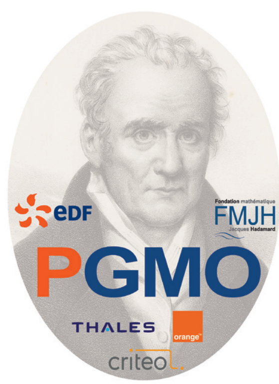
Book of Abstracts

PGMO Days 2018

EDF Lab Paris-Saclay

Nov 20-21, 2018



Preface

This volume contains the extended abstracts of the talks presented at PGMODAYS 2018 held on November 20-21, 2018 at EDF Labs Paris-Saclay.

We especially acknowledge the support of Criteo, EDF, Orange, Thales, FMJH, Labex LMH and ICODE institute. We thank GDR Jeux, GDR MASCOT-NUM, GDR MOA, GDR RO, ROADEF, SFdS, SMAI, SMF, CNRS, Ecole polytechnique, ENSTA and Inria. We are also grateful to the organizers of invited sessions.

November 14, 2018 — The organizers of the PGMO days
Palaiseau – Orsay

Organization Committee

Fréderic Bonnans	Inria and CMAP, École polytechnique	
Pierre Carpentier	ENSTA ParisTech	(adjoint coordinator of PGMO)
Antonin Chambolle	CMAP, Ecole Polytechnique, CNRS	
Sandrine Charousset	EDF R&D	(coordinator of IROE)
Sourour Elloumi	CEDRIC-Cnam / ENSTA-Paristech	
Stéphane Gaubert	Inria and CMAP, Ecole Polytechnique	(coordinator of PGMO)
Éric Gourdin	Orange	
Georges Hébrail	EDF R&D & IRT SystemX	(co-coordinator of IRSDI)
Anthony Larue	Thales	(co-coordinator of IRSDI)
Magali Le Chaponnier	FMJH	
Gilles Stoltz	LMO, Université Paris Sud, CNRS	(adjoint coordinator of PGMO, coordinator of IRSDI)
Emmanuel Vazquez	L2S, CentraleSupélec	

Program Committee

Gregoire Allaire	Ecole Polytechnique	
Walid Ben Ameur	Télécom SudParis	
Frederic Bonnans	Inria and CMAP, École polytechnique	
Nadia Brauner	G-SCOP, Université Grenoble Alpes	
Luce Brotcorne	Inria	
Jean-Baptiste Caillau	Université Côte d'Azur & CNRS/Inria	
Pierre Carpentier	ENSTA ParisTech	
Antonin Chambolle	CMAP, Ecole Polytechnique, CNRS	(chair)
Sandrine Charousset	EDF	
Johanne Cohen	LRI, Université Paris-Sud, CNRS	
Claudia D'Ambrosio	LIX, Ecole Polytechnique, CNRS	
Michel De Lara	CERMICS, École des Ponts ParisTech	
Sourour Elloumi	CEDRIC-Cnam / ENSTA-Paristech	
Stéphane Gaubert	INRIA and CMAP, Ecole Polytechnique	
Antoine Girard	L2S, CentraleSupélec, CNRS	
Eric Gourdin	Orange	
Georges Hébrail	EDF R&D & IRT SystemX	
Balázs Kegl	LAL, Université Paris Sud, CNRS	
Anthony Larue	Thales	
Jerome Malick	LJK, Université Grenoble Alpes, CNRS	
Mathilde Mougeot	ENSIIE & LPSM	
Vianney Perchet	ENS Paris Saclay	(co-chair)
Patrice Perny	Sorbonne Université	
Alain Quilliot	ISIMA & LIMOS	
Frédéric Roupin	Université Paris 13	
Joseph Salmon	Université de Montpellier	
Filippo Santambrogio	Université Claude Bernard Lyon 1	
Pierre Senellart	DI, École normale supérieure, PSL Research University	
Gilles Stoltz	Université Paris-Sud, CNRS	
Emmanuel Vazquez	CentraleSupélec	

Organizers of Invited Sessions

Network, population games and applications	Cheng Wan, Paulin Jacquot
Optimal control and applications	Jean-Baptiste Caillau, Hasnaa Zidani
New methods for multistage stochastic optimization	Vincent Leclre
Optimization of telecom networks	Eric Gourdin, Nancy Perrot
Dynamic games and applications	Bruno Ziliotto, GDR Jeux
Semialgebraic Optimization and Applications	Victor Magron, Simone Naldi, Mohab Safey El Din
Mean Field Games (MFG) and applications	Francisco Silva, Filippo Santambrogio, Daniela Tonon
Decomposition/Coordination Methods in Multistage Stochastic Optimization	Jean-Philippe Chancelier

Table of Contents

Auction theory from the bidder standpoint

Noureddine El Karoui[1,2]
[1]Criteo AI Labs
[2]Departement of Statistics, University of California, Berkeley

Most classical auction theory has been developed from the standpoint of the seller, trying to understand how to optimize auctions to maximize seller revenue for instance. Billions of auctions are now run on the internet everyday and this creates a need to better understand auctions from the bidder perspective. In this talk I will present some recent results on this question, showing for instance that auctions that are reputed to be truthful are not truthful anymore when the seller optimizes the auction format based on bidders' past bids, provide explicit (and simple to implement) shading strategies that improve bidders' utility and discuss various equilibrium questions. No prior knowledge of auction theory is assumed and the talk will be self-contained.

Based on joint works with Thomas Nedelec, Marc Abeille, Clément Calauzènes, Benjamin Heymann and Vianney Perchet while doing research at Criteo.

Reinforcement learning, energy systems and deep neural nets

Damien Ernst[1]
[1]Université de Liège

Reinforcement leaning is a highly-successful subfield of artificial intelligence where an agent is ought to interact with its environment to maximize a sum of rewards. In this talk, I will argue that this learning paradigm can be very powerful to solve many decision-making problems in the energy sector, as for example investment problems, the design of bidding strategies for playing with the intraday electricity market or problems related to the control of microgrids. I will also describe some very recent progresses in the field on deep reinforcement learning that could be used to foster the performances of reinforcement learning agents when confronted with environments that can exhibit sudden changes in their dynamics, as it is often the case with energy systems.

Algebraic Vision

Rekha Thomas[1]
[1]University of Washington

Algebraic Vision is an emerging viewpoint of problems in computer vision that aims to examine polynomial models in vision through the lens of algebra. A key problem in computer vision is the estimation of the three-dimensional shape of a world scene from images and the parameters (position, orientation, etc.) of the cameras that captured them. This problem, studied under the name structure-from-motion or multi-view geometry, has its origins in photogrammetry and perspective drawings. The modeling language for these problems is projective geometry, which naturally leads to polynomial models with rich and beautiful structure that beg for algebraic tools. In this talk I will show some of the surprising structure, properties, and algorithmic successes that have emerged from this algebraic viewpoint.

Data-driven Distributionally Robust Optimization Using the Wasserstein Metric: Performance Guarantees and Tractable Reformulations

Daniel Kuhn[1]
[1]Ecole Polytechnique Fédérale de Lausanne

We consider stochastic programs where the distribution of the uncertain parameters is only observable through a finite training dataset. Using the Wasserstein metric, we construct a ball in the space of (multivariate and non-discrete) probability distributions centered at the uniform distribution on the training samples, and we seek decisions that perform best in view of the worst-case distribution within this Wasserstein ball. The state-of-the-art methods for solving the resulting distributionally robust optimization problems rely on global optimization techniques, which quickly become computationally excruciating. In this paper we demonstrate that, under mild assumptions, the distributionally robust optimization problems over Wasserstein balls can in fact be reformulated as finite convex programs – in many interesting cases even as tractable linear programs. Leveraging recent measure concentration results, we also show that their solutions enjoy powerful finite-sample performance guarantees. Our theoretical results are exemplified in mean-risk portfolio optimization, uncertainty quantification and machine learning.

Optimization Models and Algorithms for Network Reconfiguration

Brigitte Jaumard[1]
[1]Concordia University Montreal

In future cognitive networks, thanks to Software Defined Networking (SDN), network reconfiguration and traffic migration will be triggered by intelligent software tools. This requires efficient algorithms, but also clear objectives in order to know went trigger and how to conduct network reconfiguration. In this talk, we will discuss seamless network reconfiguration, as well as various minimum disruption objectives, when a seamless reconfiguration cannot be conducted, i.e., minimize *(i)* the number of disruptions, *(ii)* the maximum number of concurrent disruptions, *(iii)* the overall duration of the disruptions, and *(iv)* the maximum disruption duration. We survey these four different minimum disruption objectives for the RWA (Routing and Wavelength Assignment) and RSA (Routing and Spectrum Assignment) lightpath migration in optical networks. For each of them, the defragmentation problem can be reduced to a graph theory problem (Minimum Feedback Vertex, Vertex Separation, Graph Bandwidth, Minimum Sum Cut) or formulated as an Integer Linear Program. We investigate the most efficient available exact algorithms. For seamless reconfiguration, we will discuss a nested decomposition scheme. Extensive numerical experiments are conducted on different traffic and network instances, in order to compare the level of disruption entailed by the different objectives.

Geometric and Dual Approaches to Cumulative Scheduling (PhD Prize Lecture)

Nicolas Bonifas[1]
[1]IBM Research, France

Citation from the prize committee:

> The work of Nicolas Bonifas falls in the scope of constraint-based scheduling. In this framework, the most frequently encountered resource constraint is the cumulative, which enables the modeling of parallel processes. In his thesis, Nicolas studies the cumulative constraint with the help of tools rarely used in constraint programming (polyhedral analysis, linear programming duality, projective geometry duality) and propose two contributions for the domain. Cumulative strengthening is a means of generating tighter redundant cumulative constraints, analogous to the generation of cuts in integer linear programming. This is one of the first examples of a redundant global constraint. Energy Reasoning is an extremely powerful propagation for cumulative constraint, with hitherto a high complexity of $O(n^3)$. Nicolas Bonifas proposes an algorithm that computes this propagation with a $O(n^2 \log n)$ complexity, which is a significant improvement of this algorithm known for more than 25 years.

Stochastic approximation and least-squares regression, with applications to machine learning (PhD Prize Lecture)

Nicolas Flammarion[1]
[1]University of California, Berkeley

Citation from the prize committee:

> Many problems in machine learning are naturally cast as the minimization of a smooth function defined on a Euclidean space. While small problems are efficiently solved by classical optimization algorithms, large-scale problems are typically solved with first-order techniques based on gradient descent. Nicolas Flammarion considers, in his thesis, the particular case of the quadratic loss. He addresses its minimization when gradients are only accessible through a stochastic oracle and proposes optimal algorithms in different cases. His work offers many perspectives of applications of the quadratic loss in machine learning. Clustering and estimation with shape constraints are the two first applications already considered.

A Nonatomic Congestion Game Approach to Net (Non-)Neutrality

Patrick Maillé[1] Bruno Tuffin[2]
[1]IMT Atlantique, Rennes, France, patrick.maille@imt.fr
[2]Inria, Rennes, France, bruno.tuffin@inria.fr

Key words: Network neutrality, Congestion games, Quality of service, Nonatomic games

While the volume of data exchanged on the Internet has considerably increased in recent years, most of it is due to a very small number of content providers (CPs): as of 2015 in North America, Netflix and YouTube were accounting for more than 50% of all traffic. To ensure the right service to their customers, those CPs report the quality provided by the various ISPs.

It is then natural to assume that such information will be taken into account by customers when selecting an ISP to subscribe to. This may create an incentive for ISPs to differentiate services and favor big CPs in order to receive the best grades and attract more customers, at the expense of small CPs. Such a differentiated treatment among flows is directly linked to the *network neutrality debate*.

We propose in this paper a model to analyze the decisions of ISPs with regard to service differentiation of CP flows (bandwidth allocation among CPs), in a context of two competing ISPs. Among the key components in such a game among ISPs, will be the user preferences in terms of their interests for the different CPs; we assume a distribution over the subscriber population, leading to a nonatomic congestion game among users over the ISP choice. Based on that distribution and on its competitor's choice, each ISP has to determine the amount of capacity to devote to each CP.

We investigate the strategies of competing ISPs in terms of capacity assignment to user-attractive CPs; should there be a differentiated treatment? What is the impact with respect to a "neutral" sharing, where the capacity used for a CP would be proportional to its total traffic?

References

[1] T.M. Lenard and R.J. May (Eds.). *Net Neutrality or Net Neutering: Should Broadband Internet Services be Regulated.* Springer, 2006.

[2] P. Maillé, P. Reichl, and B. Tuffin. Internet governance and economics of network neutrality. In A. Hadjiantonis and B. Stiller, editors, *Telecommunications Economics - Selected Results of the COST Action IS0605 EconTel*, pages 108–116. Lecture Notes in Computer Science 7216, Springer Verlag, 2012.

[3] P. Maillé and B. Tuffin. *Telecommunication Network Economics: From Theory to Applications.* Cambridge University Press, 2014.

[4] T. Wu. Network neutrality, broadband discrimination. *Journal of Telecommunications and High Technology*, 2(1):141–176, 2003.

How to use mean field approximation for 10 players?

Nicolas Gast[1,2]
[1]Inria, France, nicolas.gast@inria.fr
[2]Univ. Grenoble Alpes, Grenoble, France

Key words: Mean field approximation, Population games, Mean field games.

Abstract : Mean field games are a good approximation of finite games with a large number of interacting players. The fundamental idea of mean field approximation is that the behavior of a system of N interacting players simplifies as N goes to infinity. In this talk, I will introduce the key concepts behind mean field approximation, by giving some examples of where it can be applied. I will review some of the classical models and their convergence properties. I will try to answer a very natural question: how large should the system be for mean-field to apply? This leads to a follow-up question: can we refine this approximation to make it applicable for 10 players ?

References

[1] N. Gast Expected values estimated via mean-field approximation are 1/N-accurate. *Proceedings of the ACM on Measurement and Analysis of Computing Systems (SIGMETRICS 2017)*, 2017.

[2] N. Gast, B. Van-Houdt. A Refined Mean Field Approximation. *Proceedings of the ACM on Measurement and Analysis of Computing Systems (SIGMETRICS 2018)*. 2017. `https://github.com/ngast/rmf_tool`

[3] N. Gast, L. Bortolussi, M. Tribastone. Size Expansions of Mean Field Approximation: Transient and Steady-State Analysis. *Performance Evaluation*. 2018 `https://github.com/ngast/sizeExpansionMeanField`

Traffic Routing: Efficiency, Equilibrium, and Dynamics

Panayotis Mertikopoulos[1]
[1]Univ. Grenoble Alpes, CNRS, Inria, LIG, F-38000 Grenoble, France
panayotis.mertikopoulos@imag.fr

Key words: Nonatomic congestion games; price of anarchy; multiplicative weights.

Traffic routing in congested networks is a notoriously difficult problem. Even in its convex incarnations, it suffers from the curse of dimensionality (for instance, in the number of origin-destination pairs in the network or the number of paths per O/D pair), limited information at the decision-maker end (be it the network controller or an individual user), delays and asynchronicities, etc. Nevertheless, empirical studies in real-world networks have shown that the gap between optimality and equilibrium (typically referred to as the price of anarchy) is surprisingly small, under both light and heavy traffic. This work focuses on whether these observations can be justified theoretically and what kind of algorithmic schemes can be used to overcome the challenges cited above.

This talk is based on the papers [CBCMS18, GHMS].

References

[CBCMS18] Riccardo Colini-Baldeschi, Roberto Cominetti, Panayotis Mertikopoulos, and Marco Scarsini, *When is selfish routing bad? The price of anarchy in light and heavy traffic*, https://arxiv.org/abs/1703.00927, 2018.

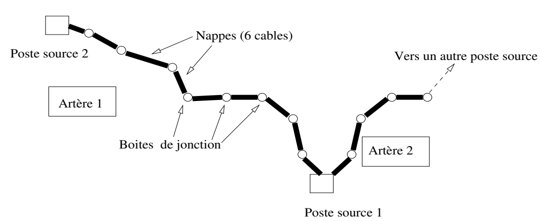
[GHMS] Bruno Gaujal, Amélie Héliou, Panayotis Mertikopoulos, and Marco Scarsini, *Distributed routing in large networks*, in preparation.

Forecasting failure on Paris network utility

A. K. Fermin[1] N. Hengartner[2] E. Matzner-Løber[3]
[1] Modal'X, Univ. Paris Nanterre
[2] Los Alamos National Laboratory
[3]CREST, ENSAE-Cepe, eml@ensae.fr

Key words: times series, failure, machine learning.

The goals of the project is to try to forecast in time and in space the failure occuring on cables for Paris utility network. Paris utility network has the property of being closed (that means that a cable could connect to different sources but obviously at a time given only one source is used) and is composed of **arteres** and **tronçons** wich are cables. A simplified version of the network is given below.



In a first part of the work, we focus on the time series analysis of the 246 **arteres** along the period of interest (2sd Jan 2012, to 31st Dec 2014) which corresponds to 1095 daily measures. However the number of failure is very limited and the times series are almost equal to zero for a long period. We caracterise some failures by the **arteres** components (type of cables, age, length). Results from machine learning methods (logistic regression, constrained logistic regression, SVR, random forest and neural network) will be presented. Even if the number of failures is very small, the results are relatively good. However it is impossible to predict the localisation of the failure which is of importance in order the prevent them and engage the preventive work. In a second step, we have to scale to **tronçons** which are 1884 along the same period. Again the number of failures are small compared to the number of non failures and forecasting the failures is a real challenge, we try to use bags of words technics as in [1] or [2] but we faced some scale problems and the results are not completely obtained. However, such techniques will be presented at the conference.

References

[1] O. Mizumo and H. Hata, "Prediction of fault-prone modules using a text filtering based metric", *International Journal of Engineering and Technology*, 2010.

[2] M. Bertini and A. Del Bimbo and L. Seidenari, "Multi-scale and real-time non-parametric approach for anomaly detection and localization", *Computer Vision and Image Understanding*, 2011

A multivariate extreme value theory approach to anomaly clustering and visualization

Key words : functional data analysis, anomaly detection, multivariate extreme theory, visualization techniques for anomalies

Motivated by a wide variety of applications from fraud detection to aviation safety management, unsupervised anomaly detection is the subject of much attention in the machine-learning literature. We developed novel statistical techniques for tackling anomaly detection borrowing concepts and tools from machine-learning and multivariate extreme value analysis both at the same time. Usually, anomaly detection algorithms declared extremes as anomaly, whereas all extremes values are not anomalies. We study the dependance structure of rare events in the context of high dimensional and propose an algorithm to detect this structure under a sparse assumption [3]. This approach can reduce drastically the false alarm rate : anomalies then correspond to the observation of simultaneous very large/extreme values for groups of variables that have not been identified yet. A data-driven methodology for learning the sparse representation of extreme behaviours has been developed in [1]. An advantage of this method lies in its straightforward interpretability. In addition, the representation of the dependance structure in the extremes thus designed induces a specific notion of (dis-)similarity among anomalies, that paves the way for elaborating visualization tools for operators in the spirit of those proposed for large graphs. We illustrate our algorithm with an application to functional data from aircraft after a preliminary filtering stage.

References

[1] Goix, N., Sabourin, A. and Clémençon, S. (2017). Sparse representation of multi- variate extremes with applications to anomaly detection. Journal of Multivariate Analysis, 161:12-31.

[2] M. Chiapino, A. Sabourin, Clémençon, V. Feuillard. A multivariate extreme value theory approach to anomaly clustering and visualization. (Submitted)

[3] M. Chiapino, A. Sabourin. Feature clustering for extreme events analysis, with application to extreme stream-flow data. (ECML 2016)

Optimisation of maintenance strategies using piecewise deterministic Markov processes

Benoîte de Saporta[1] François Dufour[2] Huilong Zhang[3]
[1]Montpellier University, France, benoite.de-saporta@umontpellier.fr
[2]Bordeaux INP, France, francois.dufour@math.u-bordeaux.fr
[3]Bordeaux University, France, Huilong.Zhang@math.u-bordeaux.fr

Key words: Impulse control, numerical approximation, stochastic process, availability.

This aim of this project is to propose a numerical method to compute an approximation of the optimal maintenance cost for a multi-component equipment subject to random degradation and failures. We first propose a generic model for the dynamics of such equipments based on piecewise deterministic Markov processes (PDMPs). PDMPs are a generic class of non-diffusive random hybrid processes introduced by Davis in the 80's [1]. Basically, the process follows deterministic trajectories punctuated by random jumps.

The maintenance optimisation problem consists in selecting the maintenance dates and operations (do nothing, change or repair for each component) in order to minimize some cost while keeping a high level of availability. This translates into an impulse control problem for PDMPs. The optimal performance is called the value function of the problem [2]. It can be obtained by iterating some dynamic programming operator.

We implemented the approximation procedure described in [3] on a four-component model. In this talk, we will present the numerical results we obtained for this model, and how the different parameters have been calibrated in order to validate the approximation. The optimal performance will also be compared to reference strategies.

References

[1] M. H. A. Davis, Markov models and optimization, Monographs on Statistics and Applied Probability, Chapman & Hall, London (1993)

[2] O. L. V. Costa, M. H. A. Davis, Impulse control of piecewise-deterministic processes, Math. Control Signals Systems, 2 (1989), pp. 187–206.

[3] B. de Saporta, F. Dufour, Numerical method for impulse control of piecewise deterministic Markov processes, Automatica J. IFAC, 48 (2012), pp:779–793.

Pareto front characterization for finite horizon optimal control problems with two different objectives

Ana P. Chorobura[1] Hasnaa Zidani[2]
[1] Universidade Federal do Paraná (UFPR), Brazil, ana.chorobura@gmail.com
[2] ENSTA ParisTech, France, housnaa.zidani@ensta-paristech.fr

Key words: Hamilton-Jacobi-Bellman approach, multi-objective optimization, optimal control problem.

In this talk, we present a characterization of the weak and strong Pareto fronts for optimal control problems with two objective functions of different nature that need to be minimized simultaneously. One objective is in the classical Bolza form and the other one is defined as a maximum function. Our approach is based on the Hamilton-Jacobi-Bellman framework [1] and on the technique for solving optimal control problems with state constraints introduced in [2]. Based on [3], first we define an auxiliary optimal control problem without state constraints and show that the weak Pareto front is a subset of the zero level set of the corresponding value function. Then with a geometrical approach we establish a characterization of the Pareto front. Some numerical examples will be considered to show the relevance of our approach.

References

[1] M. Bardi and I. Capuzzo-Dolcetta. *Optimal Control and Viscosity Solutions of Hamilton-Jacobi-Bellman Equations.* Birkhauser, Boston, 1997.

[2] A. Altarovici, O. Bokanowski and H. Zidani. *A General Hamilton-Jacobi Framework for Non-linear State-Constrained Control Problems.* ESAIM: Control, Optimisation and Calculus of Variations 19(2): 337-357, 2013.

[3] A. Désilles and H. Zidani. *Pareto Front Characterization for Multi-Objective Optimal Control Problems using HJB approach*, preprint, 2018.

Robust Bang-Bang Control through redundancy

Thomas Haberkorn[1] Antoine Olivier[2] Emmanuel Trélat[2]
[1]Laboratoire IDP Orléans, France, thomas.haberkorn@univ-orleans.fr
[2]Laboratoire Jacques-Louis Lions, France, prenom.nom@sorbonne-universite.fr

Key words: Optimal Control, Robust Control, Uncertain Systems.

Here, we are interested in a finite dimension nonlinear control system of the form

$$\dot{x}(t) = f(x(t), u(t)). \tag{1}$$

Various problems built on such dynamics only allow for bang-bang control, that is the control can only take 2 distinct values. Given an initial (resp. final) condition x_0 (resp. x_f) we denote the input-ouput application by $E(x_0, t_f, u) = x(t_f)$, where $x(\cdot)$ is the solution to (1) with initial condition $x(0) = x_0$ and control $u(\cdot)$. We look for bang-bang control strategies u such that $E(x_0, t_f, u) = x_f$.

In the optimal control framework, bang-bang control strategies appear naturally, for example when minimum time or L^1-norm criterion are considered. However, it is important to note that such controls, due to their optimality, are in general not robust, and have a minimal number of switching times (see for instance [1]).

A natural idea to enhance the robustness of such controls is to add switching times that can be viewed as additional degrees of freedom. Assuming its initial value is known, a bang-bang control is uniquely defined by its switching times $\mathcal{T} = (t_1, \cdots, t_N)$. We see that a variation $\delta\mathcal{T} = (\delta t_1, \cdots, \delta t_N)$ of $\mathcal{T}$ yields N variation vectors $(v_1(t_f), \cdots, v_N(t_f))$ such that

$$E(x_0, t_f, \mathcal{T} + \delta\mathcal{T}) = E(x_0, t_f, \mathcal{T}) + \delta t_1 \cdot v_1(t_f) + \cdots + \delta t_N \cdot v_N(t_f) + \mathrm{o}(\|\delta\mathcal{T}\|)$$

The cone spanned by those variation vectors $v_i(t_f)$ is then an approximation of the accessible set. We then note that the more switching times there is, the more accurate the approximation. We will present a method to add switching times in order to make the control strategies and the underlying trajectories more robust. In particular, we look for additional switching times $(s_1, \cdots, s_l)$ such that $E(x_0, t_f, t_1, \cdots, t_N, s_1, \cdots, s_l) = x_f$. We add those times in the form of *needle-like variations*, as introduced in a proof of the Pontryagin maximum principle (see [2]).

Moreover, we will show that dealing with a control problem with uncertainties can be done by solving an overdetermined nonlinear system, which can be treated thanks to a least-square method. This approach also uncovers a natural robustness criterion for bang-bang trajectories.

We will illustrate this method with an attitude problem for a satellite delivery system.

References

[1] A. J. Krener, H. Schättler, *The structure of small-time reachable sets in low dimensions*, Siam J. Control Optim., 1989.

[2] L. S. Pontryagin, V. G. Boltyanskii, R. V. Gamkrelidze, and E. F. Mischenko, *The mathematical theory of optimal processes*, Interscience Publishers John Wiley & Sons, Inc, 1962.

Real-time optimal control of aerospace systems with state-control constraints and delays

Riccardo Bonalli[1] Bruno Hérissé[2] Emmanuel Trélat[3]
[1]ONERA, France, riccardo.bonalli@onera.fr
[2]ONERA, France, bruno.herisse@onera.fr
[3]Sorbonne Université, France, emmanuel.trelat@sorbonne-universite.fr

Key words: Nonlinear optimal control, aerospace systems, indirect methods, homotopy and continuity methods.

In many aerospace applications, for both the design of systems and the preparation of a mission, it is required to optimize performance of trajectories. For example, for cost reasons, it is required that a rocket trajectory minimize propellant consumption. Thus, trajectory generation can be reduced to an optimization problem. Direct methods of optimization are generally used to solve the problem offline, ensuring global convergence to optimal solutions. However, when managing dynamic problems such as, for example, an intercept missile dealing with maneuvering targets, precomputed trajectories can quickly lose their optimality, or worse, lead to a failure of the mission. In this uncertain situations, real-time computation (usually in a 1-10 Hz frequency range) of optimal trajectories are needed to ensure achieving the mission. In this work, we address real-time optimal guidance of launch vehicles with the objective of designing a fast autonomous algorithm for optimal control computation. The approach is based on indirect methods generally known to be more precise and faster than direct methods when they are well initialized [1]. We first provide an accurate geometric analysis in the presence of mixed control-state constraints to recover a well-posed framework and correctly apply indirect methods. A practical numerical algorithm is proposed by efficiently combining indirect methods with homotopy procedures, increasing robustness to initialization problems and computational speed [2]. We also consider state and control delays in the dynamic model by introducing a well-posed homotopy framework to recover solutions [3]. All those contributions made possible the development of an efficient C/C++ software, first dedicated to Missile applications, now extended to other aerospace applications such as Reusable Launch Vehicles and Aerial Robotics.

References

[1] Trélat, E. (2012). Optimal control and applications to aerospace: some results and challenges. Journal of Optimization Theory and Applications, 154(3), 713-758.

[2] Bonalli, R., Hérissé, B., Trélat, E. (2017). Optimal Control of Endo-Atmospheric Launch Vehicle Systems: Geometric and Computational Issues. arXiv preprint arXiv:1710.11501.

[3] Bonalli, R., Hérissé, B., Trélat, E. (2018). Continuity Of Pontryagin Extremals With Respect To Delays In Nonlinear Optimal Control. arXiv preprint arXiv:1805.11990.

A Trust Region Algorithm for the DA/ID Problem

Vincent Leclere[1] Thomas Martin[2]
[1]CERMICS, ENPC, France, vincent.leclere@enpc.fr
[2]CERMICS, ENPC, France, thomas.martin@eleves.enpc.fr

Key words: Bundle Methods, Bender Decomposition, SDDP, Trust Region.

We model the day-ahead/intraday trading problem as a two-scale multistage stochastic optimization problem. We consider a price taker battery owner that can trade in both markets. At time $t = 0$, by trading on the day-ahead market,which is deterministic, he defines a first planning q for the next day. Then, at the beginning of step t he discovers costs on the intraday market and trades a quantity u_t, the quantity going through the system is $q_t + u_t$.

The problem can be seen as a multistage problem with 25 steps, with a first stage variable of dimension 24. Consequently, solving the extensive formulation is intractable, and a classical dynamic programming (or SDDP like) approach will likely fail. Therefore we propose a decomposition approach by splitting day-ahead and intraday problems. More precisely, the Master problem consists in minimizing day-ahead costs plus the expected cost of the intraday market given day-ahead planning q, denoted $V(q)$, that is solving

$$\begin{aligned} \min_{q\in\mathbb{R}^{24}} \quad & c^T q + V(q) \\ s.t. \quad & Aq \leq b \end{aligned}$$

where function V represents the optimum cost on the intraday market when q has been decided on the day-ahead market. It is polyhedral but hard to compute, as the solution of a parametrized multistage stochastic program, thus it is approximated by cuts.

More precisely we propose a Bundle trust region method to solve the coupled Day-Ahead/Intraday problem. The oracle called to compute new cuts consists in approximately solving the Indraday Problem via an SDDP method. Since the value of the intraday problem and its subgradient are inexact, applying a classic Kelley cut algorithm is not possible and is the prime motivation behind the use of bundles.

In this work we give elements relative to the convergence and accuracy of such an algorithm. We then proceed to compare its performances to frontal extensive and SDDP resolution of the problem as well as other types of oracle.

References

[1] W. de Oliveira, C. Sagastizábal, Bundle Method in the XXIst century: A bird's-eye view, Pesquisa Operacional, 3 (2014), pp. 647-670.

[2] W. Hare, C. Sagastizábal, M, Solodov, A Proximal Bundle Method for Nonconvex Functions with Inexact Oracles, 2010.

