for solution that have few nonzero components. We consider problems where sparsity is exactly measured by the so-called l0 pseudo norm (and not by susbtitute penalizing terms). Since the l0 pseudo norm is not convex, such problems do not generally display convexity properties, even if the criterion to minimize is convex.

One route to attack such problems consists in replacing the sparsity constraint by a convex penalizing term, that will induce sparsity [2, 1]; thus doing, one loses the original exact sparse optimization formulation, but gains convexity for the susbtitute problem (benefiting especially of duality tools with the Fenchel conjugacy). We propose another route in which we keep the original exact sparse formulation and obtain convex programs that are lower bounds.

First, we display a suitable conjugacy for which we show that the l0 pseudo norm is ”convex” in the sense of generalized convexity (equal to its biconjugate). As a corollary, we also show that the l0 pseudo norm coincides, on the sphere, with a convex lsc function [4]. This somehow comes as a surprise, as the l0 pseudo norm is a function of combinatorial nature.

Second, thus equipped, we display a lower bound for the original exact sparse optimization problem. Under mild additional assumptions, we show that this bound is a convex minimization program over the unit ball of a so-called support norm.

Third, we introduce generalized sparse optimization problems, where the solution is searched among a finite union of subsets (sparsity). When the closed subspace spanned by each subset is equipped with a local norm (amplitude), we provide a systematic way to design a global norm and a lower bound convex minimization program formulated over the unit ball [3]. Thus, we recover most of the sparsity-inducing norms used in machine learning [5].

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Wednesday, Sept. 18, 17:00-17:20 (IBV)

A Primal-Dual Bundle Method for Nonsmooth Nonconvex Optimization

M. Cordova[1], W. de Oliveira[2], C. Sagastizábal[3]

For nonconvex optimization problems with nonlinear constraints, possibly nonsmooth, a convergent primal-dual solution algorithm is proposed. The approach applies a proximal bundle method to a dual problem that arises in the context of generalized augmented Lagrangians, and that yields a zero duality gap. The methodology is tailored so that Lagrangian subproblems can be solved inexactly without hindering the primal-dual convergence properties of the algorithm. Primal convergence is ensured even when the dual solution set is empty. The interest of the new method is assessed on some sparsity-constrained optimization problems.

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Wednesday, Sept. 18, 17:20-17:40 (IBV)

First-order Linear Programming Algorithm with Real-time Applications

M. Demenkov[1]

We investigate first-order algorithm for linear programming based on the conversion of the problem into finding an intersection between a *zonotope* and a line [1] (in case we have all problem variables constrained to a box). Zonotope is an affine transformation of m - dimensional cube:

$$\mathbf{Z} = \{y \in \mathbb{R}^n : y = y_0 + Hx,\ ||x||_\infty \leq 1\},\, x \in \mathbb{R}^m,\, n \leq m.$$

If we know an interior point of $\mathbf{Z}$ on the line, it is possible to derive a linearly convergent (in terms of projection steps) algorithm based on the bisection of an interval on the line. At each iteration we apply a projection onto a simple set (e.g. using Frank-Wolfe [2, 3]) to construct an oracle deciding if the point is inside or outside the zonotope. Due to the fact that the number of iterations can be computed in advance for the given accuracy, we investigate an application of the algorithm for dynamic optimization in automatic control [4, 5].

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Wednesday, Sept. 18, 17:40-18:00 (IBV)

Combining Duality and Splitting Proximal Point Methods for Constrained Optimization Problems

S.-M. Grad[1], O. Wilfer[2]

We approach via conjugate duality some constrained optimization problems with intricate structure that cannot be directly solved by means of the existing proximal point type methods. A splitting scheme is employed on the dual problem and the optimal solutions of the original one are recovered by means of optimality conditions. We use this approach for minmax location (see [1]) and entropy constrained (see [2]) optimization problems, presenting also some computational results where our method is compared with some recent ones from the literature.

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Wednesday, Sept. 18, 16:00-16:20 (Fizeau)

The Geometry of Sparse Analysis Regularization

S. Vaiter[1], X. Dupuis[2]

Analysis sparsity is a common prior in inverse problem or linear regression. We study the geometry of the solution set (a polyhedron) of the analysis ℓ_1-regularization when it is not reduced to a singleton. Leveraging a fine analysis of the sublevel set of the regularizer, we prove that extremal points can be recovered thanks to an algebraic test. Moreover, we draw a connection between the sign pattern of a solution and the ambiant dimension of the smallest face containing it. Finally, we provide numerical examples on how to use these results.

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Wednesday, Sept. 18, 16:20-16:40 (Fizeau)

Off-the-Grid Wasserstein Group Lasso

P. Catala[1], V. Duval[2], G. Peyré[3]

In this contribution, we propose a new off-the-grid (i.e. without spatial discretization) solver for a sparse regularization method for multi-canal inverse problems, which integrates a Wasserstein distance between the recovered measures. This solver uses a semidefinite programming (SDP) relaxation based on Lasserre's hierarchy.

The goal is to estimate two (hopefully sparse, i.e. sums of Diracs) positive Radon measures (μ_0, ν_0) on the torus $\mathbb{T}^d$ from low-resolution noisy measurements of the form $u = \mathcal{F}\mu_0 + w$ and $v = \mathcal{F}\nu_0 + \varepsilon$, where $\mathcal{F}$ is a linear operator and w, ε account for some unknown noises. We assume that $\mathcal{F}$ is a convolution with a low-pass filter, so that without loss of generality, we may consider a Fourier transform $(\mathcal{F}\mu)_k = \int_{\mathbb{T}^d} e^{-2\imath\pi\langle k,x\rangle}\mathrm{d}\mu(x)$, for $k \in \Omega_c \overset{\text{def.}}{=} [\![-f_c, f_c]\!]^d$. In practice, the sought after sources (μ, ν) are linked to physical or biological phenomena, and one wishes to constrain the relative positions of the spikes in both measures. The classical approach (often called the group-Lasso problem) is to use a vectorial total variation norm, which imposes that μ and ν share the same support. This constraint is often too strong, and following [1] we propose to relax this assumption by rather penalizing their respective Wasserstein "distance". This distance is defined, for some cost $C(x, y)$, by $W_C(\mu, \nu) = \min_{\gamma_1=\mu,\gamma_2=\nu} C(x, y)\mathrm{d}\gamma(x, y)$ where (γ_1, γ_2) are the two marginals of the transport plan γ, which is a positive measure over the product space $\mathbb{T}^d \times \mathbb{T}^d$. The sources are thus estimated by solving the following infinite dimensional optimization problem

$$\min_{\mu,\nu\in\mathcal{M}_+(\mathbb{T}^d)} \frac{1}{2}\|u - \mathcal{F}\mu\|^2 + \frac{1}{2}\|v - \mathcal{F}\nu\|^2 + \lambda|\mu|(\mathbb{T}^d) + \lambda|\nu|(\mathbb{T}^d) + \tau W_C(\mu, \nu). \tag{4}$$

Instead of considering a fixed spatial discretization, we rather search for the Fourier moments of the transport plan γ. For $\ell \geq f_c$, we consider $z_{(s,t)} \overset{\text{def.}}{=} \int_{\mathbb{T}^d\times\mathbb{T}^d} e^{-2\imath\pi\langle s,x\rangle}e^{-2\imath\pi\langle t,y\rangle}\mathrm{d}\gamma(x, y)$ for $s, t \in [\![-\ell, \ell]\!]^d$, and $R_\ell(z) = (z_{(s-s',t-t')})_{s,s',t,t'\in[\![0,\ell]\!]^d}$. We denote by $\hat{C}$ the Fourier coefficients of C. Let also $z_1 = z_{(\cdot,0)}$, $z_2 = z_{(0,\cdot)}$ and $z_0 = z_{(0,0)}$. Then the sequence of SDP problems

$$\min_{z\in\mathbb{C}^{|\Omega_c|}} \frac{1}{2}\|u - z_1\|^2 + \frac{1}{2}\|v - z_2\|^2 + 2\lambda z_0 + \tau\langle\hat{C}, z\rangle \quad \text{s.t} \quad R_\ell(z) \succeq 0 \tag{$\mathcal{P}_\ell$}$$

can be shown to define a "Lasserre" hierarchy of increasingly tighter relaxations of (4), and in many cases, one can recover the support of a solution of (4) from a solution of $(\mathcal{P}_\ell)$. Note that when $\lambda = 0$ and as $\tau \to 0$, solving (4) defines a low-frequency approximation of the celebrated optimal transport problem. In this talk, I will outline the theoretical aspects of the relaxation $(\mathcal{P}_\ell)$, explain efficient tailored numerical solvers and showcase numerical illustrations.

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Wednesday, Sept. 18, 16:40-17:00 (Fizeau)

Primal-Dual Optimization for Supervised Learning

M. Barlaud[1]

This paper deals with supervised classification and feature selection in high dimensional space. A classical approach is to project data on a low dimensional space and classify by minimizing an appropriate quadratic cost. A strict control on sparsity is moreover obtained by adding an ℓ_1 constraint, here on the matrix of weights used for projecting the data. It is well known that using a quadratic cost is not robust to outliers. We cope with this problem by using an ℓ_1 norm both for the constraint and for the loss function. However the drawback with the ℓ_1 loss $\|Y\mu - XW\|_1$ is that it enforces equality of the two matrices out of a sparse set. We deal with this issue by using a Huber loss instead. By optimizing simultaneously the projection matrix and the centers used for classification, we are eventually able to provide a biologically relevant signature (selected genes for each class). We implement a primal-dual algorithm to solve our problem and discuss both convergence and choice of parameters. Extending our primal-dual method to other criteria is easy provided that efficient projection (on the dual ball for the loss data term) and prox (for the regularization term) algorithms are available. We illustrate such an extension in the case of a Frobenius norm for the loss term. The effectiveness of the proposed approach is demonstrated on three datasets (one synthetic, two from biological data).

