Book of Abstracts

PGMO Days 2017

EDF Lab Paris-Saclay

Nov 13-14, 2017

Preface

This volume contains the extended abstracts of the talks presented at PGMODAYS 2017 held on November 13-14, 2017 at EDF Labs Paris-Saclay.

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October 23, 2017 The organizers of the PGMO days
Palaiseau

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Organizers of Invited Sessions

Continuous multiobjective optimization of expensive-to-evaluate function	Emmanuel Vazquez, on behalf of GDR MASCOT-NUM
Continuous Optimization for Machine Learning	Joseph Salmon
Data science for industry	George Hébrail, Michel Prenat and Gilles Stoltz
Game Theory	Miquel Oliu-Barton, on behalf of GdR Jeux
Mean Field Games and applications	Daniela Tonon
Numerical Optimal Transport	Marco Cuturi and Gabriel Peyré
Numeric and Symbolic Convex Programming for Polynomial Optimization	Victor Magron
Operational Research	Alain Quilliot, on behalf of GdR RO
Optimal control and applications to biology	Axel Kroener and Hasnaa Zidani
Optimal control of PDEs and related field	Jean-Baptiste Caillau
Optimization of Telecom Networks	Eric Gourdin and Walid Ben Ameur

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Regaining tractability in some large scale/uncertain engineering optimization problems

Aharon BEN-TAL

Technion, Tel-Aviv

The need to solve real-life optimization problems poses frequently a severe challenge, as the underlying mathematical programs threatens to be intractable. The intractability can be attributed to any of the following properties: large dimensionality of the design dimension; lack of convexity; parameters affected by uncertainty. In problems of designing optimal mechanical structures (truss topology design, shape design, free material optimization), the mathematical programs typically have hundreds of thousands of variables, a fact which rules out the use of advanced modern solution methods, such as Interior Point method. Some Signal Processing and Estimation problems may result in nonconvex formulations. In the wide area of optimization under uncertainty classical approaches, such as chance (probabilistic) constraints, give rise to nonconvex NP-hard problems. Nonconvexity also occurs in some Robust Control problems.

In all the above applications we explain how the difficulties were resolved. In some cases this was achieved by mathematical analysis, which converted the problems (or its dual) to a tractable convex program. In other cases novel approximation schemes, based on Robust Optimization, are used to address intractable probability inequalities. In the case of large-scale convex programs, novel first order algorithms were employed. In the Robust Control example, a parameterization scheme is developed under which the problem is converted to a tractable deterministic convex program.

Optimization and Games in Congested Networks

Roberto COMINETTI

UAI, Santiago

In this talk we will survey the use of optimization and game theory models in urban transport and telecommunications. After a brief review of equilibrium flows in congested networks, we will describe our recent work on stochastic traffic equilibrium, risk-averse route choice, dynamic equilibrium, and the limiting behavior of the Price-of-Anarchy under heavy congestion.

Robust Solution Approaches for Challenging Network Optimization and Air-Traffic Management Problems

Frauke LIERS

FAU Erlangen-Nürnberg

One way of protecting against uncertainties that occur in real-world applications is to apply and to develop methodologies from robust optimization. The latter takes these uncertainties into account already in the mathematical model. Then, the task is to determine solutions that are feasible for all considered realizations of the uncertain parameters, and among them one with best guaranteed solution value. In this talk, we give an overview over some robust approaches for real-world applications, and also talk about recent advances.

In particular, we study dynamic network flows with uncertain input data under a robust optimization perspective, where protection is sought against uncertain travel times. For operating gas networks, we present robust approaches for protecting against uncertain physical parameters. Already in the stationary case, gas network operation is complex as nonconvex quadratic optimization taks need to be solved. Robust approaches are presented for their operation that differ in the level of adjustability of the physical state variables such as pressures and flows in the network.

Finally, we will also cover an application of robust combinatorial optimization in air-traffic management. For the runway scheduling problem, we will point out modelling and solution techniques using recoverable robust solution approaches.

(Robust dynamic flows is joint with C. Gottschalk, A. Koster, B. Peis, D. Schmand, and A. Wierz. Robust gas networks is joint with D. Aßmann, M. Stingl, and J. Vera. Robust runway scheduling is joint with A. Heidt, M. Kapolke, and A. Martin.)

Risk-Averse Control of Markov Systems

Andrzej RUSZCZYŃSKI

Rutgers University

We shall focus on risk-averse control of discrete-time and continuous-time Markov systems. We shall refine the concept of time consistency for such systems, introduce the class of Markovian risk measures, and derive their structure. This will allow us to derive a risk-averse couterpart of dynamic programming equations. Then we shall extend these ideas continuous-time Markov chains and derive the structure of risk measures and dynamic programming equations in these cases as well. In the last part of the talk, we shall discuss risk-averse control of diffusion processes and present a risk-averse counterpart of the Hamilton--Bellman--Jacobi equation. Finally, we provide brief information o n current research on partially-observable problems in discrete and continuous time.

Stakes and overview of research works in Artificial Intelligence and Operations Research at Orange

Henri SANSON

Orange

The object of the presentation is to explain how Artificial Intelligence and Operations Research techniques permit to answer operator Orange 's big stakes in terms of infrastructure performances, operational efficiency and customer relationship. After introducing these stakes, we will review some of our major research works in Artificial Intelligence and Operations Research contributing directly to these objectives, mainly in the field of networks optimization, data mining as well as content and interaction technologies.

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Complexity Analysis of Lot-Sizing Models for Energy Management

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Key words: lot-sizing, energy management, single-item, complexity, dynamic programming.

We address lot-sizing problems in the context of energy management where a single non-reversible energy source is used to fulfill a discrete energy demand over a planning horizon. 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 management of the energy storage is required to optimize the total production cost. The non-reversible source is characterized by an efficiency function allowing to get the amount of usable energy for a given cost. The inverse of this function is used in lot-sizing models to get the cost related to the produced amount of energy over the planning horizon. Similarly, efficiency aspects have to be considered for the reversible source. Losses can also be assumed when carrying energy units from a period to another.
Energy management was already considered within production scheduling problems [1, 2], but very few works address energy management in lot-sizing problems. We quote the work of Masmoudi *et al.* [3] that introduce explicitly the price of electricity as well as availability limitations in the considered lot-sizing models.
The aim of our study is to provide a classification of this new class of lot-sizing problems for energy management mainly based on the structure of the efficiency functions. Our focus is on drawing the boundary between polynomially solvable and NP-complete cases. We prove that some classes remain polynomially solvable while several other classes turn to be NP-Hard. We also study some classes when considering inventory losses from one period to another.

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Semi-Definite Programs for Discrete-time Piecewise Affine Systems

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Key words: Semi-definite programming, Piecewise affine systems, Verification, Piecewise quadratic Lyapunov functions, Copositive matrices.

In this presentation, the verification problem consists in checking *automatically* whether a given set C is an invariant for the analyzed discrete-time piecewise affine system i.e. $\mathcal{R} \subseteq C$ where $\mathcal{R}$ is the reachable values set of the piecewise affine system. Moreover, we suppose that the set C is a sublevel set of some piecewise quadratic function. Then the verification problem is equivalent to solve a maximization problem where the decision variable is constrained to belong to $\mathcal{R}$.

In [1], the author exhibited a semi-definite program that overapproximates the latter maximization problem. Then if the optimal value of the relaxed semi-definite problem is smaller than the level defined by C, we can conclude that the property holds. Otherwise, we cannot conclude.

In this talk, we propose to study the duality gap between the initial maximization problem and its semi-definite relaxation. More precisely, we want to exhibit a computable class of piecewise affine systems where the related semi-definite program relaxation is exact.

The semi-definite program is constructed as a relaxation of piecewise quadratic Lyapunov equations and copositive constraints using the decompositions proposed in [2, 3]. However, some existing results discuss cases where the decompositions are exact. These results are the first step to describe our computable class of piecewise affine systems.

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Smooth Primal-Dual Coordinate Descent Algorithms for Nonsmooth Convex Optimization

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Key words: Smoothing, primal-dual algorithm, coordinate descent

We propose a new randomized coordinate descent method for a convex optimization template with broad applications. Our analysis relies on a novel combination of four ideas applied to the primal-dual gap function: smoothing, acceleration, homotopy, and non-uniform sampling. As a result, our method features the first convergence rate guarantees that are the best-known under a variety of common structure assumptions on the template. We provide numerical evidence to support the theoretical results with a comparison to state-of-the-art algorithms.

Extraction and partitioning for regularity extraction: application to dialogue analysis

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Key words: Graph algorithms, Regularities extraction, Polyhedral study, K-partitioning.

In the context of dialogue analysis, a corpus of dialogues can be represented as a set of arrays of annotations encoding the dialogue utterances. In order to identify the frequently used dialogue schemes, we design a two-step methodology in which recurrent patterns are first extracted and then partitioned into homogenous classes constituting the regularities [1].

Two methods are developed to extract recurrent patterns: LPCA-DC and SABRE. The former is an adaptation of a dynamic programming algorithm. The latter is obtained by formally modeling the extraction of local alignment in the form of a maximum weight arborescence problem in a particular graph. The partitioning of recurrent patterns is realised using various heuristics from the literature as well as two original formulations of the K-partitioning problem in the form of mixed integer linear programs. Throughout a polyhedral study of a polyhedron associated to these formulations, facets are characterized (in particular: 2-chorded cycle inequalities, 2-partition inequalities and general clique inequalities) [2]. These theoretical results allow the establishment of an efficient cutting plane algorithm.

We developed a decision support software called VIESA which implements these different methods and allows their evaluation during two experiments realised by a psychologist. Thus, regularities corresponding to dialogical strategies that previous manual extractions failed to identify are obtained.

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Single and multi-site modeling of temperature fluctuations with a Markov switching model based on coupled meteorological variables. Calibration and application for Metropolitan France

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Key words: Markov switching autoregressive process, Stochastic weather generators, Climatology, the Weather Research and Forcasting (WRF) model.

Weather prediction and time series are of crucial interest for climate dependent activities. At the space and time scales of a territory during a year, the dynamical processes involved in the weather prediction leaves rooms for uncertainty modeling approaches.

In this work, we are particularly interested in the temperature dynamics uncertainty. As others time series modeling approaches in the literature of Stochastic Weather Generators, we propose a single/multi-site modeling based on a Markov switching stochastic model.

The originality of our approach is twofold. First we are interested in the calibration of a fluctuation model around a mean temperature dynamics or/and a predicted temperature dynamics $\bar{T}_t$. We then focus on the modeling of the perturbation vector dynamics Y_t from the seasonal/annual cycle $\bar{T}_t$ or/and from an ensemble averaged prevision.

Second, we use the climatology of the studied territory to select a pertinent choice of coupled variables (rainfall, pressure, wind,...) and use those auxiliary and downscaled meteorological information as a Markov chain (X_t) that locally (on a set of chosen sites of interest) drives the switching regime of the vector of temperature fluctuation: $Y_{t+1} = Y_t - \Psi(X_t, X_{t+1})Y_t + \sigma\xi_{t+1}$, where ξ is a renormalized and correlated vector process of noises.

We present the model, its calibration methodology, and a summery of calibration/simulation experiments based on a set of french cities. We used both meteorological observations and a downscalled climatology provided by Metigate[1]. We illustrate the use of our model with the computation of probability of occurrence of some climate change index defined by ETCCDI such as Cold Spell Duration Index (CSDI).

A particular attention is paid to the level of restitution by the model of the spatial correlations between the sites, and to the identification of the law of the noises for the temperatures times series in France reconstituted with our calibration procedure.

[1]http://metigate.com/en

Stochastic dominance and the bijective ratio of online algorithms

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Key words: Online algorithms, performance measures, bijective analysis, stochastic dominance, k-server problems.

Stochastic dominance is a technique for evaluating the performance of online algorithms that provides an intuitive, yet powerful stochastic order between the compared algorithms. Accordingly this holds for bijective analysis, which can be interpreted as stochastic dominance assuming the uniform distribution over requests. These techniques have been applied to some online problems, and have provided a clear separation between algorithms whose performance varies significantly in practice. However, there are situations in which they are not readily applicable due to the fact that they stipulate a stringent relation between the compared algorithms. In this paper, we propose remedies for these shortcomings. First, we establish sufficient conditions that allow us to prove the bijective optimality of a certain class of algorithms for a wide range of problems; we demonstrate this approach in the context of some well-studied online problems. Second, to account for situations in which two algorithms are incomparable or there is no clear optimum, we introduce the bijective ratio as a natural extension of (exact) bijective analysis. Our definition readily generalizes to stochastic dominance. This renders the concept of bijective analysis (and that of stochastic dominance) applicable to all online problems, and allows for the incorporation of other useful techniques such as amortized analysis. We demonstrate the applicability of the bijective ratio to one of the fundamental online problems, namely the continuous k-server problem on metrics such as the line, the circle, and the star. Among other results, we show that the greedy algorithm attains bijective ratios of $O(k)$ consistently across these metrics. These results confirm extensive previous studies that gave evidence of the efficiency of this algorithm on said metrics in practice, which, however, is not reflected in competitive analysis.

Full paper available at arXiv:1607.06132

Fiber Cables Network Design

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Key words: FTTH, network design, integer programming, complexity.

The Fiber To The Home (FTTH) networks are currently being deployed by many telecommunications operators, due to the high bandwidth they provide. Huge investments are necessary for their deployment (almost 30 billion euros are estimated necessary to cover the French territory). An abundant literature is available on the theme of FTTH deployment optimization, focusing on many sub-problems. These include for instance the selection of the civil engineering infrastructure to be used, the selection and location of the active and passive optical equipment. The fiber cables network design arises after these decision-making steps. This issue is highlighted as an incomplete field of study by the survey [1], especially regarding separation techniques. The works [3] and [2] include some separation costs and the splicing technique.

Fiber cables have to connect one central equipment location to several lower level equipment. The optical cables usually have a 3-layered structure: one cable containing fiber modules, and one module containing fibers. A large cable can be separated into several smaller cables, using either the splicing or tapping technique, for a variable cost. These separation decisions lead to a complex combinatorics problem.

We introduce the fiber cables network design decision problem, with associated mixed integer formulations and complexity results. Computational solutions are proposed and assessed on real life instances.

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Mining and Proving Conjectures: Discovering Invariants on Integer Sequences

(with an application for short term replanification)

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Key words: Data Mining, Automatic Proof, Automata, Short term replanification.

We describe a method for discovering and proving generic invariants linking together several characteristics of a same integer sequence; *generic invariants* are independent from the integer values used in the sequence, and possibly parametrized by the sequence size. The method consists of two steps, namely:

- A *mining phase* where we systematically generate integer sequences up to a given size, and extract conjectures from the corresponding data sets. Given a conjunction of two time-series constraints on a same sequence of variables, the *mining phase* generates in a systematic way all solutions for small sequences sizes; then it uses a simple bias based on Boolean combinations of arithmetic constraints, possibly parametrized by the sequence size, to come up with conjectures, which characterize subsets of infeasible points that are located within the convex hull of all feasible points, and that occur for all generated sequence sizes.

- A *proof phase* where we try to prove conjectures by checking that the intersection of a set of constant size automata is empty. The *proof phase* synthesizes, from each arithmetic constraint that occurs in a Boolean expression characterizing a subset of infeasible points, a finite automaton without accumulators that has a constant size; having a *constant size* is crucial for generating *sequence size independent invariants*. We sketch for several arithmetic constraints how to generate the corresponding constant size automata that do not use any accumulators.

The linear constraints approximating the convex hull of feasible points found in [1] are used together with the new invariants characterizing infeasible set of points inside the convex hull for each suffix of the sequence of variables used in a conjunction of time-series constraints. Preliminary tests indicate that the discovered generic invariants can significantly speed up both, the proof of infeasibility, and more surprisingly, the generation of solutions for a conjunction of time-series constraints using characteristics of short term electricity production data.

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Second order optimality conditions in semigroup setting for bilinear optimal control problems with control bounds and singular arcs

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Key words: optimal control, bilinear partial differential equation, second order conditions, singular optimal control.

We present second order optimality conditions for a bilinear optimal control problem governed by the following equation:

$$\dot{\Psi} + \mathcal{A}\Psi = f + u(\mathcal{B}_1 + \mathcal{B}_2\Psi); \;\; t \in (0,T); \quad \Psi(0) = \Psi_0, \tag{1}$$

where $\mathcal{H}$ is a Banach space, $\mathcal{A}$ is the generator of a strongly continuous semigroup on $\mathcal{H}$, and

$$\Psi_0 \in \mathcal{H}; \;\; f \in L^1(0,T;\mathcal{H}); \;\; \mathcal{B}_1 \in \mathcal{H}; \;\; u \in L^1(0,T); \;\; \mathcal{B}_2 \in \mathcal{L}(\mathcal{H}).$$

For this equation we consider *a cost that is affine in the control,* and bounds on u of the type

$$u_{\min} \le u(t) \le u_{\max}, \quad \text{a.e. on } [0,T].$$

This general framework includes, in particular, optimal control problems for the bilinear heat and wave equations.

For the described class of problems we derive first and second order optimality conditions. We then apply the results to the heat and wave equations. We comment on the extension to the complex setting and application to the Schrödinger equation.

The results are published in [1, 2, 3].