Asynchronous level bundle methods

Franck Iutzeler[1] Jérôme Malick[2] Welington de Oliveira[3]

[1] UGA, Lab. J. Kuntzmann, Grenoble, France, franck.iutzeler@univ-grenoble-alpes.fr
[2] CNRS, Lab. J. Kuntzmann, Grenoble, France, jerome.malick@univ-grenoble-alpes.fr
[3] MINES ParisTech, PSL - Research University, CMA - Centre de Mathématiques Appliquées, Sophia Antipolis, France, welington.oliveira@mines-paristech.fr

Key words: Nonsmooth optimization, distributed computing, asynchronous algorithms

This work describes asynchronous level bundle methods for minimizing complicated nonsmooth convex functions with additive structure. Problems of this type arise, for instance, when one is interested in computing bounds on the solution values of difficult mixed-integer optimization problems such as stochastic integer programs. Existing methods for solving these distributed problems in a general form are synchronous, in the sense that they wait for the answers of all the oracles (black-boxes) before performing a new iteration. In this work, we propose efficient algorithms handling asynchronous oracles working in parallel. We illustrate their practical performance on a Lagrangian decomposition problem.

A Dual Stochastic Dual Dynamic Programming algorithm

V. Leclère[1], P. Carpentier[2], J-Ph. Chancelier[1], A. Lenoir[3], F. Pacaud[1]
[1]CERMICS, ENPC, France, vincent.leclere@enpc.fr
[2]UMA, ENSTA ParisTech, France
[3]OSIRIS, EdF R&D, France

Key words: SDDP, Stochastic Programming, Fenchel transform.

The Stochastic Dual Dynamic Programming (SDDP) algorithm has become one of the main tools to address convex multistage stochastic optimal control problems. Recently a large amount of work has been devoted to improve the convergence speed of the algorithm through cut selection and regularization, or to extend the field of applications to non-linear, integer or risk-averse problems. However one of the main downside of the algorithm remains the difficulty to give an upper bound of the optimal value, usually estimated through Monte Carlo methods and therefore difficult to use in the stopping criterion of the algorithm.

In this paper we show that the Fenchel transform of the cost-to-go function also follow a recursive equation and can thus be approximated by SDDP. Thus we obtain a dual SDDP algorithm that yields a converging exact upper bound for the optimal value of the optimization problem.

Incidently we show how to compute an alternative control policy based on an inner approximation of Bellman value functions instead of the outer approximation given by the standard SDDP algorithm.

We illustrate the approach on an energy production problem involving zones of production and transportation links between the zones. The numerical experiments we carry out on this example show the effectiveness of the method.

References

[1] V. Leclère, P. Carpentier, J-Ph. Chancelier, A. Lenoir, F. Pacaud, Exact converging bounds for Stochastic Dual Dynamic Programming via Fenchel duality, Optimization Online `http://www.optimization-online.org/DB_HTML/2018/04/6575.html`

Linear programming for Influence Diagrams : exact approaches

Victor Cohen [1] Vincent Leclère [2] Guillaume Obozinski [3] Axel Parmentier [4] Joseph Salmon [5]
[1,2,3,4] Ecole des Ponts Paristech, Champs-sur-Marne, `firstname.lastname@enpc.fr`
[5] Université de Montpellier, Montpellier, `joseph.salmon@umontpellier.fr`

Key words: *Partially Observed Markov Decision Processes, Probabilistic graphical models, Linear Programming.*

Influence Diagrams (ID) are a flexible tool to represent discrete stochastic optimization problems, including Markov Decision Process (MDP) and Partially Observable MDP as standard examples. More precisely, given random variables considered as vertices of an acyclic digraph, a probabilistic graphical model defines a joint distribution via the conditional distributions of vertices given their parents. In ID, the random variables are represented by a probabilistic graphical model whose vertices are partitioned into three types : chance, decision and utility vertices. The user chooses the distribution of the decision vertices conditionally to their parents in order to maximize the expected utility. Leveraging the notion of strong junction tree, we present a mixed integer linear formulation for solving an ID, as well as valid inequalities, which lead to a computationally efficient algorithm. We also show that the linear relaxation yields an optimal integer solution for instances that can be solved by the “single policy update”, the default algorithm for addressing IDs.

Dynamic chance constraints under continuous random distribution

Wim van Ackooij[1] Tatiana González Grandón[2] René Henrion[3] Pedro Pérez-Aros[4]
[1]OSIRIS, EDF R&D, Palaiseau, France, wim.van-ackooij@edf.fr
[2]Humboldt University, Berlin, Germany, gonzalet@hu-berlin.de
[3]Weierstrass Insttute Berlin, Germany, henrion@wias-berlin.de
[4]Universidad de OHiggins, Rancagua, Chile, pedro.perez@uoh.cl

Key words: Dynamic chance constraints, stochastic programming, probability functions

A dynamic chance constraint is an inequality of the type

$$\mathbb{P}(g_i(x_1, x_2(\xi_1), x_3(\xi_1, \xi_2) \ldots, x_T(\xi_1, \ldots, \xi_{T-1}), \xi_1, \ldots, \xi_T) \leq 0 \quad (i = 1, \ldots, m)) \geq p, \qquad (1)$$

where $(\xi_1, \ldots, \xi_{T-1})$ is a finite stochastic process, $(x_1, \ldots, x_T)$ is an adapted process of decision policies depending on previously observed outcomes of the random process, $\mathbb{P}$ is a probability measure and $p \in [0, 1]$ is a probability level. A typical example arises in water reservoir control subject to level constraints where (1) figures as a constraint in some optimization problem. The talk presents some structural results for the associated probability function assigning to each set of decision policies the probability occuring above. For instance, strong and weak semicontinuity results are provided for the general case depending on whether policies are supposed in L^p or $W^{1,p}$ spaces. For a simple two-stage model corresponding to the one of reservoir control, verifiable conditions for Lipschitz continuity and differentiability of this probability function are derived and endowed with explicit derivative formulae. Numerical results are illustrated for the solution of such two-stage problem.

Finite Sample Bounds for Superquantile Linear Prediction

Evgenii Chzhen[1] Joseph Salmon[2] Zaid Harchaoui[3]
[1]Université Paris-Est, France, evgenii.chzhen@univ-paris-est.fr
[2]Université de Montpellier , France, joseph.salmon@umontpellier.fr
[3]University of Washington, USA, zaid@uw.edu

Key words: Superquantile, linear regression, empirical risk minimization.

We present a non-asymptotic theoretical analysis of superquantile linear prediction, based on a method originally proposed by Rockafellar, Uryasev and Zabarankin. Super-quantile regression allows one to learn linear predictors with strong guarantees on the test error when the testing distribution may differ from the training distribution. Indeed classical statistical machine learning methods trained using empirical risk minimization work under the assumption that the testing distribution and the training distributions are identical. Should this assumption fail to be satisfied at test time, classical linear predictors may behave unpredictably and perform arbitrarily badly.

The notion of α-superquantile allows one to model such catastrophic risks in a precise manner. Instead of minimizing the average of the loss, we then minimize the superquantile of the loss. The associated minimization problem enjoys an intuitive interpretation owing to its Fenchel dual representation. We establish non-asymptotic bounds for kernel-based methods trained by minimizing the new objective, demonstrating the stronger robustness of the approach compared to classical counterparts when the testing distribution departs from the training distribution. We present numerical illustrations using a first-order optimization algorithm in different settings showing the interest of the approach.

Linear size MIP formulation of Max-Cut: new properties, links with cycle inequalities and computational results

Viet Hung Nguyen Michel Minoux
Sorbonne Université, CNRS, Laboratoire d'Informatique de Paris 6, LIP6, F-75005 Paris, France
Hung.Nguyen@lip6.fr, Michel.Minoux@lip6.fr

Key words: Max-Cut, cycle inequalities, triangle inequalities, semi-metric polytope.

We consider the Max-Cut problem on an undirected graph $G = (V, E)$ with $|V| = n$ nodes and $|E| = m$ edges. We investigate a linear size MIP formulation, referred to as (MIP-MaxCut), which can easily be derived via a standard linearization technique. However, the efficiency of Branch-and-Bound procedure applied to this formulation does not seem to have been investigated so far in the literature. Branch-and-bound based approaches for Max-Cut usually use the semi-metric polytope which has either an exponential size formulation consisting of the cycle inequalities or a compact size formulation consisting of $O(mn)$ triangle inequalities [1], [2]. However, optimizing over the semi-metric polytope can be computationally demanding due to the slow convergence of cutting-plane algorithms and the high degeneracy of formulations based on the triangle inequalities. In this paper, we exhibit new structural properties of (MIP-MaxCut) that link the binary variables with the cycle inequalities. In particular, we show that fixing a binary variable at 0 or 1 in (MIP-MaxCut) can result in imposing the integrity of several original variables and the satisfaction of a possibly exponential number of cycle inequalities in the semi-metric formulation. Numerical results show that for sparse instances of Max-Cut, our approach exploiting this capability outperforms the branch-and-cut algorithms based on separating cycle inequalities when implemented on the same framework; and even without any extra sophistication, the approach already appears to be competitive with state of-the-art cycle inequalities based branch-and-cut algorithms.

References

[1] Barahona, F., Mahjoub, A.R.: On the cut polytope. Math. Prog. **36**, 157–173 (1986)

[2] Nguyen, V.H., Minoux, M., Nguyen, D.P.: Reduced-size formulations for metric and cut polyhedra in sparse graphs. Networks **69**(1), 142–150 (2017)

Robust network dimensioning - the case of FSO networks

Marinela Shehaj[1] Dritan Nace[1] Michał Pióro[2] Michael Poss[3]
Fabio D'Andreagiovanni[1] Ilya Kalesnikau[2] Artur Tomaszewski[2]
[1]Sorbonne Universités, Université de Technologie de Compiègne, CNRS, Heudiasyc UMR 7253, France,
marinela.shehaj@hds.utc.fr, dritan.nace@hds.utc.fr, d.andreagiovanni@hds.utc.fr
[2]Institute of Telecommunications, Warsaw University of Technology, Poland, m.pioro@tele.pw.edu.pl
i.kalesnikau@tele.pw.edu.pl, a.tomaszewski@tele.pw.edu.pl
[3]UMR CNRS 5506 LIRMM, Université de Montpellier, Montpellier, France, michael.poss@lirmm.fr

Key words: FSO, robust optimization, multi-comodity flows.

The considerations of our work are devoted to the problem of networks link dimensioning. The main application area we investigate are networks that apply Free Space Optics (FSO) - a well-established broadband wireless optical transmission technology where the communication links are provided by means of a laser beam sent from the transmitter to the receiver placed in the line of sight. A major disadvantage of FSO links (with respect to fiber links) is their sensitivity to weather conditions such as fog, rain and snow, causing substation loss of the transmission power over the optical channel due mostly to absorption and scattering. Thus, although FSO technology allows fast and low-cost deployment of broadband networks, its operation will be affected by this sensitivity, manifested by substantial losses in links' transmission capacity with respect to the nominal capacity. Therefore, a proper approach to FSO network dimensioning should take such losses into account so that the level of carried traffic is satisfactory under all observed weather conditions.

To construct our approach we start with building a reference failure set using a set of meteorological records for a given time period against which the network must be protected. Next, the mathematical formulation of the robust network dimensioning problem uses the above failure set, which makes the problem untraceable because of the size of the failure set. All this calls for a more sophisticated approach which uses a cut-generation algorithm. Still the problem remains difficult and we need to reduce the size of the failure set. We propose to approximate the reference failure set with a so-called K-set, which roughly speaking covers all possible failures involving at most K links. This K-set stands for uncertainty polytope of failures in our case. We have shown that the cut-generation algorithm works quite well for all K-set failure instances. Finally, a substantial part of our work is devoted to present a numerical study of FSO network instances that illustrate the promising effectiveness of the proposed approach.

Multi-Path Alpha-Fair Resource Allocation at Scale in Distributed SDNs*

Zaid Allybokus[1] Konstantin Avrachenkov[2] Jérémie Leguay[1] Lorenzo Maggi[3]
[1]Huawei Technologies Paris Research Center, name.surname@huawei.com
[2]Inria Sophia Antipolis, konstantin.avratchenkov@inria.com
[2]Nokia Bell-Labs, lorenzo.maggi@nokia.com

Key words: Software Defined Networks, Multi-Path Resource Allocation, Alpha Fairness, Alternating Directions Method of Multipliers, Distributed SDN Control Planes.

Software Defined Networking (SDN) technologies are radically transforming network architectures by offloading the control plane (e.g., routing, resource allocation) to powerful remote platforms that gather and keep a local or global view of the network status in real-time and push consistent configuration updates to the network equipment. The computation power of SDN controllers fosters the development of a new generation of control plane architecture that uses compute intensive operations. Initial design of SDN architectures [2] had envisioned the use of one central controller. However, for obvious scalability and resiliency reasons, the industry has quickly realized that the SDN control plane needs to be partially distributed in large network scenarios [3]. Hence, although logically centralized, in practice the control plane may consist of multiple controllers each in charge of a SDN domain of the network and operating together, in a flat [4] or hierarchical [5] architecture.

In this talk, we propose a distributed algorithm based on the Alternating Direction Method of Multipliers [6] (ADMM) that tackles the multi-path fair resource allocation problem in a distributed SDN control architecture. Our ADMM-based algorithm continuously generates a sequence of resource allocation solutions converging to the fair allocation while always remaining feasible, a property that standard primal-dual decomposition methods often lack. Moreover, it controls the sparsity of the solution to ensure, e.g., small number of path re-sizing, or small number of allocated paths for a same flow. Thanks to the distribution of all computer intensive operations, we demonstrate that we can handle large instances at scale.

References

[1] Allybokus, Z., Avrachenkov, K., Leguay, J., and Maggi, L. (2018) . Multi-Path Alpha-Fair Resource Allocation at Scale in Distributed Software Defined Networks. arXiv preprint arXiv:1809.01050

[2] Vaughan-Nichols, S. J. (2011). Openflow: The next generation of the network? Computer.

[3] Kreutz, D., Ramos, F. M., Verissimo, P. E., Rothenberg, C. E., Azodolmolky, S., and Uhlig, S. (2015). Softwaredefined networking: A comprehensive survey. Proc. of the IEEE.

[4] Stallings, W. (2013). Software-defined networks and openflow. The internet protocol Journal.

[5] Hassas Yeganeh, S. and Ganjali, Y. (2012). Kandoo: a framework for efficient and scalable offloading of control applications. In Proc. of ACM HotSDN.

[6] Boyd, S., Parikh, N., Chu, E., Peleato, B., and Eckstein, J. (2011). Distributed optimization and statistical learning via the alternating direction method of multipliers. Foundations and Trends in Machine Learning.

*This work is the topic of the paper *Multi-path Alpha-Fair Resource Allocation at Scale in Distributed Software Defined Networks* [1], accepted for publication in the IEEE SI on Scalability Issues and Solutions for Software Defined Networtks in August 2018.

Multi-leader disjoint-follower game: formulation and regularity of stationary points

D. Aussel[1], G. Bouza[2], S. Dempe[3], S. Lepaul[4]
[1] Université de Perpignan, France, aussel@univ-perp.fr
[2] University of La Habana, Cuba, gemita23@gmail.com
[3] Technical University Bergakademie Freiberg, Germany, dempe@tu-freiberg.de
[4] EDF correspondent, France, sebastien.lepaul@edf.fr

Key words: Multi-leader-disjoint-follower problems, Bilevel optimization, Mathematical programs with equilibrium constraints, Genericity, Regularity.

Nowadays non-cooperative games have many applications. A particular case is the so-called multi-leader disjoint-follower (MLDF) problem where several leaders act according to a Nash equilibrium and having each a number of exclusive followers. In the presentation we consider the mathematical program with complementarity constraints (MPCC) formulation of the bilevel problem corresponding to each leader, see [1]. We focus to the case in which the sets of feasible solutions of the follower do not depend on the variable of the corresponding leader. We show that, generically, good properties such as constraint qualification and non degeneracy of the solutions, are satisfied at each bi-level problem. In particular, given a problem, we obtain that except for a zero-Lebesgue measure set, with at most quadratic perturbations of the involved functions, the MPCC-LICQ for the MPCC as well as the LICQ at solutions of the follower's problems are satisfied. Using the ideas in [2] it can be shown that these properties will remain stable under small perturbations of the involved functions. We discuss the consequences of this result for the particular MLDF model that appears when agents have to design the contracts they will propose to their clients, knowing that the clients will choose the best option.

References

[1] Aussel, D. and Bouza, G. and Dempe, S. and Lepaul, S.: Multi-leader disjoint-follower game: formulation as a bilevel optimization problem, Preprint No. 2018 - 10, Fakult"at f"ur Mathematik und Informatik, TU Bergakademie Freiberg, 2018.

[2] Guddat, J., Guerra, F. and Jongen, H. Th.: Parametric optimization: singularities, path-following and jumps. Teubner and John Wiley, Chichester, 1990.

A Rolling Horizon Method for a Bilevel Demand Side Management Problem

Luce Brotcorne[1] Sébastien Lepaul[2] Léonard von Niederhäusern[3]
[1]Inocs Team, Inria Lille-Nord Europe, France, luce.brotcorne@inria.fr
[2]OSIRIS, EDF R&D, France, sebastien.lepaul@edf.fr
[3]Inocs Team, Inria Lille-Nord Europe, France, leonard.von-niederhausern@inria.fr

Keywords: Demand side management, smart grid, bilevel programming, stochastic optimization.

With the emergence of the smart grid paradigm, combined with the breakthrough of distributed generation, demand side management has become more important than ever. Since distributed generation is by nature unpredictable, scattered, and irregular, the electricity distribution system undergoes many constraints. It it thus essential to be able to control the demand (and the rest of the production) as much as possible. This work focuses on one specific tool to achieve an efficient management of the demand: time-of-use pricing. Offering differing prices to customers who are going to optimally adapt their consumption is indeed a good way to induce load shifts that are beneficial: in this case, they aim to improve the revenue of an electricity furnisher.

The presented problem is based on [1], but incorporates the management of storage capacities and distributed generation, e.g. solar panels. Furthermore, scenario trees are considered to handle the unpredictability of the distributed generation. However, the inherent complexity of bilevel problems, combined with the potentially huge size of scenario tree-based models, makes the problem hard to solve. This talk addresses the problem with a rolling horizon method, whose efficiency is validated with numerical tests using real data.

References

[1] Afşar, S., Brotcorne, L., Marcotte, P., & Savard, G. (2016). Achieving an optimal trade-off between revenue and energy peak within a smart grid environment. Renewable Energy, 91, 293-301.

How to use tropical geometry to solve bilevel programming problems ?

Marianne Akian Jean-Bernard Eytard Stéphane Gaubert
INRIA, CMAP, Ecole Polytechnique, CNRS, France,
{marianne.akian,jean-bernard.eytard,stephane.gaubert}@inria.fr

Key words: Tropical geometry, bilevel programming, face enumeration, discrete convexity, mobile data networks

Bilevel programming deals with nested optimization problems involving two players. A leader announces a decision to a follower, who responds by selecting a solution of an optimization problem (low level problem) whose data depend on the decision of the leader. The optimal decision of the leader is the solution of another optimization problem (high level problem) whose data depend on the follower's response.

We study a special class of bilevel problems, in which the value of the low level problem is equal to the evaluation of a certain tropical polynomial, depending on the leader's decision. Tropical geometry allows one to represent the response of the follower to the leader's decision by a polyhedral complex. This is motivated by an application of tropical geometry to an auction problem, introduced by Baldwin and Klemperer [1], and further developed by Yu and Tran [2].

Thanks to the tropical approach, we reduce the bilevel problem into a series of optimization subproblems, each one being associated to a cell of the previous polyhedral complex. These cells being a projection of faces of a certain polyhedral, we use a classical face enumeration algorithm developed by Fukuda et al. [3] to define each subproblem. This leads to parametrized complexity results for the bilevel problem, based on the combinatorics of polyhedral complexes.

In particular, we identify a class of bilevel programs that can be solved in polynomial time. This result is also based on discrete convexity results provided by Murota [4].

We finally present an application to a large scale bilevel problem arising in the optimal pricing of data traffic in a telecom network.

References

[1] Elizabeth Baldwin and Paul Klemperer, Understanding Preferences: "Demand Types", and the Existence of Equilibrium with Indivisibilities, Economics Group, Nuffield College, University of Oxford, Economics Papers, 2015-W10, August 2015.

[2] Ngoc Tran and Josephine Yu, Product-mix auctions and tropical geometry, 2015.

[3] Komei Fukuda, Thomas M Liebling, and François Margot. Analysis of backtrack algorithms for listing all vertices and all faces of a convex polyhedron. Computational Geometry, 8(1):1-12, 1997.

[4] Kazuo Murota. Discrete convex analysis. SIAM, 2003.

Runtime Analysis for Self-adaptive Mutation Rates

Benjamin Doerr[1] Carsten Witt[2] Jing Yang[1]
[1]École Polytechnique, CNRS, Laboratoire d'Informatique (LIX),Palaiseau, France
[2]DTU Compute, Technical University of Denmark, Kgs. Lyngby, Denmark

Key words: Evolutionary algorithms, runtime, self-adaptive

We propose and analyze a self-adaptive version of the $(1, \lambda)$ evolutionary algorithm in which the current mutation rate is part of the individual and thus also subject to mutation. A rigorous runtime analysis on the Onemax benchmark function reveals that a simple local mutation scheme for the rate leads to an expected optimization time (number of fitness evaluations) of $O(n\lambda/\log\lambda + n\log n)$ when λ is at least $C\ln n$ for some constant $C > 0$. For all values of $\lambda \geq C\ln n$, this performance is asymptotically best possible among all λ-parallel mutation-based unbiased black-box algorithms as showed in [1].

Our result shows that self-adaptation in evolutionary computation can find complex optimal parameter settings on the fly. At the same time, it proves that a relatively complicated self-adjusting scheme for the mutation rate proposed in [2] can be replaced by our simple endogenous scheme.

On the technical side, the paper contributes new tools for the analysis of two-dimensional drift processes arising in the analysis of dynamic parameter choices in EAs, including bounds on occupation probabilities in processes with non-constant drift.

References

[1] Golnaz Badkobeh, Per Kristian Lehre, Dirk Sudholt, Unbiased black-box complexity of parallel search, Proc. of PPSN '14 892–901

[2] Benjamin Doerr, Christian Gießen, Carsten Witt, Jing Yang, The (1+λ) evolutionary algorithm with self-adjusting mutation rate, Proc. of GECCO '17 777-784

Benchmarking Results of Bayesian, Stochastic, and Classical Solvers for Expensive Numerical Blackbox Problems

Dimo Brockhoff
Inria and CMAP, Ecole Polytechnique
Palaiseau, France, dimo.brockhoff@inria.fr
PGMO project AESOP (http://aesop.gforge.inria.fr)

Key words: continuous optimization, blackbox optimization benchmarking, Bayesian optimization, expensive objective functions, simulation-based optimization, surrogate-model-based optimization.

One of the main aims of the PGMO project "Algorithms for Expensive Simulation-Based Optimization Problems" (AESOP, http://aesop.gforge.inria.fr/) is to exploit the Comparing Continuous Optimizers platform (COCO, https://github.com/numbbo/coco) and extend its reach towards the Bayesian/expensive/simulation-based/surrogate-model-based optimization community. In this talk, I will give a short overview of our project progress towards this goal and detail joint work with Pierre Marion, Lu Lin, Anne Auger, and Nikolaus Hansen.

In particular, I will present experimental data about the performance of the well-known Bayesian approaches EGO, Spearmint, TPE, and SMAC and how they compare to other well-performing (blackbox) solvers such as the Covariance Matrix Adaptation Evolution Strategy (CMA-ES), trust region methods like DFO-TR and NEWUOA and the classical Quasi-Newton BFGS. A brief introduction about how the COCO platform works and how COCO displays algorithm performance through a natural extension of the well-known data profiles will complete the talk. This will make the talk accessible to everybody interested in the performance of (blackbox) solvers in continuous domain—with a special focus on recommending well-performing methods for small budgets of function evaluations.

Bayesian Optimization for non-stationary problems using Deep Gaussian Processes

Ali Hebbal[12], Mathieu Balesdent[1], Loic Brevault[1], El-Ghazali Talbi[2], Nouredine Melab[2]
[1]ONERA, DTIS, Université Paris Saclay, ali.hebbal@onera.fr
[2]Université de Lille, CNRS/CRIStAL, Inria Lille

Key words: Global Optimization, Deep Gaussian Processes, Non-stationary Kriging.

Bayesian optimization is widely used to deal with expensive black-box function optimization. It is based on surrogate models, allowing the emulation of the statistical relationship between the design variables and the response (objective function and constraints), to predict its behaviour using a Design of Experiments (DoE). The evaluation cost of the surrogate models is cheaper, so it is possible to evaluate a greater number of design candidates, then via the use of an acquisition function also called infill criterion one can determine the most promising point(s). One of the most popular Bayesian optimization methods is "Efficient Global Optimization"(EGO) developed by Jones *et al.* [1]. It uses Kriging surrogate model which is based on the Gaussian Process (GP) theory.

Classical Kriging is a GP with a stationary covariance function, inducing a uniform smoothness of the prediction. While it is effective to approximate stationary functions, it causes a major issue in the prediction of non-stationary ones. Indeed, in many design optimization problems, the objective functions or constraints vary with a completely different smoothness along the input space, due to the abrupt change of a physical property for example. The main approaches used to overcome this issue are not applicable for problems with large dimensions (direct formulation of non-stationary covariance function [2], non-linear mapping of the input space [3]) or for problems with sparse data (local stationary covariance functions [4]).

In this talk, we explore the coupling of Bayesian Optimization and Deep Gaussian Processes (DGP) [5] a class of surrogate models based on the structure of neural networks, where each layer is a GP, to deal with the non-stationary issues. The induced challenges and opportunities of this coupling are investigated. Then, numerical experimentations on single and multi-objective analytical problems are displayed to confirm the interest of DGPs for bayesian optimization.

References

[1] Donald R Jones, Matthias Schonlau, and William J Welch. Efficient global optimization of expensive black-box functions. *Journal of Global optimization*, 13(4):455–492, 1998.

[2] Christopher J Paciorek and Mark J Schervish. Spatial modelling using a new class of nonstationary covariance functions. *Environmetrics*, 17(5):483–506, 2006.

[3] Ying Xiong, Wei Chen, Daniel Apley, and Xuru Ding. A non-stationary covariance-based kriging method for metamodelling in engineering design. *International Journal for Numerical Methods in Engineering*, 71(6):733–756, 2007.

[4] Carl E Rasmussen and Zoubin Ghahramani. Infinite mixtures of gaussian process experts. In *Advances in neural information processing systems*, pages 881–888, 2002.

[5] Andreas Damianou and Neil Lawrence. Deep gaussian processes. In *Artificial Intelligence and Statistics*, pages 207–215, 2013.

Exploiting Antagonistic Relations in Signed Graphs under the Structural Balance Hypothesis

Nejat Arinik Rosa Figueiredo Vincent Labatut
Laboratoire Informatique d'Avignon LIA EA 4128, Avignon France
firstname.lastname@univ-avignon.fr

Key words: Multiplex Signed Graph, European Parliament, Graph Partitioning, Correlation Clustering, Structural Balance

A signed graph is considered *structurally balanced* [1] if it can be partitioned into a number of clusters, such that *positive* (*negative*) links are located *inside* (*in-between*) the clusters. Due to the imbalanced nature of real-world networks, various measures have been defined to quantify the amount of imbalance, the simplest consisting in counting the numbers of misplaced links [1]. Such measures are expressed relatively to a graph partition, so processing the graph balance amounts to identifying the partition corresponding to the lowest imbalance measure.

Our goal is to use this paradigm to study the roll-call voting activity of the Members of the European Parliament (MEPs). We want not only to detect groups of MEPs which would be cohesive in terms of votes (i.e groups of antagonistic voters), but also to identify the characteristic ways in which the MEP set is partitioned by these votes. The standard approach to study this type of system is to extract a mean vote similarity network (e.g. [2]). However, this approach suffers from several limitations. The two main ones are that 1) they rely on some temporal integration of the raw data, which causes some information loss; and/or 2) they identify groups of antagonistic voters, but not the context associated to their occurrence.

In this work, we propose a novel method taking advantage of *multiplex* signed graphs to solve both these issues. It consists in first partitioning separately each layer which models a single roll-call as a signed unweighted graph, before grouping these partitions by similarity. We show the interest of our approach by applying it to a European Parliament dataset and by comparing the results with those obtained through a standard approach in our previous work [3].

References

[1] J. A. Davis, Clustering and structural balance in graphs, Human Relations 20 (2) (1967) 181–187.

[2] A. S. Waugh, L. Pei, J. H. Fowler, P. J. Mucha, M. A. Porter, Party polarization in congress: A network science approach, arXiv physics.soc-ph (2009) 0907.3509.

[3] N. Arinik, R. Figueiredo, V. Labatut, Signed graph analysis for the interpretation of voting behavior, in: International Conference on Knowledge Technologies and Data-driven Business - International Workshop on Social Network Analysis and Digital Humanities, Graz, AT, 2017.

Robust proactive maintenance planning with a deadline

Pascale Bendotti[1,2] Philippe Chrétienne[2] Pierre Fouilhoux[2] Adèle Pass-Lanneau[1,2]
[1]EDF R&D, Palaiseau, France, {pascale.bendotti,adele.pass-lanneau}@edf.fr
[2]LIP6, Sorbonne Université, Paris, France {philippe.chretienne,pierre.fouilhoux}@lip6.fr

Key words: project scheduling, deadline, robustness, interdiction problem.

During an outage of a nuclear power plant, more than 10,000 maintenance operations must be scheduled and completed within a few weeks. When delays occur during the execution of some tasks, the schedule has to be recomputed accordingly. However, re-scheduling maintenance operations often comes at a price. Hence a robust initial schedule, called *proactive schedule*, results from a trade-off between taking margins to avoid re-scheduling, and minimizing the total makespan to perform all operations before the deadline.

In this work, maintenance planning is represented by the project scheduling problem with precedence constraints (PERT). Due to delays, these precedence constraints are subject to uncertainty, which is represented by a collection of delay scenarios to hedge against. A standard approach would be to compute a worst-case robust solution, i.e., a schedule that is feasible for every scenario [1]. An advantage of such a solution is that all jobs have the same start time for all scenarios, but the schedule may have a very large makespan and if so, it would be inapplicable in practice. Less conservative solutions can be obtained by refining the definition of the uncertainty set [2].

Our contribution is an alternative approach where the makespan of the proactive schedule is fixed, and the objective is to maximize the number of *anchored jobs*, i.e., jobs that have the same start time in all scenarios. Using previous results from [3], we prove that this problem is equivalent to a Longest Path Network Interdiction problem in a weighted transitive closure of a directed acyclic graph. We discuss consequences of this equivalence for the complexity of the problem, depending on the structure of precedence constraints and the uncertainty set.

References

[1] P. Kouvelis and G. Yu. Robust discrete optimization and its applications. Kluwer Academic Publishers, Norwell, MA, 1997.

[2] D. Bertsimas and M. Sim. Robust discrete optimization and network flows. *Mathematical Programming Series B*, 98 (2003) 49–71.

[3] P. Bendotti, P. Chrétienne, P. Fouilhoux, and A. Quilliot. Anchored reactive and proactive solutions to the CPM-scheduling problem. *European Journal of Operational Research*, 261 (2017) 67–74.

Communicating Zero-Sum Product Stochastic Games

Tristan Garrec[1]
[1]Toulouse School of Economics & Université Paris Dauphine, France, tristan.garrec@ut-capitole.fr

Key words: stochastic games, zero sum, uniform value, asymptotic value, communication property

We study the asymptotic and uniform values in two classes of zero-sum product stochastic games, with a finite state space and compact action sets. The two classes we are interested in assume a communication property on the state spaces of the players.