Joint work with A. Chambolle (Paris) and J.-B. Caillau (Nice).

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Wednesday, Sept. 18, 17:00-17:20 (Fizeau)

M* Regularized Dictionary Learning

M. Barré[1], A. d'Aspremont[2]

Dictionary learning seeks to decompose signals on a few atoms using a dictionary learned from the data set, instead of a predefined or sampled one. Classical dictionary learning methods simply normalize dictionary columns at each iteration, and this basic form of regularization has no clear link with generalization performance (e.g. compression ratio on new images). Here, we derive a tractable performance measure for dictionaries based on the low M^* bound from compressed sensing and use it to regularize dictionary learning problems to improve performance on new samples. We detail numerical experiments on both compression and inpainting problems and show that this more principled regularization approach consistently improves reconstruction performance on new images.

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Wednesday, Sept. 18, 17:20-17:40 (Fizeau)

Box Constrained Optimization for Minimax Supervised Learning

C. Gilet[1], S. Barbosa[2], L. Fillatre[3]

The authors thank the Provence-Alpes-Côte d'Azur region for its financial support

Context: To classify samples between $K \geq 2$ classes, the task of supervised learning is to fit a decision rule δ from a set of labeled training samples by minimizing the empirical risk of misclassification $\hat{r}(\delta_{\hat{\pi}}) = \sum_{k=1}^{K} \hat{\pi}_k \hat{R}_k(\delta_{\hat{\pi}})$, where $\hat{\pi} = [\hat{\pi}_1, \ldots, \hat{\pi}_K]$ corresponds to the class proportions of the training set, $\delta_{\hat{\pi}}$ means that δ is fitted under the class proportions $\hat{\pi}$, and where $\hat{R}_k(\delta_{\hat{\pi}})$ is the conditional risk of misclassification associated to the class k. However, it is common that $\hat{\pi}$ appears uncertain since the unknown state of nature π^{true} might be not truly represented in the training set.

Problem statement: Learning a classifier when the class proportions $\hat{\pi}$ of the training set differs from π^{true} changes linearly the risk of misclassification when classifying other test samples. As described in [1], a common approach to make a decision rule δ robust when dealing with uncertain $\hat{\pi}$ is to fit δ by minimizing the empirical risk under the least favorable class proportions $\bar{\pi}$ over the K-dimensional probabilistic simplex $\mathbb{S}$. Sometimes, due to some prior knowledge of experts, for some $k \in \{1, \ldots, K\}$ we are able to bound π_k^{true} in a more precise fixed interval $[a_k, b_k] \subset [0, 1]$. In these cases it is therefore necessary to constrain the least favorable priors over $\mathbb{U} := \mathbb{S} \cap \mathbb{B}$, where $\mathbb{B} := \{\pi \in \mathbb{R}^K : \forall k = 1, \ldots, K,\ 0 \leq a_k \leq \pi_k \leq b_k \leq 1\}$ is a box constraint which delimits independently each class proportion. Hence, to fit a robust decision rule δ when $\hat{\pi}$ is uncertain over $\mathbb{U}$, we consider the following minimax problem

$$\bar{\delta} \;=\; \operatorname*{argmin}_{\delta \in \Delta} \max_{\pi \in \mathbb{U}} \hat{r}(\delta_{\pi}). \tag{5}$$

Contributions: We focus here on the case where the descriptive features are discrete or discretized, which is quite common in medicine for example. When considering discrete features we propose the following contibutions: (i) we calculate the Bayes rule δ^B which performs the minimum empirical risk (called empirical Bayes risk); (ii) this empirical Bayes risk $\hat{V} : \pi \mapsto \hat{r}(\delta_{\pi}^B)$ considered as a function of the class proportions is a concave non-differentiable multivariate piecewise affine function over $\mathbb{U}$; (iii) hence, the optimization problem (5) is equivalent to compute the constrained least favorable priors $\bar{\pi}^{\star} = \operatorname{argmax}_{\pi \in \mathbb{U}} \hat{V}(\pi)$; (iv) to compute $\bar{\pi}^{\star}$ we derive a projected subgradient algorithm based on [2] whose convergence is established. The exact subgradient projection onto $\mathbb{U}$ is performed with [3].

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Bayesian Optimization and Dimension Reduction with Active Subspaces

M. Binois[1], N. Wycoff[2]

Black-box problems, with no available derivatives, possibly noisy, and expensive to evaluate are a common occurrence. Bayesian Optimization (BO) showed its efficiency in such setups, but generally for a moderate number of variables. To scale BO with high-dimensional parameter spaces, we present a Gaussian process (GP) based methodology that incorporates active subspace estimation. The latter, see e.g., [1], identifies the most influential directions in the original domain. Here, we show that the active subspace of a GP as well as its update with new designs can be expressed directly. It thus enables a sequential uncertainty reduction strategy balancing dimension reduction and optimization goals. We discuss relations with existing methods from the literature and present results on several examples.

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Thursday, Sept. 19, 08:30-08:50 (Fizeau)

A Privacy-Preserving Disaggregation Algorithm for Nonconvex Optimization Based on Alternate Projections

P. Jacquot[1], O. Beaude[2], S. Gaubert[3], N. Oudjane[4]

We consider a resource allocation problem involving a large number of agents N subject to individual constraints that they wish to keep private, and a central operator whose objective is to optimize a global, possibly non-convex, cost function while satisfying the agents' constraints. This is motivated by applications in the field of energy, in which an operator optimizes its production cost to meet the demand of consumers, whereas consumers wish to keep private some of their consumption characteristics. Formally, we represent the allocation received by agent n by a vector $\mathbf{x}_n = (x_{nt})_{1\leq t\leq T}$, that must belong to a subset $\mathcal{X}_n \subset \mathbb{R}^T$, *only known to agent* n. The global allocation, $\mathbf{p} = (p_t)_{1\leq t\leq T} = \sum_n \mathbf{x}_n$, is required to belong to a publicly known set $\mathcal{P} \subset \mathbb{R}^T$, representing the operator's contraints. In the application to energy, T is the number of time steps, and x_{nt} is the consumption of customer n at time t. Denoting by f the operator's cost, the problem can be written as follows:

$$\min_{\mathbf{x}\in\mathbf{R}^{N\times T},\ \mathbf{p}\in\mathcal{P}} f(\mathbf{p}) \quad \text{s.t. } \mathbf{x}_n \in \mathcal{X}_n,\ \forall 1\leq n\leq N, \quad \sum_{1\leq n\leq N} x_{n,t} = p_t,\ \forall 1\leq t\leq T\ .$$

We introduce a privacy-preserving algorithm that does compute an optimal allocation of resources $\mathbf{p}$ without the need for each agent to reveal her private information (constraints $\mathcal{X}_n$ and individual solution profile $\mathbf{x}_n$) neither to the central operator nor to a third party. Our method relies on an aggregation procedure: we maintain a global allocation of resources, and gradually disaggregate this allocation to enforce the satisfaction of private constraints, by a protocol involving the generation of polyhedral cuts on $\mathbf{p}$, and secure multiparty computations (SMC). To obtain these cuts, we use an alternate projection method [1], which is implemented locally by each agent, preserving her privacy needs. When the constraints describe a transportation polytope, we prove that the alternate projection method converges at a geometric rate, by exploiting methods of spectral graph theory. This theoretical result, along with numerical tests, shows that the proposed method scales well as the number of agents gets large. This talk is based on [2].

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A Bundle Method for DC-Constrained Optimization Problems

P. Javal[1], W. van Ackooij[2], S. Demassey[3], H. Morais[4], W. de Oliveira[5]

This work concerns the design and convergence analysis of a bundle method for dealing with nosmooth and nonconvex optimization problems of the form

$$(\mathbf{P}) \qquad \min_{x \in \mathbb{X}} f_1(x) - f_2(x) \quad \text{s.t.} \quad c_1(x) - c_2(x) \leq 0,$$

where $\emptyset \neq \mathbb{X} \subset \mathbb{R}^n$ is a bounded polyhedron contained in an open set $\mathcal{O} \subset \mathbb{R}^n$, and $f_i, c_i : \mathcal{O} \to \mathbb{R}$, $i = 1, 2$, are convex but possibly nonsmooth functions. As both the objective and the constraint functions are represented by the *Difference-of-Convex* (DC) functions, problem ($\mathbf{P}$) is a *general DC program.* Specialized algorithms for general DC programs either employ penalization techniques or iteratively approximate the nonconvex constraint by a convex one obtained by linearizing c_2. While in the first case we may have issues related to the penalization techniques (choice of a proper penalization parameter/function), the second approach may face feasibility issues caused by the linearization. To avoid these difficulties when handling ($\mathbf{P}$), we propose a proximal bundle method based on the so-called improvement function, depending on two parameters $\tau_f, \tau_c \in \mathbb{R}$:

$$h_\tau(x) := \max\{f_1(x) - f_2(x) - \tau_f,\, c_1(x) - c_2(x) - \tau_c\}\,.$$

At each iteration of our method we update the parameters τ_f and τ_c and define iterates by minimizing a convex quadratic program approximating the convexly-constrained DC problem $\min_{x\in\mathbb{X}} h_\tau(x)$. We discuss the convergence analysis of the new proposal and access its numerical performance on a class of stochastic programming, namely, optimization problems with probability constraints. In this particular case, probability functions can be modeled/approximated by using several approaches, each one leading to its own DC formulation.

