The Gaspard Monge Program for Optimisation and operational research

2013-2014 Review

PGMO-COPI 14
October 28th, 2014

Sandrine Charousset
Stéphane Gaubert

Agenda

- FMJH and PGMO : organisation, main research topics
- Invited Professors
- Scientific events
- Review of 2013 Projects

What is PGMO ?

A joint initiative of EDF and the Jacques Hadamard Mathematical Foundation (FMJH)

- A new kind of research partnership :
  - Based on corporate patronage (non-profit support)
  - For optimization and operations research
  - Involving academic and industrial researchers
- Main objectives :
  - Develop a research community
  - Stimulate joint research projects
  - Support and improve education in optimization
  - Promote job opportunities for students in this field

Organization of PGMO

PGMO is a program of the FMJH

- **A general optimization program (PRMO)**
  - Optimization education
    - Scholarships (4 were attributed in 2012, 4 in 2013, 1 in 2014)
    - Support for optimization classes
    - Promote industrial job opportunities
  - Academic research projects
  - Seminars, workshops, conferences…
- **Optimisation and Energy Research Initiative (IROE)**
  - Focused on industrial applications in the field of energy
  - Created at the instigation of EDF

PRMO and IROE projects

- Projects are open to any academic researchers in France and abroad (but at least one french partner is required)
- IROE projects involve EDF and academic researchers
- Due to the non-profit character of EDF patronage, all results of PGMO projects are made freely available to the community
- Other industrial partners are welcome to join in sponsoring new dedicated initiatives
- PGMO is not yet another funding agency ! Collaboration and networking is strongly encouraged
- Projects can be of various sizes

Organization of PGMO

Gaspard Monge Program for Optimization and operations research

Coordinator : Stéphane Gaubert

« Mathematical Research on Optimisation » (PRMO)

- Education
- Research projects
- Seminars and Conferences

Research Initiative « Optimization and Energy » (IROE)

Managing Officer : Sandrine Charousset

Joint research projects

Other Future Research Initiatives

Master classes, training, scholarships

Seminars, conferences, Web site

Academic research projects, publications, Joint applied research projects, Optimization algorithms and open software, …

Governance

Steering Commitee

- Florian de Vuyst (ENS Cachan)
- Gregoire Allaire (Ecole Polytechnique)
- Hans Rugh (FMJH, Paris-Sud)
- Eric Lunéville (ENSTA)
- Bertrand Maury (Paris-Sud)

Executive Board

- Stéphane Gaubert (INRIA, Coordinator of PGMO)
- Grégoire Allaire (Ecole Polytechnique)
- Frédéric Bonnans (INRIA, Ecole Polytechnique)
- Pierre Carpentier (ENSTA)
- Sandrine Charousset (In charge of IROE, EDF R&D)
- Michel Minoux (UPMC)

Scientific Council

- Alexandre d'Aspremont (CNRS-ENS Ulm)
- Marie-Christine Costa (ENSTA)
- Michel de Lara (Ponts)
- Laurent Dumas (UVSQ)
- Leo Liberti (Ecole Polytechnique)
- Patrice Perny (UPMC)
- Filippo Santambrogio (Paris-Sud)
- Roberto Wolfler Calvo (Paris-Nord)
- FMJH Scientific Council representative

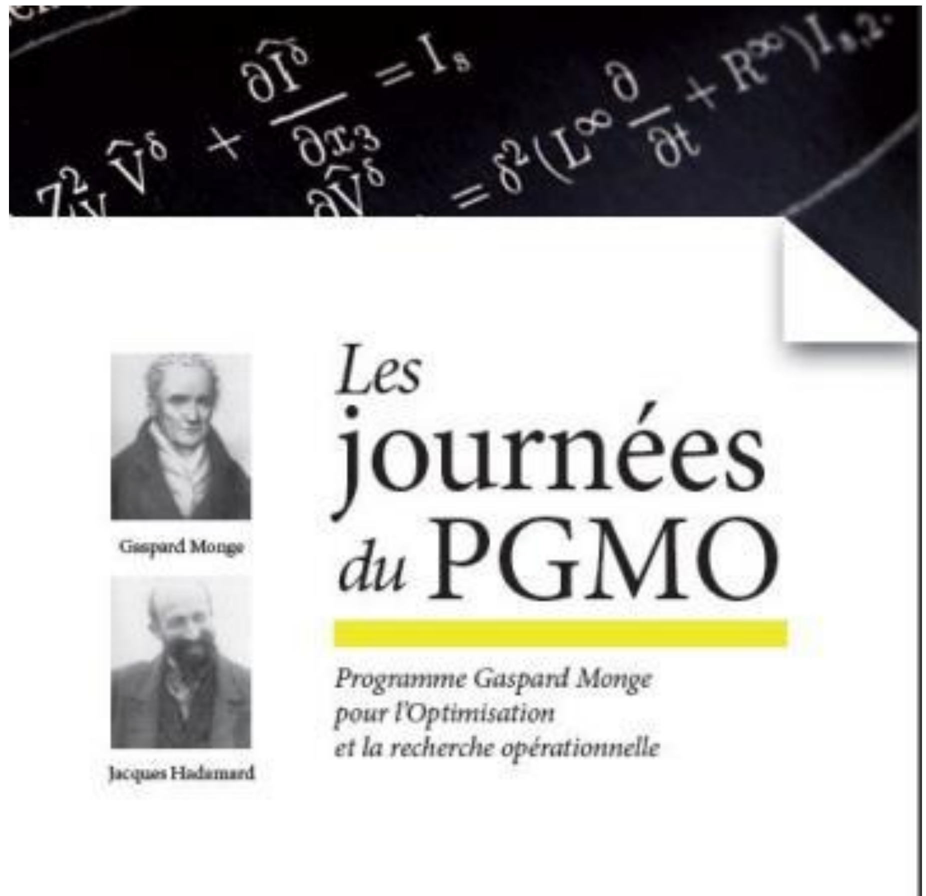
Invited Professors

Invited Professors 2012-2013

- **PGMO proposes 6 months (separable) of invited professor each year :**
  - **Research project**
  - **Optimization teaching (6h/Month, PhD level)**
- **2013 : Laurent El Gahoui (Univ Berkeley)**
  - **« Robust Data Approximation for Large-Scale Convex Programs »**
- **2014 : Georg Pflug (University of Vienna)**
  - **invited by Ecole Polytechnique (CMAP) , 1 month**

Scientific Events

The second PGMO Conference (Oct. 2013)



ROADEF 2014 : Review of PGMO Projects

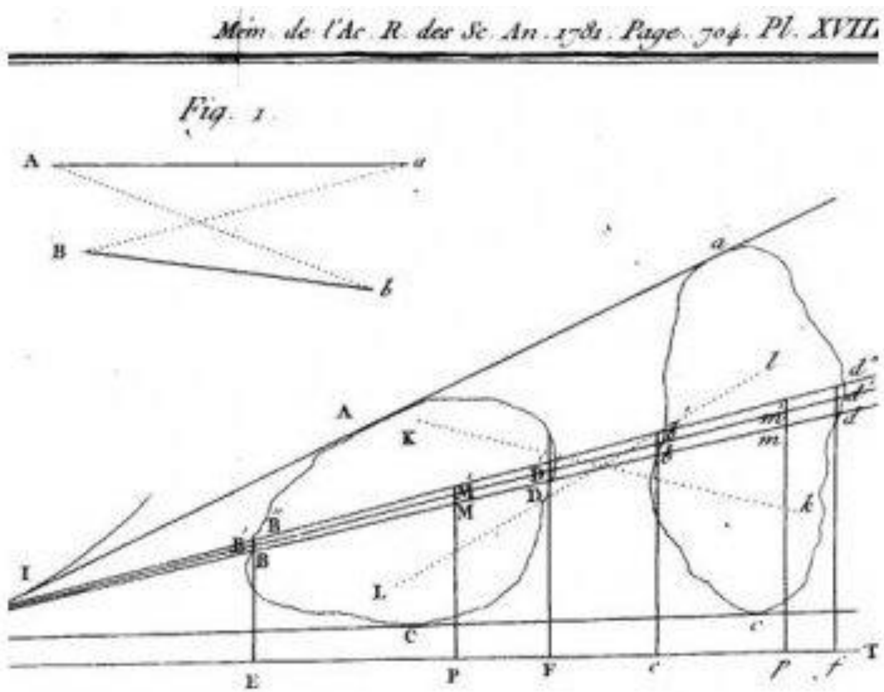
Le Programme Gaspard Monge pour l'Optimisation et la recherche opérationnelle

Rex et Discussion

Sandrine Charousset

•Euro CSP 2014

Recent Advances in linear optimization



•NetCo 2014

NetCo 2014

New trends in optimal control

23-27 June 2014
Vinci International Congress Center
Tours, France

http://netco2014.sciencesconf.org

ANR HJNET

ITN SADCO
Initial Training Network
Sensitivity Analysis for Deterministic Controller Design

•Modélisation Mathématique en Mécanique

MODELISATION MATHEMATIQUE EN MECANIQUE

UNIVERSITE DE VERSAILLES
20 MARS 2014

Exposés autour de différents modèles mathématiques en mécanique

Conférenciers:
Adel Blouza (Université Rouen)
Paul de Nazelle (IRT SystemX)
Boris Desmorat (Université Pierre et Marie Curie)
François Jouve (Université Paris Diderot)

Comité d'organisation:
Laurent Dumas, Paolo Vannucci (LMV, Université de Versailles)

Programme, inscription: http://dumas.perso.math.cnrs.fr/ModMec14.html

PGMO seminars

11 semina

- Andrzej Ruszczynski (Rutgers University) : Dynamic Risk-Averse Optimization.
- Jesús Antonio De Loera (University of California at Davis) : "Integral versions of Helly's theorem and Applications to Optimization"
- Shinji Mizuno (Tokyo Institute of Technology) : "The LP-Newton method for standard form linear programming problems"
- Jon LEE (U. Michigan) : "Two stories of matrix optimization"
- Marcia FAMPA (Universidade Federal de Rio de Janeiro) "Formulations and solution approaches for the Euclidean Steiner Problem in-n-space"

- Mickael POSS (Heudiasyc, CNRS) "Optimisation robuste ajustable, applications dans la conception de réseaux"

PGMO seminars

- Georg PFLUG (University of Vienna) "Multistage stochastic optimization : approximations, bouds and time consistency"
- Matthieu Kowalski (Université Paris-sud) "Inverse problems: a sparse synthesis approach"
- Nicolas Chauffert (CEA) "From compressed sensing to realistic sampling: the example of MRI«
- Immanuel Bomze (University of Vienna) "Copositive relaxation beats Lagrangian dual bounds in quadratically and linearly constrained QPs"
- Abdel Lisser (LRI, Université d'Orsay) "Joint probabilistic constraints"

Research Projects

PGMO call for projects

Topics

- Research Projects (Optimisation)
- Teaching projects

3 kinds of projects

A : trainees, material, trips,...