The first class is the class of strongly communicating on one side zero-sum product stochastic games. In such games, for one player, there exists a fixed time T such that independently of his choice of strategy (depending only on his own history), there is a positive probability of passing from any state to any other state in his component of the state space in exactly T stages. This assumption, of ergodic nature, implies that the current state of the player having the strong communication property has in the long run little importance.

The second class is the class of weakly communicating on both sides zero-sum product stochastic games. In such games, for both players there exists a time T and a strategy (depending only on their own history) such that, for any two states in their components of the state space, they can move from one to the other with positive probability in exactly T stages. Thus players totally control the dynamics on their components of the state space.

For strongly communicating on one side games, we prove the existence of the uniform value, which does not depend on the initial state of the player having the strong communication property. Furthermore we prove that this player has ε-optimal strategies that have a simple structure.

Regarding weakly communicating on both sides games, we provide an example of a game which does not have an asymptotic value (and hence neither has a uniform one).

References

[1] R. Laraki, J. Renault, Acyclic gambling games, ArXiv:1702.06866 (2017).

[2] J. Flesch, G. Schoenmakers, K. Vrieze, Stochastic games on a product state space, Mathematics of Operations Research 33 (2008) 403–420.

[3] G. Vigeral, A zero-sum stochastic game with compact action sets and no asymptotic value, Dynamic Games and Applications 3 (2) (2013) 172–186.

[4] S. Sorin, G. Vigeral, Reversibility and oscillations in zero-sum dis- counted stochastic games, Journal of Dynamics and Games 2 (1) (2015) 103–115.

[5] B. Ziliotto, Zero-sum repeated games: counterexamples to the existence of the asymptotic value and the conjecture maxmin=lim v(n), Annals of Probability 44 (2) (2016) 1107–1133.

Random Location Games

Gaëtan Fournier[1] Marco Scarsini[2] Karine Van der Straeten[3]
[1]AMSE, France, gaetan.fournier@univ-amu.fr
[2]LUISS, Italy, marco.scarsini@luiss.it
[3]TSE, France, karine.van-der-straeten@tse-fr.eu

Key words: Nash equilibrium, efficiency of equilibium, location games

A location game is a competition between a finite number of players who select simultaneously a location in order to attract as many consumers as possible. In random location games, we consider that sellers have small differentiation, and consumers have specific preferences for this differences. Because firms can not determine this preferences, they act as if the choice of consumers were driven by a random variable. We investigate the impact of such randomness in the Nash equilibrium of the game.

References

[1] Fournier, Scarsini, Location Games on Networks: Existence and Efficiency of Equilibria, Mathematics of Operation Research (online)

[2] Fournier, General distribution of consumers in pure Hotelling games, Working Paper

[3] Fournier, Van der Straeten, Spatial competition with binary demand, Working Paper

Repeated zero-sum games with varying duration

S. Sorin[1] G. Vigeral[2]
[1] IMJ, UPMC, France
[2] CEREMADE, U. Paris-Dauphine, France

Key words: Game theory, repeated games, zero-sum, dynamic games

We study the links between the values of stochastic games with varying stage duration h, the corresponding Shapley operators $\mathbf{T}$ and $\mathbf{T}_h = h\mathbf{T} + (1-h)Id$ and the solution of the evolution equation $\dot{f}_t = (\mathbf{T} - Id)f_t$. Considering general non expansive maps we establish two kinds of results, under both the discounted or the finite duration framework that apply to the class of "exact" stochastic games. On the one hand, for a fixed horizon or discount factor, the value converges as the stage duration go to 0. On the other hand, the asymptotic behavior of the value as the horizon goes to infinity, or as the discount factor goes to 0, does not depend on the stage duration. Finally these properties imply the existence of the value of the finite duration or discounted continuous time game (associated to a continuous time Markov process), as the limit of the value of any discretization with vanishing mesh.

Hybrid models for time series forecasting. Application to capacity planning

A. Bondu[1], T. Guyet[2], A. Lemaire[1] and S. Malinowski[3]
[1] Orange Labs
[2] AGROCAMPUS-OUEST/IRISA-UMR6074
[3] Univ Rennes, CNRS, Inria, IRISA

Keywords: Time series, forecasting, ensemble methods, hybrid models.

Capacity planning is the process of determining the infrastructure needed to meet future customer demands for online services. A well-made capacity planning helps to reduce operational costs, and improves the quality of the provided services. Capacity planning requires accurate forecasts of the differences between the customer demands and the infrastructure theoretical capabilities. The Hyptser project makes the assumption that this information is captured by key performance indicators (KPI), that are measured continuously in the service infrastructure. Thus, we expect to improve capacity planning capabilities by making accurate forecasts of KPI time series.

Recent methods about time series forecasting make use of ensemble models ([1], for instance). In this project, we are interested in developing hybrid models for time series forecasting. Hybrid models aim at jointly partitioning the data, learning forecasting models in each partition and learning how to combine their outputs.

We are currently developing two different approaches for that purpose, one based on the MODL framework and the other based on neural networks. We describe these approaches below:

- MODL is a mathematical framework that turns the learning task into a model selection problem. It aims at finding the most probable model given the data. The MODL approach has been applied on numerous learning tasks. In all cases, this approach leads to a regularized optimization criterion. We formalize a new MODL criterion able to learn hybrid models on time series in order to: i) make a partition of time series; ii) learn local regression models. This approach formalizes these two steps in a unified way.
- We are also developing an hybrid neural network structure that is able to learn automatically a soft partitioning of the data together with local models on each partition.

In the next steps of this project, we will analyze the performance of this two strategies on KPI time series provided by Orange and compare them to classical ensemble methods.

References

[1] Vítor Cerqueira, Luís Torgo, Fábio Pinto, and Carlos Soares. Arbitrated ensemble for time series forecasting. In *Joint European Conference on Machine Learning and Knowledge Discovery in Databases*, pages 478–494. Springer, 2017.

Predicting aircraft type from radar based trajectory measurements

Sami Jouaber[1] Silvère Bonnabel[2] Santiago Velasco-Forero[3] Jesus Angulo[4]
[1]Mines ParisTech, France, sami.jouaber@mines-paristech.fr
[2]Mines ParisTech, CAOR, France, silvere.bonnabel@mines-paristech.fr
[3]Mines ParisTech, CMM, France, santiago.velasco@mines-paristech.fr
[4]Mines ParisTech, CMM, France, jesus.angulo@mines-paristech.fr
We thank Clément Pira, Hervé Pasquereau, Philippe Chopin,
and Frédéric Barbaresco from the company Thales.

Key words: Time series, classification, machine learning.

Introduction: The first goal of a traffic control center is to yield a clear vision of the state of the air traffic. This vision is based on various information about the flying aircrafts, namely radar measurements and information provided by the planes themselves about their position and their characteristics through the Automatic Dependence Surveillance Broadcast (ADSB) system. To provide air traffic controllers with efficient decision making tools, one should be able to automatically detect a number of features regarding an aircraft, solely based on radar measurements that do not depend on whether the aircraft is cooperating or not. In particular, it is desirable to establish whether the aircraft is civilian or military, if its behavior is aggressive or not, what kind of maneuvers it is capable of doing, and which category of aircraft we are dealing with.

Considered classification task: As radar measurements are classified, since they contain information about French military operations and trips, we have collected many aircraft trajectories (i.e., position over time) using the publicly available ADSB data. Those trajectories serve as a publicly available alternative to the radar position measurements. The goal of the classification task is then to be able to recognize automatically a number of features being as follows: type of aircraft (helicopter, liner, fighter), category (light, middle, heavy), type of engine (piston, turboprop, reaction), number of engines (1 or 2). Those features being also transmitted through the ADSB, we are dealing with a supervised classification problem.

Contribution: After proper treatment of the data, we extracted various kinematic and dynamic features characterizing the trajectories, namely norm of velocity, curvature, torsion, their projected counterpart on a 2D plane, and altitude and its derivatives. Those features have the property of being invariant to rotation around a vertical axis, that is, they do only depend on the physical motion of the aircraft, not on whether it is heading, e.g., north or east. We used recurrent neural networks for the classification task. The overall classification accuracy obtained is 30%, with an accuracy of 88% regarding aircraft type, 75% regarding type of engine, and 57% regarding number of engines.

Model-Based Functional Co-Clustering for the Analysis and the Prediction of Electric Power Consumption

C. Bouveyron[1] L. Bozzi[2] J. Jacques[3] F.-X. Jollois[4]
[1]Université Côte d'Azur, Lab. Dieudonné, France, charles.bouveyron@math.cnrs.fr
[2]EDF R&D, France, laurent.bozzi@edf.fr
[3]Université de Lyon, Lyon 2 & ERIC EA3083s, France, julien.jacques@univ-lyon2.fr
[4]Université Paris Descartes, LIPADE, France, francois-xavier.jollois@parisdescartes.fr

Key words: Co-clustering, functional data, electric power consumption.

After the installation of 300.000 smart meters "Linky" between 2009 and 2011 in the area of Lyon and Tours, the authorities have decided to generalize these meters throughout the territory. By 2021, 35 million meters should be replaced in French households by Linky meters, allowing electricity operators to record electricity consumption. For an operator like EDF with 27 millions of residential dwellings, these new smart meters represent a great opportunity to gather customer consumption data and therefore to improve client knowledge. Indeed, so far, customer data were recorded only every six months, while with the smart meter, the data can be taken up to every second. In practice, EDF plans to access the data every half hour, which means 17472 measures per year for each of the 27 million clients. Nevertheless, this data flood may also be a drawback since they represent a mass of data to store and manage. To this end, it will be necessary to build « summaries » of these data, and one of the way to achieve that is to cluster the data. However, because of the nature of the data, which are time series for each customer, the interest in the simultaneous clustering of customers and time increases considerably.

We have proposed a new co-clustering methodology [1], based on the functional latent block model (funLBM), which allows to build "summaries" of these large consumption data through co-clustering. The funLBM model extends the usual latent block model to the functional case by assuming that the curves of one block live in a low-dimensional functional subspace. Thus, funLBM is able to model and cluster large data set with high-frequency curves. A SEM-Gibbs algorithm is proposed for model inference and an ICL criterion is derived to address the problem of choosing the number of row and column groups. Numerical experiments on simulated and original Linky data show the usefulness of the proposed methodology. An R package for functional data co-clustering has been developed. This package is called funLBM and is available on CRAN.

Recently, an extension of this model to peak like curves has been developed using wavelet analysis.

References

[1] Bouveyron, C., Bozzi, L., Jacques, J. and Jollois, F-X., The Functional Latent Block Model for the Co-Clustering of Electricity Consumption Curves, preprint hal-01533438 (2017).

Platform for Data Science Competitions on Data Streams

Albert BIFET[1], Nedeljko RADULOVIĆ[2]

[1]Télécom ParisTech, France, albert.bifet@telecom-paristech.fr
[2]University of Paris-Saclay, France, radulovic.nedeljko@telecom-paristech.fr

Keywords: Information Flow Processing, Stream Data Mining, Data Science Competition

Streaming data are data that are generated continuously from a vast variety of sources. With all new technologies and so many portable devices data are collected and generated in real time. Also, the high pace of development, trading, and business demand that these data should be used instantly, so important decisions can be made in a short time. Streaming data are processed in near real-time applications and processing is done record by record or over sliding time windows. Building prediction models in a streaming setting is a challenging task. Many companies, in order to find the best prediction model, organize competitions where they publish some of their data and give a task to competitors to build a model. Until now this is done only for static datasets.

In this work, we propose a platform for data science competitions on data streams. The platform has been built on top of the pillars of Information Flow Processing[1]: processing on-the-fly, high availability and scalability. The platform is implemented using several new big data technologies such as Kafka, gRPC, Protobuf, Spark, and MongoDB. When the competition is scheduled, the system will pull data from sources, generate the stream according to competition setting and provide it to multiple competitors. Competitors will build their model and submit the predictions which are evaluated immediately. The platform supports several types of competitions: regression and classification, single or multi-label and competitors can use different languages: Python, Java and, R. We plan to run competitions on real use cases provided by EDF such as Forecast and Disaggregation[2].

References

[1] M. Stonebraker, U. Çetintemel, and S. Zdonik, “The 8 requirements of real-time stream processing,” *ACM Sigmod Record*, vol. 34, no. 4, pp. 42–47, 2005.

[2] J. Z. Kolter and M. J. Johnson, “Redd: A public data set for energy disaggregation research,” in *Workshop on Data Mining Applications in Sustainability (SIGKDD), San Diego, CA*, vol. 25, no. Citeseer. Citeseer, 2011, pp. 59–62.

Viability of an Open Set for Stochastic Control Systems

Marc Quincampoix[1]
[1]Université de Brest, France

Key words: Stochastic Control, State constraints, Optimal Control.

The problem of compatibility of a stochastic control system and a set of constraints - the so called viability property - has been widely investigated during the last decade. The question is to characterize sets A such that for any initial condition belonging to A there exists a control ensuring that the associated process remains forever almost surely in A (this is called the viability property of the constrained set). When A is closed and the dynamics is continuous, the viability property has been characterized in the literature through several equivalent geometrical conditions involving the set A, the drift and the diffusion of the control system. Here we give a necessary and sufficient geometrical condition on the boundary of an open set A ensuring the viability property of A. For this we only need to assume that A has a $C^{2,1}$ boundary and that the dynamics is Lipschitz. When we assume moreover a classical convexity condition on the control dynamics we obtain that the viability property of the open set A of constraints is equivalent to the viability of the closure of A. This result is rather surprizing, because several very elementary examples in the deterministic framework show that this equivalence is, in general, wrong for a general open set A. We will also discuss examples showing that the above equivalence is wrong when either the set A does not have enough regularity, or the coefficients of dynamics are not Lipschitz continuous.

References

[1] Buckdahn, R.; Frankowska, H. ; Quincampoix, M. Viability of an Open Set for Stochastic Control Systems, (submitted)

Generic Fuller singularities of single-input control-affine systems

Francesco Boarotto[1] Mario Sigalotti[2]
[1]Sorbonne Université, France, boarotto@ljll.math.upmc.fr
[2]Inria & Sorbonne Université, France, mario.sigalotti@inria.fr

Key words: optimal control, Fuller phenomenon, chattering.

Let M be a smooth n-dimensional manifold and denote by $\mathrm{Vec}(M)$ the space of smooth vector fields on M. Consider the control-affine system

$$\dot{q}(t) = f_0(q(t)) + u(t)f_1(q(t)), \quad q(t) \in M, \quad u(t) \in [-1, 1]. \tag{1}$$

The kind of results we are interested in concern the regularity of time-optimal trajectories. This is a hopeless task in full generality since, as proved in [3], for any given measurable control $u(\cdot)$, there exist a dynamical system of the form (1) and an initial datum $q_0 \in M$ for which the admissible trajectory driven by u and starting at q_0 is time-optimal. It makes then sense to look for better answers imposing some genericity conditions on (f_0, f_1).

The problem of the regularity of extremal trajectories for generic control-affine systems is known to be delicate. In his striking example, Fuller [1] exhibited a polynomial system of the kind studied here, in which controls associated with optimal trajectories have a converging sequence of isolated discontinuities. If the dimension of M is sufficiently high, such behavior is structurally stable, i.e., it cannot be destroyed by a small perturbation of the initial system [2].

The main goal of this talk is to bound the worst stable behavior for generic single-input systems of the form (1), in terms of the maximal order of its Fuller times. Given an admissible trajectory $q : [0, T] \to M$, we denote by O the maximal open subset of $[0, T]$ such that there exists a control $u(\cdot)$, associated with $q(\cdot)$, which is smooth on O. We also define Σ by $\Sigma = [0, T] \setminus O$, Σ_0 as the set of isolated points in Σ, and, by recurrence, Σ_k as the set of isolated points of $\Sigma \setminus (\cup_{j=0}^{k-1}\Sigma_j)$. The points of Σ_k, $k \geq 1$, are *Fuller times of order k*. Our main result is the following: Given a n-dimensional smooth manifold M, there exists $\mathcal{V} \subset \mathrm{Vec}(M) \times \mathrm{Vec}(M)$ open and dense for the C^∞ Whitney topology such that, if (f_0, f_1) is in $\mathcal{V}$, then any time-optimal trajectory $q(\cdot)$ of (1) has at most Fuller times of order $(n-1)^2$, i.e., $\Sigma = \Sigma_0 \cup \ldots \cup \Sigma_{(n-1)^2}$.

References

[1] A. T. Fuller. Study of an optimum nonlinear system. *J. Electronics Control*, 15:63–71, 1963.

[2] I. Kupka. The ubiquity of Fuller's phenomenon. *Nonlinear controllability and optimal control*, 133:313–350, 1990.

[3] H. J. Sussmann. A weak regularity theorem for real analytic optimal control problems. *Rev. Mat. Iberoamericana*, 2(3):307–317, 1986.

Towards the optimization of a new type of cancer therapy

Yannick Viossat[1]
[1]Université Paris-Dauphine, France viossat@ceremade.dauphine.fr

Key words: cancer therapy, modelling, optimal control .

Many cancer treatments are administered at the maximal tolerated dose, and eventually fail as the tumor becomes resistant. Adaptive therapy, a new kind of cancer therapy, aims at delaying the emergence of resistance by delivering smaller or less frequent doses. The precise schedule and dosage depend on each patient,Äôs response to the treatment. Experimental results are highly promising, but protocols and models are still crude. An ongoing PGMO project aims at clarifying why and when adaptive therapy should be expected to improve on current therapies, and how to choose optimally the timing and dosage of drug delivery. A preliminary step is to establish sound models of adaptive therapy. In this talk, we will discuss modelling choices, such as the basic tumor growth model, the number of cell types, the degree of resistance of resistant cells, the treatment effect on the irrigation of the tumor, the way to model the tumor spatial structure, and the impact of these choices on the optimal treatment.

Exact verification of discrete-time affine dynamical systems

Assalé Adjé
LAMPS, Université de Perpignan Via Domitia, France, assale.adje@univ-perp.fr

Key words: Discrete-time affine systems, Optimization in dynamical systems, Robust Optimization, Verification, Semi-definite programming.

Our very first concern is the resolution of the verification problem for the class of discrete-time affine dynamical systems. This problem is widely studied in computer science community [1] or in control theory [2]. Optimization theory [3] are more and more used to solve verification problems. The proposed approach follows this line of research : our verification problem is reduced to solve an optimization problem with dynamical system constraints. Actually this particular subclass of optimization problems is called the robust-to-dynamics optimization [4].

In our presentation, we consider the maximization of a convex quadratic function over the reachable values set of an asymptotic stable affine system. For verification purposes, we assume that the initial condition set is a polytope. The difficulty in solving the optimization problem is to handle infinite sequences in the constraints set. To solve this optimization problem, we truncate the infinite sequences belonging to reachable values set at a rank which is uniform with respect to the initial conditions i.e. valid for all possible initial conditions. This uniform rank is constructed from basic tools of matrix theory such as matrix norms, extremal eigenvalues or generalized Rayleigh quotients. We also need a solution of the discrete Lyapunov equation that permits to define a useful matrix norm. Finally, we introduce a new non-convex semi-definite program to compute the optimal uniform rank. The exact resolution of this semi-definite problem is, for the moment, left open and we just provide an over-approximation of its optimal value. By doing so, it does not degrade the exact resolution of the verification problem.

In practice, we use semi-definite programming to solve the discrete Lyapunov matrix equation and to compute extremal eigenvalues that we need. We end the talk by some experimental results that measure the accuracy of our approach.

References

[1] A. Miné, Tutorial on Static Inference of Numeric Invariants by Abstract Interpretation, Foundations and Trends® in Programming Languages, 2017, pp. 120–372.

[2] P. S. Duggirala, A. Tiwari, Safety verification for linear systems, Proceedings of the International Conference on Embedded Software (2013), pp. 1–10.

[3] M. Roozbehani, A. Megretski, E. Feron, Optimization of Lyapunov Invariants in Verification of Software Systems, IEEE Transactions on Automatic Control (2013), pp. 696–711.

[4] A. A. Ahmadi, O. Günlük, Robust-to-dynamics linear programming, 54th IEEE Conference on Decision and Control (2015), pp. 5915–5919.

New hints on Campanato's nearness condition

Annamaria Barbagallo[1] Octavian-Emil Ernst[2] Michel Théra[3]
[1] University of Naples "Federico II", annamaria.barbagallo@unina.it
[2]Université de Aix-Marseille , emil.ernst@univ-amu.fr
[3] Université de Limoges and Federation University Australia, michel.thera@unilim.fr

Key words: Elliptic PDEs, Birkoff-James orthogonality, Campanato's nearness.

I propose to survey the theory of nearness between operators acting on normed spaces and developed by S. Campanato at the end of the eighties in a series of papers (see e.g. [1]). The aim of S. Campanato was to study existence and regularity results for some differential elliptic equations. Given X a set with at least two elements, and $(Y, \|\cdot\|)$ a real normed space, he said that the function $a : X \to Y$ is *near* the function $b : X \to Y$ if the inequality

$$\| (b(x_2) - \alpha\, a(x_2)) - (b(x_1) - \alpha\, a(x_1)) \| \leq \kappa \, \|b(x_2) - b(x_1)\| \qquad \forall x_1, x_2 \in X \tag{1}$$

holds for some positive constant α, and some real number κ such that $0 < \kappa < 1$.

Obviously nearness is a reflexive relation. The first part of the talk adresses the natural question of the **symmetry** of the nearness relation. We observe that when (Y is an **inner product space** and a is near b for the constants α and κ, then b is near a, but for the different constants $\frac{1-\kappa^2}{\alpha}$ and κ. When the dimension of Y is greater or equal to three, then the three following properties are equivalent : Y is an inner product space, the Birkhoff-James orthogonality is symmetric, and the Campagnato nearness is symmetric.

In a second part of the talk, I will introduce a new concept which extends Campanato's definition to multifunctions. In particular, given two set-valued mappings $A, B : X \rightrightarrows Y$, we consider a compatible set-valued mapping, namely a set-valued mapping $T : X \rightrightarrows Y$ such that

1. for every $x \in X$ and every $y \in B(x)$ $T(y) \cap A(x) \neq \emptyset$,
2. for every $x \in X$ $\bigcup_{y \in B(x)} T(y) \supset A(x)$.

We say that A is *near* B if there exist a compatible set-valued mapping $T : Y \rightrightarrows Y$ and two positive constants α and k with $0 < k < 1$ such that for every s_A selection of A and every s_B selection of B satisfying:

$$s_A(x) \in T(s_B(x)), \quad \forall x \in X,$$

s_A is near in Campanato's sense s_B with constants α and k. After that we investigate which properties of set-valued mappings are preserved by nearness. Moreover, we discuss some examples and deduce that the surjectivity and the bijectivity properties are preserved with some additional conditions on the set-valued mappings. Such remarks leave some open questions which will give new research ideas.

References

[1] S. Campanato, *On the condition of nearness between operators*, Ann. Mat. Pura Appl. (4), vol. 167, pp. 243–256, (1994).

[2] A. Barbagallo, E. Ernst, M. Théra, *Symmetry of Campagnato's nearness condition and the measure of right angles in a normed space*, Preprint (2018).

On some nonmonotone variational inequalities

Cheng Wan[1] Daoli Zhu[2] Lei Zhao[3]
[1]Université Paris-Sud, France, cheng.wan.2005@polytechnique.org
[2]Shanghai Jiao Tong University, China, dlzhu@sjtu.edu.cn
[2]Shanghai Jiao Tong University, China, l.zhao@sjtu.edu.cn

Key words: variational inequality, restricted strong monotonicity, restricted co-coercivity, proximal projection, linear-convergence.

This paper studies two classes of nonmonotone variational inequality problems called restricted co-coercive ones and restricted strongly monotone ones. Their relations with each other and with strongly monotone and co-coercive variational inequalities are presented. In particular, if a restricted co-coercive variational inequality satisfies a so called restricted linear growth condition, then it is also restricted strongly monotone. The relation between restricted strongly monotone variational inequalities and the so-called restricted secant inequality and restricted convex functions in recent research work on nonconvex optimization [3, 2, 4, 1] is also discussed. Non pseudomonotone examples of both restricted co-coercive and restricted strongly monotone variational inequalities are given. The convexity and connectedness of the solution set of a restricted co-coercive problem are studied. The linear transformation of a strongly monotone variational inequality problem is shown to be a monotone and restricted co-coercive in some special case. Finally, the convergence of proximal projection methods for restricted co-coercive variational inequality problems is proved and, furthermore, if it satisfies the restricted linear growth condition, it has a linear convergence rate.

References

[1] I. Necoara, Yu. Nesterov, F. Glineur, Linear convergence of first order methods for non-strongly convex optimization, Mathematical Programming (2018).

[2] F. Schöpfer, Linear Convergence of Descent Methods for the Unconstrained Minimization of Restricted Strongly Convex Functions, SIAM Journal on Optimization, 26 (2016), pp. 1883-1911.

[3] H. Zhang, L. Cheng, Restricted strong convexity and its applications to convergence analysis of gradient-type methods in convex optimization, Optimization Letters, 9 (2015), pp. 961-979.

[4] H. Zhang, The restricted strong convexity revisited: analysis of equivalence to error bound and quadratic growth, Optimization Letters, 11 (2017), pp. 817-833.

Dual Problems for Exact Sparse Optimization

J.-P. Chancelier[1] M. De Lara [1]
[1]ENPC ParisTech, delara@cermics.enpc.fr

Key words: sparse optimization, l_0 “norm”, Fenchel-Moreau conjugacy.

Exact sparse optimization problems (also known as sparsity-constrained problems) can be formulated as the minimization of a criterion under a constraint that the l_0 “norm” be less than a given integer, that measures the sparsity of the solution. Since the l_0 “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 is to replace the sparsity constraint by a convex penalizing term, that will induce sparsity [2, 1]. Thus doing, we lose the original exact sparse optimization problems, but we gain convexity (benefiting especially of duality tools with the Fenchel conjugacy).

We propose another route, where we lose convexity but where we gain at keeping the original exact sparse optimization formulation. For this purpose, we introduce an adapted conjugacy, induced by a novel coupling [4, 3], the Fenchel coupling after primal normalization. This coupling has the property of being constant along primal rays, like the l_0 “norm”. Thus equipped, we present a way to build a dual problem, that is a lower bound of the original exact sparse optimization problem. We illustrate our result on the classical least squares regression sparse optimization problem.

References

[1] F. Bach, R. Jenatton, J. Mairal, and G. Obozinski. Optimization with sparsity-inducing penalties. *Found. Trends Mach. Learn.*, 4(1):1–106, Jan. 2012.

[2] A. M. Bruckstein, D. L. Donoho, and M. Elad. From sparse solutions of systems of equations to sparse modeling of signals and images. *SIAM Rev.*, 51(1):34–81, 2009.

[3] J. E. Martínez-Legaz. Generalized convex duality and its economic applications. In S. S. Hadjisavvas N., Komlósi S., editor, *Handbook of Generalized Convexity and Generalized Monotonicity. Nonconvex Optimization and Its Applications*, volume 76, pages 237–292. Springer Verlag, 2005.

[4] J. J. Moreau. Inf-convolution, sous-additivité, convexité des fonctions numériques. *J. Math. Pures Appl. (9)*, 49:109–154, 1970.

A generic coordinate descent solver for nonsmooth convex optimization

Olivier Fercoq
LTCI, Télécom ParisTech, Université Paris-Saclay, France, olivier.fercoq@telecom-paristech.fr

Key words: Coordinate descent, solver implementation, convex optimization.

Coordinate descent methods decompose a large optimization problem into a sequence of one-dimensional optimization problems. The algorithm was first described for the minimization of quadratic functions by Gauss and Seidel. Coordinate descent methods have become unavoidable in machine learning because they are very efficient for key problems, namely Lasso, logistic regression and support vector machines. Moreover, the decomposition into small subproblems means that only a small part of the data is processed at each iteration and this makes coordinate descent easily scalable to high dimensions.

One of the main ingredients of an efficient coordinate descent solver is its ability to compute efficiently partial derivatives of the objective function [Nes12]. In the case of least squares for instance, this involves the definition of a vector of residuals that will be updated during the run of the algorithm. As this operation needs to be performed at each iteration, and millions of iterations are usually needed, the residual update and directional derivative computation must be coded in a compiled programming language.

We propose a generic coordinate descent method for the resolution of the convex problem

$$\min_{x\in\mathbb{R}^N} \sum_{j=1}^{J} f_j(A_j^f x - b_j^f) + \sum_{i=1}^{I} g_i(D_i^g x^{(i)} - b_i^g) + \sum_{l=1}^{L} h_l(A_l^h x - b_l^h) \ .$$

We shall call f_j, g_i and h_l atom functions. Each of them may be different and is pre-compiled. We will assume that f_j's are differentiable and convex, g_i's and h_l's are proximal-friendly convex functions. As before A_j^f and A_l^h are matrices of appropriate sizes, D_i^g is a diagonal matrix of size N_i, b_j^f, b_i^g and b_l^h are vectors.

The algorithm we implemented is described in [FB15] and can be downloaded on `https://bitbucket.org/ofercoq/cd_solver`. It deals with residual updates and dual variable duplication in a generic fashion and includes a modelling interface in Python for the definition of the optimization problem.

References

[FB15] Olivier Fercoq and Pascal Bianchi. A Coordinate Descent Primal-Dual Algorithm with Large Step Size and Possibly Non Separable Functions. *arXiv preprint arXiv:1508.04625*, 2015.

[Nes12] Yurii Nesterov. Efficiency of coordinate descent methods on huge-scale optimization problems. *SIAM Journal on Optimization*, 22(2):341–362, 2012.

An Experimental Comparison of SONC and SOS Certificates for Unconstrained Optimization

Henning Seidler[1] Timo de Wolff[2]
[1]Technische Universität Berlin, Germany, seidler@math.tu-berlin.de
[2]Technische Universität Berlin, Germany, dewolff@math.tu-berlin.de

Session: Semialgebraic Optimization and Applications

Key words: Nonnegativity, Polynomial optimization, Sum of nonnegative circuit polynomials, Sum of squares, Unconstrained.

Finding the minimum of a multivariate real polynomial is a well-known hard problem with various applications. We present a polynomial time algorithm to approximate such lower bounds via sums of nonnegative circuit polynomials (SONC). As a main result, we carry out the first large-scale comparison of SONC, using this algorithm and different geometric programming (GP) solvers, with the classical sums of squares (SOS) approach, using several of the most common semidefinite programming (SDP) solvers. SONC yields bounds competitive to SOS in several cases, but using significantly less time and memory. In particular, SONC/GP can handle much larger problem instances than SOS/SDP.

References

[1] H. Seidler, T. de Wolff, An Experimental Comparison of SONC and SOS Certificates for Unconstrained Optimization, (2018), preprint; see ArXiv 1808.08431.

[2] M. Dressler, S. Iliman, T. de Wolff, An Approach to Constrained Polynomial Optimization via Nonnegative Circuit Polynomials and Geometric Programming, (2016), to appear in the Journal of Symbolic Computation (special issue for "MEGA 2017"); see also ArXiv 1602.06180.