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Scheduling under energy constraints and objectives

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Key words: Scheduling, energy, mixed-integer programming, constraint programming

A rising combinatorial optimization challenge is the integration of energy constraints and objectives in deterministic scheduling and resource allocation models. This talk will survey research work in this area carried out at LAAS-CNRS. Several real-life scheduling problems involving energetic issues in manufacturing and in the process industry will be introduced, along with generic problems abstracted from these applications. Solution methods based on mixed-integer programming, such as column generation algorithms, and constraint programming, in particular new developments of the "energy reasoning" constraint propagation algorithm, will be presented.

Computing fuel optimal impulsive maneuvers for collision avoidance : an approach by chance-constrained optimization.

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Key words: chance constrained optimization, scenario approach, collision avoidance, orbital collision.

Since the collision between the Russian satellite COSMOS 1934 and a debris of COSMOS 926 in December 1991, no less than eight collisions have been recorded in orbit between operational satellites or between satellites and debris. The risks of collision are particularly important in low orbits and the various space agencies (CNES, ESA, NASA) and the operators of the field (Airbus Defense and Space, GMV) have set up alert procedures to evaluate collision risks for controlled satellites, and allowing the initiation of avoidance maneuvers if the risk of collision exceeds some tolerance threshold. These procedures have undergone many changes in recent years and the field of collision avoidance is currently in full development.

This talk focuses on collision avoidance between an operational spacecraft and an orbital debris in the context of long-term encounters. Under the assumption of impulse control laws, the problem of collision avoidance is formulated as a chance-constrained optimization problem for which we propose two approaches: an efficient resolution algorithm based on the work of R. Henrion and A. Möller [1] and the Alan Genz code for computing probabilities of collision and their gradients w.r.t. to the maneuvers, and an alternative approach leading to a mixed integer linear program [2].

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Disaggregated Electricity Forecasting using Clustering of Individual Consumers

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Key words: time series, wavelets, electricity demand

Electricity load forecasting is crucial for utilities for production planning as well as marketing offers. Recently, the increasing deployment of smart grids infrastructure requires the development of more flexible data driven forecasting methods adapting quite automatically to new data sets. New metering infrastructures as smart meters provide new and potentially massive informations about individual (household, small and medium enterprise) consumption[1].

We propose to build clustering tools useful for forecasting the load consumption. The idea is to disaggregate the global signal in such a way that the sum of disaggregated forecasts significantly improves the prediction of the whole global signal. The strategy is in three steps: first we cluster curves defining numerous super-consumers, then we build a hierarchy of partitions, and then the best one is finally selected with respect to a disaggregated forecast criterion.

The shape of the curves exhibits rich information about the calendar day type, the meteorological conditions or the existence of special electricity tariffs. Using the information contained in the shape of the load curves, [1] proposed a flexible nonparametric function-valued forecast model called KWF (`Kernel+Wavelet+Functional`) well suited to handle nonstationary series.

In [2] we applied this strategy to a dataset of individual consumers from the French electricity provider EDF. A substantial gain of 16 % in forecast accuracy comparing to the 1-cluster approach is provided by disaggregation while preserving meaningful classes of consumers.

This project's aim is to evaluate the upscaling capacity of the strategy developed in [2] to cope with the up-growing volume of data. For this, we explore different strategies with simulated datasets ranging from thousands to tens of millions of consumers. Our experiments show that no sophisticated computing technology is needed to solve this problem. We developed a R package that will be available soon where our strategies are implemented.

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When quasi-variational inequalities can be solved as variational inequalities: the case of a Radner equilibrium problem

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Key words: Quasi-variational inequality, Variational inequality, Radner equilibrium.

A quasi-variational inequality corresponds to a variational inequality in which the constraint set depends on the current value of the variable. In the literature, there are only few existence results for those difficult problems. In this work is we identify a class of quasi-variational inequalities for which each solution of an auxiliary (classical) Stampacchia variational inequality provides a solution of the quasi-variational inequality. This class of quasi-variational inequalities is directly inspired by a Radner equilibrium problem. Existence of solutions for this class of quasi-variational inequalities is then deduced. This talk is based on [1].

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Clustering with feature selection in biology

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Key words: Clustering, gradient-projection, sparsity induction, alternate optimization, feature selection, single-cell RNA sequencing

In many biomedical applications, the goal is to establish diagnosis or prognosis using a limited number of biomarkers. New RNA-seq devices provide high dimensional gene expression (20000 genes, typically). The challenge is then to select the smallest number of genes necessary to achieve accurate biological prediction. We propose a method to perform clustering and feature selection. Our approach relies on an alternate scheme using K-means to update centroids, and splitting to perform dimension reduction [4]. Feature selection is achieved thanks to an outer iteration to strenghthen an ℓ^1 constraint that induces sparsity in the matrix used to reweight the features and reduce the dimension. The splitting is a gradient-projection method [2] that takes advantage of an exact ℓ^1 projection [3]. We report clustering on three single-cell RNA-seq biological databases [5, 6, 8]. Our method compares very favourably with other approaches such as PCA-Kmeans, spectral clustering, Diffrac [1] and Sparcl [7]. On this biological data, the analysis of the accuracy versus the number of selected features allows us to estimate the number of relevant genes for clustering.

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The probability to reach an agreement as a foundation for axiomatic bargaining

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Keywords: cooperative bargaining, target-based preferences, Nash solution, copulas.

The axiomatic foundations laid out by Nash (1950) stands out as a cornerstone of two-person cooperative bargaining theory for simplicity and elegance. Given a convex and compact subset $S \subset \mathbb{R}^2$ of von Neumann-Morgenstern utilities and a point $d \in S$, Nash proved that the unique solution satisfying four axioms is defined as the maximiser of the product $(u_1 - d_1)(u_2 - d_2)$ and $u_i \geq d_i$ for $i = 1, 2$. Many economic models turn this precept into a shortcut for predicting how unstructured bargaining will be resolved, but hardly anybody use it in real situations. One reason is that the Nash solution "lacks a straightforward interpretation since the meaning of the product of two von Neumann–Morgenstern utility numbers is unclear" Rubinstein *et al.* (1992).

We move from a utility-based language to a probability-based language. The couple (S, d) is a condensed version ofthe model $(A, \delta, \succsim_1, \succsim_2)$, where A is a set of possible (feasible) agreements, δ the disagreement outcome and $\succsim_i$ is a preference relation over A. Consider a mediator hired to suggest a solution that maximises the probability to strike an agreement. We provide a benchmarking procedure that allows him to associate to every outcome $a \in A$ a vector of acceptance probabilities $(P_1(a), P_2(a))$. If players' acceptance probabilities are stochastically independent, the (joint) probability that they both accept a is given by the product $P_1(a) \cdot P_2(a)$. The Nash solution maximizes the probability of reaching a deal when acceptance probabilities are independently distributed.

More generally, the mediator may have different beliefs about the dependence structure of bargainers' acceptance probabilities. We provide a behavioural characterization under which the mediator recommends a proposal a^* that maximises a copula: $a^* \in \arg\max_{a \in A} C(P_1(a), P_2(a))$. Copulas are functions that link multivariate distributions to their one-dimensional marginal distributions, see Sklar (1959). Besides Nash's solution, the copula approach allows us to recover two other major solutions as special cases, the egalitarian and the utilitarian solutions.

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Relaxation and Rounding for Epidemic Defense

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Key words: software-defined networking, network security, spectral graph theory, semidefinite programming, Erdös-Rényi model.

Software-defined networking (SDN) technology allows administrators to manage a network algorithmically. In this talk we explore the possibility of automating network security against the spread of any kind of malware by modifying the topology of a SDN architecture.

Recent advances in the analysis of mathematical epidemic models have uncovered the relationship between the survival of an epidemic spreading over a network and the spectrum of the adjacency matrix of the underlying contact graph. In [1] the largest eigenvalue of the adjacency matrix is shown to control the spread of an epidemic. Following these results, the authors of [2] studied the problem of removing edges in a graph to prevent the spread of an epidemic and introduced an algorithm based on the relaxation and rounding framework to solve it.

To understand the performance of this algorithm we perform an experimental analysis of solutions obtained by solving the semidefinite programming relaxation and explore the links between randomized rounding and results on spectral parameters of the Erdös-Rényi random graph model such as [3]. We will also describe the process of turning matrix concentration inequalities such as those developed in [4] to obtain approximation guarantees for this class of algorithms.

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Most Critical Elements for Optimization Problems

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Key words: most vital, graphs, complexity, 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, difficulties and preliminary results.

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Variational inequalities in mean field games

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Key words: PDE, mean field games, variational inequalities.

In [1], we present the suitable notion of solutions for the study of the PDE system which arises from a MFG model with optimal stopping time. Indeed the Hamilton-Jacobi-Bellman equation of some optimization problem (optimal stopping, impulse control) is a variational inequality and this class of equation does not enter in the usual theory of solutions of mean field games. We present here in which sense a mean field game system can be interpreted in such a situation. Namely we prove existence and uniqueness of the appropriate notion of solutions.

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Destination Prediction by Trajectory Distribution Based Model

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Key words: Trajectory Classification, Final Destination Prediction, Clustering, Classification.

Monitoring and predicting road traffic is of great importance for traffic managers. With the increase of mobile sensors, such as GPS devices and smartphones, much information is at hand to understand urban traffic. In the last few years, a large amount of research has been conducted in order to use this data to model and analyze road traffic conditions.

In this talk we propose a new method to predict the final destination of vehicle trips based on their initial partial trajectories. We first review how we obtained clustering of trajectories that describes user behaviour [1]. Then, we explain how we model main traffic flow patterns by a mixture of 2d Gaussian distributions[2]. This yielded a density based clustering of locations, which produces a data driven grid of similar points within each pattern. We present how this model can be used to predict the final destination of a new trajectory based on their first locations using a two step procedure: We first assign the new trajectory to the clusters it mot likely belongs. Secondly, we use characteristics from trajectories inside these clusters to predict the final destination. Finally, we present experimental results of our methods for classification of trajectories and final destination prediction on datasets of timestamped GPS-Location of taxi trips. We test our methods on two different datasets, to assess the capacity of our method to adapt automatically to different subsets.

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Building a Platform for Data Science Competitions on Data Streams

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Key words: Stream Data Mining, Information Flow Processing, Competition Platform

Data streams have increasingly gained the interest of researchers and companies, and are currently widely studied in data science. Data Stream Mining is challenging task, thus companies tend to organize competitions on specific data themes using dedicated platforms. However existing platforms are limited and do not deal with continuous streams. They only allow users to download a static data set and submit results all at once. Afterwards, platform evaluates the results. We propose a novel platform that tackles this limitation and allows organizing competitions on flows using online learning techniques. The platform is able to pull data from sources and handle bi-directional streams to send and receive data. The proposed architecture takes advantage of big data technologies and falls within the field of Information Flow Processing Systems.

An *Information Flow* or *Data Stream* F is an ordered and potentially infinite sequence of events $(e_1, e_2, ..., e_i, ...)$ where an *Event* is the basic data unit. Information that is conveyed by an event can represent either an observed reality or an abstract information such as the end of the stream [3]. We build the data stream competition platform according to IFP systems stakes introduced by [2] among which we mention: processing on-the-fly, high availability, scalability or real time processing. The platform is implemented using several new technologies such as Kafka, gRPC and Protobuf, they are highly used in Real time applications and stream processing. The platform ensures the security of data transfer based on authentication secret tokens. A web application is also provided to allow users to browse through multiples interfaces and display competition results in real time. We plan to run competitions on real use cases provided by EDF such as Forecast or Disaggregation[1].

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A note on genericity multi-leader-one follower problems

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Key words: genericity, MPCC, muti-leader-one follower problems, regularity, stationary points.

Abstract
Nowadays non-cooperative games have many applications. In particular, they model deregulated electricity markets with location prices. In this case, there exists a regulator that decides, given the prices of the agent, how much shall they produce and how to distribute the electricity. So, each producer solves a bi-level problem, where the common lower level problem corresponds with the regulator optimization, i.e. the minimization of the total cost of the electricity that the regulator has to paid to the agents. This problem has been studied in [1] and [3]. This leads to the so called muti-leader-one follower model.

In this contribution we consider the mathematical program with complementarity constraints (MPCC) formulation of the muti-leader-one follower problem. We analyze which properties will remain stable under perturbations of the involved functions, as it was done in [2] for bilevel problems. The stability of MPCC-LICQ and properties of the stationary points are studied in particular cases.

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Polynomial Feedback Laws for Infinite-Dimensional Bilinear Optimal Control Problems

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Key words: Feedback laws, Hamilton-Jacobi-Bellman equation, Value function, Riccati and Lyapunov equations, Fokker-Planck equation.

We consider in this talk the following bilinear optimal control problem:

$$\mathcal{V}(y_0) = \min_{u \in L^2(0,\infty)} \int_0^\infty \|y(t)\|^2 + \frac{\alpha}{2} u(t)^2 \mathrm{d}t,$$

$$\text{u.d.N.} \quad \dot{y}(t) = Ay(t) + (Ny(t) + B)u(t), \quad y(0) = y_0.$$

A Taylor expansion of the value function $\mathcal{V}$ can be computed in the neighborhood of the origin by repeated differentiation of the associated Hamilton-Jacobi-Bellman equation. The obtained approximation provides a polynomial feedback law, that we analyse theoretically [3] and numerically [2] with a control problem of the Fokker-Planck equation, a parabolic differential equation modelling the evolution in time of the distribution of a set of physical particles [1].

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Reduction methods for grid cover problem used in radar applications

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Key words: Combinatorial optimization, set cover problem, row/column elimination, computational complexity

Modern radars are highly flexible and can dynamically perform adaptive covering to operational constraints. Set covering is an efficient formulation for optimizing radar search patterns [1], as displayed in Figure 1, but is known to be NP-hard to solve [2]. In practice, computation time is directly dependant on the problem size, i.e. number of variables (columns) n and number of constraints (rows) m. In case of grid covering by rectangles, the number of variables is usually quadratic in the number of constraints: $n \sim m^2$

Removals of rows and columns is a common preprocessing step in solving covering problems [3]. A column is redundant if another column covers the same constraints for equal or inferior cost. A row makes another row redundant if the covers of the former are all covers for the latter. Naive removal of redundant rows is performed by comparisons of all pairs of columns in $O(n^2m) = O(m^5)$, and similarly, naive removal of redundant rows is $O(nm^2) = O(m^4)$.

Exploiting the geometrical properties of rectangular covers, it is possible to perform exhaustive removal of columns in $O(m^2)$ and removal of rows in $O(m^3)$. In practical cases, row removal does not make such a difference a computational time, as the number of constraints is usually low to begin with (within a few thousands), but column removal can lead to a significant speed-up as the number of variable can be high (up to several hundred thousand), allowing real-time optimization of adaptive radar search patterns in operational situations.

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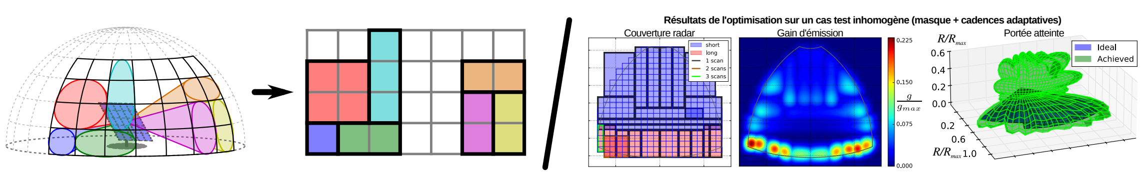

Figure 1: Radar search pattern representation as grid cover (left) and simulation example (right)

On Numerical Benchmarking of Multiobjective Blackbox Optimizers

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Key words: Numerical blackbox optimization, benchmarking, multiobjective optimization.

Numerical benchmarking is an important step towards recommending practically relevant (blackbox) optimization algorithms and understanding their properties. The actual implementation of numerical benchmarking experiments, however, is known to be tedious and is not as trivial as it looks at first sight. For these reasons, the Comparing Continuous Optimizers platform (COCO, https://github.com/numbbo/coco/) has been developed with the aims of (i) automatizing the benchmarking experiments and (ii) implementing a thorough benchmarking methodology (choice of scalable, well-understood test functions with practically relevant features and difficulties, decisions on meaningful performance measures, visualization aspects, statistical tests, ...). COCO further aims at providing comparable data sets from a wide range of optimization algorithms and a long-term support in various programming languages.

In the single-objective unconstrained/bound constrained case of blackbox optimization, the COCO platform has become a quasi-standard with 150+ algorithm data sets freely available to the optimization community. In 2016, an extension of COCO towards bi-objective blackbox optimization has been proposed—following a well-founded methodology for performance assessment of multiobjective optimization algorithms when multiple objective functions have to be optimized simultaneously.

In this talk, I will detail how to use COCO, how we build the (multiobjective) test functions, which concepts lie behind the general performance assessment methodology of COCO, and finally show results we obtain from 16 multiobjective optimization algorithms that have been submitted to the Blackbox Optimization Benchmarking (BBOB) workshops at GECCO'2016 and GECCO'2017.

This is joint work with the entire COCO/BBOB community and relevant for the two currently running PGMO projects NumBER and AESOP.

Unit Commitment under Market Equilibrium Constraints

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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, or in more recent and more realistic approaches, that a set of possible demand scenarios is known (leading to stochastic or robust optimization problems).

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. 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.

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 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, as a first approach to the problem, we assume that demand curves and offers of competitors in the market are known to the operator. This is a very strong and unrealistic hypothesis, but necessary to develop a first model. 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. Then we present some preliminary results on the performance of MIP solvers on this model. Our future research will focus on strengthening the model using its structure to include new valid inequalities or to propose alternative extended formulations, and then study a stochastic version of the problem where demand curves are uncertain.