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A New Method for Global Optimization

A. Kosolap[1]

This paper presents a new method for global optimization. We use of exact quadratic regularization for transformation of the multimodal problems to a problem of a maximum of norm a vector on convex set. We will consider of nonlinear programming problems of the form

$$\min\{f_0(x)|f_i(x) \leq 0, i = 1, ..., m, x \geq 0, x \in E^n\} \tag{6}$$

where all functions $f_i(x)$ are twice continuously differentiable, x is a vector in n-dimensional Euclidean space E^n. Let the solution of a problem (1) exist, its feasible domain is bounded and x^* – the point of global minimum (1). The problem (1) is transformed to the following

$$\max\{||z||^2|f_0(x) + s + (r-1)||z||^2 \leq d, f_i(x) + r||z||^2 \leq d, i = 1, ..., m, z \geq 0, z \in E^{n+1}\} \tag{7}$$

where $z = (x, x_{n+1})$, the value s is chosen so that $f_0(x^*) + s \geq ||x^*||^2$. The value $r > 0$ exists so that all functions $f_i(x) + r||z||^2$ are convex on the bounded feasible domain of the problem (2). It follows from the fact that Hessians of these functions are positively defined matrixes (matrixes with a dominant main diagonal).

There is a minimum value d_0 for which condition $r||z^*||^2 = d_0$ holds (z^* is the solution of the problem (2) for $d = d_0$). Then z^* is the point of global minimum of a problem (1). Such values d we find to a dichotomy method. In some cases the problem (2) will be unimodal. For example, when the convex feasible domain of a problem (2) is a regular polyhedron, rectangular parallelepiped, the convex set inscribed in a ball (all extreme points lies on its sphere) and in other cases. If $e^T z^* > e^T z^i$ (z^i are the points of local minima of a problem (1), $e = (1, ..., 1)$) then the problem $\max\{||z||^2|z \in S(z, d)\}$ ($S(z, d)$ is convex feasible set of the problem (2)) is equivalent of a unimodal problem $\max\{||z + h||^2|z \in S(z - h, d)$, where $h > 0$. For example, the multimodal problem $\max\{||z||^2|a^T z = 1, z \geq 0\}$ is equivalent to the unimodal problem $\max\{||z + h||^2|a^T z = 1, z \geq 0\}$ for $h \geq (a_i/(b(b - a_i))$ where $a_i = \min a_j, b = \min a_j (j \neq i)$. There exist $h > 0$, that the problem $\max\{||z||^2|z \in S(z - h, d)$ will be unimodal.

In general case, we again use of exact quadratic regularization for checking of the value d_0 on a minimum and receive a problem $\max\{||z||^2|z \in S_0 \cap S(z - h, d_0)\}$ where $S_0 = \{z| - ||z - h||^2 + s + 2||z||^2 \leq d\}$. The solution of this problem can be obtained from solutions n to the convex problems

$$\min\{(z^*)^T z|((c^i)^T z \geq \sqrt{d_0/r}, z \in S(zt - h, d_0))\}, i = 1, ..., n.$$

where $c^i = (1, .., 1, (\sqrt{d_0/r} - \sum_{j=1}^n z_j^*)/z_i^*, 1, .., 1), zt \in \partial S_0$ (∂S_0 is the boundary S_0).

We have solved many difficult optimizing problems in optimal designing, clustering, sensor networks and chemistry. We have found the solutions in more than 400 difficult test problems using this method (see example: http://www.gamsworld.org/global/globallib.htm). This method can be used for the solution of discrete problems. The comparative numerical experiments have shown that this method are very efficient and promising.

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Thursday, Sept. 19, 09:30-09:50 (Fizeau)

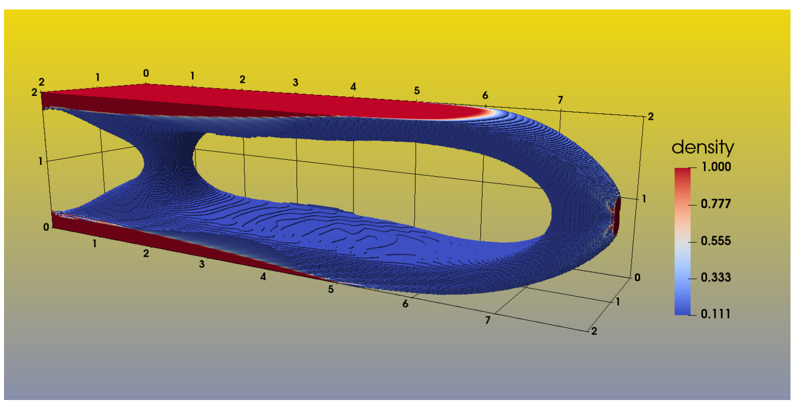
Barrier and Modified Barrier Methods for 3D Topology Optimization

A. Brune[1], M. Kočvara[2]

One of the challenges encountered in the optimization of mechanical structures, in particular in topology optimization, is the size of the problems, which can easily involve millions of variables. A basic example is the variable thickness sheet (VTS) formulation of the minimum compliance problem, which is equivalent to a convex problem. In this talk, we will propose a Penalty-Barrier Multiplier (PBM) method [1] to solve the VTS problem and present some numerical experiments, comparing the results to those obtained by an Interior Point (IP) method and an Optimality Criteria (OC) method.

The computationally most expensive part of each of these algorithms is the solution of linear systems. In the PBM algorithm, these arise from the Newton method used to minimize a generalized augmented Lagrangian. We use a special structure of the Hessian of this Lagrangian to reduce the size of the linear system and to convert it to a form suitable for a standard multigrid method. This converted system is solved approximately by a multigrid preconditioned MINRES method. The IP and OC methods both use similar iterative solver setups. We apply all three methods to different loading scenarios. In our experiments, the PBM method clearly outperforms the other methods in terms of computation time required to achieve a certain degree of accuracy.

Figure 3: Optimization result of the VTS problem for a simple cantilever loading scenario with 8 388 608 elements.



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Thursday, Sept. 19, 09:50-10:10 (Fizeau)

Power Method Tâtonnements for Cobb-Douglas Economies

V. Shikhman[1], Yu. Nesterov[2], V. Ginsburg[3]

We consider an economy with consumers maximizing Cobb-Douglas utilities from the algorithmic perspective. It is known that in this case finding equilibrium prices reduces to the eigenvalue problem for a particularly structured stochastic matrix. We show that the power method for solving this eigenvalue problem can be naturally interpreted as a tâtonnement executed by an auctioneer. Its linear rate of convergence is established under the reasonable assumption of pairwise connectivity w.r.t. commodities within submarkets. We show that the pairwise connectivity remains valid under sufficiently small perturbations of consumers' tastes and endowments. Moreover, the property of pairwise connectivity holds for almost all Cobb-Douglas economies.

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Thursday, Sept. 19, 10:10-10:30 (Fizeau)

Mathematical model of Multiphase Flow with a Dynamic Contact Line for the Simulation and Optimization of Wetting Phenomena

E. Diehl[1], S. Ulbrich[2]

In this talk, we present a simulation based optimization approach for multiphase flow in the context of wetting phenomena. The dynamic wetting or dewetting can be modeled as an multiphase flow with a liquid-gas interface and a so-called dynamic contact line, where liquid and gas touch the solid surface. The mathematical model is governed by the Navier-Stokes equations along with a transport equation for flow advection as well as suitable initial and boundary conditions. The considered transport equation originates from an algebraic Volume-of-Fluid approach, that leads to an One-Field-Formulation of the problem [1]. For this purpose we assume the whole domain to be filled with one single fluid which is not constant in density and viscosity. From a numerical point of view we need a dynamic contact angle treatment, that is included in our flow system as a boundary condition. We use the introduced model for the simulation of a doctor blade process, which is an important part in printing or coating technologies. Our aim is to develop an gradient-based multilevel optimization method for shape optimization of the doctor blade and parameter identification problems arising in wetting processes. To achieve this, we derive sensitivity equations for the continuous flow problem and show the adapted numerical solver together with preliminary numerical results.

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Thursday, Sept. 19, 16:00-16:20 (IBV)

Solving Perfect Information Mean Payoff Zero-sum Stochastic Games by Variance Reduced Deflated Value Iteration

O. Saadi[1], M. Akian[2], S. Gaubert[3], Z. Qu[4]

We introduce a deflated version of value iteration, which allows one to solve mean-payoff problems, including both Markov decision processes and perfect information zero-sum stochastic games. This method requires that there is a distinguished state which is accessible from all initial states and for all policies; it differs from the classical relative value iteration algorithm for mean payoff problems in that it does not need any primitivity or geometric ergodicity condition. Our method is based on a reduction from the mean payoff problem to the discounted problem by a Doob h-transform, combined with a deflation technique and non-linear spectral theory results (Collatz-Wielandt characterization of the eigenvalue), inspired by [1]. In this way, we extend complexity results from the discounted to the mean payoff case. In particular, Sidford, Wang, Wu and Ye [2] developed recently an algorithm combining value iteration with variance reduction techniques to solve discounted Markov decision processes in sublinear time when the discount factor is fixed. We combine deflated value iteration with variance reduction techniques to obtain sublinear algorithms for mean payoff stochastic games in which the hitting times of a distinguished state are bounded a priori.

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Thursday, Sept. 19, 16:20-16:40 (IBV)

A Unifying vision of Particle Filtering and Explicit Dual Control in Stochastic Control

E. Flayac[1], K. Dahia[2], B. Hérissé[3], F. Jean[4]

We present a multistage stochastic optimisation problem that combines a stochastic optimal control problem with imperfect information and an optimal estimation problem. Our goal is to give a more theoretically grounded justification of the use of particle filters and explicit dual controllers in stochastic optimal control. Actually, our problem can be recast as a classical stochastic optimal control problem with imperfect information considering an augmented control. The augmented controls are composed of estimation policies and of the original control policies. By applying the Dynamic Programming principle to this problem and under mild assumptions on the cost function, two steps naturally appear in the resolution of the problem. The first step is to solve a classical optimal estimation problem. We show that a certain class of particle filters, taken from [1], leads to near optimal estimators for the mean square error. The second step is to solve an optimal control problem with an additional term coming from optimal estimation. This new term matches the measure of information that is usually empirically added to the cost function in explicit dual control [2]. In fact, we claim that explicit dual control problems can be seen as natural approximations of our problem from step two, where the measure of information replaces the optimal estimation error. It also matches the practical uses as the measure of information is generally a function of the Fisher Information Matrix which is strongly linked to the optimal mean square error. This principle is demonstrated on previous controllers and estimators designed for terrain-based navigation [3, 4].