- Open to all academic teams (international jointly with a french team)

B : PHD, post-doc, invited researchers

- In priority (but not exclusively) in Saclay laboratories

C : Invited professor

- In Saclay laboratories

Criterias for elected projects

- Scientific quality at the highest international level
- Cooperation and networking between different teams
- Projects organising seminars and workshops in Saclay,
- Projects with young researchers,
- Applications to industry

Next call for projects

- Call for project published November 2014
- Pre-Submission around end of february 2015
- Final submission mid-april 2015
- Results June 2015

2014-2015 Projects

29 projects

- **On PRMO :**
  - **2 research network projects**
  - **14 research projects**
- **On IROE**
  - **2 projects about scheduling of outages for thermal plants**
  - **5 project about Unit-Commitment**
  - **2 projects about optimising hydro-valleys**
  - **2 project about economic equilibriums**
  - **2 project about smart-grids**

PRMO Projects

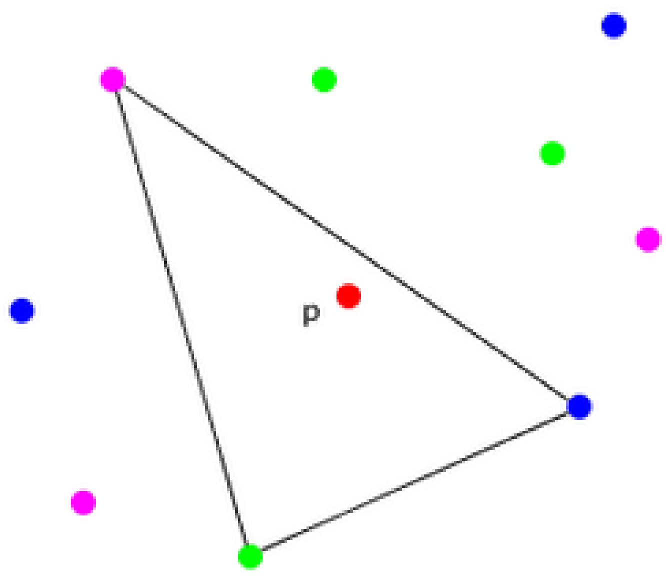
Colourful Linear Programming: geometric, combinatorial, and algorithmic aspects

- **Team :** F. Meunier, P. Sarrabezolles (CERMICS ENPC), A Deza (McMaster University)
- **Context**
  - colorful linear programming: constraint matrix with a coloring of the columns -> existence of a colorful basis?
  - defined by Barany and Onn in 1997
  - applications in discrete geometry and discrete optimization
  - generalization of linear programming
- **Objectives :** under various conditions:
  - settle complexity status
  - count the number of colorful bases

Colourful Linear Programming: geometric, combinatorial, and algorithmic aspects

❑ Results

- generalizes computation of Nash equilibria in bimatrix games
- contains PPAD-complete problems
- new NP-completness results
- proof of a conjecture of Deza, Huang, Stephen, and Terlaky about the number of colorful bases



❑ New research lines

- study special cases in discrete optimization
- some of them polynomial?

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Semi-algebraic approaches to doubly sparse problems

- **Team :** J. Bolte (Toulouse Capitole/TSE), E. Pauwels (Mines de Paris), N. Vayatis, E Richard (Stanford University), P-A. Savalle, N. Vayatis (ENS Cachan), V Perchet, (Paris 7)

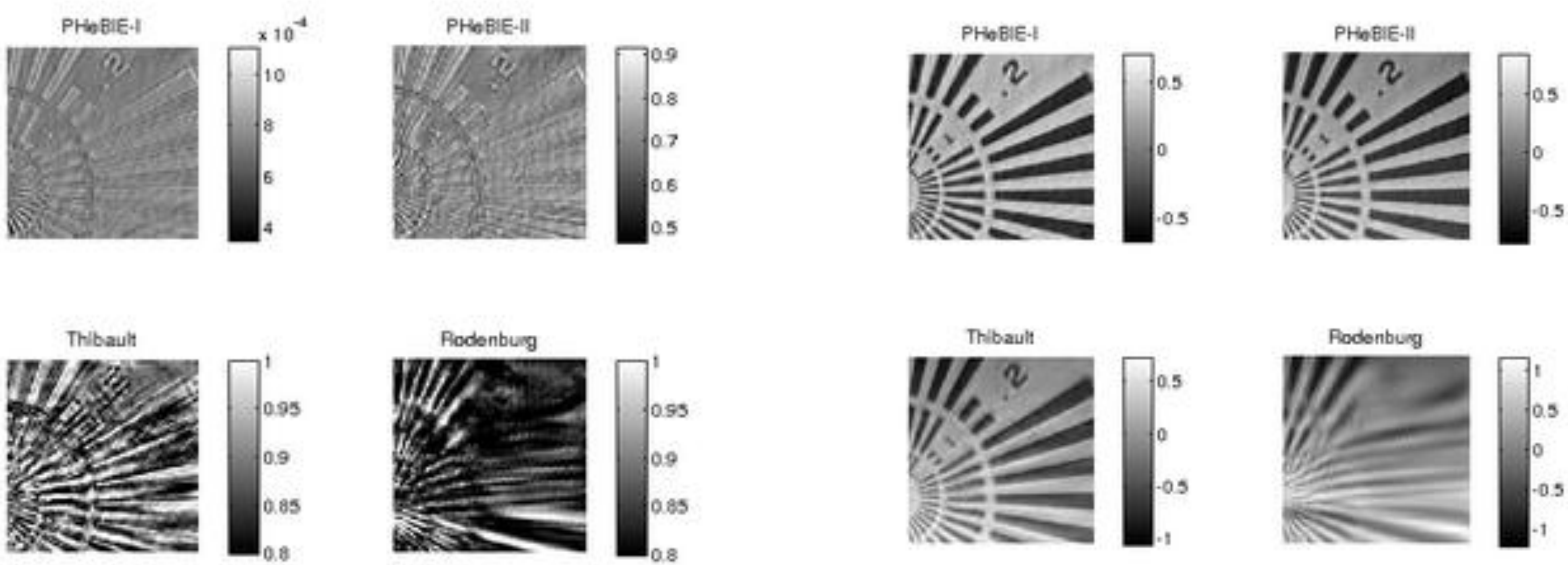
- **Context**
  - Sparse optimization, inverse problems of large size
  - Nonconvexity but semi-algebraicity

- **Objectives :**
  - Adress doubly sparse problems
  - Design specific methods for problems involving several nonconvex constraints
  - Provide convergence guarantees

Semi-algebraic approaches to doubly sparse problems

❑Results

- New algorithm: Proximal alternating forward-backward method (PALM)
- New functions promoting doubly sparse problems
- Convergence guarantees for SA problems having complex geometries



Courtesy of R. Luke (Goettingen University),
"Proximal Heterogeneous Block Input-Output Method and application to Blind Ptychographic Diffraction Imaging"
by R. Hesse, R. Luke, S. Sabach, M.Tam

Latin America Stochastic Optimization Network (LASON)

- **Team :** B. Kulnig Pagnoncelli, T. Homem-de-Mello, (Universidad Adolfo Ibáñez), F. Bonnans, L. Pfeiffer (CMAP and INRIA) , P. Carpentier (ENSTA), J-P. Chancelier, M. De Lara, (CERMICS), A Dallagi (EDF R&D)

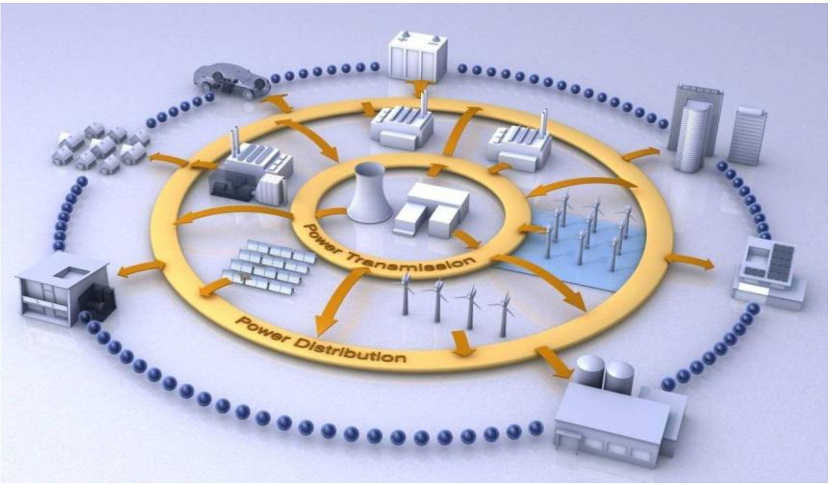
- **Context**
  - Researchers from Chile and France
  - Large scale energy optimization problems under uncertainty

- **Objectives**
  - Network of Chilean and French researchers
  - Identify relevant problems for EDF

Latin America Stochastic Optimization Network (LASON)

❑Results

- Decentralized energy management in a stochastic setting
- The inclusion of risk in energy models
- Workshops and meetings in Chile and France



Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Discrete Trace Ratio Optimization Problem

- **Team :** . Glover, M. Guignard, Y. Saad, S. Hanafi, I. Crévits, C. Wilbaut, M. Vasquez (LAMIH), N. Mladenovic, M. Bellalij, F. Baghery, I. Massa-Turpin (Université Valenciennes)