Distributed control of a fleet of batteries

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Key words: Distributed Control, Stochastic Control, Storage.

Battery storage is increasingly important for grid-level services such as frequency regulation, load following, and peak-shaving. The management of a large number of batteries presents a control challenge: How can we solve the apparently combinatorial problem of coordinating a large number of batteries with discrete, and possibly slow rates of charge/discharge? The control solution must respect battery constraints, and ensure that the aggregate power output tracks the desired grid-level signal.

A distributed stochastic control architecture is introduced as a potential solution. Extending prior research on distributed control of flexible loads, a randomized decision rule is defined for each battery of the same type. The power mode at each time-slot is a randomized function of the grid-signal and its internal state. The randomized decision rule is designed to maximize idle time of each battery, and keep the state-of-charge near its optimal level, while ensuring that the aggregate power output can be continuously controlled by a grid operator or aggregator.

Numerical results show excellent tracking, and low stress to individual batteries. It is remarkable that a fleet of 'dumb, slow batteries' can accurately track a grid level signal with much faster temporal characteristics, while maintaining individual SoC within desired bounds.

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An online disaggregation algorithm and its application to demand control

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Key words: Hidden Markov Models, Bayesian nonparametric, Gibbs samplers, particle filters.

The increase of renewable energy has made the supply-demand balance of power more complex to handle. In [1], the authors designed randomized controllers to obtain ancillary services to the power grid by harnessing inherent flexibility in many loads.

However these controllers suppose that we know the consumption of each device that we want to control. This introduce the cost and the social constraint of putting sensors on each device of each house. Therefore, our approach was to use Nonintrusive Appliance Load Monitoring (NALM) methods to solve a disaggregation problem. The latter comes down to estimating the power consumption of each device given the total power consumption of the whole house.

We started by looking at the Factorial Hierarchical Dirichlet Process - Hidden Semi-Markov Model (Factorial HDP-HSMM) introduced in [2]. In our application, the total power consumption is considered as the observations of this state-space model and the consumption of each device as the state variables. Each of the latter is modelled by an HDP-HSMM which is an extension of a Hidden Markov Model.

However, the inference method used in [2] is based on Gibbs sampling and has a complexity of $\mathcal{O}(T^2N+TN^2)$ where T is the number of observations and N is the number of hidden states. As our goal is to use the randomized controllers with our estimations, we wanted a method that does not scale with T. Therefore, we developed an online algorithm based on particle filters. Because we worked in a Bayesian setting, we had to infer the parameters of our model. To do so, we used a method called Particle Learning which is presented in [3]. The idea is to include the parameters in the state space so that they are tied to the particles. Then, for each (re)sampling step, the parameters are sampled from their posterior distribution with the help of Bayesian sufficient statistics.

We applied the method to data from Pecan Street. Using their Dataport, we have collected the power consumption of each device from about a hundred houses. We selected the few devices that consume the most and that are present in most houses. We separated the houses in a training set and a test set. For each device of each house from the training set, we estimated the operating modes with a HDP-HSMM and used these estimations to compute estimators of the priors hyperparameters. Finally we applied the particle filters method to the test houses using the computed priors.

The algorithm performs well for the devices with the highest power consumption, which is the air compressor (of the air conditioning system) in the case of Pecan Street data. We will end the presentation by an overview of the ongoing work on combining the proposed online learning algorithm with the control techniques in [1] for Thermally Controlled Loads.

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Quadratic Mean Field Games and Entropy Minimization. Part I: Theory

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Key words: MFG, entropy, Sinkhorn algorithm, Schrödinger bridges and entropic interpolation.

The minimization of a relative entropy (with respect to the Wiener measure) is a very old problem which dates back to Schrödinger. C. Leonard has established strong connections and analogies between this problem and the Monge-Kantorovich problem with quadratic cost (namely the standard Optimal Transport problem). In particular, the entropic interpolation leads to a system of PDEs which present strong analogies with the MFG system with a quadratic Hamiltonian. In this talk, we will explain how such systems can indeed be obtained by minimization of a relative entropy at the level of measures on paths with an additional term involving the marginals in time. Connection with incompressible fluid dynamics will also be discussed.

On the discretization of some nonlinear Fokker-Planck-Kolmogorov equations and applications

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Key words: Fokker Planck equations, Numerical analysis, Mean field games, Hughes model.

In this talk, which is based on the preprint [1], we consider the discretization of some nonlinear Fokker-Planck-Kolmogorov equations. The scheme we propose preserves the non-negativity of the solution, conserves the mass and, as the discretization parameters tend to zero, has limit measure-valued trajectories which are shown to solve the equation. This convergence result is proved by assuming only that the coefficients are continuous and satisfy a suitable linear growth property with respect to the space variable.

We apply our results to several examples, including Mean Field Games systems and variations of the Hughes model for pedestrian dynamics.

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A Gaussian Type Kernel for Persistence Diagrams

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Key words: Topological data analysis, kernel methods, optimal transport

Persistence diagrams (PDs) play a key role in topological data analysis (TDA), in which they are routinely used to describe topological properties of complicated shapes. PDs enjoy strong stability properties and have proven their utility in various learning contexts. They do not, however, live in a space naturally endowed with a Hilbert structure and are usually compared with non-Hilbertian distances, such as the bottleneck distance. To incorporate PDs in a convex learning pipeline, several kernels have been proposed with a strong emphasis on the stability of the resulting RKHS distance w.r.t. perturbations of the PDs. In this work [1], we show how the Sliced Wasserstein approximation of the Wasserstein distance can be used to define a new kernel for PDs, which is not only provably stable but also discriminative w.r.t. the 1-bottleneck distance between PDs. We also provide experimental data demonstrating the practicality of our kernel and illustrating how its metric behavior approaches that of the standard Gaussian kernel.

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Optimization and control of heterogeneous tumors

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Key words: tumor growth, chemotherapy, metronomic dose, singular arcs, viability

To prevent the emergence of drug resistance during cancer chemotherapy, most medical protocols use the maximal tolerated dose (MTD) of drug possible. In a series of *in vitro* experiments at the Center for Research in Oncobiology and Oncopharmacology of Marseille La Timone (CRO2, INSERM), M. Carré showed that such protocols fail if resistant cells are present in the initial tumour. However, smaller doses of treatment maintain a small, stable tumour sensitive to the drug. An ODE model of these experiments is designed, and then studied under different frameworks to create new treatment protocols, stabilizing the tumor while maintaining its heterogeneity. We use mainly analysis of ODEs, optimal control theory and Hamilton-Jacobi-Bellman framework, each corresponding to different treatment objectives.

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Towards a More Practice-Aware Theory for Evolutionary Algorithms

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Key words: Discrete Optimization, Heuristics, Evolutionary Computation

Theory of evolutionary computation (EC) aims at providing mathematically founded statements about the performance of evolutionary algorithms (EAs). The predominant topic in this research domain is *runtime analysis*, which studies the time it takes a given EA to solve a given optimization problem. Runtime analysis has witnessed significant advances in the last couple of years, allowing us to compute precise runtime estimates for several EAs and several problems.

Runtime analysis is, however (and unfortunately!), often judged by practitioners to be of little relevance for real applications of EAs. Several reasons for this claim exist. In [PD17] we address two of them: (1) EA implementations often differ from their vanilla pseudocode description, which, in turn, typically form the basis for runtime analysis. To close the resulting gap between empirically observed and theoretically derived performance estimates, we therefore suggest to take this discrepancy into account in the mathematical analysis and to adjust, for example, the cost assigned to the evaluation of search points that equal one of their direct parents (provided that this is easy to verify as is the case in almost all standard EAs). (2) Most runtime analysis results make statements about the expected time to reach an optimal solution (and possibly the distribution of this optimization time) only, thus explicitly or implicitly neglecting the importance of understanding how the function values evolve over time. We suggest to extend runtime statements to *runtime profiles*, covering the expected time needed to reach points of intermediate fitness values.

While our suggested solutions can only serve as a pointer to a more practice-aware runtime analysis theory, we are confident that our work helps to initiate a more constructive exchange between theoretical and empirically-driven research in heuristic optimization.

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Energy Management Systems and Demand Response

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Key words: Energy Management System, Battery Energy Storage System, Load-Shaving, Multi-objective Optimization.

Intermittent sources of energy represent a challenge for electrical networks, particularly regarding demand satisfaction at peak times. Demand-side management tools, more precisely load shaving, can be used to mitigate abrupt changes in the generation. Another tool to control the negative impact of the new technologies is to rely on the so-called Energy Management Systems (EMS). Typically, this virtual entity represents a group of small generators coupled with a battery. The battery stores any energy surplus at off-peak times, when generation is larger than demand. The EMS supplies energy to the system when it lacks power. The battery then functions as a “reservoir" that can be depleted when most needed. This storage is not free as some energy is lost when charging and discharging the battery.

The coordination of the EMS requires the resolution of an optimal control problem with state constraints. We consider a model similar to [1]; see also [2] with the important difference that we extend the approach to the multi-objective case, [3]. Namely, in addition to the usual cost-minimization we incorporate an environmental concern, referred to minimizing fuel emissions. A third objective, aiming at maximizing the battery life, could also be included in the formulation.

The question that arises is: can batteries be used as a replacement for load shaving? For a simple, yet representative, power mix, coupled with batteries of different capacities and output, we investigate their ability in smoothing the load peaks, when compared with the load shaving mechanism.

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The price of anarchy in light and heavy traffic: When is selfish routing bad?

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Key words: Nonatomic congestion games, price of anarchy, regular variation, social optimality, Wardrop equilibrium.

We examine the behavior of the price of anarchy as a function of the traffic inflow in nonatomic congestion games with multiple origin-destination (O/D) pairs. Empirical studies in real-world networks show that the price of anarchy is close to 1 in both light and heavy traffic, thus raising the question: can these observations be justified theoretically? We first show that this is not always the case: the price of anarchy may remain bounded away from 1 for all values of the traffic inflow, even in simple three-link networks with a single O/D pair and smooth, convex costs. On the other hand, for a large class of cost functions (including all polynomials), the price of anarchy *does* converge to 1 in both heavy and light traffic conditions, and irrespective of the network topology and the number of O/D pairs in the network.

Specifically, our main results can be summarized as follows:

- In the *low congestion* limit, we focus on cost functions that are *real analytic*, i.e., they are equal to their power series expansion near 0. Under this regularity assumption, we show that the price of anarchy converges to 1, no matter the network topology or the number of O/D pairs in the network.

- At the other end of the spectrum, to tackle the *high congestion* limit, we introduce the concept of a *benchmark function*. This is a regularly varying function $c(x)$ that classifies edges into *fast*, *slow* or *tight*, depending on the growth rate of the cost along each edge; paths are then classified as fast, slow or tight, based on their slowest edge (for instance, if all the network's cost functions are polynomials of degree d, all edges, paths and O/D pairs are tight with respect to x^d). We then establish the following general result: *if the "most costly" O/D pair in the network admits a tight path, the network's price of anarchy converges to* 1 *under heavy traffic.*

Finally, we also examine the rate of convergence of the price of anarchy to 1 in the heavy traffic limit, and we show that it follows a power law whose degree can be computed explicitly when the network's cost functions are polynomials.

Toward Large-Scale Domain Adaptation with Optimal Transport Strategies

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Key words: Domain Adaptation, Transfer Learning, Optimal Transport.

In modern machine learning, large scale datasets are commonly used on classical problems such as supervised classification. Yet, labelled data are not always available at hand. One can leverage on existing labelled datasets to enhance the performance of a given classifier, but one has generally to assume that the data to classify is a realization of the same process that generated the set used for learning. Yet, in many practical applications (*e.g. visual adaptation [1]*), it is not the case. Domain adaptation techniques aim at alleviating this issue by transferring knowledge between domains [2].

This work deals with the unsupervised domain adaptation problem, where one wants to estimate a prediction function f in a given target domain without any labeled sample by exploiting the knowledge available from a source domain where labels are known. Our work makes the following assumption: there exists a non-linear transformation between the joint feature/label space distributions of the two domain $\mathcal{P}_s$ and $\mathcal{P}_t$. We proposed a new solution of this problem [4] that builds on existing methods based on optimal transport [3]. It notably allows to recover an estimated target $\mathcal{P}_t^f = (X, f(X))$ by optimizing simultaneously an optimal coupling and f. We show that our method corresponds to the minimization of a bound on the target error, and provide an efficient algorithmic solution, for which convergence is proved. The versatility of our approach, both in terms of class of hypothesis or loss functions is demonstrated with real world classification and regression problems, for which we reach or surpass state-of-the-art results. We also discuss how to scale this approach to work on large datasets, considering that computing large scale Optimal Transport problems is still an issue.

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Multiband Robust Optimization for the Green Design of Wireless Local Area Networks

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Key words: Wireless Network Design, User Mobility Uncertainty, Wireless Propagation Uncertainty, Binary Linear Programming, Multiband Robust Optimization.

We consider an optimization problem arising in the energy-saving design (so-called Green design) of Wireless Local Area Networks (GWLAN). A WLAN can be essentially described as a set of Access Points (APs) that provide wireless telecommunication services to a set of User Terminals (UTs). The problem of optimally designing a GWLAN consists in minimizing the power consumption of a WLAN by: i) activating only a subset of APs when traffic load is low, and ii) associating UTs to activated APs, while taking into account the data rates between UTs and APs. In this work, we propose a *Multiband Robust Optimization (MRO)* model for GWLAN design to protect against adverse fluctuations in the data rates that naturally occur over short time periods. MRO is essentially based on the use of histogram-like uncertainty sets, which result particularly suitable to represent empirical distributions commonly available in real-world problems. Specifically, we propose to use MRO to model the user mobility uncertainty, while we adopt classical Γ-Robustness to model the fluctuations in the wireless channel conditions. The rationale is that a more accurate model of the user mobility, based on the adoption of multiple deviation bands, can better represent the real link data rate variations, which depend on the distance. This allows to derive an improved association of the users to the APs, and thus higher reductions in energy consumption. Computational tests on realistic WLAN instances show that our model can be solved efficiently and grants relevant advantages with respect to Γ-Robustness in terms of the robustness quality of the produced solutions, leading to relevant energy savings.

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From Estimation to Optimization: A Journey via Shrinkage

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Key words: Stochastic optimization, parameter estimation, Bayes estimator, admissible estimator, shrinkage estimator.

In practical decision making, optimization often involves uncertain elements arising from a random process. In the current data-rich environment, samples realized from the underlying random process are often used to estimate the unknown factors about the distribution of the uncertain elements. Traditionally, the estimation process is performed separately from the optimization, and its output estimator is used as a known input for the optimization problem to obtain solutions. Two interesting questions are (i) whether the estimation and optimization tasks can be performed separately without compromising the quality of the end solution, and (ii) whether these tasks can be integrated to improve the solution quality. For example in portfolio optimization, an investor may want to construct a portfolio of risky assets that maximizes his expected return against risk (Markowitz [1]). When historical data on the asset returns are used to estimate the expected returns, the separate scheme of estimation and optimization recommends to *shrink* the vector of sample averages towards a *grand average* (Jorion [2]) to obtain better portfolios. We address the question of where does this *shrinkage* idea fit in the optimization literature and how general is it.

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Dynamic programming approach for bidding problems on day-ahead markets

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Key words : Dynamic programming, day-ahead market, bi-level optimization.

In several markets, such as the electricity market, spot prices are determined via a bidding system involving an oligopoly of producers and a system operator. Once time-dependent price-quantity bids are placed by each producer for its production units, the system operator determines a production schedule that meets demand at minimal cost. The spot price charged to the customers is then set to the marginal production cost. Fampa et al. [1] have considered the problem faced by a profit-maximizing producer, whose bids depend on the behaviour of the system operator, as well as the stochastic nature of final demand, and that can be cast within the framework of stochastic bilevel programming. In this presentation, we consider an enhanced model that embeds two key features, namely the uncertainty related to competitors' bids, as well as the impact of spot prices on demand. Our aim is to develop efficient solution algorithms for addressing instances involving a large number of scenarios. Under the assumptions that production costs are linear and that demand is piecewise constant, the bilevel model can be reformulated as a large mixed integer program. Although this problem becomes numerically intractable as the number of scenarios increases, it becomes much simpler when producers are allowed to place different price-quantity bids for a given generator. This relaxation of the original problem can than be solved in polynomial time by a dynamic programming algorithm. This algorithm can then be adapted to heuristically solve the original problem, yielding very quickly feasible solutions characterized by small optimality gaps. The performance of the method has been tested on instances inspired from the Brazilian Electric System National Operator.

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How much is information worth? An insight using duality between choices and beliefs

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Key words: value of information, convex analysis, duality

It is common wisdom that information is valueless if it does not impact choices. We elaborate on this intuition using the framework of convex analysis, especially duality. We consider an agent who acquires information on a state of nature from an information structure before facing a decision problem. How much information is worth depends jointly on the decision problem and on the information structure. We sum up the decision problem in the set of all possible payoffs, in every state of nature, and we identify payoffs with choices. Taking the support function of this set (or the Fenchel transform of its characteristic function), we show that we obtain the value of information function — which maps beliefs to expected payoffs under optimal choices at these beliefs. We then derive global estimates of the value of information of any information structure from local properties of the value function and of the set of optimal choices taken at the prior belief only.