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Thursday, Sept. 19, 16:40-17:00 (IBV)

Multiplier Stabilization Applied to Two-Stage Stochastic Programs

C. Lage[1], C. Sagastizábal[2], M. Solodov[3], G. Erbs[4]

In many mathematical optimization applications dual variables are an important output of the solving process, due to their role as price signals. When dual solutions are not unique, different solvers or different computers, even different runs in the same computer if the problem is stochastic, often end up with different optimal multi-pliers that also depend on the discretization of the data.

From the perspective of a decision maker, this variability makes the price signals less reliable and, hence, less useful. We address this issue for a particular family of linear and quadratic programs by proposing a solution procedure that, among all possible optimal multipliers, systematically yields the one with the smallest norm. The approach, based on penalization techniques of nonlinear programming, amounts to a regularization in the dual of the original problem. As the penalty parameter tends to zero, convergence of the primal sequence and, more critically, of the dual is shown under natural assumptions. The methodology is illustrated on a battery of two-stage stochastic linear programs.

The variance of the Lagrange Multiplier regarding different discretizations is investigated in theoretical and numerical aspects We show the positive impact of the regularization in the price distribution of the Northern Europe hydro-generation system. This real-life example, set in a two stage perspective, helps us to better understand price signals in regularized and non-regularized settings.

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Doubly Ordinal Warping for Bayesian non-Lipschitz Optimisation

V. Picheny[1], A. Artemev[2]

Bayesian optimisation (BO) is established as a strong competitor among derivative-free optimisation approaches, in particular for computationally expensive problems. However, one of the weaknesses of vanilla BO lies in the Gaussian process (GP) assumption made on the objective function: when this assumption is strongly violated (for instance, for ill-conditioned problems), the GP model is weakly predictive and BO becomes inefficient. One remedy to this problem is to add a warping function, either on the output space [1] or on the input space [3]. However, warping usually applies only to continuous functions.

In this work, we propose to apply an "ordinal" warping to both input and output spaces, that is, a transformation that only preserves the ordering of the variables. By doing so, our approach becomes agnostic to any metric in the input and the output spaces. In the output space, this amounts to performing ordinal regression [2]. In the input space, inference requires the resolution of a large optimisation problem. This is made possible thanks to the use of variational approaches and automatic differentiation. We then tackle optimization of non-Lipschitz functions by applying classical sampling strategies, such as expected improvement, upper confidence bound or Thompson sampling.

Our approach is illustrated on several toy problems, showing that it is able to optimise severely ill-conditioned and discontinuous functions.

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A Min-plus-SDDP Algorithm for Multistage Stochastic Convex Programming

M. Akian[1], J-P. Chancelier[2], B. Tran[3]

We first consider multistage deterministic optimal control problems with finite horizon involving continuous states and possibly both continuous and discrete controls, subject to (non-stationary) linear dynamics and convex costs. In this general deterministic framework, we present a stochastic algorithm which generates monotone approximations of the value functions as a pointwise supremum or infimum of basic functions (e.g. affine or quadratic) which are randomly selected.

We give sufficient conditions on the way basic functions are selected in order to ensure almost sure convergence of the approximations to the value function on a set of interest. As already seen in the literature of SDDP, the basic functions should be tight and valid, but we stress on the fact that selecting basic functions which are tight and valid may yield non-converging upper approximations to the value functions if the trial points are not carefully selected. We present a simple two stage example illustrating this phenomena. Thus in the sufficient conditions mentioned above we give a condition on the way the trial points are selected so as to ensure almost sure convergence of the approximations to the value functions.

Then we consider risk-neutral multistage stochastic optimal control problems with linear dynamics, convex costs and independent noises with finite support. We prove how one can extend the previous deterministic study by the so-called "problem-child" criterium of Baucke, Downward and Zakeri (2018). We show how one can simultaneously build polyhedral lower approximations (by SDDP) and upper approximations as pointwise infima of quadratic convex forms (by a min-plus algorithm). The upper and lower approximations both use as trial points an optimal trajectory for the current lower approximations which is selected by the "problem-child" deterministic criterium aforementioned. We prove that the gap between the two approximations (surely) converges to 0 along the optimal trajectories of the current lower approximations. Thus, we avoid the use of Monte-Carlo sampling to get a stopping criterion for SDDP.

The first part of this work is available as a preprint [2]. The second part of this work benefited from a key idea by Zheng Qu and is currently a work in progress.

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Thursday, Sept. 19, 17:40-18:00 (IBV)

On Almost Sure Rates of Convergence for Sample Average Approximations

R. Werner[1], D. Banholzer[2], J. Fliege[3]

In this presentation we provide rates at which strongly consistent estimators in the sample average approximation approach (SAA) converge to their deterministic counterparts. To be able to quantify these rates at which a.s. convergence occurs, we consider the law of the iterated logarithm in a Banach space setting.

We first establish convergence rates for the approximating objective functions under relatively mild assumptions.

These rates can then be transferred to the estimators for optimal values and solutions of the approximated problem.

Based on these results, we further show that under the same assumptions the SAA estimators converge in mean to their deterministic equivalents, at a rate which essentially coincides with the one in the almost sure sense.

We close the talk by characterizing the convergence speed of the estimator for the optimality gap.

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Thursday, Sept. 19, 16:00-16:20 (Fizeau)

Prioritized Optimization by Nash Games : Towards an Adaptive Multi-Objective Strategy – Application to a Problem of Flight Mechanics

J.-A. Désidéri[1], R. Duvigneau[2]

A multi-objective differentiable optimization algorithm has been proposed to solve problems presenting a hierarchy in the cost functions, $\{f_j(\mathbf{x})\}$ $(j = 1, \ldots, M \geq 2;\ \mathbf{x} \in \Omega_a \subseteq \mathsf{R}^n)$. The first cost functions for which $j \in \{1, \ldots, m\}$ $(1 \leq m < M)$ are considered to be of preponderant importance; they are referred to as the "primary cost functions" and are subject to a "prioritized" treatment, in contrast with the tail ones, for which $j \in \{m + 1, \ldots, M\}$, referred to as the "secondary cost functions". The problem is subject to the nonlinear constraints, $c_k(\mathbf{x}) = 0$ $(k = 1, \ldots, K)$. The cost functions $\{f_j(\mathbf{x})\}$ and the constraint functions $\{c_k(\mathbf{x})\}$ are all smooth, say $C^2(\Omega_a)$. The algorithm was first introduced in the case of two disciplines $(m = 1,\ M = 2)$, and successfully applied to optimum shape design optimization in compressible aerodynamics concurrently with a secondary discipline [1] [2]. More recently, the theory has been enhanced in both framework and established results. In short, an initial admissible point $\mathbf{x}_A^\star$ that is Pareto-optimal with respect to the sole primary cost functions (subject to the constraints) is assumed to be known. Subsequently, a small parameter $\varepsilon \in [0, 1]$ is introduced, and it is established that a continuum of Nash equilibria $\{\bar{\mathbf{x}}_\varepsilon\}$ exists for all small enough ε. The continuum originates at $\mathbf{x}_A^\star = \bar{\mathbf{x}}_0$ (consistency). Along the continuum: (i) the Pareto-stationarity condition exactly satisfied by the primary cost functions at $\mathbf{x}_A^\star$ is degraded by a term $O(\varepsilon^2)$ only, whereas (ii) the secondary cost functions initially decrease, at least linearly with ε with a negative derivative provided by the theory. Thus, the secondary cost functions are reduced while the primary cost functions are maintained to quasi Pareto-optimality.

In this presentation, we will first outline the theoretical statement (existence and properties of the continuum of Nash equilibria) and briefly comment on the perspective it opens up to adaptive optimization. The software platform developed at Inria to construct this continuum from the specification of the cost and constraint functions will be shortly described. Lastly, the numerical method will be illustrated by the application to a problem of aeronautical design related to flight mechanics.

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A Game Theory Approach to the Existence and Uniqueness of Nonlinear Perron-Frobenius Eigenvectors

M. Akian[1], S. Gaubert[2], A. Hochart[3]

To any nonlinear order-preserving and positively homogeneous map f acting on the open orthant $\mathbb{R}_{>0}$, we associate a zero-sum two-player game that only depends on the behavior of f "at infinity". This allows us to establish a generalized Perron-Frobenius theorem, that is the existence of an eigenvector of f, under a combinatorial criterion involving dominions of the game, i.e., sets of states that can be made invariant by one player of the game. This criterion also characterizes the situation in which, for all uniform perturbations g of f, all the orbits of g are bounded in Hilbert's projective metric. This solves a problem raised by Gaubert and Gunawardena [1]. We also show that the uniqueness of an eigenvector is characterized by a dominion condition, involving a different game depending now on the local behavior of f near an eigenvector. We show that the dominion conditions can be verified by directed hypergraph methods. We finally illustrate these results by considering specific classes of nonlinear maps, including Shapley operators, generalized means and nonnegative tensors. This talk is based on the work [2].

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Optimal Control and Differential Games: Application to an Abort Landing Problem

N. Gammoudi[1], H. Zidani[2]

Key words: Optimal control problems, nonanticipative strategies, viscosity solutions, Hamilton-Jacobi approach, trajectory reconstruction.

In this talk, we consider deterministic optimal control problems of finite time horizon in the context of differential games and nonanticipative strategies. We are interested in state-constrained problems with non-linear dynamics.

Our approach is based on Hamilton-Jacobi framework. To characterize the epigraph of the value function, we introduce an auxiliary optimal control problem free of state constraints, for which the value function is Lipschitz continuous and can be characterized, without any additional assumptions, as the unique viscosity solution to an appropriate Hamilton-Jacobi-Issac equation.

Besides, we present several trajectory reconstruction procedures and discuss convergence results of these algorithms.

Finally, we consider a problem of an aircraft abort landing in windshear and we discuss several numerical simulations to analyse the relevance of our theoretical approach.