- **Context :** Optimization : Combining Mathematical Analysis & Operational Research :
  - Mathematical Analysis :
    - Trace of the function of a large matrix.
    - Trace Ratio Optimization
  - Operational Research : Mixed Integer Programming

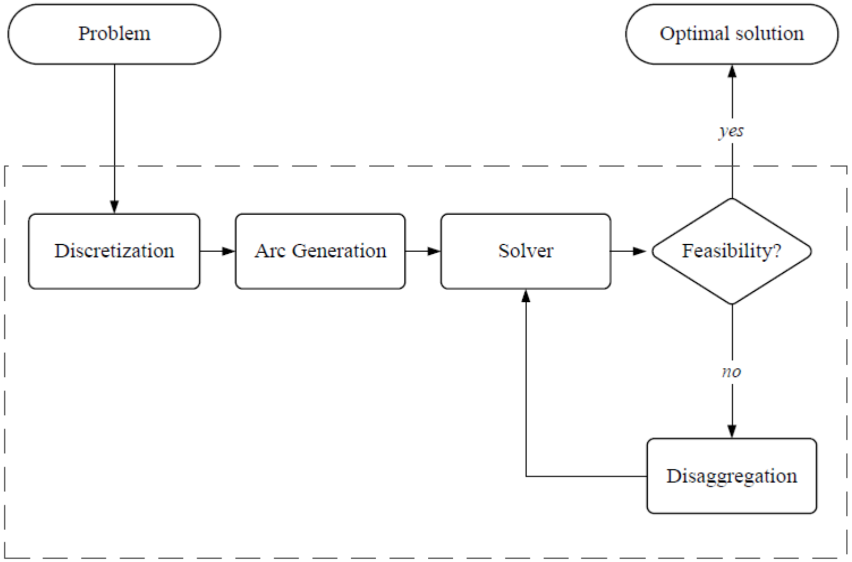
- **Objectives :** Compute the trace without evaluating the function of the matrix

  Hybrid Approaches :
  - Mathematical Analysis : Newton method & Lanczos algorithm
  - Operational Research : Variable Neighborhood Search Metaheuristic, Multi-Start

Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Discrete Trace Ratio Optimization Problem

❑ Results

- Computation of upper and lower bounds: exploiting the connection between the global block Lanczos method and Gauss-type quadrature rule
- Generalized Trace Ratio Optimization : Singular Value Decomposition
- Iterative aggregation and disaggregation of arc-flow models



❑ New research lines

- Approximation of the Estrada index
- Datamining: Dimension Reduction, Machine learning, Classification
- Cell formation problem

Polynomial Optimisation

- **Team :** JB Lasserre, D. Henrion (LAAS Toulouse) + invited visitors
- **Context :**
  - Global polynomial Optimisation
  - Approximation of basic semi-algebraic sets
  - Applications of the moments-SOS approach in various applications and some
- **Objectives**
  - Some inverse problems:
    - reconstruction of a geometric objet "K" from some measurements of a measure "mu" supported on the object (e.g. "K" is a basic semi-algebraic set)
    - Inverse optimal control. From knowledge of some trajectories (e.g.. obtained by training) find the integral cost that is minimized (e.g. in Humanoid Robotics)
  - Polynomial Optimization:
    - find an alternative to (the costly) semidefinite relaxations for global optimization.
    - analyze the impact of convexity and compactness in the moment-SOS approach

Polynomial Optimisation

❑ Results

❖Computation Inverse problems:

➢By solving a linear system, we can reconstruct exactly the polynomial "g" that define the semi-algebraic set G={x: g(x) <= 1} if one knows moments of the Lebesgue measure on G.

➢Inverse optimal control (IOCP). One has provided a rigorous definition of the IOCP via occupation measures and a hierarchy of semidefinite relaxations to approximate as closely as desired an optimal solution of the IOCP.

❖Polynomial Optimization:

➢Provided a generalization of the Lowner-John ellipsoid Theorem (cf. figure)

➢Extension of the moment-SOS approach to non-compact semi-algebraic sets.

➢defined a new hierarchy of semidefinite relaxation which is a tradeoff between the power of the (computationally costly) SOS hierarchy and the much cheaper (but less efficient) LP-hierarchy

❑ New research lines

❖Complete the results obtained for inverse problems

❖Efficient implementation of the new hierarchy with K. Toh (Sparsity, point-evaluation, etc.)

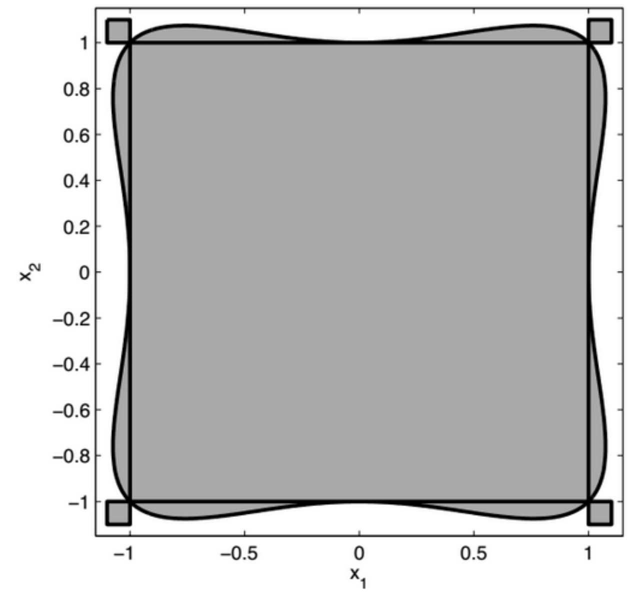


Fig : Degree 4

Steiner Tree Problems in Distribution Networks

- **Team :** JK Hao, JP Hamiez, Z Fu (LERIA Angers)
- **Context**
  - Network Design
  - Optimization Methods
  - Steiner or Spanning Tree Problems (STPs)
- **Objectives :**
  - Develop high-performance algorithms for solving STPs
  - Extend the research to real-life applications

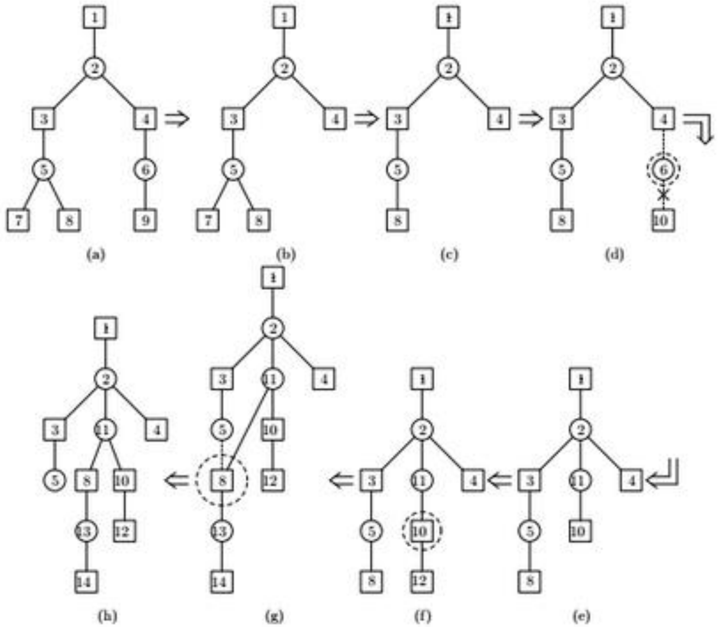


Fig. 1. Process for generating a neighboring solution for the STPRBH

Steiner Tree Problems in Distribution Networks

Results

- Several effective algorithms are proposed for STPRBH and QMSTP
- Tens of best known results are improved
- Two papers are accepted for publication and one paper is submitted

Ongoing work

- Investigating another two interesting STP variants: the classical STP and the prize-collecting STP (PCSTP)
- Participating in the 11th DIMACS implementation challenge about STPs

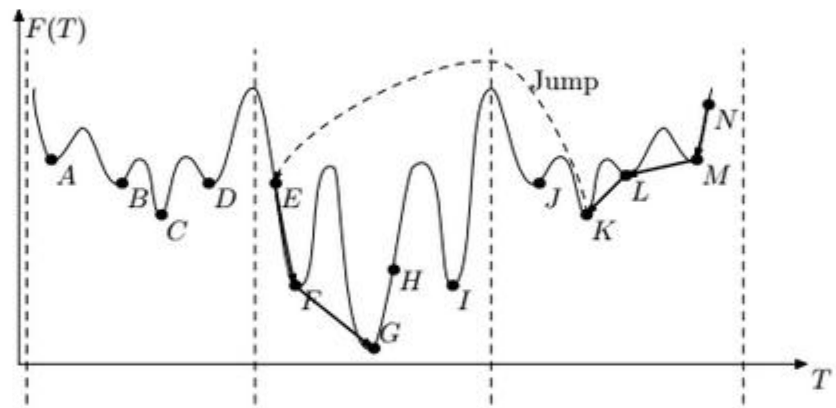
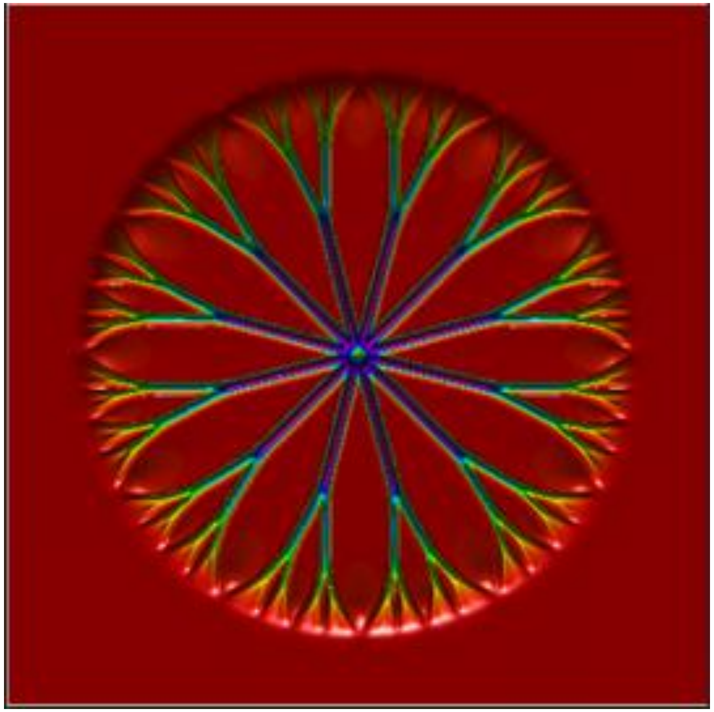