Learning how to segment flows in the dark

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Key words: software defined networks, flow segmentation, stochastic approximation, adaptive algorithms, traffic classifiers

To optimize routing of flows in datacenters, SDN controllers receive a packet-in message whenever a new flow appears in the network. Unfortunately, flow arrival rates can peak to millions per second [1], impairing the ability of controllers to treat them on time. Flow scheduling, e.g. [2], copes with such sheer numbers by segmenting the traffic between elephant and mice flows and by treating elephant flows in priority, as they disrupt short lived TCP flows and create bottlenecks.

We formulate a flow segmentation problem that segment elephant from mice flows; the aim is to schedule a maximum amount of traffic under a constraint on the maximum rate of packet-in events. We propose a learning algorithm able to perform optimal online flow segmentation. Our solution, based on stochastic approximation techniques, is implemented at the switch level and updated by the controller, with minimal signaling over the control channel.

Our approach is blind, i.e., it is agnostic to the flow size distribution. It is also adaptive, since it can track traffic variations over time. We prove its convergence properties and its message complexity. Moreover, we specialize our solution to be robust to traffic classification errors and we provide conditions under which our algorithm still converges to the optimal solution. Extensive numerical experiments characterize the performance of our approach *in vitro*. Finally, results of the implementation in a real OpenFlow controller demonstrate the viability of our method as a solution in production environments.

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A New Approach to Nonnegativity and Polynomial Optimization

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Key words: Circuit Polynomial, Geometric Programming, Nonnegativity, Relative Entropy Programming

In 2014, Iliman and I introduced a new nonnegativity certificate based on *sums of nonnegative circuit polynomials (SONC)*. Circuit polynomials are sparse polynomials, which are *not* SOS in general.

For global optimization, SONC certificates can be detected via geometric programming. For high degree polynomials, these certificates can be computed significantly faster than SOS based certificates via SDPs.

For constrained optimization, SONC certificates provide a converging hierarchy of lower bounds, which can be computed via relative entropy programming.

In this talk I give an overview about polynomial optimization via SONCs and the current state of the implementation of corresponding software.

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A Framework for Optimal Investment Strategies for Competing Camps in a Social Network

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Keywords: Social networks, opinion dynamics, common coupled constraints, decision under uncertainty, multiple phases.

Opinion dynamics is a natural and well-known phenomenon in a system of cognitive agents, and is a well-studied topic across several disciplines. We study the problem of optimally investing in nodes of a social network in a competitive setting, wherein two camps attempt to maximize adoption of their opinions by the population. This problem is highly relevant to applications such as elections, viral marketing, propagation of ideas or behaviors, etc. In particular, we propose an extension of the popular DeGroot-Friedkin model [1], show its convergence, and hence formulate the problem as a zero-sum game, where the players are the two camps and their strategies are the amounts to be invested on each node of the social network.

We consider several settings, namely, when the influence of a camp on a node is a concave function of its investment on that node, when one of the camps has uncertain information about the values of the model parameters, and when a camp aims at maximizing competitor's investment required to drive the average opinion in its favor. We also study this game under common coupled constraints concerning the combined investment of the camps on each node, and analytically derive the optimal investment strategies of both the camps. The introduction of common coupled constraints results in maxmin value to be greater than or equal to the minmax value, an opposite inequality to the case of general functions, as also deduced in [2]; this can be perceived as a consequence of the first mover advantage in our game.

We further study the possibility of campaigning in multiple phases, where the final opinion of a node in a phase acts as its initial bias for the next phase. We show that the utility functions of the two camps involve what can be interpreted as a multiphase version of Katz centrality [3]. Focusing on opinion dynamics in two phases, we analyze their optimal investment strategies and derive the extent of loss that a camp would incur if it acted myopically. We then look at the setting in which a camp's influence on a node depends on the node's initial bias, for which we present a polynomial time algorithm for optimally splitting the budget between the two phases.

We conduct a simulation study on real-world social networks for all the considered settings.

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The (1+λ) Evolutionary Algorithm with Self-Adjusting Mutation Rate

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Key words: Evolutionary algorithm, mutation rate, self-adjusting, optimization time.

In [1], we propose a new way to self-adjust the mutation rate in population-based evolutionary algorithms in discrete search spaces. Roughly speaking, it consists of creating half the offspring with a mutation rate that is twice the current mutation rate and the other half with half the current rate. The mutation rate is then updated to the rate used in that subpopulation which contains the best offspring.

We analyze how the (1+λ) evolutionary algorithm (EA) with this self-adjusting mutation rate optimizes the OneMax test function. We prove that this dynamic version of the $(1+\lambda)$ EA finds the optimum in an expected optimization time (number of fitness evaluations) of $O(n\lambda/\log\lambda + n\log n)$. This time is asymptotically smaller than the optimization time of the classic $(1+\lambda)$ EA. We observe that the mutation rate, regardless of its initial value, quickly adopts a value of $\Theta(\ln(n)/n)$, which allows to gain a logarithmic number of fitness levels per generation. When approaching the optimum, the rate adjusts to a $\Theta(1/n)$ value, which is optimal in this regime.By a result of [2], the performance of our self-adjusting $(1+\lambda)$ EA is also the best-possible among all λ-parallel mutation-based unbiased black-box algorithms.

This result shows that the new way of adjusting the mutation rate can find optimal dynamic parameter values on the fly. Since our adjustment mechanism is simpler than the ones previously used for adjusting the mutation rate and does not have own parameters itself, we are optimistic that it will find other applications.

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Fast Genetic Algorithms

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Key words: Evolutionary algorithm, mutation operator, heavy-tailed distribution.

For genetic algorithms (GAs) which use a bit-string representation of length n, the general recommendation is to take $1/n$ as mutation rate. In this work, we discuss whether this is justified (except for very easy objective functions). Taking jump functions and the $(1+1)$ evolutionary algorithm (EA) as the simplest example, we observe that larger mutation rates give significantly better runtimes. For the $\text{JUMP}_{m,n}$ function, any mutation rate between $2/n$ and m/n leads to a speed-up at least exponential in m compared to the standard choice.

However, the asymptotically best runtime, obtained from using the mutation rate m/n and leading to a speed-up super-exponential in m, is very sensitive to small changes of the mutation rate. Any deviation by a small $(1\pm\varepsilon)$ factor leads to a slow-down exponential in m. Consequently, any fixed mutation rate gives strongly sub-optimal results for most jump functions.

Building on this observation, we propose to use a random mutation rate α/n, where α is chosen from a power-law distribution. We prove that the $(1+1)$ EA with this heavy-tailed mutation rate optimizes any $\text{JUMP}_{m,n}$ function in a time that is only a small polynomial (in m) factor above the one stemming from the optimal rate for this m. We obtain similar speed-ups for two combinatorial optimization problems. First experimental work ([2] and unpublished material) shows that these improvements not only exist in asymptotic terms, but also for realistic problem sizes and real-world problems. Following the example of fast simulated annealing, fast evolution strategies, and fast evolutionary programming, we propose to call genetic algorithms using a heavy-tailed mutation operator *fast genetic algorithms*.

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Boosting Discrete Optimization Heuristics through Non-Static Parameter Choices—A Survey of Empirical and Theoretical Results

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Key words: Discrete Optimization, Heuristics, Evolutionary Computation

Heuristic optimization techniques are algorithms that trade the quality of a solution for simple algorithmic structures and fast running times. For many real-world optimization challenges—which are more often than not too complex to be addressed by exact methods—heuristics offer the only possibility to obtain reasonable solutions within a given resource budget. Heuristics are therefore among the most frequently applied techniques in the optimization of large-scale industrial and academic problems.

A key challenge of heuristic optimization, known as the **"exploration vs. exploitation trade-off"**, is balancing the risks of a too slow convergence with that of a premature one. Heuristics essentially differ in how they address this trade-off. Almost all heuristics are (explicitly or implicitly) parametrized, allowing to adjust the calibration of the two risks to the problem at hand. The choice of these parameters has a decisive influence on performance. At the same time, **parameter selection** is one of the most difficult tasks in the application of heuristic techniques, because of complex and hard to foresee interactions between the decision variables. Complicating further, the optimal parameter values can change quite drastically during the optimization process.

Parameter control aims at determining mechanisms that automatically identify and track good parameter values throughout the whole optimization process. While being well researched in continuous optimization, parameter control has not yet tapped its potential in discrete optimization, thus leaving room to improve upon state-of-the-art heuristic optimization algorithms. The purpose of this talk is to survey and to discuss online parameter update schemes that have been proposed in the literature. **The talk addresses experimentally- as well as theory-oriented researchers alike**. It is based on a recent tutorial [Doe17] held at the 2017 Genetic and Evolutionary Computation Conference. Pointers to relevant literature can be found in [Doe17] as well.

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Stability versus Optimality in Optimization over Time

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Key words: Graph algorithms, approximation algorithms, dynamic optimization.

We focus in this talk on situations where the input of an optimization problem changes over time, and a dynamic solution has to be maintained. In such situations, where a sequence of solution has to be computed, there is usually a (potentially high) transition cost between consecutive dynamic solutions. So, besides the intrinsic quality of solutions, we are interested in the stability of the sequence of solution over time (minimizing transition costs). Designing models and algorithms that explicitly take into account transition costs is a core issue of the PGMO project that led to the results of this talk. We aim at designing algorithms find good tradeoffs between (1) computational complexity issues (efficient algorithms) (2) quality issues (solutions have to be good ones) (3) stability issues (small transition costs).

Two recent articles [2, 1] considers such a model of optimization over time, where the goal is to find a sequence of solution optimizing a function which aggregates quality of solutions and transition costs. In this talk, we will present some results obtained in this framework for the Santa Claus problem. In the (static) problem, we are given a set of presents (tasks), a set of children (machines), a utility (processing time) for each present by each child. The goal is to distribute presents to children (process tasks on machines) so that the least happy child is as happy as possible (the load of the minimum loaded machine is maximal). We will present some constant ratio approximation algorithms in several cases (off-line, on-line, identical or unrelated machines) in the considered model of optimization over time.

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Price incentives in mobile data networks: bilevel programming, competitive equilibria and discrete convexity

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Key words: Smart data pricing, competitive equilibria, bilevel programming, tropical geometry, discrete convexity.

We propose a bilevel programming problem modeling a price incentives scheme in mobile data networks ([1]). A telecom operator wishes to balance the traffic, in order to ensure a sufficient quality of service to its users. He proposes price discounts at certain hours and in certain areas. Each user has a given total demand per day, which he may assign to different locations and time slots, depending on his own preferences and on price discounts proposed by the operator. We show that this can be modeled as a special bilevel programming problem. We present here a decomposition method to solve it: first, we determine the optimal traffic (which maximizes a measure of balance); next, we determine the prices generating this traffic. Our results exploit recent applications of tropical geometry to economic problems ([2],[3]) , as well as algorithms in discrete convexity ([4]). Finally, we compare this bilevel programming problem with a competitive equilibrium problem for indivisible goods ([5]). We show that the studied bilevel programming problem is a limit case of the competitive equilibrium problem.

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User preferences in Bayesian multi-objective optimization

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Key words: Bayesian optimization, Multi-objective optimization, Sequential Monte-Carlo, Expected improvement, Hypervolume measure.

In this talk, we shall present results from [1] on the taking into account of user preferences in multi-objective Bayesian optimization. More specifically, we consider the case where the objectives and constraints defining the optimization problem are expensive-to-evaluate black-box functions and introduce a new *expected improvement* criterion to be used within Bayesian optimization algorithms. This new criterion, which we call the *expected weighted hypervolume improvement* (EWHI) criterion, is a generalization of the *expected hypervolume improvement* (see e.g. [2]) to the case where the hypervolume indicator is defined using a weighted measure instead of the usual Lebesgue measure. The introduction of a weight function in the definition of the hypervolume indicator makes it possible to compare alternative non-dominated solutions according to user preferences, thus orienting the search for optimal solutions toward preferred regions of the Pareto front (see e.g. [3]).

The EWHI criterion takes the form of an integral over the space of objectives and constraints for which no closed form expression exists in the general case. To deal with its computation, we propose an importance sampling approximation method. A sampling density that is optimal for the computation of the EWHI for a set of points is crafted and a sequential Monte-Carlo approach (see e.g. [4]) is used to obtain a sample approximately distributed from this density. The variance of the Monte-Carlo approximation thus obtained is briefly discussed.

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Nonlinear Fisher Particle Output Feedback Control and its application to Terrain Aided Navigation

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

The problems of control and state estimation of a dynamical system are traditionally treated separately i.e. the controller supposes that the state estimate has already been computed to determine the control. The main advantage of this method is its simplicity and modularity. Indeed, one can choose almost any control and estimation methods, and merge both of them. The main drawback is that the control cannot influence the state estimator and, for example, it can lead the system to areas where the state is not observable. Then, one could take advantage of the control to improve the state estimation. It is then said that the control has a *dual effect* [1]. It guides the system in a standard way and, at the same time, it looks for more information about it. Our approach consists in gathering the two previous problems in one stochastic optimal control problem with imperfect state information. In this framework, the Dynamic Programming principle can still be applied with a new system which represents the evolution in time of the conditional distribution of the state with respect to the available information.

Actually, we consider one specific problem of this type that combines state estimation and control additively in its cost function, to create explicitly dual effect. Due to the curse of dimensionality, only sub-optimal policies can be computed. Thus, we propose one based on two successive approximations. The first approximation consists in replacing the term corresponding to the state estimation in the cost by a simpler one based on the *Fisher information matrix* which maintains the dual effect. The second approximation is a particle approximation close to the one described in [2] and is used, both inside the optimization problem to find the control, and outside the optimization problem to estimate the state.

This method has been applied to the localization and guidance of a drone over a known terrain with height measurements only. In this model, it is known that the state estimates are poorly accurate if the drone flies over a flat area and satisfactorily accurate if the drone flies over a rough terrain. The simulations show that the new method drives the drone over the rough terrains which improves the estimation accuracy compared to the results of a method which does not involve dual effect.

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First and Second Order Necessary Optimality Conditions in Stochastic Optimal Control Problems with End-Point Constraints

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Key words: Stochastic optimal control, maximum principle, second order variational analysis

We discuss first and second order necessary optimality condition for the stochastic optimal control problem of Mayer's type with end-point constraints. In our setting the control set may be not convex, the diffusion term may depend on the control variable and the final state constraint is described by finitely many inequalities. Using second-order variational analysis we derive in a direct way necessary optimality conditions in a very general framework. The main tools of our approach are second order stochastic variational equations, inverse mapping theorems and the duality theory, allowing to avoid the usual reformulation of the stochastic optimal control problem as an infinite dimensional mathematical programming one. To illustrate our results we also consider the case when the control set is described by mixed constraints involving both equalities and inequalities.

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Non-asymptotic bound for stochastic averaging

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Key words: Stochastic algorithms, Convex and Non-convex Optimization, Averaging.

This work is devoted to the non-asymptotic control of the mean-squared error for the Ruppert-Polyak stochastic averaged gradient descent introduced in the seminal contributions of [1] and [2]. Starting from a standard stochastic gradient descent algorithm introduced by Robbins and Monro to minimize a smooth convex function f with noisy inputs, they define a sequence $(\theta_n)_{n\geq 1}$ through:

$$\theta_{n+1} = \theta_n - \gamma_{n+1}\nabla f(\theta_n) + \gamma_{n+1}\Delta M_{n+1}.$$

where $-\nabla f(\theta_n) + \Delta M_{n+1}$ stands for a gradient step corrupted by an additive noise at each step. The averaging procedure introduced in [1, 2] consists in computing a Cesaro average:

$$\hat{\theta}_n := \frac{1}{n}\sum_{1}^{n} \theta_n. \tag{1}$$

In our main results, we establish non-asymptotic tight bounds (optimal with respect to the Cramer-Rao lower bound) in a very general framework that includes the uniformly strongly convex case as well as the one where the function f to be minimized satisfies a weaker Kurdyka-Łojiasewicz-type condition [3, 4]. In particular, it makes it possible to recover some pathological examples such as on-line learning for logistic regression (see [5]) and recursive quantile estimation (an even non-convex situation). Finally, our bound is optimal when the decreasing step $(\gamma_n)_{n\geq 1}$ satisfies: $\gamma_n = \gamma n^{-\beta}$ with $\beta = 3/4$, leading to a second-order term in $O(n^{-5/4})$.

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Targeting Well-Balanced Solutions in Multi-Objective Bayesian Optimization under a Restricted Budget

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Key words: Gaussian Processes, Parsimonious Optimization, Computer Experiments, Preference-Based Optimization

Multi-objective optimization aims at finding the Pareto set composed of all the best trade-off solutions between several objectives. When dealing with expensive-to-evaluate black box functions, surrogate-based approaches, in the vein of EGO [1] haven proven their effectiveness.

However, for extremely narrow budgets, and/or when the number of objectives is large, uncovering the entire Pareto set becomes out of reach even for these approaches. In this work, we restrict our search to well-chosen targeted parts of the Pareto set. This accelerates the search as only a subset of the objective space is considered. As an end-user would typically choose solutions with equilibrated trade-offs between objectives rather than ones favoring a single objective over the others, we will focus on the central part of the Pareto Front, which corresponds to the most well-balanced solutions.

First, we discuss how to define and estimate the center of the Pareto Front. That estimated point has to fairly represent the topology of the front, in spite of the parsimonious knowledge of the objective space. Then, three infill criteria which will guide the optimization, including the *Expected Hypervolume Improvement* [2] are studied and tailored through some of their hyperparameters to enable them to target.