[3] S. Iliman, T. de Wolff, Lower Bounds for Polynomials with Simplex Newton Polytopes Based on Geometric Programming, SIAM Journal on Optimization, **26** (2) (2016), 1128-1146.

[4] S. Iliman, T. de Wolff, Amoebas, Nonnegative Polynomials and Sums of Squares Supported on Circuits, Research in the Mathematical Sciences, **3** (1) (2016), 1-35.

Moments and convex optimization for analysis and control of nonlinear partial differential equations

Milan Korda[1], Didier Henrion[2,3], Jean Bernard Lasserre[4]
[1]Univ. California, Santa Barbara, USA, milan.korda@engineering.ucsb.edu
[2]LAAS-CNRS, Univ. Toulouse; France, henrion@laas.fr
[3] Fac. Elec. Engr., Czech Tech. Univ. Prague, Czechia, henrion@fel.cvut.cz
[4]LAAS-CNRS, Univ. Toulouse; France, lasserre@laas.fr

Key words: Partial differential equations, Occupation measure, Optimal control, Semidefinite programming, Convex optimization.

Session: Semialgebraic Optimization and Applications

This work presents a convex-optimization-based framework for analysis and control of nonlinear partial differential equations. The approach uses a particular weak embedding of the nonlinear PDE, resulting in a linear equation in the space of Borel measures. This equation is then used as a constraint of an infinite-dimensional linear programming problem (LP). This LP is then approximated by a hierarchy of convex, finite-dimensional, semidefinite programming problems (SDPs). In the case of analysis of uncontrolled PDEs, the solutions to these SDPs provide bounds on a specified, possibly nonlinear, functional of the solutions to the PDE; in the case of PDE control, the solutions to these SDPs provide bounds on the optimal value of a given optimal control problem as well as suboptimal feedback controllers. The entire approach is based purely on convex optimization and does not rely on spatio-temporal gridding, even though the PDE addressed can be fully nonlinear. The approach is applicable to a very broad class nonlinear PDEs with polynomial data. Computational complexity is analyzed and several complexity reduction procedures are described. Numerical examples demonstrate the approach.

On Exact Polynomial Optimization through Sums of Squares

Victor Magron[1,2] Mohab Safey El Din[3]

Session: Semialgebraic Optimization and Applications

[1] CNRS L2S CENTRALESUPELEC, 3 rue Joliot-Curie, 91192 Gif sur Yvette, France.
[2] CNRS LAAS, 7 avenue du colonel Roche, F-31400 Toulouse, France. magron@laas.fr
[3] Sorbonne Université, CNRS, INRIA, LIP6,
Équipe PolSys 4 place Jussieu, F-75252, Paris Cedex 05, France. mohab.safey@lip6.fr

Key words: Semidefinite programming, sums of squares decomposition, Polya's representation, Putinar's representation, hybrid numeric-symbolic algorithm.

We consider the problem of finding exact sums of squares (SOS) decompositions for some classes of non-negative multivariate polynomials, relying on semidefinite programming (SDP) solvers.

We start by providing a hybrid numeric-symbolic algorithm computing exact rational SOS decompositions for polynomials lying in the interior of the SOS cone. It computes an approximate SOS decomposition for a perturbation of the input polynomial with an arbitrary-precision SDP solver. An exact SOS decomposition is obtained thanks to the perturbation terms. We prove that bit complexity estimates on output size and runtime are both polynomial in the degree of the input polynomial and simply exponential in the number of variables. Next, we apply this algorithm to compute exact Polya and Putinar's representations respectively for positive definite forms and positive polynomials over basic compact semi-algebraic sets.

Our algorithms are implemented in the Maple package RealCertify [3]. We compare the performance of RealCertify with existing methods in computer algebra, including cylindrical algebraic decomposition [1] and critical point method [2]. These results have been recently published in [4].

References

[1] G. E Collins. Quantifier elimination for real closed fields by cylindrical algebraic decompostion. In *ATFL 2nd GI Conf. Kaiserslautern*, pages 134–183, 1975.

[2] A. Greuet and M. Safey El Din. Probabilistic Algorithm for Polynomial Optimization over a Real Algebraic Set. *SIAM Journal on Optimization*, 24(3):1313–1343, 2014.

[3] V. Magron and M. Safey El Din. RealCertify: a Maple package for certifying non-negativity. In *ISSAC'18: Proceedings of the 2018 ACM International Symposium on Symbolic and Algebraic Computation*, ACM, New York, NY, USA, 2018.

[4] V. Magron and M. Safey El Din. On Exact Polya and Putinar's Representations. In *ISSAC'18: Proceedings of the 2018 ACM International Symposium on Symbolic and Algebraic Computation*, ACM, New York, NY, USA, 2018.

SMS++: a Structured Modelling System with Applications to Energy Optimization

Antonio Frangioni[1] Rafael Durbano Lobato[2]
[1]Dipartimento di Informatica, Università di Pisa, Italy, frangio@di.unipi.it
[2]Department of Applied Mathematics, State University of Campinas, Brazil, rafael.lobato@gmail.com

Key words: Modelling Systems, Energy Optimization, Decomposition, Unit Commitment

Energy systems are extremely complex; planning their improvement over multiple decades necessarily also requires computing optimal tactical/operational decisions spanning from years to minutes. Decomposition methods are the only way to tame the corresponding huge-scale optimization problems, especially since uncertainty has necessarily to be explicitly modeled at several levels. Actually, what is needed is not just one decomposition approach, but a hierarchical combination of different decomposition methods (say, Lagrangian and Benders' ones), resulting in a heterogeneous at least three-level decomposition approach. Efficiently implementing such an algorithm is a daunting task, especially if modelling flexibility is required and distributed computation is used to exploit HPC systems, which is necessary to tackle real-world instances.

Under the auspices of several PGMO projects ("Consistent Dual Signals and Optimal Primal Solutions", "Advanced Modeling Tools for Decomposition Methods with Application to Energy Optimization Problems", and "Multilevel Heterogeneous Distributed Decomposition for Energy Planning with SMS++") and one H2020 project (No 773897 "plan4res"), the innovative, open-source *Structured Modeling System++* (SMS++) is being developed. Aim of SMS++ is to facilitate the implementation of general and flexible algorithms for structured optimization problems. In particular, the main motivating case study for the system has been the Unit Commitment (UC) problem, which is a hard Mixed-Integer NonLinear optimization problem that has to be solved in "unreasonably short" time even in its deterministic versions, even more so when uncertainty is added [1] to account for factors like increased renewables penetration and market outcomes. The ultimate aim is that of being able to developing *multi-level* decomposition approaches where the (U)UC is "just the lower level", while further levels (in themselves, hard optimization problems) regarding the long-term management of energy reservoirs (water, gas, ...) and even changes of the energy system as a whole (construction/decommissioning of generators and energy lines, ...) can be taken into account. Tackling models of this scale is perhaps nowadays technically possible, but an Herculean task in terms of the necessary programming, as current modelling systems are not designed for supporting this kind of approaches, especially if modelling flexibility and maintainability of the model over long periods of time is necessary. We will present the current state of the SMS++ system, focussing on its features that are more relevant for the implementation of multi-level decomposition approaches to hard (energy) problems.

References

[1] W. van Ackooij, I. Danti Lopez, A. Frangioni, F. Lacalandra, M. Tahanan "Large-scale Unit Commitment Under Uncertainty: an Updated Literature Survey" *Annals of Operations Research*, to appear, 2018.

Strategic bidding in Price Coupled Regions

Luce Brotcorne[1] Fabio D'Andreagiovanni[2] Jérôme De Boeck[3,1] Bernard Fortz[3,1]
[1]INOCS, INRIA Lille Nord-Europe, France, {luce.brotcorne,bernard.fortz}@inria.fr
[2]Université de Technologie de Compiègne, France, f.dandreagiovanni@gmail.com
[3]Université libre de Bruxelles, Belgium, {jboeck,bernard.fortz}@ulb.ac.be

Key words: Unit commitment, market equilibrium, day-ahead market, bilevel optimization.

The classical Unit Commitment problem (UC) can be essentially described as the problem of establishing the energy output of a set of generation units over a time horizon, in order to satisfy a demand for energy, while minimizing the cost of generation and respecting technological restrictions of the units (e.g., minimum on/off times, ramp up/down constraints). The UC is typically modelled as a (large scale) mixed integer program and its deterministic version, namely the version not considering the presence of uncertain data, has been object of wide theoretical and applied studies over the years.

Traditional (deterministic) models for the UC assume that the net demand for each period is perfectly known in advance. However, in practice, the demand is dictated by the amounts that can be sold by the producer at given prices on the day-ahead market, leading to strategic bidding problems. One difficulty therefore arises if the optimal production dictated by the optimal solution to the UC problem cannot be sold at the producer's desired price on the market, leading to a possible loss. Another strategy could be to bid for additional quantities at a higher price to increase profit, but that could lead to infeasibilities in the production plan. Furthermore, the mechanism of the bidding market considered has a considerable impact on the spot prices and the quantities bought to retailers and producers, complexifying the structure of the problem. We consider Price Coupling of Regions (PCR) as bidding market, a coupling that links national day-ahead markets in order to increase the global welfare.

Our aim is to model and solve the UC problem with a second level of decisions ensuring that the produced quantities are cleared at market equilibrium in a coupled day-ahead market. In their simplest form, market equilibrium constraints are equivalent to the first-order optimality conditions of a linear program. The UC in contrast is usually a mixed-integer nonlinear program (MINLP), that is linearized and solved with traditional Mixed Integer (linear) Programming (MIP) solvers. Taking a similar approach, we are faced to a bilevel optimization problem where the first level is a MIP and the second level linear.

In this talk, we assume that demand curves and offers of competitors in the market are known. The market considered is a PCR of the EU that considers several day-ahead markets coupled through a transmission network. Following the classical approach for these models, we present the transformation of the problem into a single-level program by rewriting and linearizing the first-order optimality conditions of the second level. A discretization of the possible optimal spot prices is made and valid inequalities are proposes to obtain a tight MILP formulation. Some aggregation and disaggregation techniques taking advantage of the properties of PCR improves considerably the computation times. A heuristic applicable to special ordered sets is also presented to reduce the number of binary variables when discretizing a continuous variable.

Robust Storage Optimization in the Expansion Planning of Power Systems

Sophie Demassey Edi Assoumou Welington de Oliveira
CMA, Mines ParisTech, PSL Research University, France, sophie.demassey@mines-paristech.fr

Key words: Expansion planning, robust optimization, power systems.

Power system periodicity is often exploited in long-term planning to reduce the model size by decomposing the time horizon (in decades) in a non-chronological way into a limited set of representative periods (days, typically). Power system dynamicity is then captured by a finer time discretization (in hours) within each period. However, this representation does not capture the temporal interdependencies between the periods. As a consequence, production ramping, storage balance, or dynamic demand response are loosely integrated to these models. The discrete variables like the investment levels or the on/off operation states are also ignored. Finally, the model is deterministic and long-term forecasts of demand, price, or renewable productions are assumed to be perfect.

We address the problem of modelling non-periodic storage in large power systems using a decomposition along the decision levels. We apply a soft-coupling [3] of a long-term generation expansion planning model, based on the MARKAL-TIMES linear programming framework [1], with a mid-term storage investment model to optimize the system operation on each milestone-year. Storage optimization is further decomposed within a two-stage approach [2]: the master decides the investments in different storage technologies while the subproblem schedules the whole system operation. This decomposition allows us to consider discrete levels of storage investments and fine-grained chronological operation constraints, as well as uncertainties on the renewable production forecasts, as the system operation is optimized together with the worst-case scenario.

The coupling is experimented on an aggregated model of the French power system.

References

[1] Loulou, R., Remme, U., Kanudia, A., Lehtila, A., and Goldstein, G. (2005). Documentation for the TIMES Model (Parts I to III). Energy Technology Systems Analysis Program.

[2] Thiele, A., Terry, T., Epelman, M. (2009). Robust linear optimization with recourse. Rapport technique, 4-37.

[3] Deane, J., Chiodi, A., Gargiulo, M., and Gallachóir, B. (2012). Soft-linking of a power systems model to an energy systems model. *Energy*, 42(1), 303-312.

On Designing Energy Storage Systems

Jean-Christophe Alais[1] Léa Boudinet[2]
[1]Air Liquide, Les Loges-en-Josas, jean-christophe.alais@airliquide.com
[2]Ecole Normale Supérieure, Paris, lea.boudinet@ens.fr

Key words: Energy storage systems, decision support, stochastic optimization, Markov decision processes, dynamic programming.

Rising concerns about climate change and global warming have led to an increasing use of renewable energies ([6]) which are commonly characterized by intermittent power generations. The resulting growing share of renewables then requires more and more flexibility from energy systems ([4, 5]). Electrical Energy Storage (EES) technologies represent high-value solutions for enabling this system flexibility. In addition, not only do storage devices can help integrate more renewable energies but they may offer a great range of services ([3]). Besides, the energy storage market is growing fast ([1]) and competitive EES technologies have to meet key expectations among: being low-cost, sustainable, offering short response time and proving to be efficient. Experts claim that today most commercial interest is in battery storage ([6]). However, there exists numerous EES technologies - mechanical, electrochemical, electrical and thermal - and none has proven to outperform all technologies in all applications yet. By now, the selection and the sizing of a EES depend on the target system structure and settings. Moreover, studies reported that the so-called hybrid storage solutions - which are based on a diverse EES portfolio - could be the most likely to compete successfully ([3, 5, 4]). Deciding a system tailor made EES based design (technologies selection and sizing) may be critical. The present work aims at proposing a decision support approach for designing EES systems through simulations by means of Stochastic Optimization ([2]).

References

[1] Bloomberg, New Energy Finance, New Energy Outlook (2017).

[2] Carpentier, P., et al., Stochastic multi-stage optimization, Probability Theory and Stochastic Modelling. Vol. 75. Springer (2015).

[3] Dunn, B. et al., Electrical Energy Storage for the Grid: A Battery of Choices, Science vol.334 (2011), p. 928-935.

[4] Gallo, A.B. et al., Energy storage in the energy transition context: A technology review, Renew. Sustain. Energy Rev. vol.65 (2016), p. 800-822.

[5] Larcher, D. et al., Towards greener and more sustainable batteries for electrical energy storage, Nat. Chem. vol.7 (2015), p. 19-29.

[6] World Energy Resources E-Storage (2016).

A MILP Formulation for Adaptive Solutions in Railway Scheduling

Zacharie Ales[1] Sourour Elloumi[1] Rémi Lucas[1,2] François Ramond[2]
[1]ENSTA ParisTech, UMA, Palaiseau (France), {ales, elloumi, lucas}@ensta-paristech.fr
[2]SNCF Innovation & Recherche, Saint-Denis (France), {remi.lucas, francois.ramond}@sncf.fr

Key words: Railway scheduling, Rolling stock, Adaptive solution, Discrete optimization.

In railway scheduling, the *rolling stock* scheduling problem adresses the assignment of train paths to physical unsplittable rolling stock units, hence defining a sequence of trains for each unit in order to cover the passenger demand. Roughly speaking, a train is defined by its departure and arrival times and stations. In practice, this problem is solved several months in advance. However, changes may occur afterwards, either prior or during operations. It is then necessary to adapt the rolling stock scheduling to the new context with a re-optimisation process, as shown in [1] for disruptions at operational time.

Rescheduling is important to maintain a good service level but it is costly as it may require additional resources and as it implies a lot of communication among actors, with risks of low coordination and bad performance. Our goal is to compute a nominal schedule designed to be *adaptive* to a set of known demand *scenarii*, with minimal mean deviation over the *scenarii*. In other words, an *adaptive* solution is a nominal solution that will not change much regardless of the *scenarii*.

This work focuses on the rolling stock scheduling problem with *scenarii* corresponding to an increasing or decreasing passenger demand for a small set of trains, requiring more or less rolling stock units than in the nominal situation. Our basic model considers a set of trains with fixed departure/arrival times and stations as well as a nominal demand. A feasible solution for our problem contains a nominal rolling stock schedule and a collection of adapted rolling stock schedules, one for each considered *scenario*.

We propose a MILP based on the oriented graph of [2], where the vertices correspond to the trains, and each edge represents a succession of two potential trains covered by the same rolling stock unit. We duplicate the nominal variables for each *scenario*, and define the deviation between the nominal and an adapted schedule as the structural differences between their graphs. The objective contains a quadratic criteria controlling the mean expected deviation. We illustrate the correctness and efficiency of the model by computational experiments.

References

[1] L. P. Veelenturf, L. Kroon, G. Maròti, Passenger oriented railway disruption management by adapting timetables and rolling stock schedules, Transp. Res. Part C (2017), 80:133-147.

[2] V. Cacchiani, A. Caprara, Solving a real-world train-unit assignment problem, Math. Program. Ser. B (2010), 124:207-231.

Optimization of multimodal routing problems

Rebecca Jeffers[1],Thomas Triboulet[2],Timothy Nibaudeau[3], Jorge Mendoza[4], Laurent Mulot[5]
[1]EDF R&D, France, rebecca.jeffers@edf.fr,
[2]EDF R&D, France, thomas.triboulet@edf.fr,
[3]EDF R&D, France, timothy.nibaudeau@edf.fr,
[4]HEC Montreal, Canada, jorge.mendoza@hec.ca,
[5]Enedis, France, laurent.mulot@enedis.fr

Key words: Vehicle Routing problem, LNS, TSP, clustering, transport.

Introduction : Utility companies manage large quantities of interventions. Itineraries that minimize cost and duration must be constructed. In dense neighborhoods, walking can be practical and economical. We tested a multimodal model based on two separate decision levels :

- **Clustering level** : The first consists of gathering points in clusters visited on foot. Each walking cluster is a macro-intervention for the next level.
- **Car routing level** : Routes by car between clusters are optimized using Vehicule Routing heuristics, considering walking clusters as macro-interventions.

The input data are a list of interventions, their durations, estimated parking time and time-windows of the technician working days. Input data also includes journey time and distance matrices between all visited points for both means of transport.

Clustering level of points visited on foot : Clusters are initialized with 1 cluster per point and merged in ascending inter-cluster distance order. The cluster's distance and time must satisfy pre-defined limits. Once the clusters are constructed, the optimization of the route within each cluster reduces to the standard travelling salesman problem (TSP)[3]. Many heuristics can solve it [4]. Here, stochastic greedy algorithm and random permutations heuristic is used.

Car routing level : This algorithm computes trajects between walking clusters or isolated points. An initial feasible solution is obtained by a Solomon heuristic approach described in [1]. This solution is improved by a Large Neighbourhood Search algorithm [2] which applies destruction and reconstruction operators on the initial solution in order to improve it.

References

[1] Solomon M. M. (1987). Algorithms for the Vehicle Routing and Scheduling Problems with Time Window Constraints. Operations Research, Vol. 35, No. 2., p. 254-265.

[2] Pisinger D., Ropke, S. (2010). Large neighbourhood search. Handbook of metaheuristics, p.399-419.

[3] Applegate D. L., Bixby R. E., Chvatal V., Cook W. J. (2007). The Traveling Salesman Problem A Computational Study. Princeton University Press.

[4] Rego C., Gamboa D., Glover F., Osterman C. (2011). TSP heuristics: leading methods, implementations and latest advances. European Journal of OR, 211 (3): p.427-441.

Exact column generation for the electrical vehicle scheduling problem

Rafael Martinelli[1] Axel Parmentier[2] Thibaut Vidal
[1]Pontifícia Universidade Católica do Rio de Janeiro, Brazil, {martinelli,vidal}@puc-rio.br
École des Ponts Paristech, France, axel.parmentier@enpc.fr

Key words: Eletrical Vehicle Scheduling Problem, Column Generation, Resource Constrainted Shortest Paths .

Green and electrical routing problems attract a growing attention [1, 2, 3]. We consider the electrical Vehicle Scheduling Problem (eVSP) [3]. A set of trips must be operated by a fleet of electrical vehicles. Each trip is scheduled between an origin and a destination at a given time. Vehicles have a limited battery capacity. Inbetween two trips, a vehicle can go to a station to charge its battery. Costs are associated to vehicle use and distance traveled. The objective is to build a sequence of trips and recharge followed by each vehicle in order to operate all trips at minimum cost. We propose an exact column generation approach to the eVSP. Numerical benchmark on instances of the literature [3] demonstrate the efficiency of our approach. Our pricing algorithm, and more precisely the way it encodes energy consumption information in an ad-hoc algebraic structure, plays a key role in the efficiency of our column generation.

References

[1] S. Erdoğan, and E. Miller-Hooks. "A green vehicle routing problem." Transportation Research Part E: Logistics and Transportation Review 48.1 (2012): p. 100-114.

[2] M. Schneider, A. Stenger, and D. Goeke. "The electric vehicle-routing problem with time windows and recharging stations." Transportation Science 48.4 (2014): p. 500-520.

[3] M. Wen, E. Linde, S. Ropke, P. Mirchandani, and A. Larsen. "An adaptive large neighborhood search heuristic for the electric vehicle scheduling problem." Computers & Operations Research 76 (2016): p. 73-83.

A tabu search for the design of robust capacitated Steiner planar networks *

Alain Hertz[1] Thomas Ridremont[2]
[1]GERAD, Polytechnique Montreal, Canada, alain.hertz@gerad.ca
[2]CNAM-CEDRIC/UMA-ENSTA/GERAD, France, thomas.ridremont@cnam.fr

Key words: Survivable networks, planar graphs, Tabu search, Graph algorithms, network flows.

The design of efficient networks is crucial in many fields such as transport, telecommunications or energy. In this paper, we focus on the design of networks which are resilient to one or several breakdowns. More precisely, let $G = (V, A)$ be a directed graph with vertex set V and arc set A, and let c and u be respectively a cost and a capacity function on A. Also, consider a subset $T \subset V$ of vertices called *terminals*, and let $r \in V \setminus T$ be a *root* in G (i.e., there is a path from r to each vertex of T). We say that G has a feasible flow if it is possible to route one unit of flow from the root to each terminal while respecting the arc capacity constraints. Given an integer $k \geq 0$, a subgraph $G' = (V, A')$ of G is said *k-survivable* if every subgraph obtained from G' by removing at most k arcs of A' contains a feasible flow. We aim at selecting a minimum cost subset $A' \subseteq A$ of arcs such that $G' = (V, A')$ is k survivable. We call this problem the Capacitated Rooted Survivable Network problem (CRSNP).

Many authors [2, 5, 7] propose algorithms for the design of capacitated survivable networks, but they aim to assign capacities to the arcs to make the network survivable, while we assume that all capacities are fixed. For surveys on survivable networks, we refer the reader to [3, 6]

The main motivation for this work is the design of a survivable wind farm collection network. One of the nodes of the network is the sub-station where the energy produced by the turbines must be transported. The potential network links have already been determined, and the aim is to select a subset of these links. Each link has a cost and a capacity. By defining each turbine as a terminal, the sub-station as the root, and reversing the direction of each arc, the problem becomes a delivery problem from the root to the terminals. Since the wind turbines are all identical, we can assume that each one produces one unit of energy, and the problem is therefore to select a subset of links so that there is a feasible flow is the corresponding subgraph, even if k arcs are removed from the chosen links. More details about this application can be found in [4].

In this paper, we focus on planar graphs which are useful in practice since many underlying graphs in real-world networks are planar. We describe a procedure that determines in polynomial time whether a given planar graph is k-survivable. We embed this procedure in a tabu search. Computational experiments and comparisons with an exact algorithm [1] allow to evaluate the performance of this procedure.

*This work was partially supported by the PGMO Programme Gaspard Monge pour l'optimisation et la recherche opérationnelle de la Fondation Mathématique Jacques Hadamard.

Learning without exploration in Linear Contextual Bandits

Frédéric Logé Erwan Le Pennec
CMAP, Polytechnique, Palaiseau, France
frederic.logemunerel@gmail.com

Key words: Online Learning, exploitation-exploration trade-off, Contextual Bandits

Linear Contextual Bandits have been studied extensively for the past ten years. They are an extension of the Multi-Armed Bandit problem where information is shared among the arms via some context vector, see [2].

To deal with the exploration-exploitation trade-off, optimistic strategies are one solution to ensure optimal upper bounds for regret, see the survey [4]. In real-life applications, enforcing exploration does not come without cost, as always. Several papers, among which [1] and [3], study the regret behavior under exploitation-focused strategies on specific instances of Linear Contextual Bandits. They showed that Greedy-like strategies ensure not only sub-linear regret but attain optimal bounds.

We extend the result from both papers to a more general setting, proving under some realistic assumptions on the context distributions that enforcing exploration is unnecessary. Whatever the strategy followed, exploration is natural and the convergence of model estimates is ensured. A particular consequence is that for UCB and Greedy strategies, the regret upper bound is of the same order: $\sqrt{dT\log^3(T)}$, where T is the number of game rounds and d the dimension of the contexts. After detailing the constant of the regret bounds we provide empirical evidence that the Greedy strategy can lead to lower high-order regret bounds and better-behaved regret in general.

References

[1] H. Bastani, M. Bayati, and K. Khosravi. Mostly exploration-free algorithms for contextual bandits. arXiv preprint arXiv:1704.09011, 2017.

[2] V. Dani, T. P. Hayes, and S. M. Kakade. Stochastic linear optimization under bandit feedback. 2008.

[3] S. Kannan, J. Morgenstern, A. Roth, B. Waggoner, and Z. S. Wu. A smoothed analysis of the greedy algorithm for the linear contextual bandit problem. arXiv preprint arXiv:1801.03423, 2018.

[4] L. Zhou. A survey on contextual multi-armed bandits. arXiv preprint arXiv:1508.03326, 2015.

Thompson Sampling for the Non-stationary Stochastic Multi-Armed Bandit

Réda Alami[1,2]
[1]Orange Labs, France. alami1859@hotmail.fr
[2]Inria Lille Nord-Europe, France.

Key words: Game theory, Multi-armed bandit, decision making under uncertainty, non-stationary environment.

In the stochastic stationary multi-armed bandit setting, the Thompson Sampling algorithm presents excellent results in practice and it has been proved to be asymptotically optimal [3]. The extension of Thompson Sampling algorithm to the switching stochastic multi-armed bandit problem, proposed in [4], is a Thompson Sampling equiped with the well-known Bayesian online change point detector [1]. In [2], the authors have proposed an another extension of the previous approach by leveraging the Bayesian aggregation of a growing number of experts seen as learners. Experiments provide some evidences that in practice, the proposed algorithm compares favorably with the previous version of Thompson Sampling for the switching multi-armed bandit problem, while it outperforms clearly other algorithms of the state-of-the-art.
This has led the community to consider the question of proving the optimality of this kind of approaches catching the change points in a non-stationary decision-making paradigm. In this talk, we will give the first mathematical intuitions behind the hypothetical optimality of the Thompson Sampling for the switching environment and highlight its impressive experimental results.

References

[1] Ryan Prescott Adams and David JC MacKay. Bayesian online changepoint detection. *arXiv preprint arXiv:0710.3742*, 2007.

[2] Réda Alami, Odalric Maillard, and Raphael Féraud. Memory Bandits: a Bayesian approach for the Switching Bandit Problem. In *Neural Information Processing Systems: Bayesian Optimization Workshop.* , Long Beach, United States, 2017.

[3] Emilie Kaufmann, Nathaniel Korda, and Rémi Munos. Thompson sampling: An asymptotically optimal finite-time analysis. In *International Conference on Algorithmic Learning Theory*, pages 199–213. Springer, 2012.

[4] Joseph Mellor and Jonathan Shapiro. Thompson sampling in switching environments with bayesian online change point detection. *CoRR, abs/1302.3721*, 2013.

A stochastic data-based traffic model applied to energy consumption estimation

Arthur Le Rhun[1,2] Frédéric Bonnans[1] Giovanni De Nunzio[2] Thomas Leroy[2] Pierre Martinon[1]
[1]CMAP, Ecole Polytechnique, Boulevard de Maréchaux, 91120 Palaiseau
[2]IFPEN, 1&4 avenue de Bois-Préau, 92852 Reuil-Malmaison

Key words: Intelligent transportation systems, clustering, Wasserstein distance

Intelligent transportation systems are now able to record large amounts of data about traffic conditions, and especially speed profiles. Using data science and optimization techniques, we propose a stochastic data-based traffic model that preserves the energy consumption distribution. From the speed profiles we construct (speed, acceleration) distributions, and apply a clustering method (k-means [1]) to obtain a manageable sized model. Different times of the day with similar speed patterns and traffic behavior are thus grouped together in a single cluster. To preserve geometrical aspect of the (speed, acceleration) distributions, we used the Wasserstein distance [2, 3] in the k-means algorithm. We tested our model with data from the traffic simulator SUMO [4] as well as with real traffic data from smartphone application "GECO air". The results show that with a small number of clusters the model is able to provide an accurate estimation of the energy consumption distribution. We plan to use this model to develop an energy management system for hybrid vehicles that is able to handle traffic conditions.

References

[1] J. MacQueen. Some methods for classification and analysis of multi-variate observations. In Proc. Fifth Berkeley Sympos. Math. Statist.and Probability (Berkeley, Calif., 1965/66), pages Vol. I: Statistics. Univ. California Press, Berkeley, Calif., 1967.

[2] L. N. Vasershtein. Markov processes over denumerable products of spaces describing large system of automata. Problemy Peredaci Informacii, 5:64-72, 1969.

[3] R. L. Dobrushin. Prescribing a System of Random Variables by Conditional Distributions. Theory of Probability & Its Applications, 15(3):458-486, 1970.

[4] Daniel Krajzewicz, Jakob Erdmann, Michael Behrisch, and Laura Bieker. Recent Development and Applications of SUMO - Simulation of Urban MObility. International Journal On Advances in Systems and Measurements, 5(3&4):128-138, December 2012

Correlation Clustering Problem with Mediations

Zacharie Ales[1] Céline Engelbeen[2] Rosa Figueiredo[3]
[1]ENSTA-ParisTech / UMA, 91762 Palaiseau and Laboratoire CEDRIC, Paris, France,
[2] QUARESMI Laboratory, ICHEC Brussels Management School, Brussels, Belgium
[3] Laboratoire Informatique dâAvignon LIA EA 4128, Avignon France,

Keywords: Correlation clustering, enumeration algorithms, MIP formulation, signed graph.

The correlation clustering problem (CC) [1] consists in partitioning the vertices of a graph such that the sum of the positive weights between the clusters and the negative weights inside the clusters is minimized. Variants of the CC problem have been presented and discussed in the literature [2, 3]. In this work, we study the one in which a set of vertices called *mediators* is additionally identified. The mediators must have *good* relations among themselves and with the other nodes. For example, in the political context, a set of mediators can constitute a group responsible for reviewing a law.