Fig. 2. Procedure of searching a high-quality feasible solution of the QMSTP

Continuous Approximation Methods for optimal networks (MACRO)

- **Team :** F Santambroggio, R Ignat, J Iouet, A Monteil (Univ Paris Sud), M Bonnivard, A Lemenant (Univ. Paris Diderot), E Oudet (Laboratoire Kuntzman Grenoble), D Bucur, B Bogosel (Univ. Savoie), G Bouchitté (Univ. Toulon), L Brasco (LATP Marseille)

- **Context**
  - Network Steiner problem on graphs: NP hard
  - Approximation results for length-penalized problems (Modica-Mortola, Ambrosio-Tortorelli...)
  - Satisfactory numerical implementations for branched networks and partition problems



- **Objectives :**
  - Develop approximation method with connectedness constraints
  - Apply them to the Steiner problem and related issues

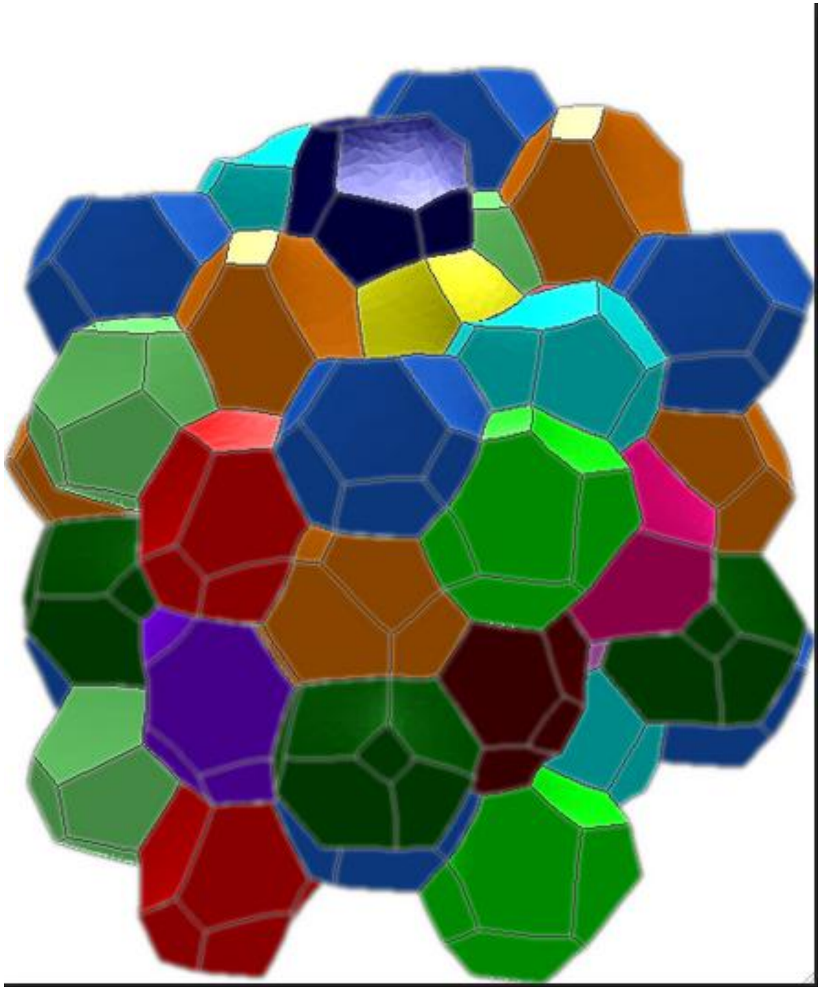
Continuous Approximation Methods for optimal networks (MACRO)

❑Results

- Several Approximation for Steiner: Gamma-convergence
- Improvement of the current general results on branched networks

❑New research lines (in progress)

- Investigating Shape optimization problems with branched networks
- Numerical implementations for Steiner



Tropical Methods in Optimization

- **Team :** X. Allamigeon, M. Akian, S. Gaubert, P. Benchimol (INRIA), R.D. Katz (CONICET, Universidad Nacional de Rosario, Argentine), Zheng Qu (Uni de Fudan, Chine)

- **Context**

Motivation: three open problems in computational optimization:

- complexity of linear programming (9th Smale's problem)
- complexity of zero-sum games
- curse-of-dimensionality in dynamic programming.

- **Objectives :**

- develop new classes of methods in optimization and game theory
- using recent advances in combinatorics and tropical geometry
- develop new numerical methods for large scale dynamic programming

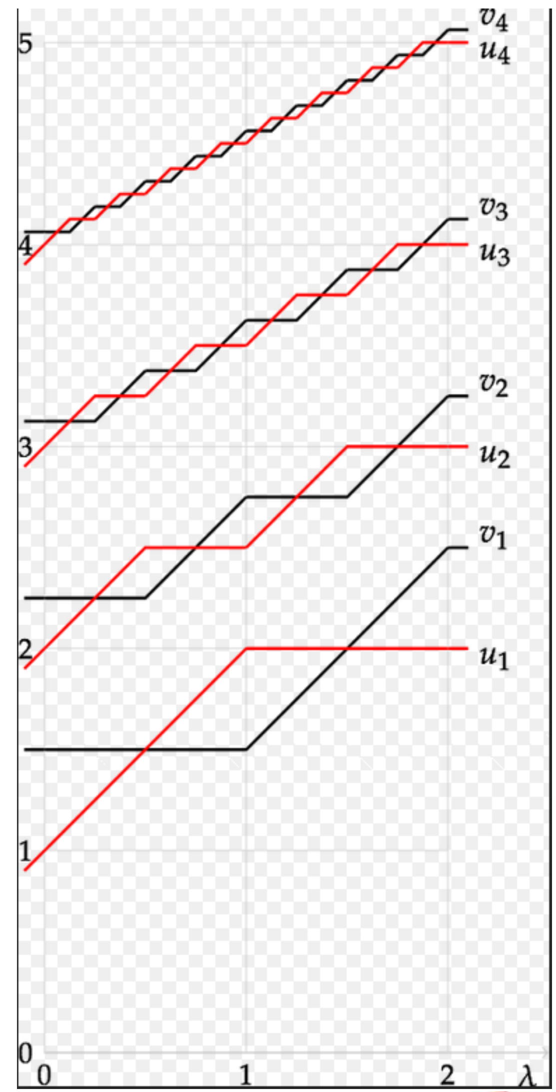
Tropical Methods in Optimization

❑ Results

- a tropical simplex algorithm solving mean payoff games in polynomial time on average
- a family of LPs where the central path has exponential curvature -> disprove the continuous Hirsch conjecture
- new (maxplus based) numerical method to attenuate the curse of dimensionality + complexity estimates

❑ New research lines (in progress)

- tropicalization of homotopy methods for polynomial systems (Shub-Smale theory)
- tropical approach to polynomial optimization, based on amoebas
- extension of max-plus basis methods to stochastic dynamic programming problems + complexity estimates based on metric entropy



Quadratic convex reformulation for mixed-integer quadratic programming

- **Team :** S. Elloumi (CEDRIC), A Lambert (CNAM), A Billionnet (ESIEE)
- **Context**
  - Quadratic Programming
  - exact solution methods
  - quadratic convex reformulation
- **Objectives :**
  - handle real variables
  - extension of the approach
  - comparison to other methods

Quadratic convex reformulation for mixed-integer quadratic programming

❑Results

- the extension is done from the theoretical point of view
- the implementation and comparison are on-going
- some preliminary results
- several aspects and details of implementation to be tuned

Pastor : perturbation analysis for deterministic and stochastic optimal control problems

- **Team :** F Silva, S Adly, R Cibulka (Univ. Limoges), J Bolte, JP Decamps, S Villeneuve (TSE), JF Bonnans (CMAP), PL Combettes (Univ. ParisVI)

- **Context**
  - Parameterized optimal control problems.
  - Stability analysis for data perturbation.
  - Sensitivity results and asymptotic behaviour.
- **Objectives :**
  - To provide a precise analysis for deterministic problems using metric regularity tools.
  - To perform a sensitivity analysis for convex stochastic optimal control problems and small noise asymptotics.
  - To perform a duality analysis for singular stochastic optimal control problems appearing in finance.
  - The study of linearization methods to solve numerically optimal control problem

Pastor : perturbation analysis for deterministic and stochastic optimal control problems

❑ Results

- Sensitivity results for the value function of some convex stochastic optimal control problems under non-convex data perturbation.
- Stability and sensitivity results for the solutions of strongly convex stochastic optimal control problems.
- Large deviation analysis for some stochastic optimal control problems.
- Second order analysis of optimal control problems involving parabolic equations and final state constraints.

❑ New research lines (in progress)

- Sensitivity results in mathematical finance.
- Stability analysis for optimal control problems of PDEs.
- First order methods to solve optimal control problems of ODEs and PDEs.

Global derivative free optimization with sparse grids

- **Team :** F Delbos (IFPEN), L Dumas (UVSQ), S Siniquet (IFPEN)
- **Context**
  - Derivative free global optimization
  - Sparse Grids surrogate models
- **Objectives :**
  - Enhance the GOSGRID algorithm

Global derivative free optimization with sparse grids

❑Results

- A matlab toolbox to be released
- Building sub-levels of sparse grids model to generate intermediate results

❑New research lines

- Weaken the building condition of sparse grid models
- Take into account more general constraints than bounds

Mathematical Programming based Algorithms in Non-linear Combinatorial Optimization

- **Team :** E Angel, KT Nguyen (Univ. Evry), E. Bampis, C Durr (Univ Paris VI)

- **Context**
  - Online algorithms, algorithms for massive data
  - Applications: Energy-aware algorithms in computational sustainability, Submodular functions in machine learning.