To assess performance, a benchmark built from real-world airfoil aerodynamic data, with variable dimension and number of objectives is used. Compared with standard techniques, the proposed methodology leads to a faster and a more precise convergence towards the Pareto Front in the targeted region.

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Learning Generative Models with the Wasserstein Distance

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Key words: Optimal transport, machine learning, generative models, neural networks

The ability to compare two degenerate probability distributions is a crucial problem arising in the estimation of generative models for high-dimensional observations such as those arising in computer vision or natural language.

It is known that optimal transport metrics can represent a cure for this problem, since they were specifically designed as an alternative to information divergences to handle such problematic scenarios. Unfortunately, training generative machines using OT raises formidable computational and statistical challenges, because of *(i)* the computational burden of evaluating OT losses, *(ii)* the instability and lack of smoothness of these losses, *(iii)* the difficulty to estimate robustly these losses and their gradients in high dimension.

This talk will introduce a tractable computational method to train large scale generative models using an optimal transport loss, and tackles these three issues by relying on two key ideas: (a) entropic smoothing, which turns the original OT loss into one that can be computed using Sinkhorn fixed point iterations; (b) algorithmic (automatic) differentiation of these iterations. These two approximations result in a robust and differentiable approximation of the OT loss with streamlined GPU execution, and its performance will be demonstrated on image generation tasks.

Eventually, we will discuss the how entropic smoothing might be a simple way to interpolate between optimal transport losses and MMD-type losses which have also recently gained interest.

On risk averse competitive equilibrium

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Key words: Stochastic Equilibrium, Stochastic Programming, Risk averse equilibrium, Electricity Markets.

Motivated by the management of electricity markets, we discuss risked competitive partial equilibrium in a setting in which agents are endowed with coherent risk measures.

In this case, [1] have shown that it is possible to define a complete market for risk. Then a perfectly competitive partial equilibrium will be efficient i.e. will also maximize risk-adjusted social welfare. If the market for risk is not complete, then equilibrium can be inefficient.

We make the following contribution:

- we show a reverse statement between risk averse equilibrium problems in complete markets adapting a result from [2],
- in contrast to social planning models, we show by example that risked equilibria are not unique, even when agents' objective functions are strictly concave,
- we also show that standard computational methods find only a subset of the equilibria, even with multiple starting points.

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Theory and numerical practice for optimization problems involving ℓ^p-functionals, with $p \in (0,1]$

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Key words: nonconvex nonsmooth optimization, monotone algorithm, fracture mechanics, optimal control, image reconstruction

Abstract

Nonsmooth nonconvex optimization problems involving the ℓ^p quasi-norm, $p \in (0,1]$, of a linear map are considered. A monotonically convergent scheme for a regularized version of the original problem is developed and necessary optimality conditions for the original problem in the form of a complementary system amenable for computation are given. Then an algorithm for solving the above mentioned necessary optimality conditions is proposed. It is based on a combination of the monotone scheme and a primal-dual active set strategy. The performance of the two schemes is studied and compared to other existing algorithms by means of a series of numerical tests in different cases, including optimal control problems, fracture mechanics and microscopy image reconstruction.

A new look at stochastic variance reduced gradient methods

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We present a new perspective on stochastic variance reduced (SVR) methods as methods that maintain an estimate of the Jacobian of an auxiliary vector valued function. This auxiliary vector valued function is formed by stacking the individual data functions from the empirical risk minimization problem. Through this observation we extend the class of SVR methods by updating the Jacobian estimate using randomized sparse sketches of the true Jacobian. By choosing different randomized sketches we recover known methods: the SAG and SAGA method, their mini-batch variants and even non-uniform sampling variants. These new SVR methods all converge linearly, as dictated by a single convergence theorem. When specialized to known methods, our convergence theorem recovers the best known convergence results for SAGA, and furthermore, we obtain new results for mini-batch and non-uniform sampling variants of SAGA. Thus our work unites all SAGA variants under one framework.

Optimal management under uncertainty of microgrid equipped with PV panels and battery: resolution using McKean-FBSDE *

Emmanuel Gobet †and Maxime Grangereau ‡

Key words: Stochastic Optimal Control, Pontryagin's Stochastic Maximum Principle, Forward-Barckward Stochastic Differential Equation, McKean-Vlasov Interaction, Energy Management.

In the context of energy management, we study the problem of the optimal control of a battery in order to reduce the operating costs of a provider of network electricity. Unlike previous works related to micro-grid management (see [1] and [2]), we consider a system connected to the network and aim at finding an optimal control of the battery that limits both the power peaks and the fluctuations of the power supplied by the network. This results in a stochastic optimal control problem with McKean interaction. We derive necessary and sufficient optimality conditions for the optimal control, using the stochastic Pontryagyn principle, see for example [3]. This gives rise to a particular Mc-Kean-FBSDE for which we establish the existence and uniqueness of a solution. A particular focus is given to the Linear Quadratic case, where the solution can be obtained by solving backward Riccati Ordinary Differential Equations and affine-linear Backward Stochastic Differential Equations and using a closed-loop feedback formula. Some numerical results are given to demonstrate the performance of the approach.

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Nuclear Power Plant Outage Planning: combining Dantzig-Wolfe and Benders decomposition to solve a large-scale industrial stochastic problem

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Key words: Nuclear Outage Scheduling, Stochastic optimization, Dantzig-Wolfe, Benders

The problem of scheduling nuclear power plant outages is of a significant economic importance to EDF (see [1] for a complete description of the problem). These here-and-now decisions have to comply with the uncertainty on the demand and power plants availability. Our study demonstrates that it is possible to improve the planning structure by using several scenarios in order to obtain a more robust solution for real data sets. We built on a deterministic extended formulation approach that enables us to solve real instances to optimality by use of a MIP solver on the original formulation. However, taking into account just a few aggregated scenarios increases the computational time significantly when solving the deterministic equivalent model. Hence, we resort to a row-and-column generation procedure (using BaPCod library [2]), combining variable generation of a Dantzig-Wolfe paradigm with Benders' cut generation to account for stochastic scenarios thanks to the row generation implementation submitted in [3]. In this way we obtain good quality solutions via primal heuristics based on the restricted master IP or diving (described in [4]) within a reasonable amount of time.

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A function space based solution method with space-time adaptivity for parabolic optimal control problems with state constraints

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Key words: Parabolic optimal control, state constraints, space-time discretization, limiting analysis

We consider the distributed optimal control of parabolic partial differential equations subject to pointwise state constraints. To cope with the low regularity of the multiplier that arises in respective first order optimality conditions, and which affects the design of optimization as well as discretization schemes, the state constraints are treated by a Moreau-Yosida regularization. The associated smoothed first order system is reformulated as an optimality condition in terms of only the state variable, which renders an elliptic boundary value problem of second order in time, and of fourth order in space. For the latter, we suggest a C^0 interior penalty method on the space-time domain with tailored terms that enforce suitable regularity in space direction, and behave like a standard P^k conforming finite element method for second order problems in time. A combined numerical analysis of the discretization scheme as well as of the Moreau-Yosida regularization method leads to a solution algorithm that intertwines mesh refinement with an update strategy for the regularization parameter. Since the underlying discrete space is a simple P^k Lagrange finite element on a regular triangulation, this method admits low complexity and high accuracy. In addition, the discretization scheme is amenable to adaptive mesh refinement and allows to simultaneously balance the a posteriori error in space and time, as well as the regularization error.

Optimal Control of Storage under Time Varying Electricity Prices

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Key words: Convex Optimization, Energy Arbitrage, Storage.

End users equipped with storage may exploit time variations in electricity prices to earn profit by doing energy arbitrage, i.e., buying energy when it is cheap and selling it when it is expensive. We propose an algorithm to find an optimal solution of the energy arbitrage problem under given time varying electricity prices. Our algorithm is based on discretization of optimal Lagrange multipliers of a convex problem and has a structure in which the optimal control decisions are independent of past or future prices beyond a certain time horizon. Exploiting this piecewise linear cost structure of the arbitrage problem we find that the optimal Lagrange multipliers can only take a discrete set of values corresponding to buying and selling prices of electricity. This transforms the continuous optimization problem into a discrete optimization problem. We indicate how to tune the Lagrange multiplier variables to these prices to find their optimal values.

From the structure of solution obtained using Lagrangian dual, we observe that to find optimal control decisions in a certain period within the total period it is sufficient to consider prices only within a sub-horizon much smaller than the whole duration. In the proposed algorithm, we show how to calculate these sub-horizons. Using the discrete nature of the optimization, we explicitly characterize the worst case running time complexity of the proposed arbitrage algorithm. The worst case run-time complexity is found to be quadratic in the number of instants for which price values are available. To show the efficacy of the proposed algorithm, we compare its run-time performance with other algorithms used in MATLAB's constrained optimization solvers. Our algorithm is found to be at least ten times faster, and hence has the potential to be used for in real-time.

Using the proposed algorithm, we conducted extended simulations for real price data from several ISOs in USA and Europe for the year 2016. We extrapolate the arbitrage gains for an end user for a five year period, considering detailed losses in the battery. The numerical evaluation suggests that only arbitrage cannot create positive net present value for storage, thus subsidies are required to incentivize investment.

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Polynomial optimization tools for answering connectivity queries in real algebraic sets

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Key words: Real algebraic geometry, Connectivity queries, Motion planning, Polynomial optimization.

Basic semi-algebraic sets are subsets of $\mathbb{R}^n$ defined by polynomial equations and inequalities with real coefficients. These sets describe geometric static situations expressed with algebraic constraints. Their geometry can be rather complicated ; in particular they may be the union of several connected subsets of $\mathbb{R}^n$.

We focus on the algorithmic problem of counting the number of connected components of a given semi-algebraic set or deciding whether two points of such a set can be path-connected in this set. This is a building subroutine to several algorithms for describing the topology of semi-algebraic sets ; it also finds many applications, in particular in robotics, since semi-algebraic sets describe naturally the configuration space of some robots.

When the input semi-algebraic set is described with s polynomials of degree bounded by D, Canny proved that counting its number of connected components can be done in time $(sD)^{O(n^2)}$.

In this talk, I will first report on joint works with Éric Schost showing that in the case of sets defined by *equations* and under some regularity assumptions, one can count their number of connected components in time $(nD)^{O(n\log(n))}$.

In the second part of the talk, I will report on joint works with Didier Henrion showing how one can compute *certificates of disconnectedness* to ensure that two given points in a semi-algebraic set cannot be path-connected in this set.

Both families of algorithms rely on the use of either computational or geometric tools of polynomial optimization.

Optimal Admission in Service in a Queue with Impatience and Set Up Costs.

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Key words: Stochastic Scheduling, Queuing system, Stochastic multistage problem, Optimal Control, Markov Decision Process.

We consider here a queuing system with impatience which could be seen as the stochastic version of a classical deterministic scheduling problem in which tasks have stochastic arrival dates, stochastic durations and stochastic deadlines. Moreover, deterministic holding costs, set up costs and loss costs are charged and one aims at deciding when starting the treatment of the task. Such models have been already studied either in the inventory field (see [1] for cases without impatiences and [3] with impatiences) or in the queuing system and networking fields (see [4, 5]).

In order to present the activity of the working group COSMOS, we focus in the first part of this talk on the main points that should be taken into account in the stochastic modeling of such problems, following the approach of Powell [6]. We then express this stochastic multistage problem in the form of a stochastic dynamic problem more precisely a Markov decision process [2]. The second part of this talk is dedicated to the study of structural properties of the optimal policy. We show in particular that certain properties can be true on average without being verified for each realization.

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

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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, clustering and classification is under development.

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Splittable Routing Congestion Games: Convergence of n-players Instances to a Nonatomic Instance

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Key words: Game Theory, Congestion games, Population Games, Equilibrium Computation, Variational Inequalities.

Interactions of a very large number of agents are usually modeled as a population (or "nonatomic") game. Here, we focus on the framework of network splittable congestion games: [2]: each player chooses a "profile" by splitting her weight onto the set of available edges while satisfying her individual constraints (a finite set of linear inequalities). Each edge's cost is an increasing and convex function of the aggregated load on it. Each player's objective function is given as the sum of the congestion cost and an individual utility term that depends on the player's action only.

We consider a nonatomic model, where there is an infinite number of players given by a continuum, each of them having an infinitesimal weight. We first study this nonatomic congestion game and show that its set of equilibria (nonempty [3]) can be characterized through infinite-dimensional variational inequalities. To compute an equilibrium of this game, we introduce an approximating atomic N-players game, where the population is splitted into *classes* of players with similar characteristics, each class defining an atomic player in the new game. We show the convergence of the aggregated flow induced by an equilibrium of this finite game to an equilibrium aggregated flow of the nonatomic game, which generalizes a result of [4].

We finally discuss an application of this framework: the computation of the aggregated consumption profile of electricity consumers enrolled in a demand response program [1].

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Numerical tools for very large scale topology optimization

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

The presentation starts with a brief introduction on 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. Several ways will be presented on how to substantially improve efficiency of topology optimization software using modern tools of numerical linear algebra and numerical optimization. These are based on domain decomposition and multigrid techniques and, for the more involved problems, on decomposition of large-scale matrix inequalities using recent results of graph theory.

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Convergence rates of moment-sum-of-squares hierarchies for optimal control problems

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Key words: optimal control, moment relaxations, polynomial sums of squares, convergence rate, semidefinite programming

We study the convergence rate of the moment-sum-of-squares hierarchy of semidefinite programs for optimal control problems with polynomial data. It is known that this hierarchy generates polynomial under-approximations to the value function of the optimal control problem and that these under-approximations converge in the L^1 norm to the value function as their degree d tends to infinity. We show that the rate of this convergence is $O(1/\log\log d)$, treating in detail the continuous-time infinite-horizon discounted problem and describing in brief how the same rate can be obtained for the finite-horizon continuous-time version and for the discrete-time counterparts of both problems.

Resource constrained shortest path algorithm for EDF short-term thermal production planning problem

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Key words: unit commitment problem, resource constraint shortest path problem, column generation

Unit commitment problems on an electricity network consists in choosing the production plan of the plants (units) of a company in order to meet demand constraints. It is generally solved using a decomposition approach where demand constraints are relaxed, resulting in one pricing subproblem for each plant. In this paper we focus on the pricing subproblem for thermal plants. Its objective is to determine an optimal two-day production plan that minimizes the overall cost while respecting several non-linear operational constraints. It is generally solved by dynamic programming. We model it instead as a resource constrained shortest path (RCSP) problem. Leveraging on RCSP algorithms recently introduced in [1] by the second author, we obtain an order of magnitude speed-up compared to the standard dynamic programming approach.

This speed-up enables us to take constraints on gas consumption by groups of plants into account. The resulting multi-unit commitment problem is once again solved by a decomposition approach.

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Using non-parametric statistical tests to compare solutions in evolutionary framework for maintenance schedule optimisation

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Key words: Maintenance optimisation, evolutionary algorithm, statistical test.

While traditional search algorithms are based on the comparison of solutions according to deterministic cost function, maintenance schedules are usually evaluated by multiple replications of stochastic event models, resulting in a distribution of Net Present Value (NPV).

In the context of simulation-optimisation, the common practice [1] to evaluate a solution is to run a predefined (usually large enough) number of replications and calculate the mean value of the obtained sample as fitness. The problem with this approach is that the apriori assumption made on the number of evaluations needed to compare solutions may not be optimal, leading to running unnecessary simulations.

In this work, we propose to apply non-parametric statistical tests within search algorithms in order to provide the confidence that a sufficient number of simulations is performed for the evolutionary process.

The choice of non-parametric statistical tests is made because the distribution of NPV of a given solution does not necessarily follow any known distribution. Non-parametric statistical tests (such as Wilcoxon or Friedman tests) require the comparison to be performed on related samples. In maintenance optimisation, each simulation is defined by the failure times generated by the failure probability distributions of the assets at hand. These failure times can be considered as failure scenarios. Non-parametric statistical tests can thus be applied on the NPVs obtained on the same failure scenarios.

In this talk we present how we integrate statistical tests into classical EA schemes. From the VME simulation tool developed by EDF'Lab [2], we have created a large test bed by randomly generating failure probability parameters and scaling the dimensionality of the problem up to 80 assets.

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Optimisation globale de programmes polynomiaux en variables binaires

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Key words: Programmation polynomiale en variables binaires, Reformulation convexe.

Dans cette présentation nous nous intéressons à minimiser un polynôme dont les variables sont binaires. La formulation d'un tel problème est la suivante:

$$(P) \begin{cases} \min f(x) = \sum_{m=1}^{M} c_m \prod_{j \in S_m} x_j \\ x \in \{0,1\}^n \end{cases}$$

où M est le nombre de monômes de f, $S_m \subset \{1,..,n\}$ est l'ensemble des indices des variables du monôme m. On suppose ici que $|S_m| \leq 4$, i.e. que f est de degré au plus 4. Ce problème est $\mathcal{NP}$-difficile. Classiquement, deux principales classes de méthodes peuvent résoudre un tel problème: les approches construites sur des hiérarchies de relaxations (c.f. [2]), et les algorithmes de Branch and Bound basés sur une relaxation de (P) (c.f. [1]). Ici, nous proposons deux méthodes de résolution par Branch and Bound basées sur une première phase de reformulation convexe de (P) avant de commencer la phase B&B. Dans la première approche, nous reformulons d'abord (P) en un problème équivalent et quadratique, puis nous convexifions la fonction f en utilisant la programmation semi-définie. Dans la deuxième méthode, nous convexifions directement la fonction f, c'est à dire en conservant son degré initial. L'avantage de ces deux méthodes réside dans le fait que nous travaillons sur des reformulations du problème de départ et non sur une relaxation. Nous illustrerons nos méthodes avec des expériences numériques effectuées sur des instances de benchmark.