Let us consider a signed digraph $D = (V, A, s)$, where V is a set of nodes, A a set of arcs and $s : A \to \{+, -\}$ a sign function which encodes, for each arc (i, j), if the relation between nodes i and j is positive or negative. The intensity (in absolute value) of the relation between two nodes is denoted by w_{ij}. Let $\delta[S] = \{(i, j) \in A : i \in S, j \in V \setminus S\} \cup \{(i, j) \in A : i \in V \setminus S, j \in S\}$ and $A[S] = \{(i, j) \in A : i, j \in S\}$. We also denote by A^+ (resp. A^-) the set of arcs with a positive (resp. negative) sign. Let α and β be two integers in $[0, 1]$. A *mediator set of vertices* is a set S which satisfies the two following inequalities:

$$\sum_{(i,j)\in A^-\cap A[S]} w_{ij} \leq \beta \sum_{(i,j)\in A^+\cap A[S]} w_{ij} \quad (1)$$

$$\sum_{(i,j)\in A^-\cap \delta[S]} w_{ij} \leq \alpha \sum_{(i,j)\in A^+\cap \delta[S]} w_{ij} \quad (2)$$

The correlation clustering problem with positive mediation (CCPM) is the problem of finding a partition of the vertices $\{P_1, P_2, \cdots\}$ such that P_1 is a mediator set and the following *total imbalance function* $I(V \setminus P_1)$ is minimized:

$$\sum_{(i,j)\in A^-:i,j\in P_k,\ k>1} w_{ij} + \sum_{(i,j)\in A^+:i\in P_k,\ j\in P_l,\ k,l>1} w_{ij}$$

The properties defined by constraints (1) and (2) are non hereditary ones. The CC problem is NP-hard [1] and the same applies to CCPM. We present an ILP formulation as well as enumeration algorithms to solve the CCPM problem. We also show preliminary computational results.

References

[1] N. Bansal, A. Blum, and S. Chawla. 2002. Correlation Clustering. In 43rd Annual IEEE Symposium on Foundations of Computer Science. 238â247.

[2] P. Doreian and A. Mrvar. 2009. Partitioning signed social networks. Social Networks 31, 1 (2009), 1â11.

[3] R. Figueiredo and G. Moura. 2013. Mixed integer programming formulations for clustering problems related to structural balance. Social Networks 35, 4 (2013), 639â651.

Toward a Database of Sharp Invariants on Time Series Characteristics

Ekaterina Arafailova[1] Nicolas Beldiceanu[1] Helmut Simonis[2]
[1]IMT Atlantique, Nantes, France nicolas.beldiceanu@imt-atlantique.fr
[2]Insight, UCC, Irlande helmut.simonis@insight-centre.org

Key words: Sharp linear invariants, non-linear invariants, time-series.

Short-term models for the next two days of production of a unit are typically expressed as a conjunction of time series constraints on a same time series telling how much must be produced by a given unit every half hour. To ease the challenge of *simultaneously satisfying all expressed constraints* the goal of the project was to produce a database of *parameterised* linear and non linear invariants: as soon as a given subset of time-series constraints is part of a model, a program can automatically pick up the appropriate invariants and add them to the model to obtain stronger formulations. The project relies on the fact that such invariants can be systematically obtained from the intersection of the automata associated with each time series constraints of a given conjunction of time series constraints.

The obbtained database of parameterised invariants contains 917 entries: 176 entries corresponding to a single constraint and 741 entries corresponding to pairs of constraints. The total number of invariants is 2347: 759 linear invariants [1], 70% of which are proved to be sharp, 899 conditional linear invariants, 666 non-linear invariants [2], and 23 manually derived invariants.

For each linear invariant for which we prove sharpness, we provide two distinct points that are both feasible and are located on the line corresponding to the linear invariant. Note that the coordinates of such points may be parameterised by the sequence length.

The machine-readable version of the database is available from the electronic time-series catalogue as a standalone file, while the human-readable version is integrated in the second release of the time-series catalogue [3].

References

[1] Ekaterina Arafailova, Nicolas Beldiceanu, Helmut Simonis. Generating Linear Invariants for a Conjunction of Automata Constraints. CP 2017, Melbourne, LNCS vol. 10416, pages 21–37.

[2] Ekaterina Arafailova, Nicolas Beldiceanu, Helmut Simonis. Automatically Mining and Proving Generic Invariants on Integer Sequences. The Second Workshop on Progress Towards the Holy Grail, CP 2018, Lille.

[3] Ekaterina Arafailova, Nicolas Beldiceanu, Rémi Douence, Mats Carlsson, Pierre Flener, María Andreína Francisco Rodríguez, Justin Pearson, Helmut Simonis. Global Constraint Catalog, Volume II, Time-Series Constraints, second edition, arXiv:1609.08925, 2018.

Upper and lower bounds for an energy scheduling problem with piecewise-linear costs and storage resources

Nabil Absi[1] Christian Artigues[2] Safia Kedad-Sidhoum[3] Sandra U. Ngueveu[2]
Felix Goupil[2]
[1]Mines Saint-Etienne and UMR CNRS 6158 LIMOS, Gardanne, France
[2]LAAS-CNRS, Université de Toulouse, CNRS, INP, Toulouse, France
[3]CNAM-CEDRIC, Paris, France

Key words: Scheduling under energy constraints and costs, Mixed-integer programming, Lot-sizing, Dynamic programming.

We address a scheduling and energy source assignment problem abstracted from several applications including data centers, smart buildings, hybrid vehicles and manufacturing. A set of energy consuming jobs with time windows has to be scheduled. A single non-reversible energy source is used to fulfill the discrete energy demand resulting from the schedule over a planning horizon. It is characterized by a piecewise linear (PWL) efficiency function allowing to get the amount of usable energy for a given cost. In addition, a reversible source (such as battery and super-capacitor) can be used to store and/or to supply energy assuming a limited capacity. Therefore, a careful tasks scheduling combined with energy storage management are required to optimize the total production cost.

We present upper and lower bounding procedures based on different decomposition approaches. The upper bounding procedure is a lot-sizing-based matheuristic resulting from the observation that when the schedule is fixed, the resulting problem is a special case of lot-sizing problem with PWL costs. In [1], the problem is shown to be NP-hard but for integer inventory levels, a pseudo-polynomial dynamic programming (DP) algorithm of complexity $O(T^2\overline{q}\overline{d})$ where $\overline{d}$ is the average demand and $\overline{q}$ is the average number of breakpoints of the PWL functions f_t is given, generalizing the previous results from the literature. The lower bounding procedure is a column generation algorithm that solves an extended formulation where columns combine feasible sets of activities with valid breakpoints of the piecewise linear cost function. Following the modeling approach of [2] for piecewise linear functions, the extended formulation also used a logarithmic number of binary variables to define the piece assignment.

In this talk, the merits and drawbacks of the different approaches are analyzed.

References

[1] Absi N., C. Artigues, S. Kedad-Sidhoum, S.U. Ngueveu and O. Saadi, Lot-sizing models for energy management, IWLS'2017, p.45-48. 2017

[2] J. P. Vielma, Mixed integer linear programming formulation techniques. SIAM Review 57, pp. 3-57, 2015.

Optimization for membrane gas separation processes

Bernardetta Addis[1] Christophe Castel[2] Eric Favre[2] Thibaut Neveux[2,3] Veronica Piccialli[4]
[1]Université de Lorraine, CNRS, LORIA, France, bernardetta.addis@loria.fr
[2]Université de Lorraine, CNRS, LRGP, France, christophe.castel,eric.favre@univ-lorraine.fr
[3]EDF R&D, France, thibaut.neveux@edf.fr
[4]DICII, Università degli Studi di Roma "Tor Vergata", Italy, piccialli@disp.uniroma2.it

Key words: Membrane gas separation process, Global optimization, MINLP.

Membrane gas separation processes are a rapidly spreading technology with applications to numerous industrial sectors: energy, chemistry, pharmacy, electronics, aeronautics, etc [1]. Indeed, membrane separation combines a series of key advantages, since they can result in energy efficient, small sized and environmental friendly processes. Nevertheless, to obtain these advantages, it is necessary to design multistage processes, that is determining the necessary number and types of membrane modules, their sizes, interconnections and operating conditions.

The underlying optimization problem is a non-convex MINLP [2]. Even if in the last decades, several optimization based strategies were proposed, all of them present limitations in terms of design and/or operating condition possibilities. Furthermore, they have not been tested on a significant number of case studies to prove their general validity [3]. For these reasons, the current industrial practice is still based on experience and simulation based approaches, that are very time-consuming and often do not produce good results in terms of product quality and process cost.

The aim of our project IMPRESS, is to propose a critical comparison of current optimization-based process synthesis approaches on a significant number of case studies to assess their advantages and inconveniences. In this presentation, we will introduce the underlying mathematical model and some general ideas we matured from the research we already developed. More specifically, we will present some of the results we obtained on a case-study from the current literature and on an industrial application [4].

References

[1] R. W. Baker, Membrane Technology and Applications, (2004) 2nd Ed. John Wiley Sons, Chichester, England.

[2] L. T. Biegler, Nonlinear Programming: Concepts, Algorithms, and Applications to Chemical Processes, (2010) MOS-SIAM Series on Optimization.

[3] Q. Chen and I. E. Grossmann, Recent developments and challenges in optimization-based process synthesis, Ann. Rev. Chem. Biomolec. Eng. (2017) 8 (1), 249–283.

[4] A. Ramirez-Santos, M. Bozorg, B. Addis, V. Piccialli, C. Castel, and E. Favre. Optimization of multistage membrane gas separation processes. Example of application to CO2 capture from blast furnace gas, J. of Membrane Science, (2018) 566, 346–366.

Lot sizing with capacity adjustment and intermittent renewable energy

Ayse Akbalik[1] Céline Gicquel[2] Bernard Penz[3] Christophe Rapine[4]
[1]Université de Lorraine, LCOMS, Metz, France, ayse.akbalik@univ-lorraine.fr
[2]Université Paris Saclay, LRI, Université Paris Sud, Orsay, F-91405, France, celine.gicquel@lri.fr
[3]Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, F-38000 Grenoble, France, bernard.penz@grenoble-inp.fr
[4]Université de Lorraine, LCOMS, Metz, France, christophe.rapine@univ-lorraine.fr

Key words: Energy-aware production planning, lot sizing, capacity adjustment, complexity, polynomial time algorithm

More and more firms opt for on-site generation of renewable energy, such as solar and wind power, to supply power for their manufacturing processes. However, since the sources of renewable energy are highly variable, dependent on the weather, on-site generated energy is not expected to fully replace grid electricity, but to be used in coordination with it. Two sources of energy are then available to supply production power: an on-site generated renewable energy, free of use but available in a limited time-varying quantity, and the grid electicity, virtually unlimited, but incurring a unit cost per kWh purchased. This motivates for considering energy-efficient production plannings [1], such that ideally large production coincide with periods when a large amount of renewable energy is available.

In this work, we focus on a mid-term capacity, production and inventory planning. We consider a firm that has to satisfy a time-varying demand, known on a given time horizon. Capacity adjustment, by setting additional shifts, is a classical way for a firm to temporally fit its production with the demand, avoiding to build too large stocks. We have to determine, for each period of the horizon, the temporary capacity adjustments to be set, the quantity to produce and the quantity to carry in stock so as to satisfy the demand on time. Our purpose is to find a production planning of minimal cost, taking into account production and holding cost, extra capacity installation and energy cost.

We model this problem as a single-item single-resource lot sizing problem. The production system has a stationary nominal capacity which can be temporarily increased by installing some extra capacities. This extra capacity is a multiple of a base value, and a fixed cost has to be paid for each period an extra capacity is set. Production and inventory holding costs are assumed to be linear and non-speculative. We establish that this problem is NP-hard, even with a single extra capacity to install. We also show that in the special case where the amount of on-site generated energy is not sufficient to fully exploit the nominal capacity, an optimal solution can be computed in polynomial time, by solving a series of Discrete Lot-Sizing Problem (DLSP).

References

[1] C. Gahm, F. Denz, M. Dirr and A. Tuma, Energy-efficient scheduling in manufacturing companies: A review and research framework, EJOR (2016), vol. 248, p. 744-757.

Self-contracted curves and extensions.

Aris Daniilidis[1] Sebastián Tapia[2]
[1]Universidad de Chile, Chile, arisd@dim.uchile.cl
[2]Universidad de Chile, Chile, stapia@dim.uchile.cl

Key words: Gradient flows, self-contracted curves, rectifiability.

A class of curves encompassing all orbits generated by a gradient flow of a quasiconvex potential, has been defined in [2]. These curves are called self-contracted curves and enjoy the following simple metric definition: Let $\gamma : I \subset \mathbb{R} \to (X, d)$ be a curve where I is an interval and (X, d) is a metric space. The curve γ is called self-contracted if for every $t_1 < t_2 < t_3$ in I, the following inequality holds:

$$d(\gamma(t_1), \gamma(t_3)) \geq d(\gamma(t_2), \gamma(t_3)).$$

In [3], when the ambient space is the Euclidean space $\mathbb{R}^n$, an upper bound for the length of the aforementioned curves is given depending only on the dimension n and the diameter of the convex hull of the image of the curve. This result has important consequences in the study of convergence of the proximal algorithm method or even in dynamics given by a convex foliation. Recently, two extensions of the class of self-contracted curves were defined in [4] (λ-curves and λ-eels) and many open questions arise out of this generalization. In this talk we shall present the main idea of [1] and we show how this idea can be used for the study of rectifiability for λ-curves, with $\lambda < 1/d$. We shall also present the main obstacle to get a complete result (without a restriction on the value of the parameter λ). Finally, we will also show some results for λ-eels.

References

[1] P. Manselli, C. Pucci. Maximum length of steepest descent curves for quasi-convex functions. Geometriae Dedicate, 38 (1991), pp. 211-227.

[2] A. Daniilidis, O. Ley, S. Sabourreau. Asymptotic behaviour of self-contracted planar curves and gradient orbits of convex functions. Journal de Mathématiques Pures et Appliquées. 94 (2010), 183-199

[3] A. Daniilidis, G. David, E. Durand, A. Lemenant. Rectifiability of self-contracted curves in the Euclidean space and applications. Journal of Geometrical Analysis. 25 (2015), pp. 1211-1239.

[4] A. Daniilidis, E. Durand, R. Deville. Metric and geometric relaxations of self-contracted curves. Journal of Optimization Theory and Applications. (2018), to appear.

On the construction of converging hierarchies for polynomial optimization based on certificates of global positivity

Amir Ali Ahmadi[1] Georgina Hall[2]
[1]Princeton University, USA a_a_a@princeton.edu
[2]INSEAD, France georgina.hall@insead.edu

Key words: Positivstellensätze, polynomial optimization, sum of squares.

In recent years, techniques based on convex optimization that produce converging hierarchies of lower bounds for polynomial optimization problems (POPs) have gained in popularity. At their heart, these hierarchies rely on Positivstellensatze from the end of the 20th century (e.g., due to Putinar [1] and Schmudgen [2]) that certify positivity of polynomials on an arbitrary basic semialgebraic set. In the first part of this talk, we show that such hierarchies could in fact be designed from much more limited Positivstellensatze dating back to the beginning of the 20th century that certify positivity of polynomials globally. In the second part of this talk, we present a converging hierarchy for lower bounds on POPs that only requires the ability to multiply polynomials together and check nonnegativity of the resulting polynomial's coefficients. In this way, it is "optimization-free" unlike previous hierarchies that, for the most part, rely on sum of squares certificates and hence semidefinite programming.

For more information relating to this talk, the interested reader can refer to [3].

References

[1] M. Putinar, Positive polynomials on compact semi-algebraic sets, Indiana University Mathematics Journal, 42 (1993), pp. 969-984.

[2] K. Schmüdgen, The k-moment problem for compact semi-algebraic sets, Mathematische Annalen, 289 (1991), pp. 203-206

[3] A. A. Ahmadi, G. Hall, On the construction of converging hierarchies for polynomial optimization based on certificates of global positivity, Mathematics of Operations Research, To appear, 2018.

An entropy minimization approach to second-order variational mean-field games

Jean-David Benamou [1,2] Guillaume Carlier [2,1]
Simone Di Marino[3] Luca Nenna [4]
[1]INRIA-Paris, MOKAPLAN, Jean-David.Benamou@inria.fr.
[2]CEREMADE, Université Paris IX Dauphine, carlier@ceremade.dauphine.fr
[3]Indam, Unità SNS, Pisa, Italy simone.dimarino@altamatematica.it.
[4] LMO, Université Paris Sud nenna@ceremade.dauphine.fr

Key words: Mean-Field Games, Fokker-Planck equation, entropy minimization, Schrödinger bridges, Sinkhorn algorithm.

We propose in [1] a new viewpoint on variational mean-field games with diffusion and quadratic Hamiltonian. We show the equivalence of such mean-field games with a relative entropy minimization at the level of probabilities on curves. We also address the time-discretization of such problems, establish Γ-convergence results as the time step vanishes and propose an efficient algorithm relying on this entropic interpretation as well as on the Sinkhorn scaling algorithm.

References

[1] Benamou, Jean-David and Carlier, Guillaume and Marino, Simone Di and Nenna, Luca, An entropy minimization approach to second-order variational mean-field games, preprint, hal-01848370, 2018 https://hal.archives-ouvertes.fr/hal-01848370

Minimal-time MFG: some progress with and without diffusion

Filippo Santambrogio[1]
[1]Université Claude Bernard Lyon 1, santambrogio@math.univ-lyon1.fr

Key words: Mean Field Games, non-autonomous optimal control, Hamilton-Jacobi equations, Dirichlet conditions.

I'll present a new class of MFG that we have been studying recently, in particular with G. Mazanti and S. Dweik. They consist in the following problem: suppose that agents want to reach a certain target (for simplicity, let's say they want to exit a given domain Ω, the target being $\partial\Omega$), but their speed at each time t is bounded by a quantity $K(t,x)$ which depends on their position x and on the global distribution of players around x at time t. The typical case should be $|x'(t)| \leq 1 - \rho(t,x(t))$ where ρ is the density of players, as it happens in the Hughes model for pedestrian motion, the difference with such a model being the rational behavior of the agents which anticipate that ρ will evolve in time, considering that each other agent will also anticipate it. This local case is very difficult to study, so we first devoted our attention to a non-local case involving a convolution (see[1]). Many nontrivial questions also arise when studying a minimal-time control problem with fixed $K(t,x)$, as soon as it is non-autonomous, in particular if one needs to find the optimal assumptions on the regularity of K in t and x separately (this has been mainly studied in [2]).

An extension that we started to consider with Mazanti is the case where players also face a small randomness in their motion (which translates into diffusion in the PDE for ρ). In this case it is possible to attack the local case, at least in the finite horizon case.

In the talk I'll present the different models, the main questions and difficulties, and the main results we obtained in different settings. A large part of the work is ongoing.

References

[1] G. Mazanti, F. Santambrogio, Minimal-Time Mean Field Games, preprint, 2018.

[2] S. Dweik, G. Mazanti, Sharp semiconcavity for non-autonomous control problems and L^p estimates in an exit-time Mean Field Game, in preparation.

Variational Mean Field Games: on estimates for the density and the pressure and their consequences for the Lagrangian point of view

Hugo Lavenant[1] Filippo Santambrogio[1]
[1] Laboratoire de Mathématiques d'Orsay, Université Paris-Sud, France

Key words: Mean Field Games, Wasserstein space, Flow interchange, Hamilton-Jacobi equation.

We will consider first-order Mean Field Games (MFG) with quadratic hamiltonian and local coupling. In this case, the density of agents is the solution of a variational problem where it minimizes its total kinetic energy and a congestion cost [1]. Using time discretization and flow interchange techniques (originally introduced by Matthes, McCann and Savaré [4] for the study of gradient flows), we are able to provide L^∞ bounds on the density of agents [3]. In the case where the density of agents is forced to stay below a given threshold (a model studied by Cardaliaguet, Mészàros and Santambrogio [2]), leading to the apperance of a pressure force, the same techniques lead to a $L^\infty(H^1)$ bound on the pressure, improving known results.

With these estimates at our disposal, we are able to give a strong Lagrangian interpretation of the MFG and ensure regularity of the value function.

References

[1] Benamou, Jean-David, Guillaume Carlier, and Filippo Santambrogio. Variational mean field games. *Active Particles*, Volume 1. Birkhauser, Cham, 2017. 141-171.

[2] Cardaliaguet, Pierre, Alpàr R. Mészàros, and Filippo Santambrogio. First order mean field games with density constraints: pressure equals price. *SIAM Journal on Control and Optimization* 54.5 (2016): 2672-2709.

[3] Lavenant, Hugo, and Filippo Santambrogio. Optimal density evolution with congestion: L^∞ bounds via flow interchange techniques and applications to variational Mean Field Games. *arXiv preprint arXiv:1705.05658* (2017).

[4] Matthes, Daniel, Robert J. McCann, and Giuseppe Savaré. A family of nonlinear fourth order equations of gradient flow type. *Communications in Partial Differential Equations* 34.11 (2009): 1352-1397.

Novelty detection in textual data streams

Antoine Bidoyen[1] Manel Boumghar[2] Clément Christophe[3]
Jairo Cugliari[4] Philippe Suignard[5] Julien Velcin[6]
[1]Université de Lyon, Lyon 2, ERIC EA 3083 antoine.bidoyen@univ-lyon2.fr
[2]EDF R&D manel.boumghar@edf.fr
[3]Université de Lyon, Lyon 2, ERIC EA 3083 / EDF R&D clement.christophe@edf.fr
[4]Université de Lyon, Lyon 2, ERIC EA 3083 jairo.cugliari@univ-lyon2.fr
[5]EDF R&D philippe.suignard@edf.fr
[6]Université de Lyon, Lyon 2, ERIC EA 3083 julien.velcin@univ-lyon2.fr

Key words: text mining, novelty detection, text stream, document representation

Textual data streams are ubiquitous nowadays and there is still room for advanced techniques to track the information flow. More precisely, we aim at studying the intertwining between the topical evolution and special texts that influence this evolution, in collaboration with EDF R&D. In this project we focus on novelty detection, that is the identification of new topics over a time-dependent corpus. More precisely the problem is to learn how to detect new information from a document stream.

After a first study of the subject leveraging topic models [1] we tackle here how different document representations may help on the detection of novelties. For this purpose, we use different representation schemes that embed the textual information into a vector space endowed by a more or less rich algebraic structure. This way working on documents can be easily performed by using basic vector operations (e.g., pairwise comparison becomes a dot product). We then assume that novelty is connected to aberrant observations: new documents that are projected far away in the vector space are assumed to carry new information.

We present the results of experiments that involve several different ways to project the documents, at different granularity levels, into the vector space. Starting from word embedding model such as the ones proposed on [2] and infersent we show on a public data set composed of abstracts of scientific articles [4] that the tested approaches based on document embedding methods perform as well as LDA-based models.

References

[1] C. Christophe, J. Velcin, M. Boumghar, *Utilisation de techniques de modélisation thématiques pour la détection de nouveauté dans des flux de données textuelles.* Actes de la conférence EGC 2018, vol. RNTI-E-34, pp.239-250

[2] M. Pagliardini, P. Gupta, M. Jaggi *Unsupervised Learning of Sentence Embeddings using Compositional n-Gram Features*, arXiv:1703.02507v2, Mars 2017.

[3] A. Conneau, D. Kiela, H. Schwenk, L. Barrault, A. Bordes, *Supervised Learning of Universal Sentence Representations from Natural Language Inference Data*, arXiv:1705.02364v5, 2017.

[4] J. Tang, S. Wu, J. Sun and H. Su, *Cross-domain Collaboration Recommendation*, In : Proceedings of the 18th ACM SIGKDD, ACM, 2012. p. 1285-1293.

Worldwide Passenger Flows Estimation

Serigne Gueye[1] Ezequiel Geremia[2] Micheli Knechtel[3]
Philippe Michelon[3] Thiago Gouveia[1] Rodrigo Acuna-Agost[2]
[1]Laboratoire d'Informatique d'Avignon, France, serigne.gueye@univ-avignon.fr
[2]Amadeus IT, ezequiel.geremia@amadeus.com
[3]Laboratoire de Mathématiques d'Avignon, France, philippe.michelon@univ-avignon.fr

Key words: O-D flows, Airline Industry, Mathematical Programming

Our research deals with the estimation of the worldwide number of passengers by Origin-Destination (O-D) pairs, on a monthly basis, in the airline industry. Deducting an O-D matrix from partial data on segments doesn't constitute a new issue by itself (see [1],[2],[3]) but the problem is particularly difficult in the airline industry because of its extremely huge size. Our problem can be stated as follows. Knowing the amount of passengers leaving and arriving to each airport, an estimated number of passengers on each flight, lower bound (limit below which the flight is cancelled) and upper bound (capacity of the plane) on the number of passengers that can be transported on each direct flight, the possible itineraries for each O-D pair and the probability of using them (estimated by statistical methods), find the number of passengers for each O-D pair. The problem has been modeled as a mathematical program for which different objective functions, corresponding to standard norms, have been considered : L_1, L_2 norms. The formulations with the L_1 norm corresponds to a linear program while the L_2 norm induces a convex quadratic program. Each formulation has been solved using an optimization software (Cplex) on randomly generated instances, and on a real-life one provided by the company Amadeus. The formulation with the L_2 norm has been also solved with a lagrangean relaxation approach. Statistical outputs measuring the deviation to the real O-D matrix (for the randomly generated instances), or to the estimated number of passengers (for the real-life instance) have been generated. The numerical results show that, for randomly generated instances, both in terms of the O-D matrices quality and processing times, the L_2 norm formulation behaves surprisingly better than the linear one. This formulation has allowed to solve a real-life instance dealing with 234 airports, 5315 legs (direct flights) and 200410 itineraries in less than 1mn. Numerical sensitivity analysis have been also conducted to empirically estimated the variation to the optimal solution values when some of the model data vary.

References

[1] Michel Bierlaire. The total demand scale : a new measure of quality for static and dynamic origin-destination trip tables. Transportation Research Part B : Methodological , 36(9) :837-850, 2002.

[2] Michel Bierlaire and Ph L Toint. Meuse : An origin-destination matrix estimator that exploits structure. Transportation Research Part B : Methodological , 29(1) :47-60, 1995.

[3] M. Bierlaire, F. Crittin, An efficient algorithm for real-time estimation and prediction of dynamic OD tables, Operations Research 52, 1, 116-127, 2004.

Cloud Database Augmentation by Synthesis

Erwan Le Pennec[1] Thierry Guillemot[2]
[1]CMAP, École polytechnique, France Erwan.Le-Pennec@polytechnique.edu
[2]CMAP, École polytechnique, France Thierry.Guillemot@polytechnique.edu

Key words: Image synthesis, Generative Adversial Network, Deep Learning.

Obtaining a very large volume of real data is complicated in some settings, for instance in the detection of target in clouds. This limitation makes difficult the use of machine learning methods, whether they are "deep" or not. The objective of this project is to propose and validate techniques for increasing the size of the databases of cloud data by texture analysis and resynthesis.

As part of this project, we studied techniques for Generative Adversial Network synthesis, a methodology introduced by Goodfellow in 2014. The principle is simple: to synthesize objects of a given class, we will build a function that transforms white noise into a synthetic object so that a computer has difficulty distinguishing between real objects and synthetized objects. To do this, on modify alternatively the synthesis functionand the detection algorithm. The most interesting results in our seeting have been obtained by using neural networks in both steps.

In this study, we uses a database public cloud (Singapore Whole Sky Imaging) to learn from GAN generating patches. We will present a comparison of possible architectures in terms of synthesis quality and representativeness for the detection.

References

[1] I. Goodfellow, J. Pouget-Abadie, M. Mirza, B. Xu, Bing, D. Warde-Farley, S. Ozair, A. Courville and Y. Bengio. Generative Adversarial Nets, NIPS'14 (2014)

Aircraft trajectory optimization under unknown dynamics

Frédéric Bonnans[1] Baptiste Gregorutti[2] Pierre Martinon[1] Cédric Rommel[1,2]
[1]CMAP, Ecole Polytechnique & INRIA, France, first-name.last-name@inria.fr
[2]Safety Line, France, first-name.last-name@safety-line.fr

Key words: Optimal Control, System Identification, Model-based Reinforcement Learning, Density Estimation.

We consider the task of optimizing an aircraft climb trajectory where the system dynamics are unknown [3]. The standard approach adopted by control engineers in this kind of setting is to gather data from the system, use it to identify its dynamics and solve a surrogate optimal control problem cast using the identified model [1, 2]. In this situation, it is important to prevent the optimized trajectory from going too far away from the domain occupied by the data used to derive the dynamics model, as the later is not guaranteed to be valid outside this region. This motivates the need for a proximity indicator between a given trajectory and a set of recorded reference trajectories. In this presentation, we propose a probabilistic criterion for such a purpose, based on the marginal density functions of an underlying random process supposed to have generated the recorded data [5]. For practical applications, a class of estimators based on the aggregation of multivariate density estimators is defined and proved to be consistent. We then introduce it as a penalty term in the optimal control problem [4]. Our approach is illustrated with an aircraft minimal consumption problem and data from real recorded flights. We observe in our numerical results the expected trade-off between the minimal consumption and the trajectory likelihood.

References

[1] L. Ljung. *System Identification: Theory for the user*. Prentice-hall, 1987.

[2] B. Recht. A tour of reinforcement learning: The view from continuous control. *arXiv preprint arXiv:1806.09460*, 2018.

[3] C. Rommel, J. F. Bonnans, B. Gregorutti, and P. Martinon. Aircraft dynamics identification for optimal control. In *Proceedings of the 7th European Conference for Aeronautics and Aerospace Sciences*, 2017.

[4] C. Rommel, J. F. Bonnans, B. Gregorutti, and P. Martinon. Gaussian mixture penalty for trajectory optimization problems. HAL report hal-01819749, 2018.

[5] C. Rommel, J. F. Bonnans, B. Gregorutti, and P. Martinon. Quantifying the closeness to a set of random curves via the mean marginal likelihood. HAL report hal-01816407, 2018.

Inverse optimal control problem: the linear-quadratic case

Frédéric Jean[1] Sofya Maslovskaya[2]
ENSTA ParisTech, France, [1]frederic.jean, [2]sofya.maslovskaya@ensta-paristech.fr

Key words: Linear-quadratic problem, optimal control, inverse optimal control.

A common assumption in physiology about human motion is that the realized movements are done in an optimal way. The problem of recovering of the optimality principle leads to the inverse optimal control problem. Formally, in the inverse optimal control problem we should find a cost-function such that under the known dynamical constraint the observed trajectories are minimizing for such cost. In this paper we analyze the inverse problem in the case of finite horizon linear-quadratic problem. In particular, we treat the injectivity question, i.e. whether the cost corresponding to the given data is unique, and we propose a cost reconstruction algorithm. In our approach we define the canonical class on which the inverse problem is either injective or admit a special structure, which can be used in cost reconstruction.

Planar curves of minimum length with bounded curvature; applications to marine seismic operations

Thomas Mensch[1] Timothée Moulinier[1]
[1]CGG, France, thomas.mensch@cgg.com, timothee.moulinier@cgg.com

Key words: optimal control, planning, minimum time, bounded curvature.

Seismic acquisition aims to collect data for imaging the subsurface of the Earth. At sea, these data are acquired by towing a large spread of sensors behind a seismic vessel sailing along predefined straight acquisition lines [1]. In-between each nominal line, a line change is performed. This maneuver stands as non-productive phase, which contributes significantly to the acquisition time and cost. Designing efficient line changes is a difficult and challenging task in survey area of complex sea currents. It relies on on-board operator experience to find an optimal trajectory for the vessel, which, at the same time, minimizes the duration of the turn while protecting the integrity of the in-sea equipment.