- **Objectives :**
  - Develop a principled method for convex and non-convex combinatorial optimization.
  - Design algorithms with improved performance guarantees.

Mathematical Programming based Algorithms in Non-linear Combinatorial Optimization

❑ Results

- ❖ Introduce a method based on Lagrangian duality for non-convex problems
- ❖ Design improved algorithms in energy scheduling

❑ New research lines

- ❖ Derive improved algorithms for other domains (sub-modular functions, matching, etc).
- ❖ Developing ideas between online algorithms and online learning.

Vehicles sharing systems: modelling, analysis and optimisation

❑ Team :
V Jost (LIX et GSCOP Grenoble), C Frikker (INRIA), L Oukhellou, E Come (IFSTARR GRETTIA), Y Chabchoubn (ISEP), H Mohamed (Univ. Nanterre)

❑ Context

- Bike/car business models: from ownership to (short-term) rental ?
- One way rental systems are inefficient without regulation !

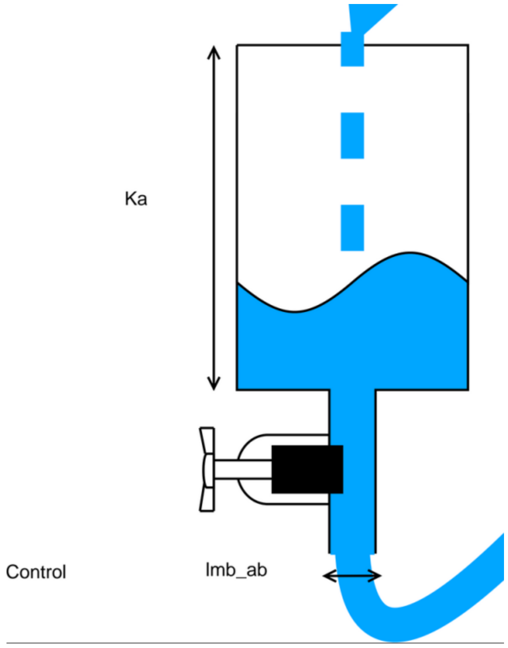
❑ Objectives :

- Understand the behavior of existing systems
- Specify general VSS using queuing network models
- Computable approximations for these networks
- Algorithms / policies for design and control issues

Vehicles sharing systems: modelling, analysis and optimisation

❑Results

- Fluid and Mean field limits
- Optimization rules for simple models
- Clustering station w.r.t. daily dynamics



❑New research lines

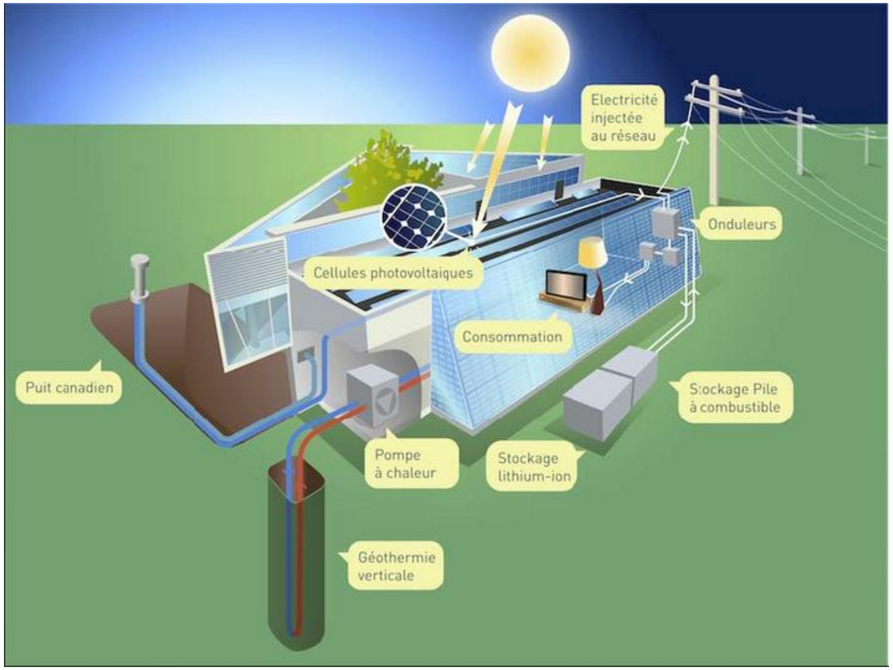
- Mean field methods for transient dynamics
- Real data: Factoring out important effects (distance, station popularity and types...)

Combinatorial Optimization with Multiple Resources and Energy Contraints

- **Team :** Sandra U. Ngueveu, Christian Artigues, Pierre Lopez (LAAS-CNRS, Toulouse)

Context

- Energy considerations are becoming paramount in the resolution of real-world applications.
- Pre-existing studies involve multiple energy sources and general non-linear efficiency functions, but generally no scheduling.
- All our previous work on scheduling under energy constraints considered linear (and even identical) energy efficiency functions, which oversimplifies the problem.



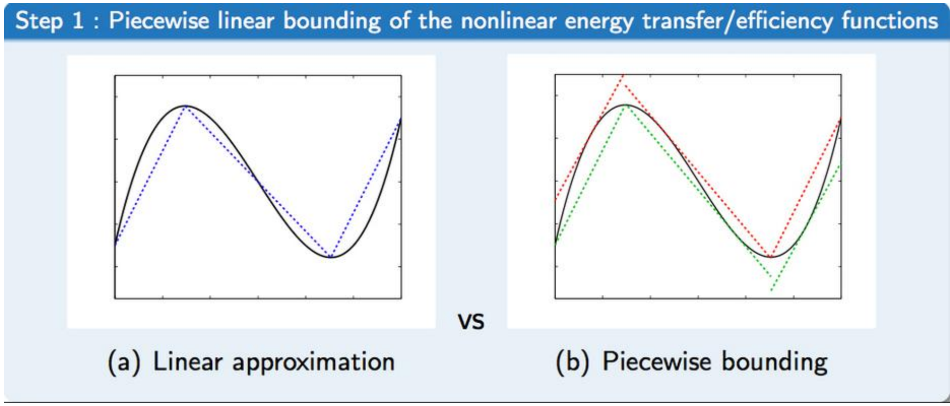
Objectives :

- Address the (combinatorial) optimization challenge of integrating energy sources constraints (physical, technological and performance characteristics) in deterministic (scheduling) models.
- Solve explicitly and in an integrated fashion the resulting energy resource allocation problems and energy-consuming activity scheduling problems with non linear energy efficiency functions.

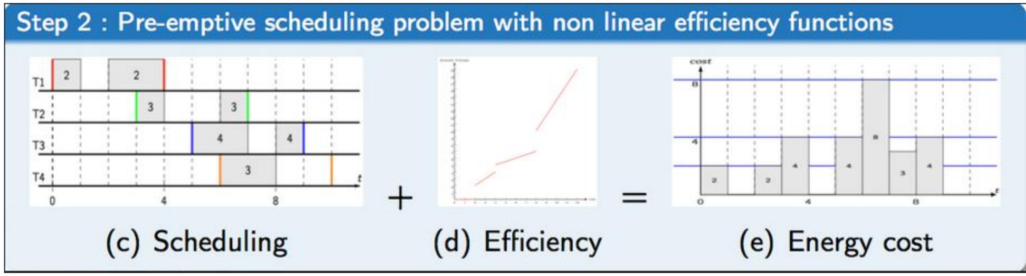
Combinatorial Optimization with Multiple Resources and Energy Contraints

❑ Results

- ❖ Proof of concept on a single-source scheduling problem involving realistic non-linear efficiency functions provided by researchers in Electrical Engineering.
  - -- validation of the piecewise bounding-based solution methodology
  - -- application on a water production optimization problem
- ❖ Analysis/study of a pre-emptive scheduling problem with multiple non reversible energy sources (i.e. sources that can only produce energy, not retrieve it)
  - -- proof of NP-hardness, proof of aggregability
  - -- dantzig-wolfe decomposition, identification of multiple subproblems, branch-and-price
  - -- resolution in less than an hour of 90% of the instances adapted from the literature



(a) Linear approximation (b) Piecewise bounding



(c) Scheduling (d) Efficiency (e) Energy cost

❑ New research lines

- ❖ Mean field methods for transient dynamics
- ❖ Real data: Factoring out important effects (distance, station popularity and types...)

MAORI --MAthematics of Optimization foR Imaging

- **Team :** S. Anthoine (LATP Marseille), J-Fr. Aujol (Univ Bordeaux 1), A. Chambolle (CMAP), C. Chaux, (CNRS, Univ Paris-Est), E. Chouzenoux (Univ Paris-Est), Ph. Ciuciu (CEA), L. Condat (CNRS ENSICaen), J.Fadili (ENSICaen), A. Fraysse, M. Kowalski (Univ Paris-Sud), A. Gramfort (Telecom ParisTech/INRIA Saclay), M. Nikolova (CNRS, ENS Cachan), G. Peyré (CNRS, Univ Paris-Dauphine) N.Papadakis (CNRS), N. Pustelnik (CNRS, ENS Lyon), P. Weiss(INSA Toulouse)
- **Context**
  - Optimization for Image/Signal Processing
- **Objectives :**
  - Facilitates some working groups
  - Organizing workshop
  - Large scale optimization for imaging

MAORI --MAthematics of Optimization foR Imaging

❑ Results

- MAORI workshop (November 2013)
- Several publications on both theory of optimization and application in imaging

❑ Further

- A second MAORI workshop (November 2015 ?)