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The multi-terminal vertex separator problem

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Keywords: separator problem, combinatorial optimization, branch-and-price, branch-and-cut-and-price, extended formulation.

Given a graph $G = (V \cup T, E)$ with $V \cup T$ the set of vertices, where T is a set of terminals, and a weight function $w : V \to \mathbb{Z}$, associated with nonterminal nodes, the multi-terminal vertex separator problem (MTVSP) consists in partitioning $V \cup T$ into $k + 1$ subsets $\{S, V_1, \ldots, V_k\}$ such that there is no edge between two different subsets V_i and V_j, each V_i contains exactly one terminal and the weight of S is minimum. The problem can be solved in polynomial time when $|T| = 2$ and it is NP-hard when $|T| \geq 3$ [1] [3]. The MTVSP has applications in different areas like VLSI conception, linear algebra, connectivity problems and parallel algorithms. It has also applications in network security. Suppose, for instance, that G represents a telecommunication network where V represents a set of routers, T a set of customers, and an edge between two vertices expresses the possibility of transferring data between each other. Suppose that with each vertex it is associated a cost, and we want to set up a monitoring system on the routers in order to monitor all data exchanged between customers. The set of routers on which the monitoring system is set up is a multi-terminal vertex separator.

In this work we propose three extended formulations for the MTVSP. We develop Branch-and-Price algorithms for all the formulations and Branch-and-Cut-and-Price algorithms for two of them. For each formulation we present a column generation scheme to solve the linear relaxation, the way to compute the dual bound and the branching scheme. We present extensive computational results and discuss the performance of each algorithm.

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Semidefinite Characterization of Invariant Measures for Polynomial Systems

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Key words: invariant measures, dynamical polynomial systems, semidefinite programming, moment-sum-of-square relaxations, Christoffel function

We consider the problem of characterizing measures which are invariant with respect to the dynamics of either discrete-time or continuous-time polynomial systems, under general semialgebraic set constraints.

First, we address the problem of approximating the density of invariant measures which are absolutely continuous with respect to the Lebesgue measure. Then, we focus on the characterization of the support of singular invariant measures.

In both cases, our results apply for discrete-time and continuous-time polynomial systems. Each problem is handled through an adequate reformulation into a linear optimization problem over probability measures. We show how to solve in practice this infinite linear problem with moment relaxations. This essentially boils down to solving a hierarchy of finite-dimensional semidefinite problems.

This general methodology is deeply inspired from previous research efforts. The idea of formulation relying on linear optimization over probability measures appears in [1], with a hierarchy of semidefinite programs also called moment-sum-of-squares or sometimes Lasserre hierarchy, whose optimal values converge from below to the infimum of a multivariate polynomial.

Previous work by the second author [2] shows how to use the Lasserre hierarchy to characterize invariant measures for one-dimensional discrete polynomial systems. We extend significantly this work in the sense that we now provide a characterization on multi-dimensional semialgebraic sets, in both discrete and continuous settings.

We also present some application examples together with numerical results for several dynamical systems admitting either absolutely continuous or singular invariant measures.

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Centralized and decentralized strategies for a stochastic energy production planning problem

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Mots-clefs : stochastic optimization, decomposition methods

We consider a set of geographical zones Z interconnected by a network of economic agreements to import or export electricity. Each arc $e = (z, z')$ carries the flow of imported energy denoted by f_{et} in each period of the time horizon $t \in [1, \ldots, T]$. We denote d_{zt} the total demand and i_{zt} the input of water resource for zone $z \in Z$ at step t (random information) . The variables are the local production levels p_{zt}, the control of hydroelectrical reserve u_{zt} and the interzonal flows f_{et}. The multistage stochastic program we face up is the following :

$$\min_{p,x,u \in L^2} \quad I\!\!E\left[\sum_{t=0}^{T-1}\left(\sum_{z\in Z} c_z(p_{zt}) + \sum_{e\in E} l_e(f_{et})\right)\right]$$

$$\text{s.t} \quad p_t + u_t - Af_t = d_t \quad (1)$$

$$x_{z,t+1} = x_{zt} - u_{zt} + i_{zt} \quad \forall z \in Z, \forall t \quad (2)$$

$$+ \text{ Zonal constraints on random variables } p_{zt}, u_{zt}, f_{et} \quad (3)$$

We compare two different strategies on a realistic but simplified model used at EDF labs :

— a centralized strategy based on a Stochastic Dual Dynamic Programming (SDDP [1]) where the solution is approximated by appropriate sampling on the scenario tree and by cut generation to build the cost-to-go objective function ;

— a decentralized strategy where a splitting method (Alternate Direction Method of Multipliers, ADMM, see [2] for former experiments on a deterministic version of the problem) allows to decompose into zonal dynamic programming subproblems. This can be done at the price of relaxing information and satisfying the demand constraints in conditional expectation.

Numerical results are presented on medium size instances with $|Z| = 8, T = 100$ and piecewise linear convex production costs that show the effective gap generated by the relaxation of information in the decentralized version.

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Optimal resource allocation for bacterial growth

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Key words: microbial growth control, biomass accumulation, singular and chattering arcs

Mechanisms of bacterial adaptation to environmental changes are of great interest for both fundamental research in biology and for engineering applications. Strategies enabling microorganisms to optimize their growth rate have been extensively studied, but mostly in stable environments. Here, we build a coarse-grained model of microbial growth and use methods from optimal control theory to determine a resource allocation scheme that would lead to maximal biomass accumulation, in agreement with evolutionary principles. Based on the analytical investigation of our problem by Pontryagin's maximum principle, we show that the obtained field of extremal states consists of chattering arcs and one steady-state singular arc [1]. Additionally, we develop a numerical method to approximate the chattering switching curve of the optimal strategy [2]. We then compare this optimal solution with several cellular implementations of growth control, based on the capacity of the cell to sense different physiological variables. Interestingly, the ppGpp alarmone system in the *enterobacterium Escherichia coli*, known to play an important role in growth control, has structural similarities with the control strategy approaching the theoretical maximum.

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From safe screening rules to working sets for faster Lasso-type solvers

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Key words: Optimization, Sparsity, Lasso, Working sets

Convex sparsity-promoting regularizations are ubiquitous in modern statistical learning. By construction, they yield solutions with few non-zero coefficients, which correspond to saturated constraints in the dual optimization formulation.

Working set (WS) strategies are generic optimization techniques that consist in solving simpler problems which only consider a subset of constraints, whose indices form the WS. Working set methods therefore involve two nested iterations: the outer loop corresponds to the definition of the WS and the inner loop calls an iterative solver for the subproblems. For the Lasso estimator a WS is a set of features, while for a Group Lasso it refers to a set of groups. In practice, WS are generally small in this context so the associated feature Gram matrix can fit in memory. Here we show that the Gauss-Southwell rule (a greedy strategy for block coordinate descent techniques [4]) leads to fast solvers in this case.

Combined with a working set strategy based on an aggressive use of so-called Gap Safe screening rules [1, 3], we propose A5G, a solver achieving state-of-the-art performance on sparse learning problems. Results are presented on Lasso and multi-task Lasso estimators.

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Advertising Competitions in Social Networks

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Key words: social networks, game theory, resource allocation.

One of the main objectives of data mining is to help companies determine to which potential customers to market and how many resources to allocate to these customers. In the context of direct marketing, which promotes a product or service exclusively to potential customers likely to be profitable, identifying to which potential customers to market and the influence maximization problem have been analyzed in Domingos and Richardson [1]. Kempe et al. [2] provided a greedy $(1 - 1/e - \varepsilon)$-approximation algorithm for the spread maximizing set while Even-Dar and Shapira [3] found an exact solution when all the customers have the same cost. In this work, we are interested on the competitive influence of marketing campaigns who need to decide how many resources to allocate to their potential customers to advertise their products. Taking into account the intrinsic value of potential customers (i.e., the expected profit from sales to him) as well as the peer influence of friends, acquaintances, etc., exerted over them, we consider the network value as a measure of their importance in the market (and we find an analytical expression for it) and we analyze the strategic allocation for the voter model of social networks. Applying game theory we characterize the optimal resource allocation in marketing competition in the following scenarios: 1) marketing campaigns allocate simultaneously their resources; 2) an incumbent, who dominates the market, knows the entrance of the challenger into the market and thus can predict its response; 3) Potential customers rank marketing campaigns according to the offers, promotions or discounts made to them.

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Minimal time mean field games

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Key words: Mean field games, minimal time, optimal control, crowd motion.

Motivated by the problem of studying crowd motion through a mean field game approach, this talk considers a mean field game model where agents wants to leave a given bounded domain through a part of its boundary in minimal time. Each agent is free to move in any direction, but their maximal speed is assumed to be bounded in terms of the local density of agents in order to take into account congestion phenomena.

After formulating this mean field game in a Lagrangian setting, we establish the existence of Lagrangian equilibria using a fixed point strategy. Thanks to some further regularity properties of optimal trajectories obtained through Pontryagin's maximum principle, we are also able to characterize equilibria through a system of a continuity equation on the density of agents coupled with a Hamilton–Jacobi equation on the value function of the optimal control problem solved by each agent. We conclude the talk by presenting some interesting open problems.

Controllability of a Magneto-Elastic Micro-Swimmer

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Key words: Micro-swimming, local controllability, control theory.

A recent promising technique to drive robotic micro-swimmers is to use magnetized materials. An external magnetic field can then be applied to bend and propel the swimmer. This leads to the following controllability issue: given an initial state (position and shape) for a micro-swimmer, is it possible to find a magnetic field that brings it to another given state? In this talk, we will consider a simple planar micro-swimmer model made of two magnetized segments connected by an elastic joint, studied in [1] and [2]. We will recall the definition of small-time local controllability (STLC), focusing on controlling the system in a neighbourhood of an equilibrium point, in small time and with small controls, and show that the system associated to the swimmer cannot be STLC except under a restrictive equality constraint [2]. We will then give perspectives on further research on this matter, including a brief look on the swimmer made of three links.

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Application of Machine Learning Algorithms to the Generation of Sub-problems in Combinatorial Optimization

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Key words: Combinatorial optimization, machine learning, sub-problem generation, recurrent problems.

The ubiquitous presence of combinatorial optimization (CO) problems in fields such as Operations Research and Artificial Intelligence as well the great wealth of results in machine learning (ML) have contributed to a recent surge in interest for applications of ML to CO. ML has been employed, for example, to automate the application of decomposition methods to mixed integer programs [1], to guide the branching in branch-and-bound algorithms [2, 3] and used to improve greedy heuristics for hard CO problems over graphs [4].

Our work focuses on the resolution of recurrent CO problems, coupling ML techniques with branch & bound algorithms, operating under a limited time budget. Assuming problems are the realization of a generative process, historical data are collected and used to train a classification model. At first, when solving a new instance, this model will select a subset of decision variables to be set heuristically to some reference values, becoming fixed parameters. The remaining variables are left free and form a smaller sub-problem whose solution, while being an approximation of the optimum, can be obtained sensibly faster. Subsequently, if some of the time allocated is available, an iterative process of blocking/unblocking variables takes place, allowing to explore other areas of the solution space. This approach is of particular interest for problems where perturbations on the instance parameters can occur unexpectedly, requiring a rapid re-optimization of a complex model.

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Numerical resolution through optimization of $\det(\mathrm{D}^2 u) = f(u)$

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Key words: Optimal transport, Brunn-Minkowski inequality, Brenier solution.

Several problems in geometry lead to equations of the form

$$g(\nabla u))\det(\mathrm{D}^2 u) = a(u), \tag{1}$$

where $g : \mathbb{R}^d \to \mathbb{R}$ is a probability density and $a : \mathbb{R} \to \mathbb{R}$ decays sufficiently fast at infinity. For $a(t) = \exp(-t)$ this equation is related to the moment measure problem studied in [1, 3], while for $a(t) = t^{-d+2}$ this equation appears in the construction of $(d-1)$-dimensional affine hemispheres in convex geometry [2]. As in optimal transport, one can define a Brenier solution to (1) as a convex function $u : \mathbb{R}^d \to \mathbb{R} \cup \{+\infty\}$ which satisfies $\nabla u_{\#} a(u) = \mu$, where μ is the measure on $\mathbb{R}$ with density g. When $a(t) = \exp(-t)$ or $a(t) = t^{-d+2}$, Brenier solutions to (1) maximize a concave functional similar to the one appearing in Kantorovich duality. We will show that this leads to efficient numerical methods when the measure μ is finitely supported. In the moment measure case, we will deduce the convergence of a Newton algorithm from a discrete version of the Brascamp-Lieb inequality.

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The Proactive Countermeasure Selection Problem: Bilevel Programming and Polyhedral Investigation

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Key words: Bilevel programming, polyhedra and facets, countermeasure selection.

The Proactive Countermeasure Selection Problem (PCSP) is defined as follows. Given 1) a directed graph $G = (V, A)$ called the *Risk Assessment Graph* [1], where $V = S \cup T$, $S \cap T = \emptyset$, and with each arc $(i, j) \in A$ is associated a weight $w_{ij} \in \mathbb{R}_+$. 2) A set of available countermeasures $K = \{(t, k) : k \in K_t, t \in T\}$ such that K_t is the set of countermeasures associated with t. The placement of k on t has a positive cost $c_t^k \in \mathbb{R}_+$, and yields an increase of the weight of the ongoing arcs of t by a positive effect $\alpha_t^k \in \mathbb{R}_+^*$. Let $c^T = (c_1, \ldots, c_{|K|})^T$ be the cost vector. 3) A positive vector $D = (d_s^t)_{s \in S, t \in T}\mathbb{R}_+$. The PCSP consists in selecting a set of countermeasures, at minimal cost, such that for each $s \in S$ and $t \in T$ the length of the $s - t$ shortest path is at least d_s^t.

The PCSP was introduced in [2] in order to manage the information systems security. The nodes S are called *access points*. They represent the attacker access points to the system. The nodes T are called *asset-vulnerability nodes*. They represent the nodes that we aim to secure. The weight of the arcs represents the difficulty of propagation of an attacker. A bilevel formulation was proposed in [2] to model the PCSP. An Integer Linear Programming (ILP) formulation is used to reformulate and solve the PCSP to optimality through a branch-and-cut algorithm. Preliminary results show that the branch-and-cut algorithm run in a critical time for instances with over 150 nodes.

The goal of this work is to investigate the PCSP polytope in order to improve the algorithmic aspect. we study the polytope associated with the PCSP ILP formulation. We characterize its dimension and study the facial aspect of its basic constraints. We further introduce a class of valid inequalities and describe necessary and sufficient conditions for these inequalities to be facet defining. Ongoing experimental results show the efficiency of the valid inequalities.

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Exact Algorithms: from Semidefinite to Hyperbolic Programming

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Key words: Semidefinite Programming, Linear Matrix Inequalities, Hyperbolic Polynomials, Algorithms

Title of the session: Numeric and Symbolic Convex Programming for Polynomial Optimization

Hyperbolic polynomials generalize univariate polynomials with only real roots to the multivariate case. Hyperbolic Programming (HP) is the problem of computing the infimum of a linear function when restricted to the hyperbolicity cone of a hyperbolic polynomial. It is a strict generalization of Semidefinite Programming, the natural extension of Linear Programming to the convex cone of positive semidefinite real matrices.

The talk will focus on an approach based on symbolic computation for solving general instances of HP, relying on the multiplicity structure of the algebraic boundary of the cone. The method that we have developed does not assume the determinantal representability of the hyperbolic polynomial. This method allows to design exact algorithms able to certify the multiplicity of the solution and the optimal value of the linear function.

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Payoff-based dynamics in transferable-utility matching markets

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Key words: assignment games, cooperative games, core, distributed optimization, evolutionary game theory, learning, linear programming, matching markets

We consider simple, payoff-driven learning dynamics that we derive from laboratory evidence of how individuals adjust their behavior when interacting in low-information environments. We study the resulting convergence properties of such dynamics for transferable-utility matching markets (i.e. multi-player bargaining, assignment game, TU many-to-one matching). The dynamics are driven by individuals? continued efforts to fulfill their aspirations and resulting aspiration adaptation. Agents have no knowledge of other agents? strategies, payoffs, or of the structure of the game, and there is no central authority with such knowledge either. Our dynamics constitute a class of simple learning processes that converge to stable and optimal outcomes (the core).

Quadratic Mean Field Games and Entropy Minimization. Part II: Numerics

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Key words: MFG, entropy, Sinkhorn algorithm, Schrödinger bridges and entropic interpolation.

In this second part, we will use the entropy minimization formulation of certain MFGs to present a new and efficient numerical method. This method relies on generalization of Sinkhorn's algorithm which has become a very efficient tool for numerical optimal transportation as shown by Cuturi. It is worth noting that in the context of MFGs with a quadratic Hamiltonian and diffusion, adding an entropy is not an approximation but a natural and tractable way to take into account diffusion. The method will be explained in details and numerical simulations will be presented both for MFGs and for problems arising in incompressible fluid dynamics.