To support marine operations, we propose to reformulate the problem in optimal control frame. A standard problem in optimal control [2, 3] is to seek for minimum length curves among those with bounded curvature that join two endpoints with given tangents. This is the so-called unicycle vehicle problem with two controls: one control is the angle and the other is the longitudinal speed. This is the simplest possible vehicle, without trail (see [4, 5, 6, 7] for generalizations, motion planning and complexity of such systems). The aim of our study is to determine the optimal track of a ship towing long underwater cables, dealing with a minimum time problem for a system with a trail, together with a curvature constraint on the trail itself. Such a constraint is responsible for additional difficulties (see, e.g., [8]).

References

[1] OGP, An overview of marine seismic operations, Report No. 448 (2011).

[2] L. E. Dubins, On curves of minimal length with a constraint on average curvature, and with prescribed initial and terminal positions and tangents, Amer. J. of Math., 79 (1957), pp. 497–516. http://www.jstor.org/stable/2372560.

[3] Y. Chitour, M. Sigalotti, Dubins problem on surfaces. I. Nonnegative curvature, J. Geom. Anal., 15 (2005), pp. 565–587.

[4] A. Bellaïche, F. Jean, J.-J. Risler, Geometry of nonholonomic systems, In Robot motion planning and control, vol. 229 (1998), pp. 55–91, Springer, London, https://doi.org/10.1007/BFb0036071.

[5] M. Fliess, J. Lévine, P. Martin, P. Rouchon, Flatness, motion planning and trailer systems. In 32th IEEE Conf. on Decision and Control, vol. 3 (1993) pp. 2700–2705.

[6] F. Jean, The car with N trailers: characterisation of the singular configurations. ESAIM Control Optim. Calc. Var., 1 (1996), pp. 241–266. http://www.numdam.org/item/COCV_1996__1__241_0.

[7] D. Tilbury, J.-P. Laumond, R. M. Murray, S. S. Sastry, G. Walsh, Steering car-like systems with trailers using sinusoids, In IEEE Conf. on Robotics and Autom. (1998), pp. 1993–1998, Nice, France.

[8] H. Maurer, On optimal control problems with bounded state variables and control appearing linearly, SIAM J. Control Optimization, 15 (1977), pp. 345–362. https://doi.org/10.1137/0315023.

Mixing Decomposition-Coordination Methods in Multistage Stochastic Optimization

P. Carpentier[1] J.-P. Chancelier[2] M. De Lara [2]
[1]ENSTA ParisTech
[2]ENPC ParisTech, delara@cermics.enpc.fr

Key words: stochastic optimization, decomposition-coordination, stochastic dynamic programming, stochastic programming.

Multistage stochastic optimization problems are, by essence, complex because their solutions are indexed both by stages (time) and by uncertainties (scenarios). Hence, their large scale nature makes decomposition methods appealing. We present, in an unified framework, three main approaches and methods to decompose multi-stage stochastic optimization problems for numerical resolution: time decomposition (and state-based resolution methods, like stochastic dynamic programming, in stochastic optimal control); scenario decomposition (like progressive hedging in stochastic programming); spatial decomposition (like dual approximate dynamic programming). We point on the difficulties raised by the mixing of such methods to tackle large scale problems. We provide illustrations for the management of new energy systems (smart grids).

References

[1] D. P. Bertsekas and S. E. Shreve. *Stochastic Optimal Control: The Discrete-Time Case.* Athena Scientific, Belmont, Massachusetts, 1996.

[2] P. Carpentier and G. Cohen. *Décomposition-coordination en optimisation déterministe et stochastique.* Springer, 2017.

[3] M. De Lara, P. Carpentier, J.-P. Chancelier, V. Leclère. *Optimization Methods for the Smart Grid.* Report commissioned by Conseil Français de l'Énergie, october 2014.

[4] R.T. Rockafellar and R. J-B. Wets. Scenarios and policy aggregation in optimization under uncertainty. *Mathematics of operations research*, 16(1):119–147, 1991.

Mixing Dynamic Programming and Scenario Decomposition Methods

P. Carpentier[1] J.-P. Chancelier[2] M. De Lara [2]
T. Rigaut[2,3]
[1]ENSTA ParisTech, pierre.carpentier@ensta-paristech.fr
[2]ENPC ParisTech
[3]Efficacity

Key words: Stochastic optimization, decomposition/coordination, dynamic programming, stochastic programming.

We provide a method to decompose multistage stochastic optimization problems by time blocks. Our framework covers both stochastic programming and stochastic dynamic programming. We formulate multistage stochastic optimization problems over a so-called history space, with solutions being history feedbacks. We prove a general dynamic programming equation, with value functions defined on the history space. Then, we consider the question of reducing the history using a compressed "state" variable. This reduction can be done by time blocks, that is, at stages that are not necessarily all the original unit stages. We prove a reduced dynamic programming equation. Then, we apply the reduction method by time blocks to two time-scales stochastic optimization problems and to a novel class of so-called *decision hazard decision problems*, arising in many practical situations, like in stock management.

References

[1] P. Carpentier, J.-P. Chancelier, M. De Lara, T. Rigaut, *Time Blocks Decomposition of Multistage Stochastic Optimization Problems*. hal-01757113v1.

Mixing Dynamic Programming and Spatial Decomposition Methods

P. Carpentier[1] J.-P. Chancelier[2] M. De Lara [2]
F. Pacaud[2,3]
[1]ENSTA ParisTech, pierre.carpentier@ensta-paristech.fr
[2]ENPC ParisTech
[3]Efficacity

Key words: Stochastic optimization, decomposition/coordination, dynamic programming, stochastic programming.

We consider a stochastic optimization problem where different units are connected together via a network. Each unit is a (small) control system, located at a node. Each unit state evolution is affected by uncertainties and by controls from the neighbor units transmitted through edges. Static constraints couple all units at each time. We formulate a global stochastic optimization problem. We propose two decomposition methods, whether we decouple the constraints by prices or by quantities. We show that the global Bellman function can be bounded above by a sum of quantity-decomposed nodal value functions, and below by a sum of price-decomposed nodal value functions. We provide conditions under which these nodal value functions can be computed by dynamic programming. We illustrate these results with numerical studies that tackle the decentralized optimization of urban micro-grids.

References

[1] P. Carpentier and G. Cohen, Décomposition-coordination en optimisation déterministe et stochastique, Springer, 2017.

[2] F. Pacaud, Decentralized Optimization Methods for Efficient Energy Management under Stochasticity, PhD Thesis, University Paris-Est, 2018.

Efficient algorithms for answering connectivity queries on real algebraic sets defined by quadrics

Mohab Safey El Din[1] Éric Schost[2]
[1]Sorbonne Université, CNRS, Inria, France, mohab.safey@lip6.fr
[2]University of Waterloo, Canada, eschost@uwaterloo.ca

Key words: real algebraic geometry, computer algebra, connectivity.

Answering connectivity queries in real algebraic sets is a key algorithmic challenge for motion planning. All known algorithms run in time which is exponential in the dimension of the ambient space (and polynomial in the maximum of the degrees of the input polynomials).

In this talk, we focus on real algebraic sets defined by quadrics under some genericity assumptions (smoothness). I will present a new algorithm which runs in time *subexponential* in the dimension of the ambient space, polynomial in the maximum of the degrees of the input polynomials and exponential in the number of equations.

A lower bound on the positive semidefinite rank of convex bodies

Hamza Fawzi[1] Mohab Safey El Din[2]
[1]Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK.
[2]Sorbonne Universités, UPMC Univ Paris 06,
CNRS, INRIA Paris Center, LIP6, Equipe PolSys, F-75005, Paris, France.

Key words: Semidefinite programming, positive semidefinite rank, algebraic degree.

The positive semidefinite rank of a convex body C is the size of its smallest positive semidefinite formulation. We show that the positive semidefinite rank of any convex body C is at least $\sqrt{\log d}$ where d is the smallest degree of a polynomial that vanishes on the boundary of the polar of C. This improves on the existing bound which relies on results from quantifier elimination. Our proof relies on the Bézout bound applied to the Karush-Kuhn-Tucker conditions of optimality. We discuss the connection with the algebraic degree of semidefinite programming and show that the bound is tight (up to constant factor) for random spectrahedra of suitable dimension. This is based on [1].

References

[1] Hamza Fawzi and Mohab Safey El Din, A Lower Bound on the Positive Semidefinite Rank of Convex Bodies, SIAM Journal on Applied Algebra and Geometry 2018 2:1, 126-139.

Efficient Algorithms in Hyperbolic Programming

Simone Naldi (Université de Limoges, France)

Session: Semialgebraic Optimization and Applications

Key words: Hyperbolic Polynomials, Hyperbolic Programming, Semidefinite Programming, Algorithms.

The talk will highlight the main topics and the first results of the project "Optimisation Hyperbolique: Algorithmes et Implantations", funded by Fondation Hadamard under the Programme Gaspard Monge pour l'Optimisation. This is a joint project between the author and Timo de Wolff (Technische Universität Berlin), Mario Kummer (Technische Universität Berlin), Daniel Plaumann (Technische Universität Dortmund) and Rainer Sinn (Freie Universität Berlin).

A real univariate polynomial is hyperbolic whenever all its roots are real or, in other words, if it equals the characteristic polynomial of a real symmetric matrix. This property can be extended to the multivariate case via the classical algebraic tool of symmetric determinantal representations. By the way, not every multivariate hyperbolic polynomial admits such a representation/certificate. Hyperbolic Programming (HP) is the natural convex optimization problem asking to minimize a linear function over the hyperbolicity cone of a multivariate hyperbolic polynomial. HP generalizes Linear (LP) and Semidefinite Programming (SDP), central problems in mathematics and its applications.

The goal of this project is to contribute to the following two research directions:

- the development of symbolic-numerical algorithms and implementations for the general Hyperbolic Programming problem, and
- efficient computation of hyperbolicity certificates such as symmetric determinantal representations.

The two items above are highly related since when a polynomial has a symmetric determinantal representation or, more generally, when its hyperbolicity cone is a section of the cone of positive semidefinite matrices, then the associated HP problem reduces to a SDP problem.

Comparing Oblivious and Robust Routing Approaches

Thibaut Cuvelier[1,2], Zwi Altman[1], Richard Combes[2], Eric Gourdin[1]
[1]Orange Gardens, Châtillon, France
[2]Centrale-Supélec, Orsay, France.

Key words: Network routing, traffic engineering, optimisation under uncertainty.

Network routing is an already well-studied problem: the routers in the network know which path a packet must follow in order to reach its destination. Traffic engineering attempts to tune the routing to meet some requirements, such as avoiding congestion or a reducing end-to-end delays. Several approaches have been devised to perform these adaptations, but only few of them deal with the uncertainty in some parameters. Mostly, the uncertainty lies in the demand, the total amount of traffic that goes through the network; however, links and nodes may also fail.

Robust routing approaches have been proposed to tackle this issue: indeed, they consider that traffic matrices are not know precisely but that they lie in an uncertainty space that can be analytically described [1].

Oblivious routing is the extreme case where the uncertainty space is the whole set of possible traffic matrices and the prescribed routing must be as close as possible to the optimum routing, whatever traffic matrix effectively occurs. It has been proved that oblivious routing achieves a polylogarithmic competitive ratio with respect to congestion [2].

Several variants of robust or oblivious routing approaches will be considered and compared on series of realistic instances, some of which are based on Orange network topologies. Future works include dealing with other sources of uncertainty (for instance, survivability to failures [3]) within a common robustness framework.

References

[1] Sözüer, S., and Thiele, A. C. (2016). The State of Robust Optimization. In Robustness Analysis in Decision Aiding, Optimization, and Analytics.

[2] Räcke, H. (2002). Minimizing congestion in general networks. In Foundations of Computer Science, 2002.

[3] Li, L., Buddhikot, M. M., Chekuri, C., and Guo, K. (2005). Routing bandwidth guaranteed paths with local restoration in label switched networks. IEEE Journal on Selected Areas in Communications, 23(2), 437–449.

Dynamic Access Point Selection and Resource Allocation in Multi-technology Wireless Network

Iaad BEN DHIA[1] Mustapha BOUHTOU[1] Taoufik EN-NAJJARY[1]
Lamer LAHOUD[2] Xavier LAGRANGE[3]
[1]Orange Labs Network, Chatillon, France, iaad.bendhia@orange.com
[2]Saint Joseph University, Beyrouth, Liban, samer.lahoud@usj.edu.lb
[3]IMT Atlantique, Rennes, France, xavier.lagrange@telecom-bretagne.eu

Key words: Multi-technology Wireless Networks, Access Point Selection, Resource Allocation, Handover.

The past few decades reveal a rapid increase in terms of data transfer and number of wireless devices connected to the network. As exhibited in [1], statistics show an important annual growth to 2020. This increase motivated network operators to work on Heterogeneous Network (HetNet) that creates some new challenges (resources management, offload, network access mechanism...). One can find a survey on HetNet access point selection issues in [2].

In this work, based on [3], we propose a method to optimize the Radio Access Technologies (**RAT**s) selection and resource allocation in multi-technology wireless networks during a time period. We optimize it on a realistic topology of Base Stations (**BS**) with overlaps of the cellular coverage and dynamic users traffic (arrival and departure). The optimization takes into account the requested services, different users' contract and user satisfaction. Furthermore, in the proposed approach, we added constraints to ban the session drops and handovers for static users. For each instant we formulate the problem as a linear optimization problem and we optimize it successively. The aim of the optimization is to jointly maximize the overall user satisfaction and the number of users connected. Comparing to a legacy approach, numerical results show that our solution outperforms in terms of user satisfaction.

References

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019 White Paper

[2] W. Lusheng and K. Geng-Sheng, Mathematical modeling for network selection in heterogeneous wireless networks - A tutorial, IEEE Communications Surveys & Tutorials (2013), pp. 271-292

[3] I. Ben Dhia and M. Bouhtou and T. En-Najjary and S. Lahoud and X. Lagrange, Optimization of access points selection and resource allocation in heterogeneous wireless network, 2017 IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications - PIMRC (2017)

Benders decomposition for the Virtual network function placement and routing problem (VNFP-RP)

Ahlam MOUACI[1,3], Eric GOURDIN[1], Ivana LJUBIĆ[2,3], Nancy PERROT[1]
[1]Orange Labs, France, eric.gourdin,nancy.perrot@orange.com
[2]Essec Busniss school, France, ivana.ljubic@essec.edu
[3]Universite Paris Dauphine, France, ahlam.mouaci@orange.com

Key words: Software Defined Networking, Network Function Virtualization, Service Function Chaining, Combinatorial optimization, Benders decomposition.

One of the most studied problems that arise in the fields of *Network Function Virtualization* (NFV) and *Software Defined Networking* (SDN) is the Virtual Network Function Placement and Routing Problem (VNFP-RP). In this talk we adress a very general VNFP-RP problem, involving node and function capacity constraints, latency constraints, anti-affinity rules, multi commodity flow constraints and total order constraints. Our objective is to minimize the function placement costs in addition to the node activation costs. We show that the problem is *NP-hard* and we model the problem as an Integer Linear Program (ILP). We propose various valid inequalities and a Benders decomposition scheme allowing us to solve the problem, within a Branch and Benders cut algorithm. Finally, we provide numerous computational results to compare some variants of the proposed formulations and show very significant improvements over an approach based on automatic Benders cuts (generated with Cplex).

Stochastic bounds for Max Flow with random capacity

J.M. Fourneau[1], O. Gacem[1], N. Pekergin[2]
[1]DAVID, UVSQ, Université Paris Saclay, Versailles, France
[2]LACL, Univ. Paris Est, Créteil, France

Key words: strong stochastic bound, increasing convex bound, Max Flow, random discrete capacity.

We present an algorithmic approach to compute stochastic bounds for the max flow of a network with discrete random capacity. The stochasticity assumption drastically changes the complexity of the problem. We propose an approach based on stochastic ordering to provide stochastic bounds for the distribution of Max-Flow. We consider two orderings for random variables: the strong stochastic ordering ($\preceq_{st}$) and the increasing concave ordering $\preceq_{icv}$). The approach is based on the following result (see ref 3): Let $X_1, ..., X_m$ be a set of independent random variables, let $Y_1, Y_2, ..., Y_m$, be another set of independent random variables.

- If $X_i \preceq_{st} Y_i$ for all i, then, for any increasing function $\psi : R^m \to R$, one has
$$\psi(X_1, X_2, ..., X_m) \preceq_{st} \psi(Y_1, Y_2, ..., Y_m)$$
- If $X_i \preceq_{icv} Y_i$ for all i, then, for any increasing concave function $\phi : R^m \to R$, one has
$$\phi(X_1, X_2, ..., X_m) \preceq_{icv} \phi(Y_1, Y_2, ..., Y_m)$$

As Flow-Max = Min Cut, it is obtained through the "Min" and the "Sum" operators which are increasing and concave. We use two recently proposed algorithms (ref 1 and 2) to bound discrete distributions for $\preceq_{st}$ or $\preceq_{icv}$ with less atoms. Therefore they require less computation steps to obtain the distribution of Max-Flow. We consider several algorithms using the graph properties to obtain stochastic bounds and we prove an algorithm to combine bounds to improve their accuracy. This work was supported by a public grant as part of the Investissement d'avenir project, reference ANR-11-LABX-0056-LMH, LabEx LMH, in a joint call with Gaspard Monge Program for optimization, operations research and their interactions with data sciences.

References

[1] Ait Salaht, F. , Cohen, J., Castel Taleb, H., Fourneau, J. M., and Pekergin, N., Accuracy vs. Complexity: the stochastic bound approach, 11th Int. Workshop on Discrete Event Systems (WODES), N 8, 2012.

[2] J. Cohen, A. Fauquette, J.M.Fourneau, G. C. Noukela, N. Pekergin: Convex Stochastic Bounds and Stochastic Optimisation on Graphs. Electr. Notes Theor. Comput. Sci. V 337, pp 23-44, (2018).

[3] M. Shaked, J.G. Shantikumar, Stochastic ordering, 2006, Springer series in statistics, N.Y. .

Multivariate stochastic ordering and tasks graphs with correlated random delays

J.M. Fourneau[1], S. Kaada[1], N. Pekergin[2]
[1]DAVID, UVSQ, Université Paris Saclay, Versailles, France
[2]LACL, Univ. Paris Est, Créteil, France

Key words: Stochastic Pert networks, Multivariate stochastic ordering, completion time.

We present an approach to provide stochastic bounds for stochastic perts or task graphs completion time when the elementary delays are stochastic and not independent. Such an assumption drastically changes the complexity of the problem. Furthermore we assume that these random variables are somehow correlated. We propose to give stochastic bounds (both upper and lower bounds) based on stochastic order for discrete multivariate random variables. First, we prove how we can simplify a discrete distribution to obtain bounding distributions which are easier to deal with, leading to a tradeoff between the computation complexity and the accuracy of the bounds. The main property we use rely on the following theorem (see Shaked and Shatikumar 2006, Thm 6.B.16 item b):

Let $X_1, ..., X_m$ be a set of independent random vectors where the dimension of X_i is k_i, let $Y_1, Y_2, ..., Y_m$, be another set of independent random vectors where the dimension of Y_i is k_i. Denote $k = \sum_i k_i$. If $X_i \preceq_{st} Y_i$ for all i, then, for any increasing function $\psi : R^k \to R$, one has $\psi(X_1, X_2, ..., X_m) \preceq_{st} \psi(Y_1, Y_2, ..., Y_m)$.

We advocate to combine stochastic bounds to reduce the size of the supports of the input distributions (and therefore the complexity of the problem) and a naive approach based on conditioning on all the random variables to obtain a problem with deterministic inputs which is solved in a linear time in the size of the graph. We have to deal with all the possible values of the random variables leading to a number of deterministic problems to solve equal to the product of the number of atoms. As the random variables are not independent we consider random vectors to represent delays on dependent nodes. We consider three ordering for multivariate random variables: the strong multivariate ordering ($\preceq_{st}$), the upper orthant ordering $\preceq_{uo}$) and the lower orthant ordering $\preceq_{lo}$. We derive an algorithm to check if two discrete random vectors are ordered with the $\preceq_{lo}$ or $\preceq_{uo}$ ordering. We also prove an algorithm to derive an upper or a lower bound with a smaller number of atoms for all these ordering. Finally, we present some heuristics to compute some stochastic bounds on the completion time when the random delays are correlated. This work was supported by a public grant as part of the Investissement d'avenir project, reference ANR-11-LABX-0056-LMH, LabEx LMH, in a joint call with Gaspard Monge Program for optimization, operations research and their interactions with data sciences.

References

[1] M. Shaked, J.G. Shantikumar, Stochastic ordering, 2006, Springer series in statistics, N.Y. .

The shadow vertex algorithm solves colorful one-versus-all tropical polynomial systems

M. Akian[1] X. Allamigeon[1] M. Boyet[1] S. Gaubert[1]
[1]INRIA and CMAP, École Polytechnique, marianne.akian@inria.fr, xavier.allamigeon@inria.fr, marin.boyet@inria.fr, stephane.gaubert@inria.fr

Key words: tropical algebra, Markov decision processes, convex geometry

In the tropical semifield $\mathbb{R}_{\max} = (\mathbb{R} \cup \{-\infty\}, \max, +)$, a polynomial in the indeterminate x corresponds to the maximum of an arbitrary number of affine functions in x (with integer slopes). Likewise, a tropical polynomial in $x_1, \dots, x_n$ is a maximum of finitely many affine functions of $x = (x_1, \dots, x_n)$. 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 fundamental problem which arises in tropical geometry, 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]. Fixed point equation arising in the solution of Markov decision processes are also special cases of one-versus-all problems.

We show that the idea of tropical polyhedral homotopy, developed by Jensen for a different class of systems [2], can be extended to solve a class of one-versus-all tropical polynomial systems which includes Markov decision processes. Then, we show that the dual of Jensen's homotopy is equivalent to a policy improvement algorithm, which coincides with a simplex algorithm implemented with the shadow vertex pivoting rule. We show that the same remains true if the tropical polynomials (P_i, Q_i) of the system satisfy a certain condition involving colored sets of point configurations. We study properties of such configurations and provide a necessary condition for the the method to work, using results on supporting hyperplanes to convex bodies [3].

References

[1] X. Allamigeon, V. Bœuf, S. Gaubert, Performance Evaluation of an Emergency Call Center: Tropical Polynomial Systems Applied to Timed Petri Nets, Formal Modeling and Analysis of Timed Systems, (2016), pp. 10–26

[2] A.N. Jensen, Tropical Homotopy Continuation (2016)

[3] S.E. Cappell, J.E. Goodman, J. Pach, R. Pollack & M. Sharir, Common Tangents and Common Transversals, Advances in Mathematics, (1994), 106(2) 198–215.

Online Maximum Matching with Recourse

Spyros Angelopoulos[1] Christoph Dürr[1] Shendan Jin[1]
[1]Sorbonne Université, CNRS, LIP6, France, firstname.lastname@lip6.fr

Key words: Competitive ratio, maximum cardinality matching, recourse.

We study the online maximum matching problem in a model in which the edges are associated with a known recourse parameter k. An online algorithm for this problem has to maintain a valid matching while edges of the underlying graph are presented one after the other. At any moment the algorithm can decide to include an edge into the matching or to exclude it, under the restriction that at most k such actions per edge take place, where k is typically a small constant. This problem was introduced and studied in the context of general online packing problems with recourse by Avitabile et al. [1], whereas the special case $k = 2$ was studied by Boyar et al. [2].

In the first part of this work, we consider the *edge arrival* model, in which an arriving edge never disappears from the graph. Here, we first show an improved analysis on the performance of the algorithm AMP given in [1], by exploiting the structure of the matching problem. In addition, we extend the result of [2] and show that the greedy algorithm has competitive ratio 3/2 for every even k and ratio 2 for every odd k. Moreover, we present and analyze an improvement of the greedy algorithm which we call L-Greedy, and we show that for small values of k it outperforms the algorithm of [1]. In terms of lower bounds, we show that no deterministic algorithm better than $1 + 1/(k-1)$ exists, improving upon the lower bound of $1 + 1/k$ shown in [1].

The second part of this work is devoted to the *edge arrival/departure model*, which is the fully dynamic variant of online matching with recourse. The analysis of L-Greedy and AMP carry through in this model; moreover we show a lower bound of $\frac{k^2-3k+6}{k^2-4k+7}$ for all even $k \geq 4$. For $k \in \{2, 3\}$, the competitive ratio is 3/2.

References

[1] Tess Avitabile, Claire Mathieu, and Laura H. Parkinson. Online constrained optimization with recourse. Information Processing Letters, 113(3):81-86, 2013.

[2] Joan Boyar, Lene M. Favrholdt, Michal Kotrbčík, and Kim S. Larsen. Relaxing the irrevocability requirement for online graph algorithms. In Proceedings of the 15th Workshop on Algorithms and Data Structures, (WADS), pages 217-228. Springer, 2017.

Towards Online Algorithm Configuration: A Case Study

Sander van Rijn[1] Carola Doerr[2] Thomas Bäck[1]
[1]LIACS, Leiden University, Niels Bohrweg 1, 2333CA Leiden, The Netherlands
[2]Sorbonne Université, CNRS, Laboratoire d'Informatique de Paris 6, Paris, France

Key words: Continuous Black-Box Optimization Online Algorithm Configuration CMA-ES.

The Covariance Matrix Adaptation Evolution Strategy (CMA-ES) is a derivative-free randomized heuristic for numerical optimization. Several variants of this algorithm have been proposed in the literature. Fitting these variants into a modular approach, new variants not previously studied by human experts can be efficiently analyzed. Going beyond a static configuration of this modular CMA-ES, we investigate in this work the potential of an adaptive configuration, which in addition allows to adjust the algorithm to the state of the optimization process. We show that switching the configuration only once can already result in significant performance gains.

The presentation is based on [vRDB18].

References

[vRDB18] Sander van Rijn, Carola Doerr, and Thomas Bäck. Towards an adaptive CMA-ES configurator. In *Proc. of Parallel Problem Solving from Nature - PPSN XV, Part I*, volume 11101 of *Lecture Notes in Computer Science*, pages 54–65. Springer, 2018.

Some advances and perspectives in the PGMO SOOT project on over-time optimization

Bruno Escoffier[1]
[1]LIP6, Sorbonne Université, bruno.escoffier@lip6.fr

Key words: Graph algorithms, approximation algorithms, over-time optimization.

The PGMO SOOT project focuses on situations where the input of an optimization problem changes over time, and a solution has to be maintained all along the time horizon. In such situations, where a sequence of solutions has to be computed, there is usually a (potentially high) transition cost between consecutive solutions. So, besides the intrinsic quality of solutions, we are interested in the *stability* of the sequence of solutions over time (minimizing transition costs).

[1, 3, 4] considers such a model of optimization over time, where the goal is to find a sequence of solutions optimizing a function which aggregates quality of solutions and transition costs. Building on this, I will present in this talk some results obtained in the SOOT project for a matching problem over time, recently published in [2]. I will also present some on-going work on the topic of the project.

References

[1] E. Bampis, B. Escoffier, S. Mladenovic: Fair Resource Allocation Over Time. AAMAS 2018: 766-773

[2] E. Bampis, B. Escoffier, M. Lampis, V. Th. Paschos: Multistage Matchings. SWAT 2018: 7:1-7:13

[3] D. Eisenstat, C. Mathieu, N. Schabanel: Facility Location in Evolving Metrics. ICALP (2) 2014: 459-470.

[4] A. Gupta, K. Talwar, U. Wieder. Changing bases: multistage Optimization for Matroids and Matchings. ICALP 2014: 563-575.

A multigrid interior point method for large scale topology optimization

Michal Kočvara
University of Birmingham, UK, m.kocvara@bham.ac.uk

Key words: Large-scale optimization, topology optimization, nonlinear programming, multigrid methods.

The presentation starts with a brief introduction of topology optimization as a mathematical tool for optimal design of mechanical components. Although now routinely used in the industry, software for topology optimization suffers from limitations, in particular when used for complex three-dimensional structures. Our aim is to design an interior point method for the solution of large scale three-dimensional topology optimization problems. The linear systems arising in the method are solved by a Krylov subspace method preconditioned by geometric multigrid. We will explain the (expected as well as unexpected) difficulties connected with switching from two-dimensional topology optimization to three dimensions, where the dimension of a practical problem reaches tens or even hundreds of millions variables.

References

[1] M. Kočvara and S. Mohammed. Primal-dual interior-point multigrid method for topology optimization. SIAM Journal on Scientific Computation. 38(2016), pp. B685–B709.

Shape optimization for a fluid flow via topological gradient method

M. Abdelwahed[1]
[1] Department of Mathematics, College of Sciences, King Saud University, Saudi Arabia
mabdelwahed@ksu.edu.sa

Key words: Shape optimization, Stokes equations, Topological gradient, Topological sensitivity.

Optimal shape design problems in fluid mechanics have wide and valuable applications in aerodynamic and hydrodynamic problems such as the design of car hoods, airplane wings, inlet shapes for jet engines, etc. The majority of works dealing with optimal design of flow domains fall into the category of shape optimization and are limited to determine the optimal shape of an existing boundary [2, 3]. It is only recently that topological optimization has been developed and used in fluid design problems. It can be used to design features within the domain allowing new boundaries to be introduced into the design.

We propose in this work a new approach based on the topological sensitivity analysis [1, 4, 5]. The studied problem is concerned with an optimal shape design problem in fluid mechanics. The fluid flow is governed by the Stokes equations. The theoretical analysis and the numerical simulation are discussed in two and three-dimensional cases. The proposed approach is based on a sensitivity analysis of a design function with respect to the insertion of a small obstacle in the fluid flow domain. An asymptotic expansion is derived for a large class of cost functions using small topological perturbation technique. A fast and accurate numerical algorithm is proposed. The efficiency of the method is illustrated by some numerical examples.

References

[1] M. Abdelwahed, M. Hassine, Topology optimization of time dependent viscous incompressible flows, Abstract and Applied Analysis, Volume 2014, Article ID 923016.

[2] M. Gunzburger, H. Kim, S. Manservisi, On a shape control problem for the stationary Navier-Stokes equations, M2AN Math. Model. Numer. Anal. 34 (6) (2000) 1233–1258.

[3] B. Mohammadi, O. Pironneau, Applied Shape Optimization for Fluids, Numer. Math. Sci. Comput., Oxford Univ. Press, New York, 2001.

[4] G. Allaire, F. Jouve, A.-M. Toader, Structural optimization using sensitivity analysis and a level-set method, J. Comput. Phys. 194 (1) (2004) 363–393.

[5] Ph. Guillaume, K. Sid Idris, Topological sensitivity and shape optimization for the Stokes equations, SIAM J. Control Optim. 43 (1) (2004) 1–31.

Shape reconstruction of deposits inside a steam generator using eddy current measurements

Hugo Girardon[1,2,3], hugo.girardon@polytechnique.edu
Houssem Haddar[1,2],houssem.haddar@inria.fr
Lorenzo Audibert[2,3], lorenzo.audibert@edf.fr
[1]CMAP, École Polytechnique, France [2]DéFI, INRIA Saclay, France [3]PRISME, EDF R&D, France

Key words: Shape optimization, inverse problems, level set, eddy-current approximation.