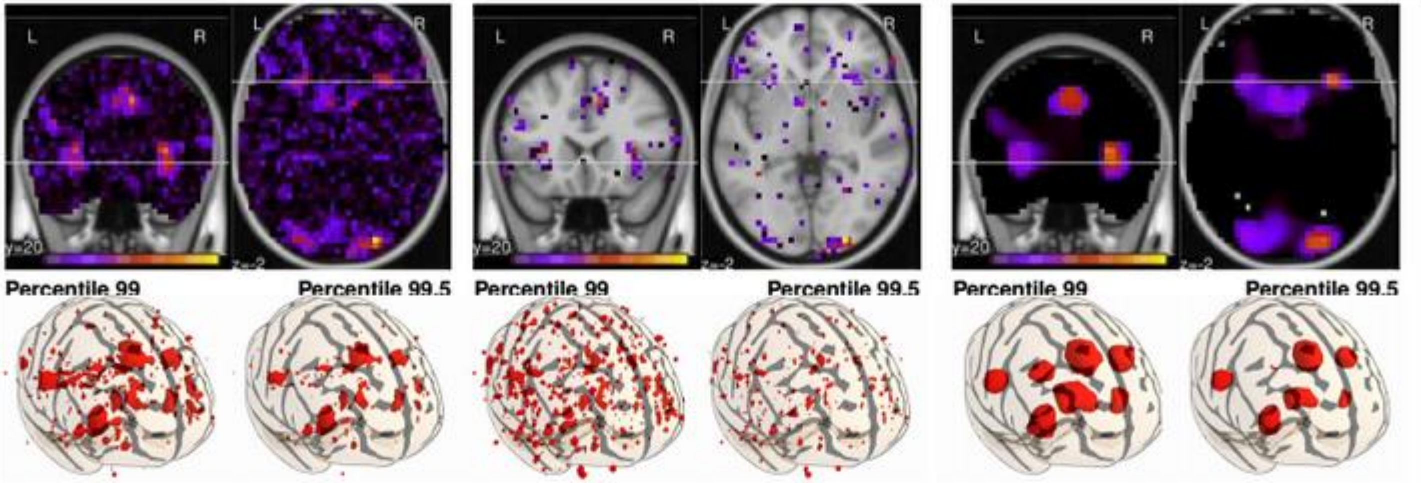


Figure 2. Results on fMRI data from [4] (from left to right F-test, ElasticNet and TV-ℓ_1). The TV-ℓ_1 regularized model segments neuroscientificly meaningful predictive regions in agreement with univariate statistics while the ElasticNet yields sparse although very scattered non-zero weights.

Adjustable robust optimisation applied to network design problems

Team : M. Poss, D Nace (CNRS, UTC), W. Ben-Ameur (CNRS, TelecomSud),A. Pessoa (UFF, Brazil), S. Mattia (IASI-CNR, Italia), C. Busing (RWTH-Aachen, Germany)

Context

- Adjustable robust optimization is flexible
- Classical approach: decision rules
- Successfully applied to network design problems

Objectives :

Going beyond classical decision rules through:

- Decomposition algorithms
- Exact approaches

Adjustable robust optimisation applied to network design problems

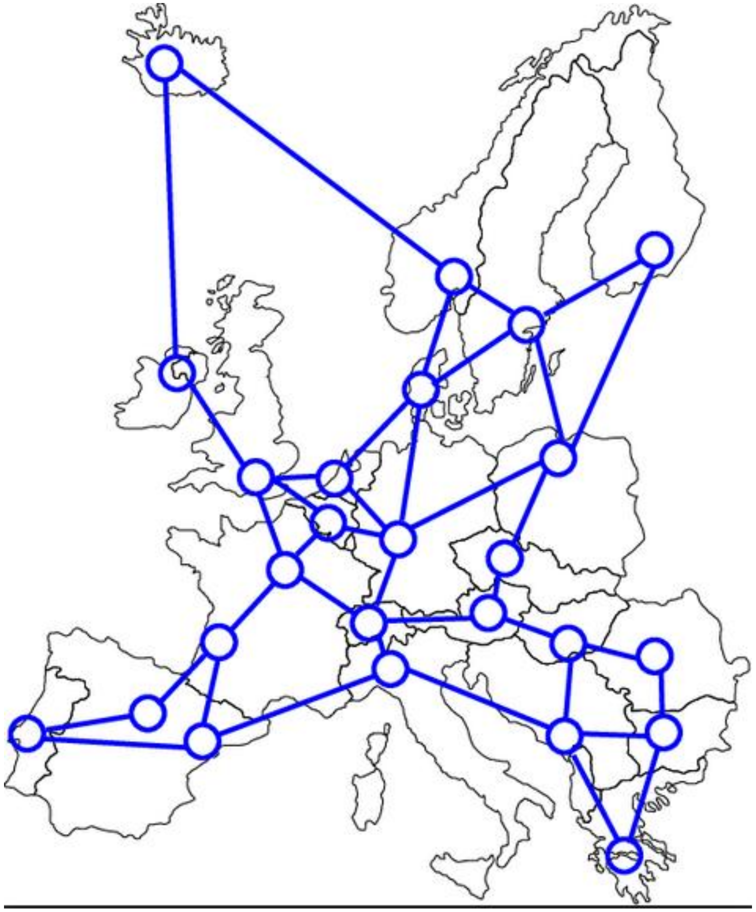
❑ Results

Very good computational results

- ❖ Classical robust network design (RND)
- ❖ (RND) with outsourcing

❑ New research lines

- ❖ Extension to multistage problems
- ❖ Application to lot-sizing



IROE Projects

Energy Management main optimization problems

IROE Projects

Scheduling outages for nuclear plants

The problem

Compute outage schedules for all 58 nuclear plants, taking into account uncertainties (robustness) and recourses linked to the fact that schedules may be updated each month

Operational difficulties

- Robustness to local and global uncertainties
- Stability of the schedules regarding the operationnal process

Scientific difficulties

- Solving a huge stochastic MILP
- Modeling recourses
- Robustness depends on time horizon

Stochastic Nuclear Outage problems with chance constraints

- **Team :** A. Lisser, C. Giquel, J. Cheng (Uni. Paris Sud), R. Zorgati, M. Porcheron (EDF)

- **Context**
  - Combinatorial stochastic optimization problems with joint probabilistic constraints
  - Conic based approximation methods (SOCP, SDP)
  - Applications to energy management)

- **Objectives :**
  - Joint probabilistic constraints with independent random variables
  - Distributionally robust optimization problems for joint probabilistic constraints
  - Joint probabilisitc constraints with dependent random vatiables

Stochastic Nuclear Outage problems with chance constraints

❑Results

- ❖Approximation methods for solving joint chance constraints with independent normally distributed random variables.
- ❖Approximation methods for solving joint chance constraints with dependent elliptical distributed random variables using copulae.
- ❖New reformulations for distributionally robust optimization problems with joint chance constraints.
- ❖•Development of new sampling method for chance constrained problems.
- ❖ Applications to energy management.
- ❖•Organization of the first European Stochastic Programming Conference on applications of stochastic optimization to energy problems (90 participants from 24 different countries from all over the world).

❑New research lines

- ❖Extension of our results to more general probability distributions using more copulae

Stochastic Nuclear Outage problems with chance constraints

- **Team :** A. Lisser, C. Giquel, J. Cheng (Uni. Paris Sud), R. Zorgati, M. Porcheron (EDF)

- **Main features**

Application : **planning outages for nuclear power plants**

- Find and optimal scheduling of the outages w.r.t. several constraints related to the energy production, and to limited refueling resource constraints, and also to maintenance operation constraints.
- Find the optimal refueling load in order to satisfy the customers demand, and minimizing the total costs.

Objectives :

- Dealing with uncertainty by using chance constraints in combinatorial optimization problems
- Studying new algorithms based on conic optimization (SOCP, SDP, Copositive Programming)
- Solving methods for individual chance constraints and binary variables
- Challenge: Solving joint chance constraints and binary variables in real world energy planning problems.

Mettre à jour

Stochastic Nuclear Outage problems with chance constraints

Results

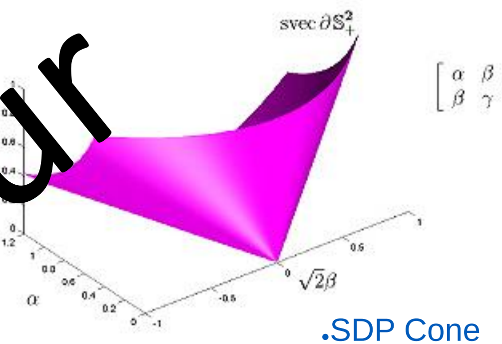
Theoritical/algorithmic/software prototypes

- **Individual chance constraints and binary variables**
  - SOCP reformulation + B&B
  - SDP relaxations + B&B
- **Joint chance constraints and binary variables (in progress)**
  - SDP reformulations + B&B
  - Copositive reformulations + B&B
  - Distributionally robust Reformulations
  - Convexity results
- **Publications : conferences with/without proceedings et international journals**
- **B&B software prototype development**

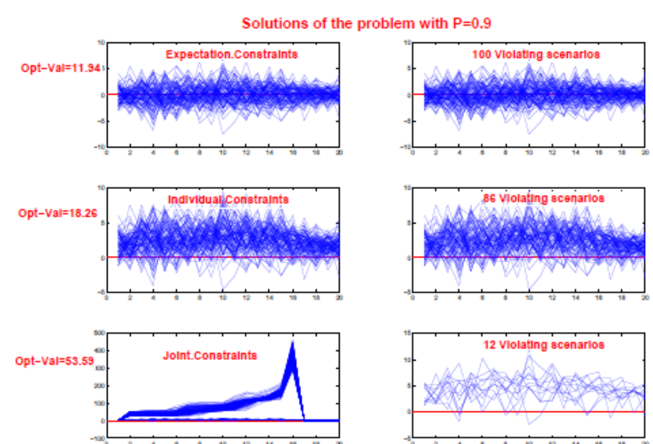
Applications to energy management problems

- **Solving energy management problems with joint probabilistic constraints**
- **Application to supply/demand energy balance problems.**
- **Application in progress to the scheduling nuclear outages problem,**

Mettre à jour



•SDP Cone



•Individual vs joint chance constraints

Optimization of the scheduling of the Nuclear Power Plant stops

❑ Team :

R. Wolfer-Calvo, A. Rozenknop, C. Pira (Paris XIII), V. Jost ,D. Savourey, (CNRS, LIX), F. Vanderbeck, N. Dupin, (Bordeaux 1, INRIA), P. Bendotti, M. Porcheron (EDF)

❑ Context

- Nuclear Power Plan
- Planning stops for refuelling and Maintenance
- Minimize cost under Energy demand satisfation constraints