An Efficient Primal-Dual Algorithm for Fair Combinatorial Optimization Problems

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Key words: Fair Optimization, Generalized Gini Index, Ordered Weighted Averaging, Matching, Subgradient Method.

We consider a general class of combinatorial optimization problems including among others allocation, multiple knapsack, matching or travelling salesman problems. The standard version of those problems is the maximum weight optimization problem where a sum of values is optimized. However, the sum is not a good aggregation function when the fairness of the distribution of those values (corresponding for example to different agents' utilities or criteria) is important. In this paper, using the Generalized Gini Index (GGI), a well-known inequality measure, instead of the sum to model fairness, we formulate a new general problem, that we call fair combinatorial optimization. Although GGI is a non-linear aggregating function, a $0,1$-linear program (IP) can be formulated for finding a GGI-optimal solution by exploiting a linearization of GGI proposed by Ogryczak and Sliwinski [1]. However, the time spent by commercial solvers (e.g., CPLEX, Gurobi...) for solving (IP) increases very quickly with instances' size and can reach hours even for relatively small-sized ones. As a faster alternative, we propose a heuristic for solving (IP) based on a primal-dual approach using Lagrangian decomposition. We demonstrate the efficiency of our method by evaluating it against the exact solution of (IP) by CPLEX on several fair optimization problems related to matching. The numerical results show that our method outputs in a very short time efficient solutions giving lower bounds that CPLEX may take several orders of magnitude longer to obtain. Moreover, for instances for which we know the optimal value, these solutions are quasi-optimal with optimality gap less than 0.3%.

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Optimization of Energy Production and Transport A stochastic decomposition approach

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Key words: Dynamic programming, stochastic decomposition, DADP, SDDP

Stochastic optimal control (SOC) is a powerful method to manage dynamic electrical systems confronted to uncertainty (e.g. demands or weather). Among other methods, dynamic programming (DP) proves to be an effective algorithm to solve such problems [2]. Unfortunately, DP faces the curse of dimensionality: the complexity of solving DP equations grows exponentially with the number of stocks we control.

For a large class of SOC problems, which includes important practical applications in energy management, we propose an original way of obtaining near optimal controls. The algorithm we introduce is based on Lagrangian relaxation, of which the application to decomposition is well-known in the deterministic framework. However, its application to such closed-loop stochastic problems is not straightforward and an additional statistical approximation concerning the dual process is needed. The resulting methodology is called Dual Approximate Dynamic Programming (DADP) [3, 4]. We give interpretations of DADP, and enlighten the error induced by the approximation.

The presentation is mainly devoted to applying DADP to the management of large networks. We will present a framework to model such systems, as well as a practical implementation of the methodology. Numerical results are provided on a European network, with 8 interconnected countries. We compare our approach with the state of the art SDDP method [1].

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Very Large Time Series Analysis for Predictive Maintenance

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Key words : time series, data analytics, predictive maintenance

Manufacturing plants (including electricity manufacturing plants) are currently monitoring the operation of their facilities using sensors. The historical and streaming data gathered in this way need to be analyzed [1], in order to reason on the operation health of the plant, identify abnormal and potentially dangerous situations, and perform predictive maintenance that leads to reduced maintenance costs. More specifically, applications cover detection, diagnostic and prognosis for maintenance tasks using multi-dimensional data analytics approaches. For example, the identification and selection of data or combinations of data that have consequences on the behavior, or on some "health" states of the system. The sensor time series will need to be analyzed in order to identify periods of normal and stable behavior, as well as periods of abnormal behavior. Subsequently, characteristic patterns should be extracted that can reveal, or predict behaviors of interest [2].

The first part of our work has been based on the development of algorithms to detect several types of interesting patterns (defined by the domain experts), including linear trends, high-frequency oscillations, and abrupt changes. In all the above cases, we are interested in identifying the patterns in time-windows of different lengths (varying from days to months), and automatically selecting the most appropriate time-length for each pattern. Moreover, we used algorithms that allow us to label patterns with information related to the explanation and the correlation that a pattern may have with other operational parameters of the plant. This allows the analyst to easily filter out patterns that (even though interesting) constitute expected behavior (based on already known operational settings). The second part of our work will consist on the identification of early warning patterns for the detected anomalies, exploiting techniques such as lag correlation and the matrix profile [3]. We will analyze the applicability and usefulness of these techniques, and adapt them to our specific problem of predictive maintenance.

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Decomposability in Adjustable Robust Optimization

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Key words: Adjustable robust optimization, decomposition method, mixed-integer linear programming

Uncertainty has become the central notion to capture for the optimal solving of various real-world optimization problems including design, sizing, location, scheduling and transportation as well as their various combinations. For this purpose, set-induced robust optimization (RO) constructs solutions that are deterministically immune against any realization of the parameters/data uncertainty in some compact sets. Less conservative set-induced RO methods rely on the assumption that it is unlikely that all uncertain parameters reach simultaneously their worst-case value by adjusting the geometry of these sets, by limiting the cardinality of the uncertainty sets or by budgeting the total deviation from their nominal value. In set-induced RO, all variables represent "here and now" decisions; they must be determined before the realization of the uncertain parameters becomes known. In contrast, adjustable RO (ARO) enables to choose a subset of (adjustable) variables only after the realization of the uncertain data while the subset of nonadjustable variables must be determined before its realization. The former variables represent "wait and see" decisions that can be made when revealing part of the uncertain data and that can adjust to the corresponding part of the data. The ARO method produces adjustable robust counterparts (ARC) which yields solutions that are less conservative than their corresponding RC though computationally harder as in most cases, the ARC is computationally intractable (NP-hard). By restricting adjustable variables to be affine functions of the uncertain data, in particular when assuming past is known, present and future are unknown, the resulting affinely adjustable robust counterpart (AARC) problem has been shown to be either equivalent to a tractable LP or having a tight approximation which is tractable. On the other hand, preserving the decomposability property of the OP remains essential in order to allow solving of ARCs. Decomposition methods exploit the structure of the OP to split it into subproblems that are repeatedly solved in order to obtain further information about its structure that can be incorporated into a master problem (MP). The major strength of these methods stems from their ability to reformulate the OP into a MP together with the generation of subproblems that are significantly easier to solve than the OP and that can be solved concurrently (if subproblems are independent). However, the decomposable structure of the uncertain OP may disappear when formulating ARC of mixed-integer linear programs (MILP) using standard techniques.

In this paper, we show that when the past is known but present and future are unknown, the ARC of a very general class of MILP is subject to a fundamental tradeoff between efficiency of the computational method and the quality of the solution. Such problems translate, for instance, situations where resource adjustments are themselves dependent on allocation variables (and not determined by parametric safety constraints). We further analyze the properties of decomposability preserving RC formulations for these uncertain MILP and provide a characterization of the fundamental tradeoff between decomposability and robustification. Finally, we propose an algorithm for the solving of such problems that relies on the Benders method for the decomposition of the OP before robustification of the subproblems.

A Random Block-Coordinate Douglas-Rachford Splitting Method with Low Computational Complexity for Binary Logistic Regression

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Key words: Stochastic optimization, proximal tools, machine learning, logistic regression, block coordinate methods

In this work, we propose a new optimization algorithm for sparse logistic regression based on a stochastic version of the Douglas-Rachford splitting method. Our algorithm sweeps the training set by randomly selecting a mini-batch of data at each iteration, and it allows us to update the variables in a block coordinate manner. Our approach leverages the proximity operator of the logistic loss, which is expressed with the generalized Lambert W function. Experiments carried out on standard datasets demonstrate the efficiency of our approach w.r.t. stochastic gradient-like methods.

Incorporating Model Error in the Management of Financial and Electricity Portfolios

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Key words: Multistage stochastic optimization, model ambiguity, distributionally robust decisions

We consider the problem of optimally managing financial or energy portfolios. These problems require models for the uncertain parameters. Typically these models are based on statistical estimation from empirical observations and contain therefore some estimation error. This error affects the decisions obtained by solving the associated stochastic optimization problem.

In order to safeguard ourselves against the effect of model error, we consider decisions, which are robust with respect to some deviations from the estimated model. In particular, we adopt a nonparametric approach by considering ambiguity sets based on the nested distance (multiperiod Wasserstein distance). We demonstrate the influence of the size of the ambiguity set to the optimal minimax decision.

Our approach is based on risk functionals, which define levels of acceptability. A portfolio decision is acceptable, if the value of associated risk functional lies below a given threshold. In the context of model ambiguity, this acceptability constraint means that the risk value must lie below a certain level for all probability models in the ambiguity set. In the context of indifference decision making under ambiguity, the indifference constraint means that the acceptability of the portfolio after the transaction must not be smaller than before the transaction, for all probability models under consideration.

In an empirical study, we estimate sizes of ambiguity sets given implicitly by electricity future prices observed on the market.

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Weighted Functional Spaces in Infinite Horizon Optimal Control Problems

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Key words: Optimal Control, Infinite Horizon, Weighted Sobolev spaces

Optimal control problems with infinite horizon arise from different points of view. On the one hand, considering a control problem with a long, but not bounded, finite horizon T leads to the limiting process $T \to \infty$ and to the infinite horizon $T = \infty$ as the idealization of this limiting procedure. In this sense, most applications are studied and most of the theoretical results follow from these ideas. On the other hand, the concept of designing a feedback controller such that an integral of the square of the tracking error over an infinite horizon is minimized was first proposed by Wiener [3] , 1943, and is based on Fourier and Laplace transforms and is restricted to the case of autonomous problems. In [1], 1960, Kalman proposed another approach to the problem. In his ground-breaking paper he recommended to use the theory of an receding horizon regulator problem to design a feedback control law. However, the integration over an unbounded time interval indicates some difficulties which are specific to this class of problems. For this reason, one needs other techniques to cope with typical difficulties arising in infinite horizon control problems. The suggestion of introducing Weighted Sobolev spaces as state spaces (and Hilbert spaces) made in [2] holds many interesting effects and advantages both for the modeling itself and the theoretical and numerical treatment of the control problem. The systematic analysis and discussion of these effects build the main issue of this contribution.

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Robust Bilateral Trade over 0/1 Polytopes

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Key words: Mechanism design, Bilateral trade, Integer Linear Programming, Robustness .

The problem of designing a trade mechanism (for an indivisible good) between a seller and a buyer is studied in the setting of discrete valuations of both parties using tools of finite-dimensional optimization. A robust trade design is defined as one which allows both traders a dominant strategy implementation independent of other traders' valuations with participation incentive and no intermediary (i.e., under budget balance). The design problem which is initially formulated as a mixed-integer non-linear non-convex feasibility problem is transformed into a linear integer feasibility problem by duality arguments, and its explicit solution corresponding to posted price optimal mechanisms is derived along with full characterization of the convex hull of integer solutions. A further robustness concept is then introduced for a central planner unsure about the buyer or seller valuation distribution, a corresponding worst-case design problem over a set of possible distributions is formulated as an integer linear programming problem, and a polynomial solution procedure is given. When budget balance requirement is relaxed to feasibility only, i.e., when one allows an intermediary maximizing the expected surplus from trade, a characterization of the optimal robust trade as the solution of a simple linear program is given. A modified VCG mechanism turns out to be optimal.

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Micro influence and macro dynamics of opinion formation

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Key words: social influence, opinion polarization, Internet, field experiment

Recent political events such as Brexit and the U.S. elections intensified the debate about effects of online social influence on micro-level opinion formation and resulting opinion polarization on the macro level. To empirically test competing social-influence theories as well as their macro predictions, we introduce a general model that describes opinion shifts in terms of the moments of the observable opinion distribution. We show that its parameters capture prominent social-influence theories. Conducting an online lab-in-the-field experiment, we estimate the model parameters and observe strong social influence with individual opinions shifting linearly towards the mean of others' opinions. With this finding, we predict the macro-level opinion dynamics resulting from social influence and test our predictions with a second lab-in-the-field experiment. Contrary to many recent theories, we find support for our prediction that social influence reduces opinion polarization. We corroborate these findings with large-scale field data from a natural experiment.

Stochastic lot-sizing for remanufacturing: a multi-stage stochastic integer programming approach

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Key words: Stochastic lot-sizing, remanufacturing system, polyhedral approach, Cut-and-Branch algorithm, multi-stage stochastic programming.

Remanufacturing systems are defined as sets of processes transforming end-of-life products (returned products) into like-new products, once again usable by customers, mainly by rehabilitating damaged components. Within this project, we consider a remanufacturing system involving three production echelons: (1) *disassembling* the used products brought back by customers, (2) *refurbishing* the recovered parts and (3) *reassembling* them into like-new finished products. We seek to plan the production activities on this system over a multi-period horizon so as to minimize the total production costs. This leads to the formulation of a multi-echelon lot-sizing problem with lost sales, mathematically expressed as a Mixed-Integer Linear Programming model.

We consider the stochastic variant of the problem, in which the uncertainties on the quantity and quality of returned products and the customers' demand are explicitly taken into account. We propose a multi-stage stochastic programming approach relying on scenario trees to represent the uncertain information structure. We develop a Cut-and-Branch algorithm in order to solve the resulting mixed-integer linear program to optimality. This algorithm relies on a new set of tree valid inequalities obtained by combining valid inequalities previously known for each individual scenario of the scenario tree [1, 2]. These inequalities are added to the problem formulation using a cutting-plane generation procedure based either on an exact or on a heuristic resolution of the corresponding separation problem.

Some computational results carried out on medium-size randomly generated instances of the problem are provided. They show that the proposed Cut-and-Branch algorithm is capable of significantly improving the quality of the solutions obtained within a limited computation time as compared to the use of a stand-alone mathematical solver. More specifically, numerical results show that the new tree cut generation improves the quality of the solution up to 93.89%.

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Network Flow Oriented Approaches for Vehicle Sharing Relocation Problems

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Key words: Operations Research, Network Flow, Routing, Scheduling

Managing a one-way *vehicle sharing system* means periodically moving free access *vehicles* from *excess* to *deficit stations* in order to avoid local shortages. We propose and study here several network flow oriented models and algorithms which deal with a static version of this problem while unifying *preemption* and *non preemption* as well as *carrier riding cost*, *vehicle riding time* and *carrier number* minimization. Those network flow models are *vehicle driven*, which means that they focus on the way *vehicles* are exchanged between *excess* and *deficit* stations. We perform a lower bound and approximation analysis which leads us to the design and test of several heuristics which involves implicit dynamic network handling.

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Polynomial time algorithms for the lot-sizing problem under energy constraints

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Key words: Energy-efficient manufacturing, lot sizing, energy constraints, capacity acquisition, polynomial time algorithm

We consider a single-item lot sizing problem integrated with some energy constraints. Lot-sizing problem aims at determining a compromise between production costs and inventory costs in order to satisfy a deterministic demand over a given time horizon constituted of T periods. The system we consider in this study is composed of M parallel identical machines, each one having a limited production capacity, in each period. Costs in the system are incurred by the start-up of the machines, the production of units, and the holding of units in stock from one period to another. One has to decide how many machines to start and how much to produce to serve the demand and/or to replenish the inventory, in order to satisfy the demand at minimal cost. The originality of this paper is to consider energy as a scarce resource. Specifically, in each period, we have a limited amount of available energy. Energy is consumed in the system by both the start-up of the machines and the production of units. Thus, we need to arbitrate how to use energy in each period. We develop a new and very efficient approach for some particular cases of this problem. Our results are two-fold : (1) We show that without energy restriction, the related problem is similar to the capacity acquisition problem considered by Atamtürk and Hochbaum (2001), but without subcontracting. For this case we propose an $O(T \log T)$ time algorithm, significantly improving the existing result. (2) We show that the same efficient algorithm can be extended to some special cases of the problem with energy constraint, namely, if only the start-up or only unit production consumes energy.

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Two-Time Scales Stochastic Dynamic Optimization

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Key words: multi time scales, stochastic optimization, energy management

Microgrids control architecture is often decomposed into multiple levels to handle multiple time scales. Voltage and power stability have to be ensured every seconds while energy tariff arbitrage is made between different hours of the day. We focus on microgrids with energy storage that is used to mitigate renewable production and demand uncertainty. Such dynamical systems can be managed using Stochastic Optimal Control (SOC) techniques [1].

However the interaction between multi-time scales decisions and uncertain phenomenon requires to model the optimization problem with a massive amount of time steps. It is therefore not straightforward to apply classical methods such as Stochastic Dynamic Programming (SDP) or Model Predictive Control [2].

We propose hereby a methodology to model optimization problems with multiple time scales as well stochasticity and information revelation throughout time. That kind of problem and methods have been already studied in a deterministic setting [3]. Our contribution is to highlight the difficulties that arise in a stochastic setting. Then we present a method based on SDP by blocks to solve that kind of problems with a massive amount of time steps. Throughout the talk we apply the theory to a two time scales example where energy storage short term operation as well as long term aging are managed. We present numerical results showing the effectiveness of the method to compute two-time scales closed loop decisions.

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New Formulations for Generator Maintenance Scheduling in Hydropower Systems

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Key words: Hydroelectric power generation, integer linear programming, mathematical programming, optimal maintenance scheduling

Maintenance activities help prevent costly power generator breakdowns but because generators under maintenance are typically unavailable, the impact of maintenance schedules is significant and their cost must be accounted for when planning maintenance. In this paper we address the generator maintenance scheduling problem in hydropower systems. While this problem has been widely studied, see e.g. [2], specific operating conditions of hydroelectric systems have received less attention.