Non-destructive testing is an essential tool to assess the safety of the facilities within nuclear plants. In particular, conductive deposits on U-tubes in steam generators constitute a major danger as they may block the cooling loop. To detect these deposits, eddy-current probes are introduced inside the U-tubes to generate currents and measuring back an impedance signal. Based on the work of [1], we develop a shape optimization technique with regularized gradient descent to invert these measurements and recover the deposit shape. To deal with the unknown, and possibly complex, topological nature of the latter, we propose to model it using a level set function as it is introduced in [2]. The methodology is first validated on synthetic axisymmetric configurations and fast convergence in ensured by careful adaptation of the gradient steps and regularization parameters. We then consider a more realistic modeling that incorporates the support plate and the presence of imperfections on the tube interior section. We employ in particular an asymptotic model to take into account these imperfections and treat them as additional unknowns in our inverse problem. A multi-objective optimization strategy, based on the use of different operating frequencies, is then developed to solve this problem. We shall present various numerical examples with synthetic data showing the viability of our approach.

References

[1] Z. Jiang, *Some inversion methods applied to non-destructive testings of steam generator via eddy current probe*, PhD thesis, École Polytechnique (2014) .

[2] G. Allaire, F. De Gournay, F. Jouve, A.-M. Toader, Structural optimization using topological and shape sensitivity via a level set method, *Control and Cybernetics*, 34(1):59-80, 2004.

Mean field games with incomplete information

Eran Shmaya[1] and Bruno Ziliotto[2]
[1]Northwestern University, eranshmaya@gmail.com
[2]CNRS, Paris Dauphine University, brunoziliotto01@gmail.com

Key words: Dynamic Games, Continuum of Players, Incomplete Information

We consider a mean-field game model where the payoff depends on a fixed parameter, that is unknown to players. Players receive a stream of private signals on this parameter along the game. We derive a mean field system satisfied by the equilibrium payoff of the game with fixed duration. Under some monotonicity assumption, we prove the uniqueness of the solution. As an example, we consider a product differentiation model, in which players are firms that sell the same product and the unknown parameter represents the preferences of the consumer on the features of the product.

Learning and convergence analysis in finite mean field games

Saeed Hadikhanloo[1] Francisco J. Silva[2]

[1]CMAP, École Polytechnique and INRIA-Saclay, saeed.hadikhanloo@polytechnique.edu

[2]TSE-R, Université de Toulouse I Capitole, and XLIM, Université de Limoges, francisco.silva@unilim.fr

Key words: Mean field games, finite time and finite state space, fictitious play, first order systems.

In this presentation we consider a MFG problem where the number of states and times are finite as [1]. Our contributions to finite MFGs will be twofold: firstly, we study an iterative method, similar to *fictitious play*, and prove its convergence to an equilibrium, and secondly, we investigate the relation between continuous and finite MFGs.

Let us give a brief definition of the model and our contributions on it. Let $\mathcal{S}$ be a finite set and $\mathcal{T}$ consists of $0 = t_0 < t_1 < \ldots < t_m = T$, representing the set of states and time. We denote by $\mathcal{P}(\mathcal{S})$ the set of probability measures over $\mathcal{S}$. We call a tuple (U, M) with $U : \mathcal{T} \times \mathcal{S} \to \mathbb{R}$, $M : \mathcal{T} \to \mathcal{P}(\mathcal{S})$, an equilibrium solution to the finite MFG, if there exists $\hat{P} : \mathcal{S} \times \mathcal{S} \times \mathcal{T} \setminus \{T\} \to [0, 1]$ such that:

$$\begin{aligned}
(i) \quad & U(x, t_k) = \inf_{p \in \mathcal{P}(\mathcal{S})} \sum_{y \in \mathcal{S}} p_y \Big(c_{xy}(p, M(t_k)) + U(y, t_{k+1}) \Big), \\
(ii) \quad & \hat{P}(x, \cdot, t_k) \in \arg\min_{p \in \mathcal{P}(\mathcal{S})} \sum_{y \in \mathcal{S}} p_y \big(c_{xy}(p, M(t_k)) + U(y, t_{k+1}) \big), \\
(iii) \quad & M(x, t_{k+1}) = \sum_{y \in \mathcal{S}} M(y, t_k) \hat{P}(y, x, t_k),
\end{aligned} \tag{1}$$

where $U(\cdot, T)$ and $M(0)$ are given. Finding an equilibrium will be subtle. For achieving this goal, we apply an iterative scheme similar to the fictitious play procedure defined by Brown (1951) and construct $\{(U^n, M^n, \bar{M}^n)\}_{n \in \mathbb{N}}$ in the following recursive way. Let U^{n+1} be obtained from $(i)(1)$ by putting $M = \bar{M}^n$. Denote P^n the corresponding minimiser of problem $(ii)(1)$ for $M = \bar{M}^n$. Then, we obtain M^{n+1} from $(iii)(1)$ by setting $\hat{P} = P^n$. At last set $\bar{M}^{n+1} = \frac{1}{n+1} M^{n+1} + \frac{n}{n+1} \bar{M}^n$. We proved the convergence of (U^n, M^n) to equilibrium, under monotonicity and suitable continuity assumptions. Our second contribution is the convergence of the solutions of finite MFG system (1) to the solution of first-order MFG system when discretization becomes finer. We answered to this question for the case of $c_{xy}(p, M) := \Delta t_n \left(L\left(x, \frac{y-x}{\Delta t_n}\right) + f(x, M) \right) + \epsilon_n \log(p_y)$, and suitable assumptions on the rate of convergence of $\epsilon_n, \Delta t_n, \Delta x_n$ to zero. Numerical results and simulations are done by the help of the developed iterative method.

References

[1] D. A. Gomes, J. Mohr, R. R. Souza *Discrete time, finite state space mean field games*, Journal de mathématiques pures et appliquées, 93(3), 308-328.

[2] P. Cardaliaguet, S. Hadikhanloo *Learning in mean field games: The fictitious play*, ESAIM: Control, Optimisation and Calculus of Variations, 23(2), 569-591.

On the long time convergence of potential MFG

Marco Masoero[1]
[1]Université Paris-Dauphine, CEREMADE, Place de Lattre de Tassigny, F- 75016 Paris, France

Key words: Ergodicity, weak KAM theory, PDE control.

We look at the long time behavior of potential Mean Field Games (briefly MFG) using some standard tools from weak KAM theory. We first show that the time-dependent minimization problem converges to an ergodic constant $-\lambda$, then we provide a class of examples where the value of the stationary MFG minimization problem is strictly greater than $-\lambda$. This will imply that the trajectories of the time-dependent MFG system do not converge to static equilibria.

References

[1] Briani, Ariela, and Pierre Cardaliaguet. "Stable solutions in potential mean field game systems." Nonlinear Differential Equations and Applications NoDEA 25.1 (2018): 1.

[2] Fathi, Albert. "Weak KAM theorem in Lagrangian dynamics preliminary version number 10." by CUP (2008).

[3] Lions, Pierre-Louis, Georgios Papanicolaou, and SR Srinivasa Varadhan. "Homogenization of hamilton-jacobi equations." unpublished work (1986).

[4] Masoero, Marco. "On the long time convergence of potential MFG." arXiv preprint arXiv:1807.10710 (2018).

Wasserstein regularization for sparse multi-task regression

Hicham Janati[1] Marco Cuturi[2] Alexandre Gramfort[1]
[1] INRIA, hicham.janati@inria.fr
[2]ENSAE, CREST

Key words: Multi-task learning, Optimal transport, Regression, Sparsity

Two important elements have driven recent innovation in the field of regression: sparsity-inducing regularization, to cope with high-dimensional problems; multi-task learning through joint parameter estimation, to augment the number of training samples. Both approaches complement each other in the sense that a joint estimation results in more samples, which are needed to estimate sparse models accurately, whereas sparsity promotes models that act on subsets of related variables. This idea has driven the proposal of block regularizers such as ℓ_1/ℓ_q norms, which however effective, require that active regressors strictly overlap.

However, in many applications the assumption of shared active features between all tasks can be too restrictive. For instance, in the context of functional brain imaging, where features are de facto brain regions, ℓ_1/ℓ_q models suggest that the exact same brain locations are active for each human subject in the study. This assumption is clearly not realistic Gramfort et al. [2015]. To solve that issue, Jalali et al. [2010] proposed to split the regression coefficients into two parts, one that is common and one that is task specific, and to penalize these two parts differently. An ℓ_1 norm is used to regularize the task-specific part, and an $\ell_{1,q}$ norm is used on the common part. An alternative proposed by Lozano and Swirszcz [2012] is the *multi-level Lasso*, which considers instead a product decomposition, with ℓ_1 penalties on both composite variables.

In this work, we propose to handle non-overlapping supports in standard multi-task models using an *optimal transport distance* between the different parameters of our regression models. We rely on the elegant extension to handle non-normalized measures proposed by Chizat et al. [2017] to derive an efficient algorithm based on a regularized formulation of optimal transport Cuturi [2013], which iterates through applications of Sinkhorn's algorithm along with coordinate descent iterations. The performance of our model is demonstrated on regular grids and complex triangulated geometries of the cortex with an application in neuroimaging.

References

A. Gramfort, G. Peyré, and M. Cuturi. Fast optimal transport averaging of neuroimaging data. In *IPMI 2015*, July 2015.

A. Jalali, P. Ravikumar, S. Sanghavi, and C. Ruan. A Dirty Model for Multi-task Learning. *NIPS*, 2010.

A. Lozano and G. Swirszcz. Multi-level Lasso for Sparse Multi-task Regression. *ICML*, 2012.

L. Chizat, G. Peyré, B. Schmitzer, and F-X. Vialard. Scaling Algorithms for Unbalanced Transport Problems. *arXiv:1607.05816 [math.OC]*, 2017.

M. Cuturi. Sinkhorn Distances: Lightspeed Computation of Optimal Transport. *NIPS*, 2013.

Robust classification with feature selection using alternating minimization and Douglas-Rachford splitting method

Michel Barlaud[1], Yuxiang Zhou[1], Jean-Baptiste Caillau[2] and Marc Antonini[1]
[1]I3S, Univ. Côte d'Azur & CNRS, F-06900 Sophia Antipolis
21LJAD, Univ. Côte d'Azur & CNRS/INRIA, F-06108 Nice

Key words: Feature selection, supervised classification, proximal methods, Douglas-Rachford splitting

This paper deals with supervised classification and feature selection. A classical approach is to project data on a low dimensional space with a strict control on sparsity. This results in an optimization problem minimizing the within sum of squares in the clusters (Frobenius norm) with an ℓ_1 penalty in order to promote sparsity. It is well known though that the Frobenius norm is not robust to outliers. In this paper, we propose an alternative approach with an ℓ_1 norm minimization both for the constraint and the loss function.

$$\min_W \|Y - XW\|_1 + \lambda \|W\|_1.$$

The loss function is the sum of two ℓ_1 norms, which suggests to use a splitting algorithm. Such methods are very efficient to minimize the sum of convex functions and do not require differentiability properties. Note indeed that, having replaced the squared Frobenius norm by the ℓ_1 norm of $Y - XW$, it is not possible to use forward-backward splitting [1] as none of the functions is differentiable. Althougth the prox of the ℓ_1 norm is well known and expressed in terms of soft thresholding, there is no explicit expression for the prox of the ℓ_1 norm of the affine transform $Y - XW$. Thus, we propose to introduce the auxiliary variable $\zeta := (Y - XW)/\lambda$ in $\mathbf{R}^{m\times k}$ and to minimize

$$\min_W \|W\|_1 + \|\zeta\|_1 \qquad \text{under the affine constraint} \qquad XW + \lambda\zeta = Y\,.$$

The sum of the two ℓ_1 norms is equal to the single ℓ_1 norm of the augmented variable $\tilde{W} := (W, \zeta) \in \mathbf{R}^{(d+m)\times k}$. Let C be the affine subset of $(d + m) \times k$ matrices such that $\tilde{X}\tilde{W} = Y$ where

$$\tilde{X} := [X \ \lambda I_m] \in \mathbf{R}^{m\times(d+m)}.$$

The problem can be recast as $\min_W \|\tilde{W}\|_1$ under the affine constraint $\tilde{X}\tilde{W} = Y$.

We provide a new algorithm ADRS (with convergence proofs) based on alternating minimization and primal Douglas-Rachford splitting. Experiments on biological data sets and computer vision dataset show that our method outperforms results obtained when minimizing a quadratic loss function.

References

[1] P. L. Combettes and J.-C. Pesquet. Proximal splitting methods in signal processing. In *Fixed-point algorithms for inverse problems in science and engineering*, pages 185–212. Springer, 2011.

Sparse Recovery via Convex Quadratic Splines

Mustafa Ç. Pınar[1]
[1]Bilkent University, Ankara, Turkey mustafap@bilkent.edu.tr

Key words: Exact recovery of a sparse vector, basis pursuit, Huber loss function, convex quadratic splines, linear programming, quadratic perturbation.

Necessary and sufficient conditions (of different type) for exact recovery of a sparse vector by means of ℓ_1-norm minimization are given. The problem is central to the literature on compressive sensing [1]. An instance of a convex quadratic spline function, namely Huber loss function is studied here with a view to recover an individual sparse vector by solving strictly convex quadratic programming problems. For the most part, references of a theoretical nature in the area of sparse recovery are concerned with the nullspace condition and the Restricted Isometry Property (RIP) (in particular with random matrices satisfying the conditions requisite for recovery). Instead, the present paper deals with the recovery of an individual sparse vector.

The problem of interest in the present paper comes from the Basis Pursuit (BP) approach to sparse recovery (see [1] for an in-depth monograph on the problem of compressive sensing), and is the following problem:

$$\min_x \{\|x\|_1 : Ax = Au\}, \tag{1}$$

where $A \in \mathbf{R}^{\mathbf{m}\times\mathbf{n}}$ $(m < n)$, $u \in \mathbf{R}^{\mathbf{n}}$ is a sparse vector with $nnz(u) < m$ non-zero components. We shall also consider the problem under noisy observations:

$$\min_x \{\|x\|_1 : \|y - Ax\|_\infty \le \epsilon\}, \tag{2}$$

where $y = Au + e$, and $e \in \mathbf{R}^{\mathbf{m}}$ represents random perturbations, with $\epsilon > 0$. The conditions discussed here involve a slightly different problem based on the Huber loss function depending on a tuning constant $\gamma > 0$:

$$\rho(t) = \begin{cases} \frac{1}{2\gamma}t^2, & \text{if } |t| \le \gamma \\ |t| - \frac{\gamma}{2}, & \text{otherwise.} \end{cases}$$

The Huber loss problem that will be treated is:

$$\min_x \{\|x\|_H : Ax = y\}, \tag{3}$$

where, by abuse of notation, $\|x\|_H$ is used to denote $\sum_{i=1}^n \rho(x_i)$ although the Huber loss function is not a norm (it does not satisfy the triangle inequality).

References

[1] S. Foucart and H. Rauhut, *A Mathematical Introduction to Compressive Sensing*, New York: Springer, 2013.

Geometric and numerical methods for the saturation problem in Magnetic Resonance Imaging

B. Bonnard[1] O. Cots[2] J. Rouot[3] T. Verron[4]
[1]Université de Bourgogne, IMB, Dijon, France, bernard.bonnard@u-bourgogne.fr
[2]Université de Toulouse, INP-ENSEEIHT-IRIT, Toulouse, France, olivier.cots@irit.fr
[3]EPF : Ecole d'Ingénieur-e-s, Troyes, France, jeremy.rouot@epf.fr
[4]Institute for Algebra, Johannes Kepler University, Linz, Austria, thibaut.verron@jku.at

Key words: Geometric optimal control, medical imaging by NMR, Direct method, Shooting and continuation techniques, Moment optimization.

In this talk, we present the time minimal control problem about the saturation of a pair of spins of the same species but with inhomogeneities on the applied RF-magnetic field [1], in relation with the contrast problem in MRI [2]. We make a complete analysis based on geometric control [3] to classify the optimal syntheses [4] in the single spin case, to pave the road to analyze the case of two spins. This points out the phenomenon of bridge, which consists in linking two singular arcs by a bang arc to bypass some singularities of the singular extremal flow. In the case of two spins, the question about global optimality is more intricate. The Bocop software [6] is used to determine local minimizers for physical test cases and Linear Matrix Inequalities approach [5] is applied to estimate the global optimal value and validate the previous computations. This is complemented by numerical investigations combining shooting and continuation methods implemented in the HamPath software [7] to analyze the structure of the time minimal solution with respect to the set of parameters of the species. This reveals new complex structures, compare to the single spin case.

References

[1] B. Bonnard, O. Cots, J. Rouot & T. Verron, *Time minimal saturation of a pair of spins and application in Magnetic Resonance Imaging*, (2018), submitted.

[2] B. Bonnard, M. Claeys, O. Cots & P. Martinon, *Geometric and numerical methods in the contrast imaging problem in nuclear magnetic resonance*, Acta Appl. Math., **135** (2015), no. 1, 5–45.

[3] B. Bonnard & M. Chyba, *Singular trajectories and their role in control theory*, vol **40** of Mathematics & Applications, Springer-Verlag, Berlin (2003), xvi+357

[4] H. J. Sussmann, *Regular synthesis for time-optimal control of single-input real-analytic systems in the plane*, SIAM J. Control and Opt. **25** no. 5 (1987), 1145–1162

[5] J.-B. Lasserre, D. Henrion, C. Prieur, and E. Trélat. *Nonlinear optimal control via occupation measures and LMI-relaxations*, SIAM J. Control Optim., **47** no. 4 (2008), 1643–1666

[6] F. J. Bonnans, P. Martinon & V. Grélard. *Bocop - A collection of examples*, Technical report, INRIA (2012) RR-8053

[7] J.-B. Caillau, O. Cots & J. Gergaud, *Differential continuation for regular optimal control problems*, Optimization Methods and Software, **27** no. 2 (2011), 177–196

Optimal control and differential games

Hasnaa Zidani[1] Nidhal Gammoudi[2]
[1]UMA, ENSTA Paristech, housnaa.zidani@ensta-paristech.fr
[2]UMA, ENSTA Paristech, nidhal.gammoudi@ensta-paristech.fr

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 both unconstrained and state-constrained problems with non-linear dynamics.

Our approach is based on Hamilton-Jacobi framework. We characterize the value functions of such problems as unique solutions of an appropriate Hamilton-Jacobi-Issac equation in the sense of viscosity.

In the case of state-constrained problems, the epigraphs of the value functions can be described by auxiliary optimal control problems free of state constraints, and for which the value functions are Lipschitz continuous and can be characterized, without any additional assumption, as unique viscosity solutions to the present Hamilton-Jacobi-Issac equations.

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

Finally, some numerical examples are considered for the illustration of the theoretical results.

References

[1] R.J ELLIOTT and N.J.KALTON, *The existence of value in differential games.* 1972.

[2] Pierre Cardaliaguet *Introduction to differential games.* 2010.

[3] Hasnaa Zidani, Olivier Bokanowski, Albert Altarovici, *A general Hamilton-Jacobi framework for nonlinear state-constrained control problems.* 2012.

[4] Mohamed Assellaou, Olivier Bokanowski, Anna Désilles, Hasnaa Zidani, *Value function and optimal trajectories for a maximum running cost control problem with state constraints. Application to an abort landing problem.* 2017.

Dual Particle Output Feedback Control based on Lyapunov drifts for nonlinear systems

Emilien Flayac[1], Karim Dahia[2], Bruno Hérissé[3], and Frédéric Jean[4]
[1] ONERA, France, emilien.flayac@onera.fr
[2] ONERA, France, karim.dahia@onera.fr
[3] ONERA, France, bruno.herisse@onera.fr
[4] ENSTA Paristech, France, frederic.jean@ensta-paristech.fr

Key words: imperfect state information, dual effect, stochastic Lyapunov drift, particle filter

A dual receding horizon output feedback controller for a general non linear stochastic system with imperfect information is presented. The novelty of this controller is that stabilization is treated, inside the optimization problem, as a negative drift constraint on the control that is taken from the theory of stability of Markov chains described in [3] and [1]. The dual effect is then created by maximizing the Fisher Information Matrix over the stabilizing controls which makes the global algorithm easier to tune than our previous algorithm in [2]. We use a particle filter for state estimation to handle nonlinearities and multimodality. The performance of this method is demonstrated on the challenging problem of terrain aided navigation.

References

[1] Debasish Chatterjee and John Lygeros. On stability and performance of stochastic predictive control techniques. *IEEE Transactions on Automatic Control*, 60(2):509–514, 2015.

[2] Emilien Flayac, Karim Dahia, Bruno Hérissé, and Frédéric Jean. Nonlinear Fisher Particle Output Feedback Control and its application to Terrain Aided Navigation. In *56th IEEE Conference on Decision and Control*, Melbourne, December 2017.

[3] Sean P. Meyn and Richard L. Tweedie. *Markov Chains and Stochastic stability.* Cambridge University Press, Cambridge, 2nd edition, 2009.

Optimal mini-batch size for stochastic variance reduced methods

Nidham Gazagnadou[1] Robert M. Gower[1]
[1]LTCI, Télécom ParisTech, France, first.last@telecom-paristech.fr

Key words: Empirical risk minimization, stochastic variance reduced methods, stochastic average gradient descent, optimal mini-batch.

The empirical risk minimization problem often arises when training classical machine learning models. Today, gigantic datasets (sometimes several terabytes) from Internet, images or text, are used to train machine learning algorithms, such as logistic regression for classification or conditional random fields. Thus, one cannot perform the required minimization by computing a full gradient descent (GD) because it would be too costly.

In order to address this issue and solve such problems efficiently, the optimization community has revived an old method from the 1950's, the stochastic gradient descent (SGD) method [1]. SGD has established itself as a reference method for minimizing the empirical risk thanks to its scalability. Yet, in order to converge one has to tune a problem dependent stepsize sequence which often leads to suboptimal results.

This last issue has been tackled by the recent development of stochastic variance reduced gradient methods, which do not require any stepsize tuning to ensure convergence, like SAGA [2]. Theses methods keep an estimate of the gradient and update it using only a randomly subsampled set of the data at each iteration. The size of this subsampled set is referred to as the *mini-batch size*.

It is still unclear how to choose such a mini-batch size, and it is often left as a free parameter, both in the classic SGD setting and in stochastic variance reduced methods. By developing upper bounds on the *expected smoothness* constant, introduced recently in [3], we develop near optimal mini-batch sizes for SAGA, which in turn also leads to significantly larger stepsizes. We will also show how the expected smoothness constant is a fundamental quantity in many other stochastic gradient algorithms and can be used to establish optimal mini-batch sizes in other settings.

References

[1] H. Robbins, S. Monro, A Stochastic Approximation Method, The Annals of Mathematical Statistics, 22, 3 (1951) 400–407.

[2] A. Defazio, F. Bach, S. Lacoste-Julien, SAGA: A Fast Incremental Gradient Method With Support for Non-Strongly Convex Composite Objectives, Advances in Neural Information Processing Systems, NIPS (2014).

[3] R. M. Gower, P. Richtárik, F. Bach, Stochastic Quasi-Gradient Methods: Variance Reduction via Jacobian Sketching, In: arxiv:1805.02632 (2018).

On variance reduction for stochastic optimization with multiplicative noise

Alejandro Jofré Philip Thompson[2]
[1]CMM & DIM - Universidad de Chile, Chile, ajofre@dim.uchile.cl
[2]CREST-ENSAE, France, philipthomp@gmail.com

Key words: Stochastic approximation, Variance reduction, Multiplicative noise, Acceleration, Dynamic sampling

We propose dynamic sampled stochastic approximation methods for regularized stochastic convex optimization problems with a heavy-tailed distribution with finite second moments. Typically, it is assumed an oracle with an upper bound σ^2 on its variance (OUBV). Differently, we assume an oracle with multiplicative noise, where the variance may not be uniformly bounded over the feasible set. This includes the case of linear regression where the covariance matrix is affected by noise. With respect to tolerance, our methods achieve optimal iteration complexity and (near) optimal oracle complexity on the smooth convex and smooth strongly-convex classes improving upon Ghadimi and Lan [1] and Byrd et al. [2] where it is assumed an OUBV. Our methods possess a variance localization property: our bounds depend only on local variances $\sigma(x^*)^2$ at solutions x^* and the per unit distance multiplicative variance σ_L^2 (typically of the order of the Lipschitz constant). Moreover, we show there exist policies such that our bounds resemble, up to numerical constants, those obtained in the mentioned papers if it was assumed an OUBV but with the replacement $\sigma^2 := \sigma(x^*)^2$ in terms of variance at solutions. Our bounds are thus sharper since typically $\max\{\sigma(x^*)^2, \sigma_L^2\} \ll \sigma^2$. We also discuss related results in the setting where the Lipschitz constant is unknown. Philip Thompson is sponsored by Fondation Mathématique Jacques Hadamard at CREST-ENSAE, France (under contract with the École Polytechnique).

References

[1] S. Ghadimi and G. Lan, *Accelerated gradient methods for nonconvex nonlinear and stochastic programming*, Mathematical Programming ser. A, Vol. 156 (2016), Issue 1, pp. 59-99.

[2] R.H. Byrd, G.M. Chin, J. Nocedal and Y. Wu, *Sample Size selection in Optimization Methods for Machine Learning*, Mathematical Programming ser. B, Vol. 134 (2012), Issue 1, pp. 127-155.

MISSO: Minimization by Incremental Stochastic Surrogate for large-scale nonconvex Optimization

Belhal Karimi[1,2] Eric Moulines[1,2]
[1]CMAP, Ecole Polytechnique
[2]XPOP, Inria

Key words: Nonconvex, Incremental, Variational Inference, Optimization

We are interested in the constrained minimization of a large sum of nonconvex functions defined as $\min_{\theta\in\Theta}\left[f(\theta) \triangleq \sum_{i=1}^{N} f_i(\theta)\right]$ where Θ is a convex subset of $\mathbb{R}^p$, for all $i \in [\![1, N]\!]$, $f_i : \mathbb{R}^p \to \mathbb{R}$ are continuously differentiable, bounded from below and possibly nonconvex. In this paper, we solve this minimization problem using an MM algorithm which works by finding iteratively a surrogate function that majorizes the objective function. By minimizing at each iteration the surrogate function, we drive the objective function downwards until convergence to a stationary point.

When the objective function is a finite-sum, [1] developed an incremental MM scheme, called MISO, taking advantage of the finite-sum structure with a cost per iteration that is independent of N. However, the MISO framework rests upon the computation of tractable surrogates such as quadratic or variational functions. Yet, in many cases, those surrogates are intractable and need to be approximated. For instance, in the Bayesian machine learning literature [2], uncertainty is put on the parameters, which optimization problem boils down to finding the true distribution of those parameters given any observed data. To this end, variational inference methods, as approximate inference methods are very useful but require computing intractable integrals. Likewise, in Generalized Linear Mixed Models, Maximum Likelihood Estimation is performed to fit the parameters of a model to the observed data. Random effects are considered as latent variables and the optimization procedure requires augmenting the observed data with the latent structure. The MCEM algorithm has been developed to perform such task.

In this contribution, we propose an incremental MM algorithm, called MISSO (Minimization by Incremental Stochastic Surrogate Optimization) when the natural surrogate functions are intractable and should be approximated, for example by Monte Carlo integration. We present a unifying framework in which the mini-batch MCEM and the mini-batch Variational Inference algorithms, fall under and provide convergence guarantees of the objective function. Finally, we apply our incremental MM scheme to train a logistic regression on synthetic data and a Bayesian neural network on MNIST dataset to highlight the effectiveness of our method.

References

[1] Julien Mairal. Incremental majorization-minimization optimization with application to large-scale machine learning. SIAM Journal on Optimization, 25(2):829 855, 2015.

[2] Z. Ghahramani. Probabilistic machine learning and artificial intelligence. Nature, 521, 2015.

Some new results on generalized additive games

Stefano Moretti[1] Henk Norde[2]
[1]PSL Research University, CNRS, UMR [7243], LAMSADE,
75016 Paris, France, stefano.moretti@dauphine.fr
[2]CentER and Department of Econometrics and Operations Research, Tilburg University,
P.O. Box 90153,5000 LE Tilburg, The Netherlands, h.norde@tilburguniversity.edu

Key words: TU-games, monotonicity, balancedness, pmas, operations research games.

A Generalized Additive Game (GAG) [1] is a Transfarable Utility (TU-)game (N, v) where each player in N is provided with an *individual value* and the worth $v(S)$ of a coalition $S \subseteq N$ is obtained as the sum of the individual values of players in another subset $\mathcal{M}(S) \subseteq N$. Based on conditions on the map $\mathcal{M}$ (which associates to each coalition S a set of beneficial players $\mathcal{M}(S)$ not necessarily included in S), in this paper we characterize classes of GAGs that satisfy properties like monotonicity, superadditivity, (total) balancedness and population monotonicity, for all positive vectors of individual values. We also illustrate the application of such conditions on $\mathcal{M}$ over particular GAGs studied in the literature (for instance, the generalized airport games [5], the graph colouring games [2, 3] and the link-connection games [4]). In particular, using such conditions, we can easily show that link-connection games (that are cost games where the players are different service providers that may cooperate in order to satisfy a demand of economic exchange between pairs of nodes of a network) are monotonic, superadditive, totally balanced and pmas-admissable (i.e., they admit a *population monotonic allocation scheme*[6]).

References

[1] Cesari, G., Lucchetti, R., Moretti, S. (2016) Generalized Additive Games. International Journal of Game Theory, 46(4), 919-939.

[2] Deng, X., Ibaraki, T., Nagamochi, H., Zang, W. (2000). Totally balanced combinatorial optimization games. Mathematical Programming, 87(3), 441-452.

[3] Hamers, H., Miquel, S., Norde, H. (2014). Monotonic stable solutions for minimum coloring games. Mathematical Programming, 145(1-2), 509-529.

[4] Moretti, S. (2018) On cooperative connection situations where the players are located at the edges. In: Proceedings European Conference on Multi-Agent Systems EUMAS, Evry, France, 14-15 December 2017. Lecture Notes in Artificial Intelligence, Springer (to appear)

[5] Norde, H., Fragnelli, V., García-Jurado, I., Patrone, F., Tijs, S. (2002) Balancedness of infrastructure cost games. European Journal of Operational Research, 136(3), 635-654.

[6] Sprumont, Y. (1990) Population monotonic allocation schemes for cooperative games with transferable utility. *Games and Economic Behavior*, 2, 378-394.

ROI constrained Auctions

Benjamin Heymann
[1]Criteo, France, b.heymann@criteo.com

Key words: Auction theory, Equilibrium, HJB

A standard result from auction theory is that bidding truthfully in a second price auction is a weakly dominant strategy, or, in the language of digital advertising, 'the cost per mille (eCPM) is equal to the click through rate (CTR) times the cost per clicks (CPC)'. However, such assertion is incorrect if the buyers are subject to ROI constraints. More generally, several predictions derived by the traditional auction theory literature fail to apply in the presence of such constraint. This is what we propose to discuss in this article.

We formalize the notion of ROI constrained auctions and derive a Nash equilibrium for second price auctions. We then extend this result to any combination of first and second price payment rules and do an asymptotic analysis of the equilibrium as the number of bidders increases. Further we expose a revenue equivalence property, and finish with a proposal for a dynamic extension of the bidder ROI constrained optimization problem.