❑ Objectives :

- Uncertainty of the stops duration
- Consider at the same time: ROBUSTNESS, STABILITY and REOPTIMIZATION

Optimization of the scheduling of the Nuclear Power Plant stops

❑Results

❖Chance Constraints in Columns Generation approach

❖Multicriteria Decision Tree (MDP) for each Nuclear Power Plant (Pricing)

❖Average and Worst demand constraints for the whole problem (Master)

❑New research lines

❖Reintroduce Uncertainty in the Demand (Scenarii)

❖Combine Decision Tree (MDP) with Infeasibility Beneders Inequality

Market Equilibrium

The problem *Provide scenarios of long terme electricity, and gaz fundamentals, compute investments strategies, …*

Operational difficulties

- Computation of optimal and endogenous investment strategies
- Long term stratégies for interconnected reservoirs

Scientific difficulties

- Capacity expansion problems
- Stochastic decomposition within incomplete knowledge
- Sensitivity analysis
- Stochastic equilibrium

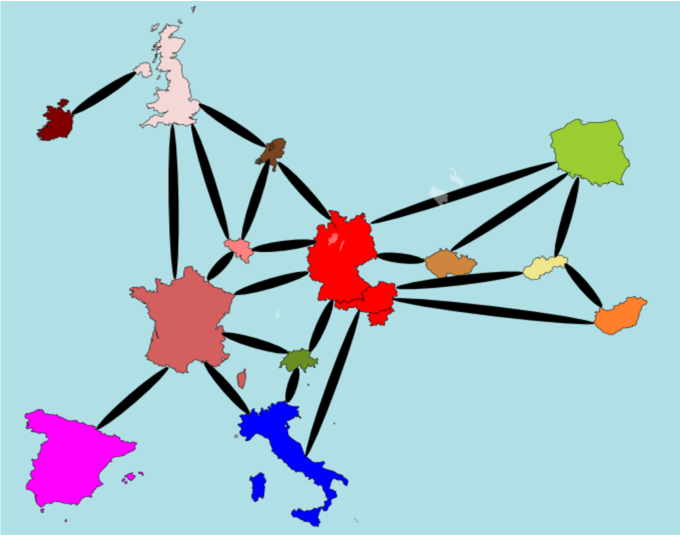
Proximal decomposition of Stochastic Zonal Long-Term Energy Production Planning

❑Team :

P. Mahey, J. Koko (LIMOS, U. Blaise Pascal), P.L. Combettes (LJLL-UPMC), A. Dallagi A. Lenoir (EDF), J.P. Dussault (U. Sherbrooke, Canada)

❑Context

- Long-term pricing simulation of electricity European market
- Stochastic interzonal Dynamic Program
- Numerical testing with EDF scenarios data for 2030



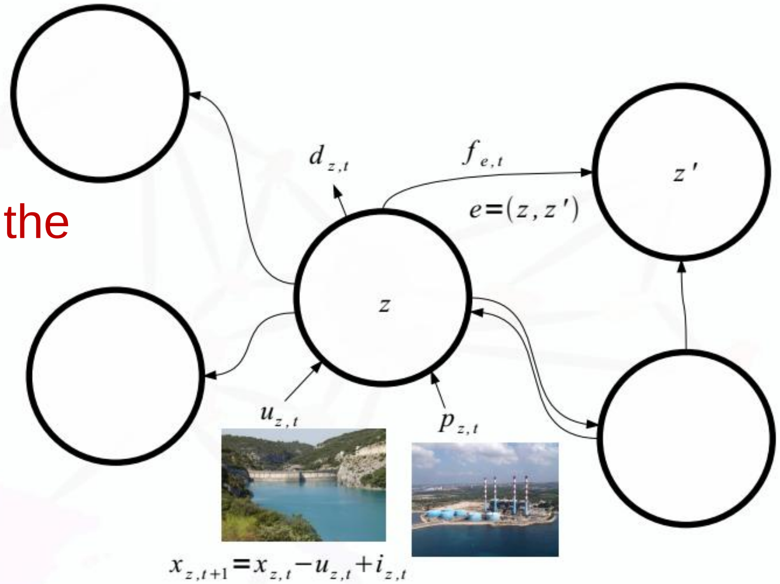
❑Objectives

- Apply splitting methods to the multizone model
- Infer transfer prices for each zone
- Propose new splitting schemes with improved performance

Proximal decomposition of Stochastic Zonal Long-Term Energy Production Planning

❑Results

- Successful proximal decomposition of the deterministic multiperiod model
- Introduce flow variable splitting to decouple the network
- New class of primal-dual Fejer monotone algorithms



❑ Remaining work

- Extending the decomposition to stochastic model
- Numerical testing with EDF scenarios for 2030
- Compare with Peaceman-Rachford splitting
- Test Quasi-Fejer block-coordinate iterations with random sweeping
- Submit publication to ICSP

Nash equilibria for the valuation of offers in the management of daily production : the point of view of the producer

❑ Team :

D. Aussel (Univ. Perpignan), Miroslav Pistek (Académie des Sciences Tchèque, Prague), P. Bendotti

❑ Context

- electricity market model with quadratic bids
- point of view of one producer

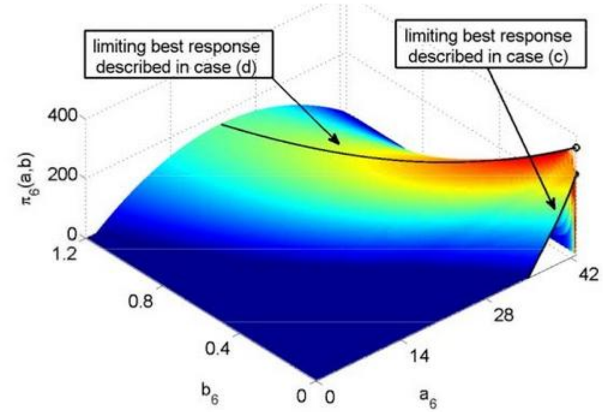
❑ Objectives

- Analysis of the best response of producer
- Stability of the best response with respect to bids of other producers

Nash equilibria for the valuation of offers in the management of daily production : the point of view of the producer

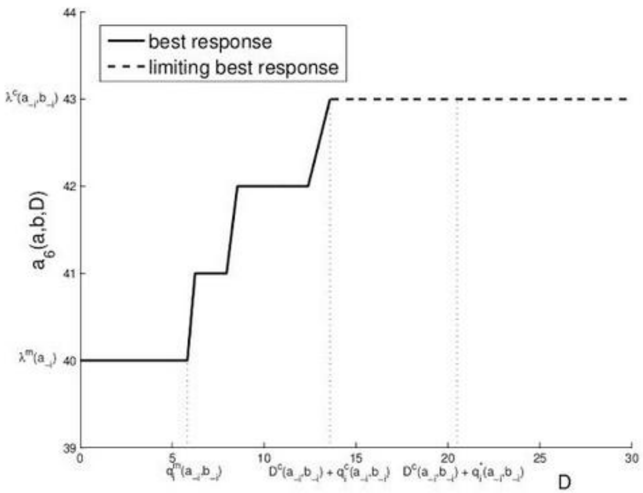
Results

- Analytic description of ISO'problem solutions
- Complete description of optimal response of the producer
- Linear bids provide optimal pure best response and quadratic bids provide optimal approximate best response



Remaining work

- Analysis of stability of the obtained best response
- Evaluation of Nash equilibrium of the market in the case of linear bids



Short terme Optimization of electricity Generation Schedules

The problem ***Compute feasible and as optimal as possible schedules, while dealing with uncertainties***

Operational difficulties

- Short calculation time vs big scale problem
- Compute robust schedules
- Strong Feasability requirements
- Infra-day coupling constraint

Scientific difficulties

- Optimising non separable and non convex fonctions
- Modeling of uncertainties and recourses

Consistent Dual Signals and Optimal Primal Solutions

❑ **Team :** A. Frangioni, (Univ Pise), C. Lemaréchal, J. Malick, (INRIA), W. Oliveira, C Sagastizabal, (IMPA), G. Petrou, N. Oudjane (EDF)

❑ Context

- coordinating production of electrical generators
- large number of units
- different unit types: thermal, hydro, nuclear, ...

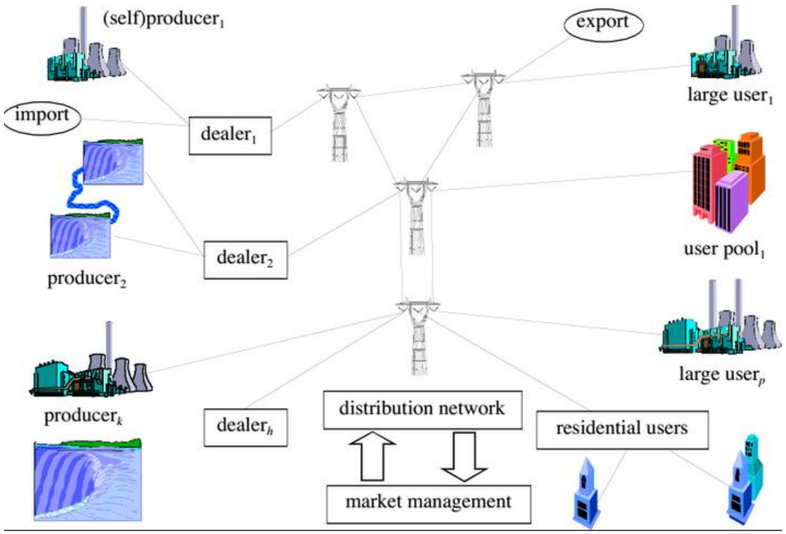
❑ Objectives

- develop advanced price-decomposition techniques
- better handling of prices (dual variables)
- obtain better (primal) solutions faster

Consistent Dual Signals and Optimal Primal Solutions

Results

- developed approaches for simplified problems
- developed models for real-world problems (EdF)
- developed generic scheme for decomposition-based heuristic



New research lines

- extend code to solve real-world problems
- collect and/or create realistic instances
- test realistic instances, use feedback to improve approaches