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The Operator Approach to Entropy Games

S. Gaubert[1], M. Akian[2], J. Grand-Clément[3], J. Guillaud[4]

Asarin et al. [1] introduced the notion of entropy game, in which one player (called Despot) wishes to minimize the growth rate of a matrix product, measuring the "freedom" of a half-player (called People), whereas the opponent of Despot (called Tribune) wishes to maximize it. We develop an operator approach to entropy games. We first show that these games can be cast as stochastic mean payoff games in which payments are given by a relative entropy. Then, we establish the existence of the value by o-minimality arguments, exploiting an approach of [3]. We also characterize the value by a Collatz-Wielandt formula. When specialized to the one player case, this leads to a convex programming characterization of the value. Using the latter characterization, together with separation bounds between algebraic numbers, we show that entropy games in which the number of states belonging to Despot is fixed can be solved in polynomial time. Finally, we use this operator approach to solve general entropy games by policy and value iteration algorithms, which we compare with the spectral simplex algorithm developed by Protasov [3]. This talk is based on [1].

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A Feasible Directions Technique for Generalized Nash Equilibrium Problems

J. Herskovits[1], C. Effio[2], J. Roche[3]

We consider the N players generalized Nash equilibrium problem, GNEP, with shared constraints, stated as follows: Find $x \in \mathbb{R}^n$ that solves simultaneously for all $\nu = 1, 2, ..., N$ the following constrained optimization problems:

$$\begin{cases} \underset{x^\nu \in \mathbb{R}^{n_\nu}}{\text{Minimize}} & f^\nu\left(x^\nu, x^{-\nu}\right) \\ \text{such that:} & g_i(x^\nu, x^{-\nu}) \leq 0, \ i = 1, ..., m, \\ & h_j^\nu(x^\nu) \leq 0, \ j = 1, ..., l^\nu, \end{cases}$$

where $f^\nu : \mathbb{R}^n \to \mathbb{R}$, $g_i : \mathbb{R}^n \to \mathbb{R}$, and $h_j^\nu(x^\nu) : \mathbb{R}^{l^\nu} \to \mathbb{R}$ are continuously differentiable, and $n = \sum_{\nu=1}^N n_\nu$. We write $x := (x^\nu, x^{-\nu})$ if we want to emphasize the decision vector x^ν in x, and the vector $x^{-\nu} = (x^1, ..., x^{\nu-1}, x^{\nu+1}, ..., x^N)$ is a short notation for the vector consisting of all decision vectors except the player's decision variables x^ν. A solution such that the Lagrange multipliers of the common constraints are the same for each player, is called normalized solution, [3]. An algorithm to find the normalized Nash equilibrium, is presented. This one is a feasible direction Newton-type method to solve the first order necessary optimality conditions. Given a feasible point for all players, at each iteration a feasible direction that is descent with respect to the potential function

$$\Theta(x, \lambda, \mu) = \sum_{\nu=1}^{N} \|\nabla_{x^\nu} L^\nu(x^\nu, x^{-\nu}, \lambda, \mu^\nu)\|^2,$$

is obtained as in FDIPA, the Feasible direction interior Point Algorithm, [2]. A line search is performed to get a new iterate with a lower potential and feasible for all the players. Global convergence to a normalized equilibrium point is proved.The presented approach was tested on a collection of problems, [1]. The results suggest that our method is strong and efficient.

Keywords: Generalized Nash equilibrium, Interior-point method, feasible direction algorithm,

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On Equilibria of Continuous and Discrete Hotelling Pure Location Games

P. von Mouche[1]

We consider two variants of a two-player game in strategic form where each player i has strategy set S and payoff function $u_i \colon S \times S \to \mathbb{R}$ as follows:

- if $S = [0, L]_{\mathbb{Z}}$: *Hotelling bi-matrix game*

$$u_i(x_1, x_2) := \sum_{y \in V_i(x_1,x_2)} f(|y - x_i|) + \frac{1}{2} \sum_{y \in V_0(x_1,x_2)} f(|y - x_i|)$$

- if $S = [0, L]$: *Hotelling game*

$$u_i(x_1, x_2) := \int_{V_i(x_1,x_2)} f(|y - x_i|)dy + \frac{1}{2} \int_{V_0(x_1,x_2)} f(|y - x_i|)dy.$$

Here: if $S = [0, L]_{\mathbb{Z}}$, then f denotes a real-valued positive function on S that is constant or strictly decreasing; if $S = [0, L]$, then f is a similar function that also is continuous. And, with $\{i, j\} = \{1, 2\}$, $V_i(x_1, x_2) := \{y \in S \mid |y - x_i| < |y - x_j|\}$ and $V_0(x_1, x_2) := \{y \in S \mid |y - x_1| = |y - x_2|\}$.

We present and compare results concerning the existence of potentials and the structure of the Nash equilibrium set.

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Friday, Sept. 20, 08:30-08:50 (Fizeau)

Two Optimization Methods for Optimal Muscular Force Response to Functional Electrical Stimulations

T. Bakir[1], B. Bonnard[2], L. Bourdin[3], J. Rouot[4]

Optimized force response to FES is an important problem for muscular reeducation and in case of paralysis. An historical model is known as the Hill model and more refined recent models are taking into account the muscular fatigue, see [1] for a discussion of the models. In this talk consequence of a collaborative work with Bonnard, Bourdin, Rouot, we shall analyze the so-called Ding et al. force-fatigue model [2] which is frequently used in practical experiments. The controls are electrical (Dirac) pulses from which we can control the times of application (controling the interpulses) and the amplitudes. Due to physical limitations there is a maximum number of pulses over a period T. This led to a sampled-data control problem. Optimization problem is associated to maximize the force response or to obtain at the final time a reference force. In this talk we present two theoretical and numerical methods to solve the optimal sampled-data control problem. The first one is a semi-direct scheme where a further numerical discretization is applied to the control and this leads to a discrete optimization. The second method is based on recent advances on Pontryagin necessary type optimality conditions for sampled data optimal control problems [3] which can be implemented numerically. Note that they have to be refined to deal in particular with the phenomenon of tetania which is the memory effect of the successive pulses [4].

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Friday, Sept. 20, 08:50-09:10 (Fizeau)

Optimal Actuation for Magnetic Micro-Swimmers

Y.E. Faris[1], L. Giraldi[2], S. Régnier[3], J.-B. Pomet[4]

Robotic micro-swimmers are able to perform small-scale operations such as targeted drug delivery, and minimally invasive medical diagnosis and surgery. However, efficient actuation of these robots becomes more challenging as their size decreases. Hence, wireless actuation is preferable over built-in actuation sources. For example, one popular strategy is the magnetization of parts of the swimmer and its actuation with an external magnetic field. In the following study, we focus on flexible magnetic micro-swimmers that are similar to spermatozoa in their design and flagellar propulsion. Our purpose is to develop a numerical model of the swimmer and apply a optimal control framework in order to improve the efficiency of the swimmer's actuation. All the resulting numerical simulations are experimentally validated on a scaled-up flexible magnetic swimmer using the same setting as [1].
Firstly, a simplified 3D dynamic model of a flexible swimmer has been developed, based on the approximation of hydrodynamic forces using Resistive Force Theory ([2]) and the discretization of the curvature and elasticity of the tail of the swimmer, generalizing the planar "N-Link" models such as [3]. By fitting the hydrodynamic and elastic parameters of our model accordingly, we are able to obtain propulsion characteristics (mainly the frequency response of the swimmer) close to those experimentally measured. Secondly, we address the optimal control problem of finding the actuating magnetic fields that maximize the propulsion speed of the experimental swimmer and solve it numerically. The optimal magnetic fields found via numerical optimization are then experimentally validated and are found to significantly improve the propulsion speed of the swimmer. Surprisingly, the optimal trajectory of the swimmer is non-planar, which makes us deduce that flexible magnetic micro-swimmers swim at a maximum speed when allowed to go out-of-plane.

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Friday, Sept. 20, 09:10-09:30 (Fizeau)

Periodical Body's Deformations are Optimal Strategies for Locomotion

L. Giraldi[1], F. Jean[2]

Most of the living organisms self-propel by a periodical cycle of body's deformation. From a bird which flaps theirs wings, a fish which beats its caudal fin, the human walking using a synchronized movement of theirs legs, the motion of living organisms derives from a periodical cycle of shape changing.

Starting from this observation, an interesting question is what are the common properties of all these various dynamical systems which imply that the strategy employeed for achieving a displacement is to deforming their body in a periodical way. We attack this problem using a three dimensional toy dynamical model and applying an optimal control framework.

Assuming that the locomotion derives from the fact that the body's deformations allow the object to self-propel by maximizing its average speed. Our main result states that, under some regularity and boundedness hypothesis, auto-propulsion of deformable object is optimally achieved using periodic strategy of body deformation. More detailed can be found in [1].

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Optimal Motion of a Scallop

M. Zoppello[1], R. Maggistro[2]

This talk will address two optimal control problems for the scallop: a two-link swimmer that is able to self-propel changing dynamics between two fluids regimes. More details can be found in [1, 2]. We analyze and solve explicitly the minimum time problem and the minimum quadratic one, computing the cost needed to move the swimmer between two fixed positions using a periodic control. We focus on the case of only one switching in the dynamics and exploiting the structure of the equation of motion we are able to split the problem into simpler ones. We solve explicitly each sub-problem obtaining a discontinuous global solution. Then we approximate it through a suitable sequence of continuous functions.

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Aerial Vehicle Path Planning Using Hamilton Jacobi Bellman Approach

H. Zidani[1], A. Desilles[2], V. Ašković[3]

Keywords: Path planning, optimal control, Hamilton Jacobi Bellman equation, viscosity solution, discontinuous dynamics.

In this talk, we formulate the aerial vehicle path planning problem as a deterministic optimal control problem in finite time horizon. Such a vehicle can be seen as a dynamical system governed by non-linear ordinary differential equations under state constraints and involving a control variable.