References

[1] B. Heymann, ROI constrained Auctions (2018). http://arxiv.org/abs/1809.08837

Games with information. Witsenhausen intrinsic model.

Jean-Philippe Chancelier[1] Michel De Lara[2] Daniel A. Kadnikov[3]
[1]CERMICS, École nationale des ponts et chaussées, jean-philippe.chancelier@enpc.fr
[2]CERMICS, École nationale des ponts et chaussées, michel.delara@enpc.fr
[3]CERMICS, École nationale des ponts et chaussées, danil.kadnikov@enpc.fr

Key words: Game theory, information, extensive form, perfect recall

In a context of competition, information – who knows what and before whom – plays a crucial role. Here, we concentrate on three models where the concept of information is present: Kuhn's extensive tree model (K-model), Alos-Ferrer, Ritzberger infinite tree model (AFR-model) and Witsenhausen model (W-model).

The model proposed by Witsenhausen has the following main ingredients: a set of agents taking decisions in a decision space, Nature taking decisions in a sample space, configuration space which is the product of the decision space by sample space equipped with a measure, information fields that are sigma-fields on the configuration space and strategies that are measurable mappings from configurations to actions w.r.t. information fields. W-model deals with information in all generality. Thus, it allows to look at a problem without a priori knowing the order in which decisions were made by agents. In the subclass of causal systems, there is at least one ordering in which agents take their decisions consistently with the given information.

The extensive form is the most richly structured way to describe game situations. In his model Kuhn uses the language of graph theory to define main ingredients of the game: players, game tree, information sets and strategies. The infinite tree AFR-model generalizes K-model to any possible tree: infinite (repeated games), transfinite (long cheap talk) and even continuous (stochastic games). The authors develop the refined partition approach that proves to be useful for giving a simple equivalent condition for a player to have perfect recall. To tame the zoo of infinite trees, authors use the language of set theory constructing not trees, but posets, thus elaborating the most general framework to describe tree structures in games existing up to now.

We study whether AFR and W-models have the same potential to model games. First, we embed the subclass of causal W-models into the AFR-formalism by building an AFR-tree and translating definitions of information and strategies from W-formalism to AFR-formalism. Second, we move in the opposite direction.

References

[1] C. Alós-Ferrer, K. Ritzberger, The theory of extensive form games, Springer-Verlag Berlin Heidelberg, Springer series in game theory, official series of the game theory society, 2016

[2] P. Carpentier, J.-P. Chancelier, G. Cohen, M. De Lara, Stochastic Multi-Stage Optimization, Springer, Probability Theory and Stochastic Modeling, 2015

[3] H. W. Kuhn, Classics in Game Theory, Princeton Paperbacks

[4] H.S. Witsenhausen, On Information Structures, Feedback and Causality, SIAM Journal Control, volume 9, Issue 2, pages 149-160, 1971

A Decomposition Method for the Cascade Hydro Unit Commitment Problem

Wim van Ackooij[1] Pascal Benchimol[1] Claudia D'Ambrosio[2] Dimitri Thomopulos[2]
[1]OSIRIS, EdF R&D, Palaiseau, France,
wim.van-ackooij@edf.fr, pascal.benchimol@edf.fr
[2]LIX CNRS (UMR7161), École Polytechnique 91128 Palaiseau Cedex, France,
dambrosio@lix.polytechnique.fr, thomopulos@lix.polytechnique.fr

Key words: Hydro Unit Commitment Problem, Graph Theory, Constrained Shortest Path Problem, Lagrangian Decomposition.

Managing the hydroelectricity produced by the plants in hydro valleys is called the hydro unit commitment problem (HUCP). Solving efficiently and rapidly HUCP, especially when considering the optimization of cascaded reservoirs, is particularly difficult (e.g., [1],[2]). The main reason for this mostly arises from the need to model reality as accurately as possible. One particular way of dealing with this difficulty is by disposing of an a priori discretization, i.e., considering a specific set of operational points, typically chosen in order to have maximal efficiency (highest derivatives). It is intuitive that a decomposition method is a valid strategy to tackle the hydro valley HUCP problem. However, it is also clear that the effectiveness of the method is subject to the efficiency of solving the obtained subproblems. Our main postulate is that a two-reservoir hydro unit commitment problem (2R-HUCP) is the essential building stone of these subproblems and can be handled efficiently.

We propose a Lagrangian decomposition for the complete hydro cascade system, obtaining subproblems modeled as 2R-HUCP. In addition, we propose an efficient approach based on Dynamic Programming for solving the subproblems, extending a path formulation for the single reservoir hydro unit commitment problem presented in [3].

References

[1] M. Tahanan, W. van Ackooij, A. Frangioni, and F. Lacalandra. Large-scale unit commitment under uncertainty: a literature survey. *4OR*, 13(2):115–171, 2015.

[2] R. Taktak and C. D'Ambrosio. An overview on mathematical programming approaches for the deterministic unit commitment problem in hydro valleys. *Energy Systems*, 8(1):57–79, 2017.

[3] W. van Ackooij, C. D'Ambrosio, L. Liberti, R. Taktak, D. Thomopulos, and S. Toubaline, Shortest Path Problem variants for the Hydro Unit Commitment Problem. *Electronic Notes in Discrete Mathematics*, 69:309–316, (2018).

HIG: the Hydro unit commitment Instances Generator

Claudia D'Ambrosio[1] Dimitri Thomopulos[2]
[1]LIX, CNRS & École Polytechnique, France, {dambrosio,thomopulos}@lix.polytechnique.fr

Key words: Hydro Unit Commitment, Instances Generator, Mathematical Programming.

We introduce a Beta version of HIG, the Instances Generator for the Hydro Unit Commitment (HUC) problem `http://www.lix.polytechnique.fr/Labo/Dimitri.Thomopulos/libraries/HIG.html`.

The HUC is an optimization problem aimed at determining the operational mode of a set of turbine/pump units within a pre-determined time horizon. Several technical and strategic constraints have to be satisfied and an objective function, representing the total operating cost, has to be minimized. HIG focus on the deterministic version of the HUC, i.e., we assume that all the data involved in constraints and objective function, such as the water inflows and the electricity prices, are forecast. We refer to [1] for a detailed overview on mathematical programming techniques for the HUC.

To the best of our knowledge, this is the first attempt to make available to the scientific community an instance generator which will ease interaction between the different researchers and computational comparison between different methods for solving the HUC problem. The generator is based on the data used in [2], thus the instances are variants of ones instances presented in [2].

In this talk, we present how we generate the data and the format of the data file. We hope to have a first feedback from the practitioners and the researchers and to stimulate them to contribute in finalizing a stable and richer HUC Library.

References

[1] R. Taktak, C. D'Ambrosio, An Overview on Mathematical Programming Approaches for the Deterministic Unit Commitment Problem in Hydro Valleys, Energy Systems, 8 (2017), pp. 57–79.

[2] A. Borghetti, C. D'Ambrosio, A. Lodi, S. Martello, A MILP Approach for Short-Term Hydro Scheduling and Unit Commitment with Head-Dependent Reservoir, IEEE Transactions on Power Systems 23 (2008), pp. 1115–1124.

A multi-stage stochastic integer programming approach for locating electric vehicles recharging stations under demand uncertainty

Ahmed Kadri[1], Mouna Kchaou-Boujelben[1], Céline Gicquel[2]
[1]United Arab Emirates University, Al Ain, United Arab Emirates
[2]Université Paris Saclay, LRI, Université Paris Sud, Orsay, F-91405, France, celine.gicquel@lri.fr

Key words: facility location, electric vehicle, stochastic integer programming, Benders decomposition, genetic algorithm.

Electric vehicles (EVs) are one of the promising solutions to face environmental and energy concerns. One of the major barriers towards the large scale adoption of EVs is the lack of charging stations to recharge vehicles during long-distance trips, i.e. during trips whose length exceeds the vehicle range. We consider the problem of optimizing the deployment of an infrastructure based on fast charging stations in order to enable EV drivers to carry out long-distance trips. This leads to the formulation of a facility location problem where the demand is not located at nodes of the underlying network but rather is represented by a set of trips to be refueled.

We focus on incorporating into the optimization problem modeling two important features: the dynamic multi-period aspect of the problem and the uncertainty on the future recharging demand. Namely, deploying an EV recharging infrastructure is not a one-shot decision but rather a step-by-step roll-out process in which location decisions are made dynamically according to the evolution of the demand and the availability of the investment budget. Moreover, as this deployment plan is likely to span several years, there will be significant uncertainties on the problem input data. Not taking these uncertainties into account means neglecting a critical part of the problem and may lead to suboptimal location decisions. We thus propose a multi-stage stochastic integer programming approach in which the uncertainties on the future recharging demand are represented through a scenario tree.

To solve the resulting large-size mixed-integer linear program, we develop two solution approaches. The first one is an exact solution method based on a Benders decomposition. In the proposed algorithm, the master problem decides upon the station deployment strategy over the whole scenario tree while each sub-problem focuses on evaluating the resulting coverage for each trip at each tree node. The second solution approach is a heuristic method based on a genetic algorithm. Here, a particular attention is devoted to the implementation of a computationally efficient fitness function and to the definition of crossover and mutation operators complying with the problem constraints.

Our numerical results show that both methods perform well as compared to a stand-alone mathematical programming solver. Moreover, we provide the results of additional simulation experiments showing the practical benefit of the proposed multi-stage stochastic programming model as compared to a simpler multi-period deterministic model.

Incentive design for coupled electric vehicles driving and charging strategies in smart cities

Benoît Sohet[1] Olivier Beaude[1] Yezekael Hayel[2]
[1]EDF R&D, OSIRIS Dept, 91120, Palaiseau, France, bsohet@ens-paris-saclay.fr, olivier.beaude@edf.fr
[2]LIA/CERI, University of Avignon, 84000, Avignon, France, yezekael.hayel@univ-avignon.fr

Key words: Electric Vehicles, Coupling Driving/Charging, Game Theory

Electric Vehicles (EV) are having more and more impact on urban systems, both when driving (e.g. noise and pollution) and when charging (potential impact on the electrical grid). For the grid, the flexibility of EV charging – in time of operation and level of power – makes it a great actor in "Demand Response" mechanisms (thanks to charging scheduling) which is an emerging field in "smart grids". For this reason, there is a need to design incentive mechanisms.

A congestion game approach is here adopted, with multiple classes of vehicles: EV and Gasoline Vehicles. Both time costs and energy operating costs are taken into account. The complexity of this framework comes from the nonseparability of individual costs, as the electricity price depends on the global (energy) charging need of all EV. Indeed, the EV (power) aggregated consumption profile is scheduled in time depending on nonflexible household consumption, following the water filling algorithm presented in [2]. This makes driving and charging decisions coupled (see Fig. 1). An adaptation of Beckmann's method used in [1] gives a proof of the existence of a Wardrop equilibrium, which is unique when the electricity unit price is an increasing function of the global charging need. A condition on the nonflexible load is given to guarantee the monotonicity of this function. This condition is tested on real consumption data in France and in Texas, USA[1]. Optimal tolls are then computed to minimize an environmental cost on a network made of two roads, one crossing a city and the other bypassing it.

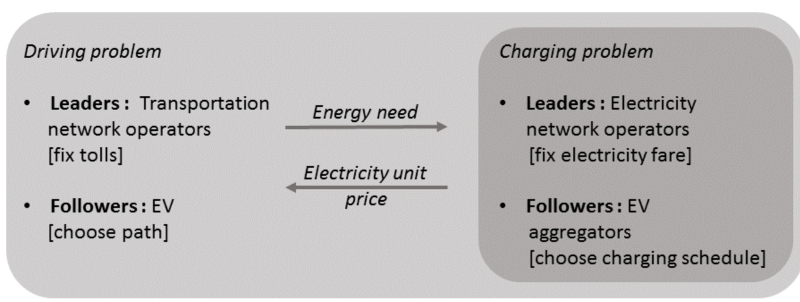


Figure 1: Schematic representation of the coupling of driving and charging problem.

References

[1] Z. Lin and Z.-Y. Peng. Beckmann's formula for multiclass traffic equilibrium problems. *International Mathematical Forum*, 10(11):513–518, 2015.

[2] A.-H. Mohsenian-Rad, V. W. Wong, J. Jatskevich, R. Schober, and A. Leon-Garcia. Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid. *IEEE transactions on Smart Grid*, 1(3):320–331, 2010.

[1]Respectively https://www.enedis.fr/coefficients-des-profils and http://www.pecanstreet.org/.

Smart Charging of Electric Car using Deep Reinforcement Learning

Olivier JUAN[1]
[1]OSIRIS, EDF Lab, olivier.juan@edf.fr

Key words: deep learning, reinforcement, smart charging

This work addresses the problem of finding an efficient strategy for charging an electric vehicule (EV). This problem can be solved by a greey approach (i.e. charging the vehicule as soon as it arrives) but the more EVs penetrate the car market, the more this strategy might overload the electric distribution grid at commuting hours. To overcome this, one can postpone the charging during night or during low prices period of the electric market.

Inspired by the work of [1], we developed an algorithm that optimizes the charging strategy to minimize the charging cost based on day-ahead prices. It has to : - satisfy different constraints : operating constraints, battery power level, quality of service for the car owner...; - operate in an uncertain environment : unknown car departure or arrival time, unknown house consumption...

We detail the problem as a Markov decision process under uncertainty. We applied an A3C reinforcement learning algorithm (as described in [2]) to learn an efficient charging strategy. We use a variation of the algorithm using LSTM [3] to cope with temporal consistency of decisions. We present some preliminary results on real data showing the improvement of the strategy over the learning iterations.

References

[1] V. FranÃ§ois-Lavet and D. Taralla, "Deep reinforcement learning solutions for energy microgrids management," 2016.

[2] V. Mnih, A. P. Badia, M. Mirza, A. Graves, T. P. Lillicrap, T. Harley, D. Silver, and K. Kavukcuoglu, "Asynchronous methods for deep reinforcement learning," *CoRR*, vol. abs/1602.01783, 2016.

[3] S. Hochreiter and J. Schmidhuber, "Long short-term memory," *Neural Comput.*, vol. 9, pp. 1735–1780, Nov. 1997.

Optimization of Radar Search Patterns for Three-Dimensional Phased-Array Radars

Yann Briheche[1,2] Frederic Barbaresco[1] Fouad Bennis[2] Damien Chablat[2]
[1]THALES, France : yann.briheche@thalesgroup.com, frederic.barbaresco@thalesgroup.com
[2]Centrale Nantes, France : fouad.bennis@ec-nantes.fr, damien.chablat@cnrs.fr

Key words: Combinatorial optimization, set covering, radar resources management

Electronic array-antennas offer new possibilities for optimization over traditional rotating antennas, thanks to bi-dimensional beam-forming and beam-steering capabilities (Fig. 1). Modern radars must perform multiple tasks simultaneously. Minimization of the search time-budget frees resources for target tracking, identification, environment analysis among others...

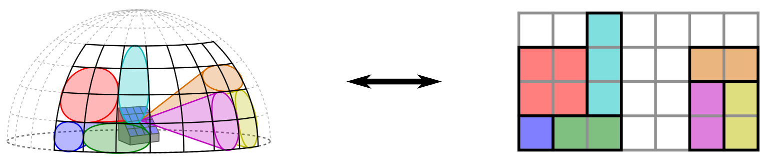


Figure 1: Electronic radar search pattern optimization is equivalent to grid covering

Design of radar covers can be viewed as an optimization problem: minimization of the search time-budget under detection constraints. This problem is closely related to combinatorial spatial problems, such as set covering (Fig. 1), and can be solved by integer programming methods.

A sensible approach is to break down the problem in successive steps (Fig. 2): by first quantifying the surveillance space on a detection grid, then by synthesizing a feasible pattern for each sub-rectangle on the grid, and finally by formulating the problem as an integer program.

This procedure offers a solid framework with several advantages: first, each step can be modified individually without impacting the rest of the framework; second, it allows environmental characteristics (rain, ground, clouds) and objective parameters (range, update rate, false alarm tolerance, etc.) to be defined locally on the grid; finally the computational cost of finding the solution can be controlled by the discrete grid resolution. Additionally, branch & bound, often used in integer programming, is suitable for producing "just-in-time" solutions for real-time applications in operational situations.

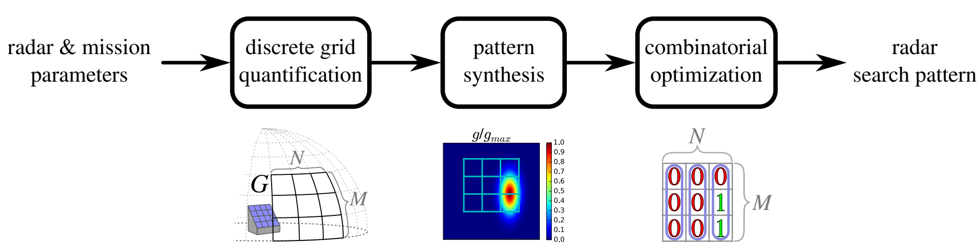


Figure 2: Framework for optimizing radar search patterns through combinatorial optimization

Computation of most threatening trajectories over blindness maps of a radar network

François Desquilbet[1] Johann Dréo[2] Jean-Marie Mirebeau[3]
[1]Ecole Normale Supérieure de Paris, France, francois.desquilbet@ens.fr
[2]Thales Research & Technology, France, johann.dreo@thalesgroup.com
[3]Université Paris-Sud, CNRS, Université Paris-Saclay, jean-marie.mirebeau@math.u-psud.fr

Key words: Non-holonomic optimal control, anisotropic eikonal equation, optimization

We aim to design a radar network which maximizes the detection probability of the worst threatening trajectory from a source to a target. In game theory, we represent it as a non-cooperative zero-sum game: a first player chooses a setting ξ for the network Ξ, and the other player chooses a trajectory γ from the admissible class Γ with full information over the network ξ. The players' objective is respectively to maximize and minimize the path cost:

$$C(\Xi,\Gamma) := \sup_{\xi\in\Xi} \inf_{\gamma\in\Gamma} \int_0^{T(\gamma)} C_\xi(\gamma(t),\gamma'(t),\gamma''(t))\mathrm{d}t$$

where the path γ is parametrized at unit euclidean speed, and the final time $T(\gamma)$ is free.

In comparison with [1], we added blindness maps depending on the distance and the radial speed, which are functions of internal parameters of the radars that can be optimized: PRI (Pulse Repetition Interval) and frequency. We also take into account RCS (Radar Cross Section) and a complex geometry with DEM (Digital Elevation Map) and Earth curvature.

The profile of the cost function with regard to the direction of movement is non-convex, which is significant only with a curvature penalization. For that, we chose the Dubins model, in which the curvature radius is bounded. The computation of optimal trajectories is performed with a specialized variant of the Fast-Marching algorithm [2]. We showcase new phenomena such as spiraling threatening trajectories, trajectories dodging radars through their blind distances, and hiding from valley to valley.

The optimization of the radar network (positioning and internal parameters) is a difficult problem (non-convex, non-differentiable), solved with optimization algorithms such as CMA-ES.

References

[1] Jean-Marie Mirebeau, Johann Dreo. *Automatic differentiation of non-holonomic fast marching for computing most threatening trajectories under sensors surveillance.* Proc of GSI 2017.

[2] Jean-Marie Mirebeau. *Fast-Marching Methods for Curvature Penalized Shortest Paths.* J Math Imaging Vis, 2018.

[3] Frédéric Barbaresco. *Computation of most threatening radar trajectories areas and corridors based on fast-marching & Level Sets.* In IEEE Symposium On Computational Intelligence For Security And Defence Applications, pages 51-58. IEEE, 2011.

Large-scale variants of CMA-ES for radar optimization problems

Konstantinos Varelas[1,2] Anne Auger[1] Dimo Brockhoff[1] Nikolaus Hansen[1]
Rami Kassab[2]
[1]Inria, RandOpt team, École Polytechnique, CMAP, France, firstname.lastname@inria.fr
[2]Thales LAS France SAS, Limours, firstname.lastname@thalesgroup.fr

Key words: evolution strategies, CMA-ES, large-scale optimization, radar, phase-coded waveforms

The CMA-ES [2] algorithm is a continuous domain, stochastic optimization algorithm addressing problems in a derivative-free setting. The quadratic space and time complexity of the method limits its applicability for problems with increasing dimensionality.

We present alternatives of CMA-ES that have been recently proposed for problems in large dimensions and outline the principal ideas of each approach [3]. The performance of these variants and of the gradient based L-BFGS algorithm in terms of runtime is compared in different experimental settings. For this, we use a newly introduced benchmarking testbed for black-box optimizers, which is also outlined and extends the standard COCO [1] BBOB testbed in dimensions up to 640.

Multiple transmit multiple receive (MIMO) radars require the use of phase-coded waveforms with low correlation properties, e.g. for good spatial resolution and interference rejection. We focus on this application formulated as a black-box optimization problem, where we compare the obtained results of methods mentioned above. We also sketch another radar application for phase-only pattern synthesis of phased-array antennas.

References

[1] Hansen, N., Auger, A., Mersmann, O., Tušar, T., Brockhoff, D.: COCO: A platform for comparing continuous optimizers in a black-box setting. arXiv:1603.08785 (2016)

[2] Hansen, N., Ostermeier, A.: Completely derandomized self-adaptation in evolution strategies. Evol. Comput. 9(2), 159-195 (2001)

[3] Varelas, K., Auger, A., Brockhoff, D., Hansen, N., Ait Elhara, O., Semet, Y., Kassab, R., Barbaresco, F.: A Comparative Study of Large-Scale Variants of CMA-ES: PPSN XV, pp. 3-15. Springer (2018)

[4] Scholnik, D. P.: A Parameterized Pattern-Error Objective for Large-Scale Phase-Only Array Pattern Design. IEEE Transactions on Antennas and Propagation, vol. 64, no. 1, pp. 89-98, (2016)

An optimization approach for balancing maintenance costs and electricity consumption in Cloud Data Centers

Luca Chiaraviglio[1], Fabio D'Andreagiovanni[2,3], Riccardo Lancellotti[4], Mohammad Shojafar[5], Nicola Blefari-Melazzi[1], Claudia Canali[4]
[1]Department of Electronic Engineering, University of Rome Tor Vergata (Italy) and CNIT (Italy), luca.chiaraviglio@uniroma2.it, nicola.blefari-melazzi@uniroma2.it
[2]National Center for Scientific Research (CNRS), France,
[3]Heudiasyc UMR 7253, Sorbonne Universités, Université de Technologie de Compiègne, CNRS, CS 60319, 60203 Compiègne, France, d.andreagiovanni@hds.utc.fr
[4]Department of Engineering, University of Modena and Reggio Emilia (Italy), riccardo.lancellotti@unimore.it,claudia.canali@unimore.it
[5]Department of Mathematics, University of Padua (Italy), mohammad.shojafar@math.unipd.it

Key words: Cloud Computing, Fatigue, Energy-efficiency, 0-1 Linear Programming.

Cloud Data Centers (CDCs) are data centers that adopt the cloud computing paradigm, according to which applications are virtualized and run in a number of distributed physical servers that may be located very distant from each other, even in distinct continents. Studies on the optimal management of CDCs have commonly focused just on minimizing the total power consumption, deciding how to switch on and off the physical servers composing the CDCs depending on the workload. However, switching the servers causes large temperature transitions in the hardware, which can sensibly increase the failure rates of components and lead to an increase in the maintenance costs.

In this work, we propose a new optimization model for managing CDCs that jointly minimizes the power consumption and the maintenance costs, derived through a material-based fatigue model that expresses the costs incurred to repair the hardware, as a consequence of the variation over time of the server power states. A major objective has been to investigate what is the impact of the maintenance costs on the total costs and whether it is beneficial to leverage the tradeoff between electricity consumption and maintenance costs. Computational results, obtained over a set of scenarios from a real CDC, show that the original heuristic that we propose to solve the optimization model largely outperforms two benchmark algorithms, which instead either target the load balancing or the energy consumption of the servers.

For a detailed description of the considered problem, optimization model and solution algorithm, we refer the reader to our recent publication [1].

References

[1] L. Chiaraviglio, F. D'Andreagiovanni R. Lancellotti, M. Shojafar, N. Blefari-Melazzi, C. Canali, An Approach to Balance Maintenance Costs and Electricity Consumption in Cloud Data Centers, IEEE Transactions on Sustainable Computing, Online first (2018), DOI: 10.1109/TSUSC.2018.2838338.

A Capacity Planning Framework for Energy-Efficient Data Centers

Rym. Regaieg[1] Omar. Hammami[1] Mohamed. Koubàa[2] Taoufik. Aguili[2]
[1]ENSTA-ParisTech, Paris-Saclay University, France, ryma.regaieg, omar.hammami@ensta-paristech.fr
[2]ENIT, Tunis-EL-Manar University, Tunisia, mohamed.koubaa, taoufik.aguili@enit.utm.tn

Key words: capacity planning framework, energy consumption efficiency, ILP model.

Nowadays, the cloud service providers are focusing much of importance in having data centers (DC) with efficient energy consumption so as to reduce the energy costs which is a major contributor of their total operational costs.

In this context, we design a capacity planning framework (CPF) for energy-efficient DCs. Technically, the proposed CPF performs an integrated offline VM placement (VMP) solution. The VMP is the way toward selecting which virtual machines (VMs) ought to be found at each physical machine (PM) in a DC. The VMP problem can be seen as a variant of the bin-packing problem [1]. The individual PMs can be considered as bins. Similarly, the VMs can be considered as objects to be packed into these bins. Several formulations have been proposed to model and solve the bin-packing problems, most of which are based on the Linear Programming (LP) techniques [1].

In this work, the proposed VMP placement approach is formalized as a Two-Objective Integer Linear Programming model (TOILP). The TOILP model aims at satisfying the number of virtual machine requests to be hosted while the energy consumption is reduced through the minimization of the used physical machines number. To the best of our knowledge, this is the first attempt in which such objectives are considered in a CPF.

To assess the performances of the proposed solution, extensive simulation scenarios has been established in a homogeneous DC, considering additional realistic VMs' and PMs' configurations. Through the simulation results, it was observed that with the proposed CPF, the number of used PMs can be minimized with an average gain of 15% [2] while meeting all the VM resource requirements, compared to a one which only considered the satisfaction of the VMs.

References

[1] F. Lopez-Pires, B. Baran : Virtual Machine Placement Literature, https://arxiv.org/pdf/1506.01509.pdf, (Septembre 2018).

[2] R. Regaieg, M. Koubàa, E. Osei-Opoku, and T. Aguili, Multi-Objective Mixed Integer Linear Programming Model for VM Placement to Minimize Resource Wastage in a Heterogeneous Cloud Provider Data Center, in Tenth International Conference on Ubiquitous and Future Network (2018), p. 401-406.

Stochastic Optimization of Energy Consumption and Performance in a Cloud System

T. Tournaire[1] T. Hoche[2] E. Hyon[3] H. Castel-Taleb[1]
[1] SAMOVAR, Telecom SudParis, CNRS, 9 rue Charles Fourier, 91011 Evry Cedex, France
hind.castel@telecom-sudparis.eu, tournaire.thomas@telecom-sudparis.eu
[2] UVSQ-DAVID, 78000, Versailles, France, toussaint.hoche@uvsq.fr
[3] UPMC, LIP6 Paris/Université Paris Nanterre, France, emmanuel.hyon@lip6.fr *

Key words: Cloud System, Stochastic optimization, Markov Chains, local search Heuristics

Managing the energy consumption of data centers is a problem, since these centers are usually over-sized to ensure the *Quality of Service* (QoS) of hosted applications. This under-utilization leads to over-consumption and it is definitely interesting to manage the consumption of data centers, because it represents a significant part of global electricity consumption. Virtualization as well as turning on and off virtual machines is a usual way to reduce the energy consumption while guaranteeing a given QoS as presented in [1]. We model the cloud by a multi-server system with an hysteresis policy [2]: activation and deactivation decisions of VM depend on thresholds on the system load.

This work aims at computing the optimal thresholds once costs and performance parameters are fixed. With our assumptions, the average overall cost of the system can be computed from the stationary probability of a Markov chain. Due to its special form, we can solve it with an exact aggregation method [2]. Computing the optimal thresholds is a complex problem since the cost function is neither linear nor convex. This is why, local search heuristics [3] are used to determine the thresholds in a faster time than an exhaustive search. We improved these heuristics by introducing the aggregation method in the cost function computation in order to reduce their running time. We implemented them (using [4]) so as to compare their efficiency. The comparisons were conclusive and showed the effectiveness of this method. Finally, we extend our researches to meta heuristics by developing a simulated annealing method.

References

[1] A.Benoit, L.Lefèvre, A-C Orgerie, I.Rais, *Reducing the energy consumption of large scale computing systems through combined shutdown policies with multiple constraints*, Int. J. High Perform. Comput. Appl., 32 (1) : 176-188 (2018).

[2] L. Golubchik, John C.S. Lui, *Stochastic Complement Analysis of Multiservers Treshold Queues with Hysteresis*, Performance Evaluation, 35(1) :19-48, 1999.

[3] M. Kandi, H. Castel-Taleb, F. Ait Salaht, E. Hyon, *Calcul des seuils optimaux d'une politique à hysteresis pour un modèle de cloud*, ROADEF 17, 2017.

[4] Alain Jean-Marie, *marmoteCore: a Markov Modeling Platform*, VALUETOOLS 2017: 60-65, 2017.

*This work was supported by the PGMO project BOBIBEE.

Most Critical Elements for Optimization Problems

Cristina Bazgan[1] Sonia Toubaline[1] Daniel Vanderpooten[1]
[1]Université Paris-Dauphine cristina.bazgan,sonia.toubaline,daniel.vanderpooten@dauphine.fr

Key words: most vital, graphs, selection, multiobjective.

In many real world applications, e.g. those involving the use of communication or transportation networks, a system can be modelled as a weighted connected graph where entities are edges or nodes. Given an optimization problem defined on a graph, the corresponding k most vital edges/nodes problem is to find a subset of k edges/nodes whose removal from the graph causes the largest perturbation on the objective function. In this talk we first establish a review of existing results concerning most critical elements of single objective optimization problems [1, 3, 4].

Our project aims at studying the determination of the most critical elements for multi-objective optimization problems [2]. In this context, solutions of interest are the efficient (or Pareto-optimal) solutions, a solution being efficient if there is no other solution that dominates it on all objectives. We will present some motivations, definitions, and results.

References

[1] C. Bazgan, S. Toubaline, and D. Vanderpooten. Efficient determination of the k most vital edges for the minimum spanning tree problem. Computers and Operations Research, 39(11):2888-2898, 2012.

[2] M. Ehrgott. Multicriteria Optimization. Springer, 2000.

[3] G. N. Frederickson and R. Solis-Oba. Increasing the weight of minimum spanning trees. Proc. 7th SODA, pages 539-546, 1996

[4] L. Khachiyan, E. Boros, K. Borys, K. M. Elbassioni, V. Gurvich, G. Rudolf, and J. Zhao, On short paths interdiction problems: Total and node-wise limited interdiction, Theory of Computing Systems, 43(2):204-233, 2008.

Author Index