We present a mixed-integer linear programming model that considers the time windows of the maintenance activities, as well as the nonlinearities and disjunctions of the hydroelectric production functions [1]. Because the resulting model is hard to solve, we also propose an extended formulation, a set reduction approach that uses logical conditions for excluding unnecessary set elements from the model, and valid inequalities. Computational experiments using a variety of instances adapted from a real hydropower system in Canada support the conclusion that the extended formulation with set reduction achieves the best results in terms of computational time and optimality gap.

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Multi-task Bolasso based aircraft dynamics identification

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Key words: aircraft dynamics identification, multi-task learning, feature selection, Bolasso.

Aircraft dynamics identification has been a longstanding problem in aircraft engineering, and is essential today for the optimization of flight trajectories in aircraft operations. This motivates the search for accurate dynamical systems identification techniques, the main topic of this study. The application we are most interested in here is civil aircraft fuel consumption reduction.

Several different classes of approaches can be found in the literature for aircraft dynamics identification, such as the Output-Error Method, the Filter-Error Method or the older Equation-Error Method (see e.g. [4]). We propose in this presentation a variation of the latter, in which we cast our dynamical system identification problem into a multi-task linear regression problem (similarly to [2]). We chose this framework after noticing that the equations forming the aircraft dynamics seem tightly coupled, hoping that multi-task approaches may benefit from it (see e.g. [3]). Solving such a problem involves learning the dynamics linear structure, which is performed thanks to a Lasso-based feature selection algorithm [1, 6]. We validate our approach with numerical results based on real data from 10 471 flights, which corresponds to approximately 8 261 619 observations. This is done by resimulating recorded flights in BOCOP [5] using the identified dynamics.

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A Methodology for Building Scalable Test Problems for Continuous Constrained Optimization

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Key words: Continuous constrained optimization, benchmarking, methodology

We present a methodology for building *scalable* constrained test problems for continuous optimization algorithms, that is, problems that can be generated in any dimension n of the search space and for any number of constraints m. Despite the practical importance of scalability, most of the available test sets for continuous constrained optimization provide problems that are only defined in a fixed dimension and for a fixed number of constraints.

The methodology we present in this work aims at overcoming this limitation and can be summarized in three main steps: (i) starting from a pseudoconvex objective function, we build a linearly constrained problem – called the *raw problem* – such that the optimum of the objective function is unfeasible, the optimum of the constrained problem is the origin $\mathbf{0}$, and all the linear constraints are active at $\mathbf{0}$, i.e. $\mathbf{0}$ lies on the boundary of the feasible domain. Then (ii) nonlinear perturbations are applied to the raw problem, while keeping the optimum in $\mathbf{0}$, to make the raw problem less "regular" and, hence, more difficult. The resulting problem is an *almost linearly constrained* problem. The final step consists in (iii) translating the resulting problem by a given vector $\mathbf{x}^{\mathbf{opt}}$ different from $\mathbf{0}$. By doing so, $\mathbf{x}^{\mathbf{opt}}$ becomes the optimum of the final constrained problem.

Following this methodology, we create a new test set for continuous constrained optimization that consists in 48 scalable, almost linearly constrained problems. Each problem is provided in dimensions $n = 2, 3, 5, 10, 20, 40$ by default and can be generated in any dimension and with any number of constraints. This test set is provided by the COCO (COmparing Continuous Optimisers) platform [1].

This work is part of the PGMO project NumBER.

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Global sensitivity analysis for optimization with variable selection

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Keywords: Variable selection, sensitivity analysis, HSIC, optimization.

The optimization of high dimensional functions is a key issue in engineering problems but it often comes at a cost that is not acceptable since it usually involves a complex and expensive computer code. In practice, engineers usually overcome this limitation by first identifying which parameters drive the most the function variations: non-influential variables are set to a fixed value and the optimization procedure is then carried out with the remaining influential variables only [1]. However, such variable selection is performed through influence measures typically designed for regression problems, and does not account for the specific structure of an optimization problem. Ideally, we would like to identify which variables have an impact on constraints satisfaction and lead to low values of the objective function.

In this paper, we propose a new sensitivity analysis that incorporates the specific aspects of optimization problems. In particular, we introduce an influence measure based on the Hilbert-Schmidt Independence Criterion to characterize [2] whether a design variable matters to reach low values of the objective function and to satisfy the constraints. This measure makes it possible to sort the inputs and reduce the problem dimension. We estimate the sensitivity for optimization measure from a design of experiments and propose a random and a greedy strategies to set the values of the non-influential variables before conducting a local optimization. We apply our methods to several test-cases from common optimization benchmarks. Our results show how variable selection for optimization and the greedy strategy can significantly reduce the number of function evaluations while still attaining satisfying minima.

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Tropical Kraus maps for optimal control of high-dimensional switched systems

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Key words: Switched system, joint spectral radius, Hamilton-Jacobi PDE, LMI-free.

Kraus maps (completely positive trace preserving linear maps) are a fundamental tool in quantum information theory. They describe the evolution of non-commutative probability measures. We introduce tropical analogues of Kraus maps, obtained by replacing the addition of positive semidefinite matrices by a multivalued supremum with respect to the Löwner order.

We show that non-linear eigenvectors of tropical Kraus maps determine piece-wise quadratic approximations of the value functions of switched optimal control problems. We solve the non-linear eigenvalue problems by a variant of the power algorithm. This leads to a new approximation method, which we illustrate by two applications: 1) approximating the joint spectral radius by computing approximate Barabanov norms like in [1], 2) computing approximate solutions of Hamilton-Jacobi PDE arising from a class of switched linear quadratic problems studied previously by McEneaney [3].

We report numerical experiments, indicating a major improvement in terms of scalability by comparison with earlier numerical schemes, owing to the "LMI-free" nature of our method. In particular, our method is able to handle instances of large dimension, for instance dimensions up to 500 for the joint spectral radius problem), probably inaccessible by dynamic programming-type approaches.

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Estimating the Loss of Efficiency due to Competition in Mobility on Demand Markets

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Key words: Mobility on Demand systems, network flows, linear programming, probabilities

Mobility-on-Demand platforms offer a means of reliable and convenient personalized transportation, enabling the convenience of personal mobility without the additional burdens of car ownership. Though a growing literature addresses the question of how to make such systems more efficient, much less is known about the cost of market fragmentation, i.e., the impact on welfare due to splitting the demand between multiple independent platforms. Our work aims to quantify how much platform fragmentation degrades the efficiency of the system. In particular, we focus on a setting where demand is exogenously split between multiple platforms, and study the increase in the supply rebalancing cost incurred by each platform to meet this demand, vis-a-vis the cost incurred by a centralized platform serving the aggregate demand. We show that this Price-of-Fragmentation (PoF) undergoes a phase transition, under scaling, depending on the structure of the exogenous demand, where the additional cost due to fragmentation either disappears or diverges to infinity. We provide conditions that characterize which regime applies to any given system, and discuss implications of this on how such platforms should be regulated.

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Sample average approximation under heavier-tails and stochastic constraints

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Key words: stochastic optimization, sample average approximation, heavy-tails, stochastic constraints.

We give statistical guarantees for the sample average approximation (SAA) of stochastic optimization problems. Precisely, we derive exponential non-asymptotic finite-sample deviation inequalities for the approximate optimal solutions and optimal value of the SAA estimator. In that respect, we give three main contributions. First, our bounds do not require *sub-Gaussian* assumptions on the data as in previous literature of stochastic optimization (SO). Instead, we just assume Hölder continuous and *heavy-tailed* data (i.e. finite 2nd moments), a framework suited for risk-averse portfolio optimization. Second, we derive new deviation inequalities for SO problems with *expected-valued stochastic constraints* which guarantee *joint* approximate feasibility and optimality without metric regularity of the *solution set* nor the use of reformulations. Thus, unlike previous works, we do not require strong growth conditions on the objective function, the use of penalization nor necessary first order conditions. Instead, we use metric regularity of the *feasible set* as a sufficient condition, making our analysis general for many classes of problems. Our bounds imply *exact* feasibility and approximate optimality for convex feasible sets with strict feasibility and approximate feasibility and optimality for metric regular sets which are non-convex or which are convex but not strictly feasible. In our bounds the feasible set's metric regular constant is an additional condition number. For convex sets, we use localization arguments for concentration of measure, obtaining feasibility estimates in terms of smaller metric entropies. Third, we obtain a general uniform concentration inequality for heavy-tailed Hölder continuous random functions using empirical process theory. This is the main tool in our analysis but it is also a result of independent interest.

Aggregation in Mean Field Games

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Key words: Variational formulation of Mean Field Games, local decreasing coupling, non-uniqueness.

In this talk, we consider time-dependent viscous Mean Field Game systems in the case of local, decreasing and unbounded couplings. These systems arise in mean field game theory, and describe Nash equilibria of games with a large number of agents aiming at aggregation, i.e. at converging to a common state. To cite an example, in [3], Guéant considered simple population models where individuals have preferences about resembling each other. From the PDE viewpoint, several issues are intrinsic in this framework, mainly caused by the lack of regularizing effects induced by increasing monotonicity of the coupling. Actually, non-existence, non-uniqueness of solutions, non-smoothness, and concentration are likely to arise, as shown by Cirant in [1], for the stationary focusing case. Even more than in the competitive case, the assumptions on the Hamiltonian, the growth of the coupling and the dimension of the state space affect the qualitative behavior of the system. We prove the existence of weak solutions that are minimisers of an associated non-convex functional, by rephrasing the problem in a convex framework. Under additional assumptions involving the growth at infinity of the coupling, the Hamiltonian, and the space dimension, we show that such minimisers are indeed classical solutions by a blow-up argument and additional Sobolev regularity for the Fokker-Planck equation. These results are obtained in a joint collaboration with Cirant [2].

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Shortest Path Problem variants for the Hydro Unit Commitment Problem

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Key words: Hydro Unit Commitment Problem, time expanded graph representation, Constrained Shortest Path Problem

In energy management, unit commitment problems are strategic in day-ahead operations (e.g., [1]). In countries where hydro-generation is abundant (e.g., France, Brazil, Canada) specifically dealing with the optimization of cascaded reservoirs is quite challenging too (e.g., [2]). The reason for this is that quite some modelling detail can be required to accurately model reality. One of the essential difficulties stems from representing the efficiency curves linking the flow rate with the actual amount of generated power. One particular way of dealing with this difficulty is by disposing of an *a priori* discretization of it. The specific set of points is typically chosen by an operational team in order to have maximal efficiency (highest derivatives).

We consider the single reservoir Hydro Unit Commitment Problem under some hypothesis: i) without head effect, i.e., without considering the non-linear effect of the level of the uphill reservoir on the efficiency ii) discrete operational points for the generated production. In particular, we focus on a single reservoir composed of several units $J = \{1, 2, \ldots, \bar{n}\}$ that can be either pumps or turbines and that the different units are ordered, thus can be aggregated in a unique unit. We propose some variants of path formulation and show that, under some assumptions, they are equivalent to classic mixed integer programming models that can be found in the literature, see, for example, [3].

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A DC Programming Approach for Economic Dispatch Problems in a Bilevel Environment

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Key words: Economic dispatch, Bilevel optimization, DC programming.

The economic dispatch problem in energy management aims at finding the optimal production schedule of a set of generation units while meeting various system-wide constraints. Nowadays, the energy landscape undergoes significant changes worldwide: large consumers have gained protagonism and can perform actions which may significantly impact on the load of the system. In particular, by using advanced information technology, large consumers are (or will soon be) able to partially control their consumption of energy. In this work we formulate this new paradigm of bilevel optimization economic dispatch as a general DC (difference of convex functions) program. A new DC algorithm exploiting the problem's structure is presented, as well as its numerical performance on a real-life instance.

Strong uniform value in gambling houses and Partially Observable Markov Decision Processes

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Key words: Dynamic programming, Markov decision processes, Partial Observation, Uniform value, Long-run average payoff.

Partial Observable Markov Decision Processes model dynamic decision. At the beginning of every stage, a decision-maker imperfectly observes the current state, and chooses an action, possibly randomly. The current state and the selected action determine a stage payoff and the law of the next state. A standard way to aggregate the stream of payoffs is to consider the Cesaro mean $n^{-1}\sum_{m=1}^{n} g_m$, where g_m is the payoff at stage m. The problem is then called the n-stage problem and the maximum expected payoff the n-stage value.

A huge part of the literature investigates *long-term* POMDP, that is, problems which are repeated a large number of times. In this article, we introduce the notion of strong uniform value and show its existence in several standard models of dynamic programming (gambling houses, MDPs, POMDPs). This solves two open problems.

First, the decision maker guarantees the limit of the n-stage values in the infinitely problem where each play is evaluated by the inferior limit of the time-averages.

Second, this shows that for any $\epsilon > 0$, the decision-maker has a pure strategy σ which is ϵ-optimal in any n-stage problem, provided that n is big enough. Hence, the decision-maker can optimize in the long-run without knowing the exact length of the game and without using randomization. This result was only shown with behavior strategies by Rosenberg, Solan and Vieille [3] for finite POMDPs and by Renault [1] and Renault and Venel [2] for more general gambling houses.

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Stochastic Bandit Models for Delayed Conversions

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Key words: Online Learning, Multi-Armed Bandits, Delayed Feedbacks.

Online advertising and product recommendation are important domains of applications for multi-armed bandit methods. In these fields, the reward that is immediately available is most often only a proxy for the actual outcome of interest, which we refer to as a *conversion*. For instance, in web advertising, clicks can be observed within a few seconds after an ad display but the corresponding sale –if any– will take hours, if not days to happen. This paper proposes and investigates a new stochastic multi-armed bandit model in the framework proposed by Chapelle [2] –based on empirical studies in the field of web advertising– in which each action may trigger a future reward that will then happen with a stochastic delay. We assume that the probability of conversion associated with each action is unknown while the distribution of the conversion delay is known, distinguishing between the (idealized) case where the conversion events may be observed whatever their delay and the more realistic setting in which late conversions are censored. We provide performance lower bounds as well as two simple but efficient algorithms based on the UCB [1] and KLUCB [3] frameworks. The latter algorithm, which is preferable when conversion rates are low, is based on a Poissonization argument, of independent interest in other settings where aggregation of Bernoulli observations with different success probabilities is required.

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Optimal transport of vector valued measures

Francois-Xavier Vialard

In this talk, we will discuss the extension of transport distances on the space of cone valued measures. We will start from a brief review of the extension of the Wasserstein distance to the space of nonnegative Radon measures in order to introduce our discussion to cone valued measures. This is rather an explorative talk in which we will present the possible approaches to define such distances and show a striking difference with standard optimal transport. Passing by, we will touch upon the available numerical algorithms. This is joint work with L. Chizat.

A trilevel pricing model for demand side management

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Key words: Multilevel optimization, demand side management, revenue management, energy markets.

With the emergence of the smart grid paradigm, combined to the breakthrough of renewable energy, demand side management has become more important than ever. Among the tools used to manage the energy demand, electricity pricing represents a powerful lever to incur load shifting. Therefore, we aim to study the exact effects of pricing in the furnisher-consumer interaction in order to optimize the benefits of an electricity furnisher.

In [1], Gkatzikis *et al.* considered a multilevel electricity market featuring three kinds of actors: a system operator at the highest level, aggregators at an intermediary level and end-users at the lowest level. We present a modification of this model, in order to:

- include competition among system operators at the highest level,
- add new actors at the intermediary level, called local agents, that own and manage their electric devices,
- allow energy exchanges among the actors of the intermediary level.

Besides the model, we present some numerical results obtained on data retrieved from EDF.

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Sharp asymptotic and finite-sample rates of convergence of empirical measures in Wasserstein distance

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Key words: Optimal transport, Wasserstein distance, empirical measures.

The Wasserstein distance between two probability measures on a metric space is a measure of closeness with applications in statistics, probability, and machine learning. In this work, we consider the fundamental question of how quickly the empirical measure obtained from n independent samples from μ approaches μ in the Wasserstein distance of any order. We prove sharp asymptotic and finite-sample results for this rate of convergence for general measures on general compact metric spaces. Our finite-sample results show the existence of multi-scale behavior, where measures can exhibit radically different rates of convergence as n grows.

See more details in [1].

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Optimal bridge players among separated networks

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Key words: Network games, Bonacich centrality, self-loops, bridge players.

We follow [3] to study the optimal bridge problem among separated networks. This paper examines optimal targeting of players, groups and central planner. We find that the optimal choice (new links connect with other groups) of the group coincides with the individual's rational choice. But, the best choice for the central planner may be different from the individual's rational choice. We have shown how player's centrality is going to be affected due to combination of separated networks, and how this is related to the self-loops and Bonacich centrality of these separated networks. We construct an exact index to identify the key bridge players linking up whom will mostly increase aggregate equilibrium effort and aggregate equilibrium welfare, and we find that the key bridge players may consist of neither each group's key players nor central players. We provides its implications on company merge, optimal targeting, community merge and network design.

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Constant payoff in zero-sum stochastic games

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Key words: stochastic games, asymptotic value, Shapley operator, Markov chains

In any one-shot zero-sum game, the payoff induced by a couple of optimal strategies is equal to the value of the game. For dynamic games, a natural refinement is that the average payoff, after any fraction of the game, is equal to the value of the game. In this paper we prove that this is the case for patient players in any finite zero-sum stochastic games, as conjectured by Sorin, Venel and Vigeral 2010.

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