We adopt an original approach based on the Hamilton Jacobi Bellman formalism. It has the advantage to offer a unified theoretical framework for various engineering issues (reachability, optimization). Firstly we propose a relevant mathematical model. Then we characterize the epigraph of the value function of the state constrained problem through an auxiliary function, which is the unique viscosity solution of an appropriate Hamilton Jacobi Bellman equation. Finally, we illustrate the approach through some physically relevant numerical results.

We extend the approach to a class of systems with discontinuous dynamics. For this purpose, using tools from nonsmooth analysis, we study the regularity of the value function and the Hamilton Jacobi Bellman equation associated to this case.

References

[1] A general Hamilton-Jacobi Bellman framework for nonlinear state-constrained control problems, ESAIM 2012, *A. Altarovici, O. Bokanowski, H. Zidani*

[2] Hamilton-Jacobi Bellman equation on multi-domains, May 2013 *Z. Rao, H. Zidani*

[3] Discontinuous solutions of Hamilton Jacobi equations on networks, 2016, *J. Graber, C. Hermosilla, H. Zidani*

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Minimum Time Optimal Control Problem in Marine Navigation

J.-B. Caillau[1], S. Maslovskaya[2], J.-B. Pomet[3]

In this talk we consider the optimum time problem applied to marine navigation for seismic acquisition. It arises from the real problem where the goal is to gain time in turns and alignment maneuvers for a marine vessel which collects data of the subsurface of the Earth. We present a model for the kinematics of the marine vessel including the towed underwater cables. The minimum time problem for the obtained model can be seen as a generalized Dubins problem of a vehicle with trailers in the sea current. Without trailers, the problem is known as Zermelo-Markov-Dubins problem [1] and was studied in context of airplane path planing [2]. We analyse the controllability properties of the system and then apply the Pontryagin Maximum Principle to minimum time problem in the case with one trailer. And finally, we characterise the structure of the optimal trajectories.

References

[1] E. Bakolas and P. Tsiotras. Optimal synthesis of the Zermelo-Markov-Dubins problem in a constant drift field. *J. Optim. Theory Appl.*, 156(2):469492, 2013.

[2] T. G. McGee and J. K. Hedrick. Optimal path planning with a kinematic airplane model. *J. Guid. Control Dyn.*, 30:629633, 2007.

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Author Index

Tuesday, September 17, 2019

TIME	EVENT
13:00 - 14:00	Opening (Theater)
14:00 - 15:30	Plenary Talk (Theater) - P1, P2 (Frankowska, Boehm - chair: TBA)
14:00 - 14:45	› Second Order Variational Analysis in Optimal Control - *Helene Frankowska, CNRS et Sorbonne Université*
14:45 - 15:30	› Waveform inversion from ultrasound to global scale - *Christian Boehm, Department of Earth Sciences, ETH Zurich*
15:30 - 16:00	Coffee break (Theater)
16:00 - 18:00	Parallel Sessions (LJAD) - MS1 (Recent trends in nonlinear optimization 1)
16:00 - 18:00	› * Recent trends in nonlinear optimization - *Simone Goettlich, University of Mannheim*
16:00 - 16:30	› Nonsingularity and Stationarity Results for Quasi-Variational Inequalities - *Axel Dreves, Institut für Mathematik und Rechneranwendung [Munchen] - Simone Sagratella, Sapienza University of Rome*
16:30 - 17:00	› Direct Methods for Mixed-Integer Optimization with Differential Equations - *Falk Hante, FAU erlangen nürnberg*
17:00 - 17:30	› Low-rank surrogates in Bayesian inverse problems - *Manuel Marschall, Weierstrass Institute Berlin*
17:30 - 18:00	› Interacting Particle Systems & Optimization - *Rene Pinnau, TU Kaiserslautern*
16:00 - 18:00	Parallel Sessions (LJAD II) - MS2 (Singular perturbations and turnpike in optimal control problems)
16:00 - 18:00	› * Singular perturbations and turnpike in optimal control problems - *Joseph Gergaud, Université de Toulouse, IRIT-ENSEEIHT*
16:00 - 16:30	› Dispersion points of ODE - *Claude LOBRY, Université de Nice Sophia Antipolis*
16:30 - 17:00	› Turnpike in Shape Design - *Gontran Lance, Laboratoire Jacques-Louis Lions (LJLL)*
17:00 - 17:30	› Bacterial growth strategies as Optimal Control problems: maximizing metabolite production - *Agustin Gabriel Yabo, Inria Sophia Antipolis - Méditerranée*
17:30 - 18:00	› The singular perturbations phenomenon and the turnpike property in optimal control - *Boris Wembé, IRIT*
16:00 - 18:20	Parallel Sessions (IBV) - CS1 (Optimization 1 - chair: TBA)
16:00 - 16:20	› Time adaptivity in POD based model predictive control - *Carmen Graessle, University Hamburg*
16:20 - 16:40	› Certified Reduced Basis Methods for Variational Data Assimilation - *Francesco Silva, RWTH Aachen University*
16:40 - 17:00	› Adaptive localized reduced basis methods in PDE-constrained optimization - *Felix Schindler, University of Münster*
17:00 - 17:20	› REDUCED BASIS METHOD FOR PARAMETER FUNCTIONS WITH APPLICATION IN QUANTUM MECHANICS - *Stefan Hain, Ulm University*
17:20 - 17:40	› Cost-Optimal Design and Operation of Decentralized Energy Networks Including Renewable Energies - *Kristina Janzen, Technische Universität Darmstadt*
17:40 - 18:00	› Numerical Solution Strategies for Finite Plasticity in the Context of Optimal Control - *Anna Walter, Nonlinear Optimization, TU Darmstadt*
18:00 - 18:20	› Goal--Oriented A Posteriori Error Estimation For Dirichlet Boundary Control Problems - *Hamdullah Yücel, Middle East Technical University*
16:00 - 18:00	Parallel Sessions (Fizeau) - CS2 (Control 1 - chair: TBA)
16:00 - 16:20	› Some regularity results for minimizers in dynamic optimization - *Piernicola Bettiol, LMBA Laboratoire de Mathématiques, Université de Brest*
16:20 - 16:40	› Higher order problems in the Calculus of Variations: Du Bois-Reymond condition and Regularity of Minimizers - *Julien Bernis, LMBA Laboratoire de Mathématiques, Université de Brest*

TIME	EVENT
16:40 - 17:00	› Optimality for minimum time control-affine problems - *Michael Orieux, Scuola Internazionale Superiore di Studi Avanzati / International School for Advanced Studies*
17:00 - 17:20	› Necessary and Sufficient optimality conditions in an optimal control problem with nonlocal conditions - *Aysel Ramazanova, Universität Duisburg-Essen*
17:20 - 17:40	› Sparse grid approximation of the Riccati operator for closed loop parabolic control problems with Dirichlet boundary control - *Ilja Kalmykov, Departement Mathematik und Informatik Universität Basel*
17:40 - 18:00	› On the Solution of a Time-dependent Inverse Shape Identification Problem for the Heat Equation - *Rahel Bruegger, Departement Mathematik und Informatik Universität Basel*
18:30 - 19:30	Cocktail (LJAD)

Wednesday, September 18, 2019

TIME	EVENT
08:30 - 10:30	Parallel Sessions (LJAD) - MS3 (Recent trends in nonlinear optimization 2)
08:30 - 09:00	› A Sequential Homotopy method for Mathematical Programming problems - *Andreas Potschka, Interdisciplinary Center for Scientific Computing*
09:00 - 09:30	› A composite step method for equality constrained optimization on manifolds - *Anton Schiela, Universität Bayreuth*
09:30 - 10:00	› Extensions of Standard Nash-Games in Finite and Infinite Dimensions - *Sonja Steffensen, RWTH Aachen University*
10:00 - 10:30	› Multilevel Augmented-Lagrangian Methods for Overconstrained Contact Discretizations - *Martin Weiser, Zuse Institute Berlin*
08:30 - 10:30	Parallel Sessions (LJAD II) - MS4 (Optimization and optimal control for biological models)
08:30 - 10:30	› * Optimization and Optimal Control for Biological Models - *Jean-Luc Gouzé, Inria Sophia Antipolis - Méditerranée*
08:30 - 09:00	› Dynamic optimality in cellular metabolism - *Diego Oyarzun, University of Edinburgh*
09:00 - 09:30	› Over-yielding phenomenon in optimal control and applications to the chemostat model - *Terence Bayen, Institut de Mathématiques et de Modélisation de Montpellier*
09:30 - 10:00	› Optimisation of a Chemotherapy to prevent the emergence of Resistance in a Heterogeneous Tumour - *Cécile Carrère, Laboratoire Jacques-Louis Lions*
10:00 - 10:30	› Optimization of Darwinian Selection of Microalgae - *WALID DJEMA, Inria Sophia Antipolis - Méditerranée*
08:30 - 10:30	Parallel Sessions (IBV) - MS5 (Nonlinear optimization methods and their global rates of convergence)
08:30 - 10:30	› * Nonlinear Optimization Methods and their Global Rates of Convergence - *Geovani Grapiglia, Departamento de Matemeatica, Universidade Federal do Parana, Centro Politecnico*
08:30 - 09:00	› Greedy Quasi-Newton Method with Explicit Superlinear Convergence - *Anton Rodomanov, Université Catholique de Louvain*
09:00 - 09:30	› Minimizing Uniformly Convex Functions by Cubic Regularization of Newton Method - *Nikita Doikov, Université Catholique de Louvain*
09:30 - 10:00	› Tensor Methods for Minimizing Functions with H\"{o}lder Continuous Higher-Order Derivatives - *Geovani Grapiglia, Universidade Federal do Paraná*
10:00 - 10:30	› Multilevel optimization methods for the training of artificial neural networks - *Elisa Riccietti, IRIT*
08:30 - 10:30	Parallel Sessions (Fizeau) - CS3 (Optimization 2 - chair: TBA)
08:30 - 08:50	› Adding long edges incident with the root to complete K-ary tree - *Kiyoshi Sawada, University of Marketing and Distribution Sciences*
08:50 - 09:10	› A linear programming approach to solve one-versus-all polynomial systems - *Marin Boyet, Inria*

TIME	EVENT
09:10 - 09:30	› A Necessary Condition For Copositive matrices - *Mourad Naffouti, Faculty of Mathematical, Physical and Natural Sciences of Tunis (FST)*
09:30 - 09:50	› Most IPs With Bounded Determinants Can Be Solved in Polynomial Time - *Miriam Schlöter, ETH Zurich*
09:50 - 10:10	› Variational and convex analysis of mean value theorems... - *Jean-Baptiste Hiriart-Urruty, Math Institute of Toulouse*
10:10 - 10:30	› On metric regularity of composed multimaps - *Meryem Meddahi, University of Hassiba Benbouali, Chlef*
10:30 - 11:00	Coffee break (Theater)
11:00 - 12:30	Plenary Talk (Theater) - P3, P4 (d'Ambrosio, Zenklusen - chair: TBA)
11:00 - 11:45	› Global Optimization methods for Mixed Integer Non Linear Programs with Separable Non Convexities - *Claudia D'Ambrosio, Laboratoire d'informatique de l'école polytechnique*
11:45 - 12:30	› Analyzing Network Robustness via Interdiction Problems - *Rico Zenklusen, ETH Zurich*
12:30 - 14:00	Lunch (Theater)
14:00 - 15:30	Plenary Talk (Theater) - P5, P6 (Basu, Diehl - chair: TBA)
14:00 - 14:45	› Representability of Optimization Models - *Amitabh Basu, Johns Hopkins University*
14:45 - 15:30	› A Survey of Generalized Gauss Newton and Sequential Convex Programming Methods - *Moritz Diehl, IMTEK, University of Freiburg*
15:30 - 16:00	Coffee break (Theater)
16:00 - 18:00	Parallel Sessions (LJAD) - MS6 (Game theory approaches in inverse problems and control)
16:00 - 18:00	› * Game Theory Approaches in Inverse Problems and Control - *Abderrahmane Habbal, J. A. Dieudonné, University of Nice, Inria Sophia Antipolis - Méditerranée*
16:00 - 16:30	› On the theory and numerics of quantum dynamics Nash games - *Alfio Borzi, University of Wuerzburg*
16:30 - 17:00	› Examples of Games in Hyperbolic Models - *Rinaldo M. Colombo, University of Brescia*
17:00 - 17:30	› Game strategies to solve inverse obstacle Cauchy-Stokes problems - *Abderrahmane Habbal, J. A. Dieudonné, University of Nice, Inria Sophia Antipolis - Méditerranée*
17:30 - 18:00	› A Nash games framework to control pedestrian behavior - *Souvik Roy, University of Texas at Arlington*
16:00 - 17:30	Parallel Sessions (LJAD II) - MS7 (Mean field games: new trends and applications)
16:00 - 17:30	› * Mean field games: new trends and applications - *Daniela Tonon, CEntre de REcherches en MAthématiques de la DEcision*
16:00 - 16:30	› Mean Field Games of Controls: theory and numerical simulations - *Ziad Kobeissi, Laboratoire Jacques-Louis Lions*
16:30 - 17:00	› From Schrödinger to Lasry-Lions via Brenier - *Luca Nenna, Laboratoire de Mathématiques dÓrsay*
17:00 - 17:30	› An existence result for a class of potential meean field games of controls - *Laurent Pfeiffer, University of Graz*
16:00 - 18:00	Parallel Sessions (IBV) - CS4 (Optimization 3 - chair: TBA)
16:00 - 16:20	› A Constrained Bundle Trust-Region Method in the Context of Shape Optimization governed by Frictional Contact Problems - *Benjamin Horn*
16:20 - 16:40	› Restarting Frank-Wolfe - *Alexandre d'Aspremont, Département dínformatique de l\'École normale supérieure*
16:40 - 17:00	› Lower Bound Convex Programs for Exact Sparse Optimization - *Michel De Lara, Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique*
17:00 - 17:20	› A primal-dual bundle method for nonsmooth nonconvex optimization - *Welington de Oliveira, Center for Applied Mathematics*
17:20 - 17:40	› First-order Linear Programming Algorithm with Real-time Applications - *Max Demenkov, Institute of Control Sciences*

TIME	EVENT
17:40 - 18:00	› Combining duality and splitting proximal point methods for constrained optimization problems - *Sorin-Mihai Grad, University of Vienna [Vienna]*
16:00 - 18:00	Parallel Sessions (Fizeau) - CS5 (Learning - chair: TBA)
16:00 - 16:20	› The Geometry of Sparse Analysis Regularization - *Samuel Vaiter, Institut de Mathématiques de Bourgogne [Dijon]*
16:20 - 16:40	› Off-the-Grid Wasserstein Group Lasso - *Paul Catala, DMA, Ecole Normale Supérieure*
16:40 - 17:00	› Primal-dual optimization for supervised Learning - *Michel Barlaud, Université Cote d'azur*
17:00 - 17:20	› M* Regularized Dictionary Learning - *Mathieu Barré, Département dínformatique de l\'École normale supérieure*
17:20 - 17:40	› Box Constrained Optimization for Minimax Supervised Learning - *Cyprien Gilet, Laboratoire dÍnformatique, Signaux, et Systèmes de Sophia Antipolis*
17:40 - 18:00	› Bayesian Optimization and Dimension Reduction with Active Subspaces - *Mickaël Binois, Inria Sophia Antipolis - Méditerranée*

Thursday, September 19, 2019

TIME	EVENT
08:30 - 10:30	Parallel Sessions (LJAD) - MS8 (Discrete Optimization and Game Theory)
08:30 - 10:30	› * Discrete Optimization and Game Theory - *Frédéric Meunier, Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique*
08:30 - 09:00	› On approximate pure Nash equilibria in weighted congestion games - *Angelo Fanelli, CNRS (UMR-6211)*
09:00 - 09:30	› On a Simple Hedonic Game with Graph-Restricted Communication - *Laurent Gourvès, Laboratoire d'analyse et modélisation de systèmes pour l'aide à la décision*
09:30 - 10:00	› Game Efficiency through Linear Programming Duality - *Kim Thang Nguyen, Informatique, Biologie Intégrative et Systèmes Complexes*
10:00 - 10:30	› Computing all Wardrop Equilibria parametrized by the flow demand - *Philipp Warode, Humboldt Universität zu Berlin*
08:30 - 10:30	Parallel Sessions (LJAD II) - MS9 (Kernel Methods in Bayesian Optimisation and Integration)
08:30 - 10:30	› * Kernel Methods in Bayesian Optimisation and Integration - *Luc Pronzato, Laboratoire I3S, CNRS, UCA*
08:30 - 09:00	› Faster Multi-Objective Optimization: Cumulating Gaussian Processes, Preference Point and Parallelism - *Rodolphe Le Riche, Ecole Nationale Supérieure des Mines de St Etienne, Laboratoire dÍnformatique, de Modélisation et dÓptimisation des Systèmes*
09:00 - 09:30	› Stepwise Entropy Reduction : Review of Theoretical Results in the Finite/Deterministic case - *Julien Bect, Laboratoire des signaux et systèmes*
09:30 - 10:00	› Goal-oriented adaptive sampling under random field modeling of response distributions - *Athénaïs Gautier, Idiap Research Institute and University of Bern*
10:00 - 10:30	› Stein Point Markov Chain Monte Carlo - *Chris Oates, Newcastle University*
08:30 - 10:30	Parallel Sessions (IBV) - MS10 (Non-smooth optimization: theory and applications 1)
08:30 - 10:30	› * Non-smooth optimization: theory and applications - *Andrea Walther, Paderborn University*
08:30 - 09:00	› Variable metric forward-backward method for minimizing nonsmooth functionals in Banach spaces - *Luise Blank, University of Regensburg*
09:00 - 09:30	› On Second-Order Optimality Conditions for Optimal Control Problems Governed by the Obstacle Problem - *Constantin Christof, Technical University of Munich*
09:30 - 10:00	› Dealing with Nonsmooth Optimization Problems in Function Spaces by Exploiting the Nonsmoothness - *Olga Weiß, Paderborn University*

TIME	EVENT
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08:30 - 10:30	Parallel Sessions (Fizeau) - CS6 (Optimization 4 - chair: TBA)
08:30 - 08:50	› A Privacy-Preserving Disaggregation Algorithm for Nonconvex Optimization based on Alternate Projections - *Paulin Jacquot, Inria Saclay, EDF R&D OSIRIS*
08:50 - 09:10	› A bundle method for DC-constrained optimization problems - *Paul Javal, Center for Applied Mathematics, EDF R&D*
09:10 - 09:30	› A new method for global optimization - *Anatolii Kosolap, University of Chemical Engineering*
09:30 - 09:50	› Barrier and Modified Barrier Methods for 3D Topology Optimization - *Alexander Brune, University of Birmingham [Birmingham]*
09:50 - 10:10	› Power method tatonnements for Cobb-Douglas economies - *Vladimir Shikhman, Chemnitz University of Technology*
10:10 - 10:30	› Mathematical model of Multiphase Flow with a Dynamic Contact Line for the Simulation and Optimization of Wetting Phenomena - *Elisabeth Diehl, Nonlinear Optimization [Darmstadt]*
10:30 - 11:00	Coffee break (Theater)
11:00 - 12:30	Plenary Talk (Theater) - P7, P8 (Krause, Malick - chair: TBA)
11:00 - 11:45	› Multilevel Optimization and Non-linear Preconditioning - *Rolf Krause, Universitá della Svizzera Italiana*
11:45 - 12:30	› Nonsmoothness can help: sensitivity analysis and acceleration of proximal algorithms - *Jérôme Malick, Laboratoire Jean Kuntzmann*
12:30 - 14:00	Lunch (Theater)
14:00 - 15:30	Plenary Talk (Theater) - P9, P10 (Neitzel, Pfetsch - chair: TBA)
14:00 - 14:45	› Optimal Control of Regularized Fracture Propagation Problems - *Ira Neitzel, Rheinische Friedrich-Wilhelms-Universitat Bonn*
14:45 - 15:30	› Resilient and Efficient Layout of Water Distribution Networks - *Marc Pfetsch, Discrete Optimization [Darmstadt]*
15:30 - 16:00	Coffee break (Theater)
16:00 - 18:00	Parallel Sessions (LJAD) - MS11 (Continuous optimization techniques for image processing applications)
16:00 - 18:00	› * Continuous optimization techniques for image processing applications - *Simone Rebegoldi, Università degli Studi di Modena e Reggio Emilia - Elena Morotti, Università degli Studi di Bologna*
16:00 - 16:30	› Linear convergence of a forward-backward splitting algorithm for strongly convex optimisation with adaptive backtracking - *Luca Calatroni, Centre de Mathématiques Appliquées - Ecole Polytechnique*
16:30 - 17:00	› Computational approaches for parametric imaging of dynamic PET data - *Serena Crisci, Department of Mathematics and Computer Science, University of Ferrara*
17:00 - 17:30	› Structural Priors in Low Dose Multi-Energy CT Reconstruction - *Alexander Meaney, University of Helsinki*
17:30 - 18:00	› Convex-Concave Backtracking for Inertial Bregman Proximal Gradient Algorithms in Non-Convex Optimization - *Peter Ochs, Saarland University*
16:00 - 18:30	Parallel Sessions (LJAD II) - MS12 (Optimal control methods and applications 1)
16:00 - 18:00	› * Optimal Control Methods and Applications - *Helmut Maurer, Institute of Computational and Applied Mathematics - Sabine Pickenhain, Mathematical Institute, Brandenburg University of Technology at Cottbus*
16:00 - 16:30	› Multi-objective Optimal Control Problems and Optimization over the Pareto Front - *Helmut Maurer, University of Muenster*
16:30 - 17:00	› Asymptotic Controllability and Infinite Horizon Optimal Control - Theory and Application of Laguerre - Fourier Approximation Methods - *Sabine Pickenhain, Brandenburg University of Technology*
17:00 - 17:30	› A Quest for Necessary Conditions for Nonregular Mixed Constrained Optimal Control Problems - *Jorge Becerril - University of Porto, Faculdade de Engenharia (UPorto)*

TIME	EVENT
17:30 - 18:00	› Optimal control of a delayed HIV model with state constraints - *Cristiana Silva, University of Aveiro*
18:00 - 18:30	› Modified Pascoletti-Serafini Scalarization Method for Multi-Objective Optimal Control Problems - *Maria do Rosário de pinho, University of Porto, Faculdade de Enegenharia, SYSTEC, DEEC*
16:00 - 18:00	Parallel Sessions (IBV) - CS7 (Optimization 5 - chair: TBA)
16:00 - 16:20	› Solving Perfect Information Mean Payoff Zero-sum Stochastic Games by Variance Reduced Deflated Value Iteration - *Omar Saadi, CMAP, École polytechnique and INRIA*
16:20 - 16:40	› A Unifying vision of Particle Filtering and Explicit Dual Control in Stochastic Control - *Emilien Flayac, DTIS, ONERA, Université Paris Saclay [Palaiseau]*
16:40 - 17:00	› Multiplier Stabilization Applied to Two-Stage Stochastic Programs - *Clara Lage, Lage Clara*
17:00 - 17:20	› Doubly Ordinal warping for Bayesian non-Lipschitz optimisation - *Victor Picheny, Unité de Mathématiques et Informatique Appliquées de Toulouse*
17:20 - 17:40	› A Min-plus-SDDP Algorithm for Multistage Stochastic Convex Programming - *Benoît Tran, Centre d'Enseignement et de Recherche en MathématIques et Calcul Scientifique (CERMICS), MAXPLUS, Centre de Mathématiques Appliquées - Ecole Polytechnique (CMAP)*
17:40 - 18:00	› On almost sure rates of convergence for sample average approximations - *Ralf Werner, University of Augsburg*
16:00 - 18:00	Parallel Sessions (Fizeau) - CS8 (Games - chair: TBA)
16:00 - 16:20	› Prioritized optimization by Nash games : towards an adaptive multi-objective strategy - Application to a problem of flight mechanics - *Jean-Antoine Désidéri, INRIA*
16:20 - 16:40	› A game theory approach to the existence and uniqueness of nonlinear Perron-Frobenius eigenvectors - *Marianne Akian, TROPICAL, Centre de Mathématiques Appliquées - Ecole Polytechnique*
16:40 - 17:00	› Optimal control and differential games: Application to an abort landing problem. - *Nidhal GAMMOUDI, UMA ENSTA Paristech*
17:00 - 17:20	› The Operator Approach to Entropy Games - *Stéphane Gaubert, Centre de Mathématiques Appliquées - Ecole Polytechnique, Tropical team*
17:20 - 17:40	› A Feasible Directions Technique for Generalized Nash Equilibrium Problems - *Jose Herskovits, IME - Military Institute of Engineering, Federal University of Rio de Janeiro*
17:40 - 18:00	› On Equilibria of Continuous and Discrete Hotelling Pure Location Games - *Pierre von Mouche, Wageningen University and Research Centre [Wageningen]*
19:00 - 23:00	Dinner (Theater)

Friday, September 20, 2019

TIME	EVENT
08:00 - 10:00	Parallel Sessions (IBV) - MS15 (Non-smooth optimization: theory and applications 2)
08:00 - 08:30	› Nonconvex bundle method with applications to PDE boundary control - *Dominikus Noll, Institut de Mathématiques de Toulouse*
08:30 - 09:00	› Lipschitz Properties of Neural Networks - *Jean-Christophe Pesquet, Centre de vision numérique*
09:00 - 09:30	› The Total Variation of the Normal as a Prior for Geometrically Inverse Problems - *Stephan Schmidt, Würzburg University*
09:30 - 10:00	› Analytical and numerical investigations of shape optimization problems constrained by VIs of the first kind - *Kathrin Welker, Helmut-Schmidt-University*
08:30 - 10:30	Parallel Sessions (LJAD) - MS13 (Optimization with PDE constraints)
08:30 - 10:30	› * Optimization with PDE Constraints - *Michael Ulbrich, Technical University of Munich*
08:30 - 09:00	› Optimal Boundary Control of Entropy Solutions for Conservation Laws with State Constraints - *Johann Michael Schmitt, Darmstadt*

TIME	EVENT
09:00 - 09:30	› Optimal control of the principal coefficient in a scalar wave equation - *Christian Clason, University of Duisburg-Essen*
09:30 - 10:00	› Computing a Bouligand Generalized Derivative for the Solution Operator of the Obstacle Problem - *Anne-Therese Rauls, TU Darmstadt*
10:00 - 10:30	› A hybrid semismooth quasi-Newton method and its application to PDE-constrained optimal control - *Florian Mannel, University of Graz*
08:30 - 10:30	Parallel Sessions (LJAD II) - MS14 (Optimal control methods and applications 2)
08:30 - 09:00	› Optimal control problem of metronomic chemotherapy under assumption of a growing mortality force. - *Valeriya Lykina, Brandenburg University of Technology Cottbus-Senftenberg*
09:00 - 09:30	› An Infinite Horizon Optimal Control Problem with Control Constraints - A Dual Based Approach with Application to an Epidemic Model - *Katharina Kolo, Brandenburg University of Technology Cottbus*
09:30 - 10:00	› Optimal Control of an Optical System for Material Testing - *Christopher Schneider, University of Applied Sciences Jena*
10:00 - 10:30	› Computation of Wind-Perturbed Ship Trajectories through Parametric Sensitivity Analysis - *Christian Meerpohl, Zentrum für Technomathematik - Universität Bremen*
08:30 - 10:30	Parallel Sessions (Fizeau) - CS9 (Control 2 - chair: TBA)
08:30 - 08:50	› Two Optimization Methods for Optimal Muscular Force Response to Functional Electrical Stimulations - *Toufik Bakir, Imagerie et Vision Artificielle (ImVia) - Bernard Bonnard, Université Bourgogne Franche Comté*
08:50 - 09:10	› Optimal Actuation for Magnetic Micro-Swimmers - *Yacine EL ALAOUI-FARIS, Inria Sophia Antipolis - Méditerranée, Laboratoire Jean Alexandre Dieudonné, Institut des Systèmes Intelligents et de Robotique*
09:10 - 09:30	› Periodical body's deformations are optimal strategies for locomotion - *Laetitia Giraldi, Inria Sophia Antipolis - Méditerranée, Laboratoire Jean Alexandre Dieudonné - Frédéric Jean, École Nationale Supérieure de Techniques Avancées*
09:30 - 09:50	› Optimal motion of a scallop - *Marta Zoppello, University of Padova*
09:50 - 10:10	› Aerial vehicle path planning using Hamilton Jacobi Bellman approach - *Veljko Askovic, École Nationale Supérieure de Techniques Avancées*
10:10 - 10:30	› Minimum time optimal control problem in marine navigation - *Sofya Maslovskaya, Inria Sophia Antipolis - Méditerranée*
10:30 - 11:00	Coffee Break (Theater)
11:00 - 12:30	Plenary Talk (Theater) - P11, P12 (Pokutta, Hintermüller - chair: TBA)
11:00 - 11:45	› Conditional Gradient Algorithms for Constraint Smooth Convex Minimization - *Sebastian Pokutta, School of Industrial and Systems Engineering [Georgia Tech]*
11:45 - 12:30	› Generalized Nash Games with PDEs and Applications in Energy Markets - *Michael Hintermüller, Weierstrass Institute for Applied Analysis and Stochastics*
12:30 - 14:00	Lunch & closing (Theater)

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