Stochastic Optimization for Unit-Commitment problems

❑Team : R. Henrion (Weierstrass Berlin), M. Minoux (LIP6), W. van Ackooij (EDF)

❑Context

- Stochastic Optimization => probabilistic constraints
- Robust Optimization
- Unit commitment with (uncertain) renewable generation

❑Objectives

- Improve structural understanding of problems with probabilistic constraints
- Move methods to large-scale

Stochastic Optimization for Unit-Commitment problems

❑Results

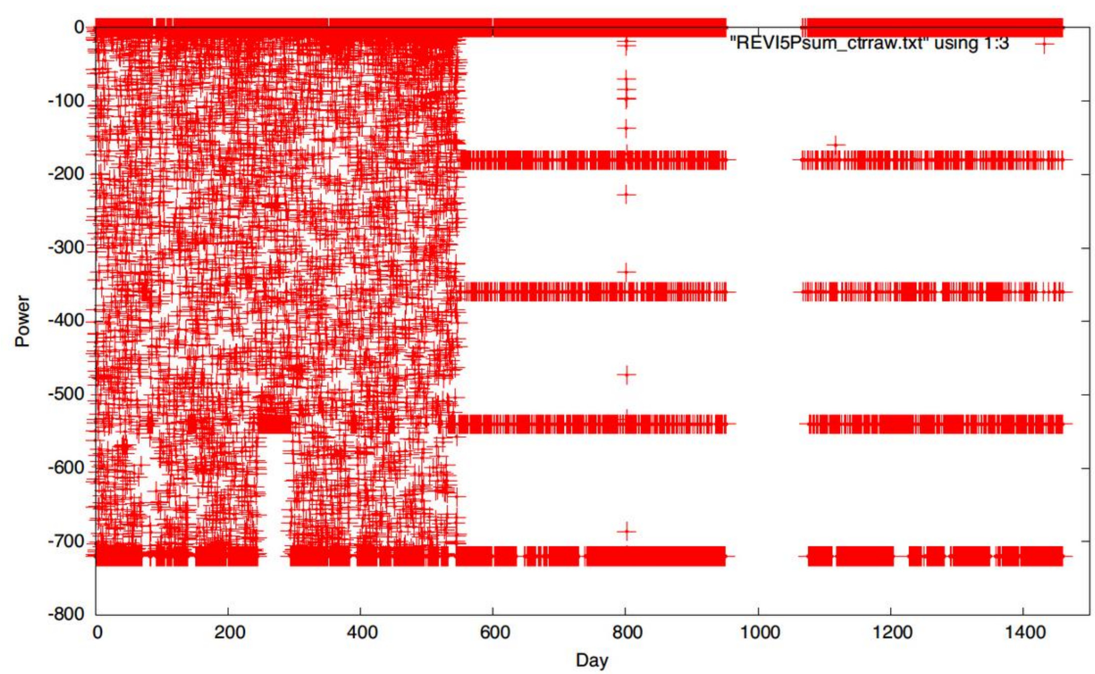
- Better understanding of differentiability properties of probabilistic constraints
- New algorithms for tackling larger instances
- Primal recovery in unit-commitment problems under joint probabilistic constraints allows one to obtain solutions within 1-2% optimality gap.

Learning Constraints for Reducing Combinatorics

❑ Team : N. Beldiceanu (Mines de Nantes), H. Simonis (Cork, Ireland), A. Lenoir, JY. Lucas (EDF)

❑ Context

- Production data from the period 2007-2010 given in half hour intervals for more than 300 plant



❑ Objectives

- Extract from data models for each plan
- Make models more robust

Learning Constraints for Reducing Combinatorics

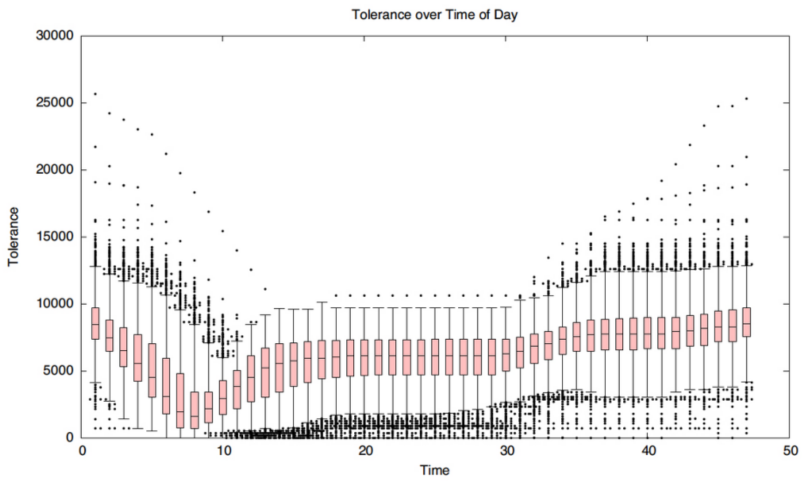
❑ Results

- Detecting Balanced Workload in EDF Plant Production Data (internal report)

  (time point when sum of production in the first part is within a stated tolerance to the production of the second part)

- Get stronger models from the learned constraints (published research paper)

  (necessary conditions for automata constraints using the concept of glue matrix)



❑ New research lines

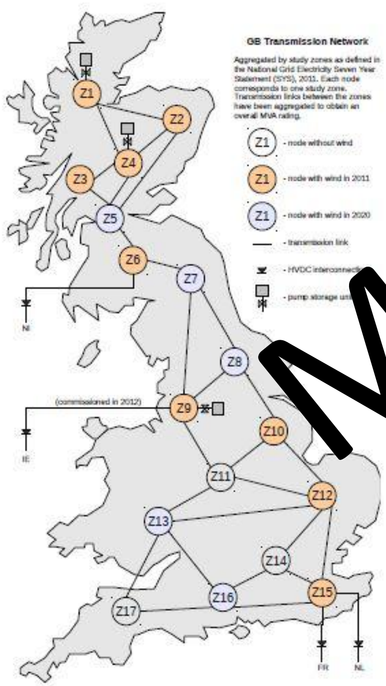
- Reformulate automata constraints as linear programs
- Identify correlations between different plants

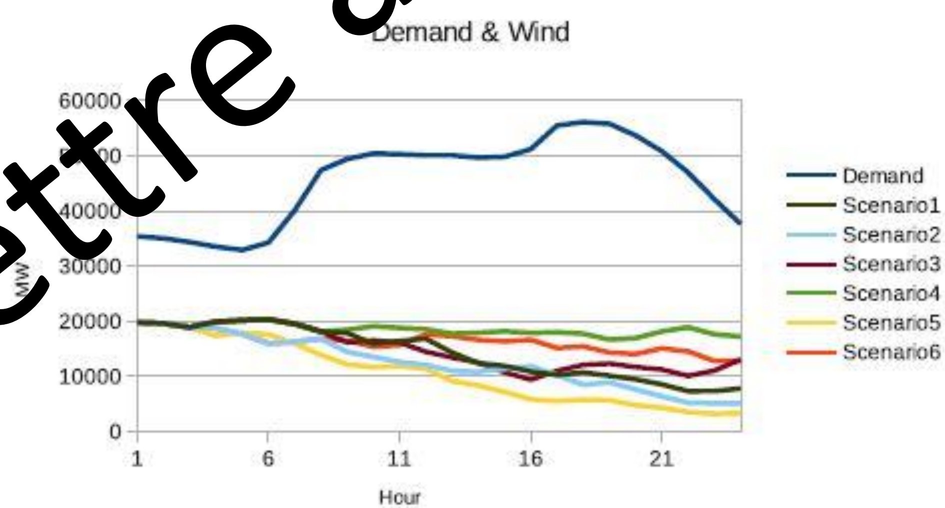
A Stochastic Programming Approach to Finding Robust Reference Schedules for the Unit Commitment problem

- **Team :** T. Schulze, A. Grothey ,K. McKinnon, (Univ. Edinburgh)

- **Objectives** : Develop decomposition methods for multistage stochastic day-ahead unit commitment problems, where the uncertainty is in the wind supply.
  - **Do we need stochastic UC models to accommodate the wind?**
  - **Can we solve the stochastic problem efficiently?**

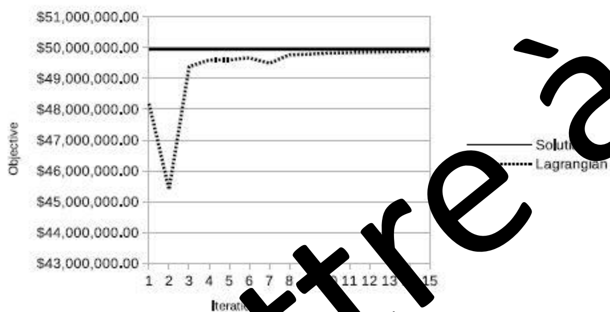
Mettre à jour

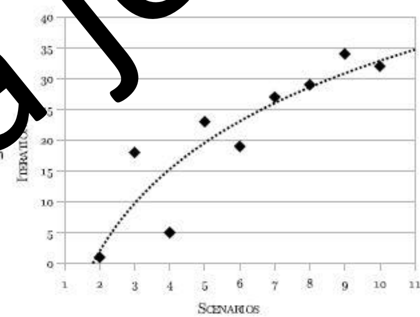




A Stochastic Programming Approach to Finding Robust Reference Schedules for the Unit Commitment problem

- **Results :** the scenario decomposition approach works well.
  - **Branch & Price decomposition can guarantee optimality, unlike e.g. Progressive Hedging, however so far no branching has been needed**
  - **The approach scales well in the number of scenarios**
  - **Primal and Dual initialization and stabilization is key**





Mettre à jour

- **Perspectives**:
  - **When is stochastic planning superior to deterministic planning?**
  - **How high can the Expected Value of Perfect Information and Value of the Stochastic Solution be?**
  - **In cases with larger wind to demand ratio solving a single scenario problem becomes harder. What can be done?**
  - **Different stochastic settings need to be explored.**

Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Environmental Unit Commitment Problem (HACE)

❑ Team : M. BELLALIJ, R. BENMANSOUR, I. CRÉVITS, S. HANAFI, R. TODOSIJEVIC, R. MACEDO, M. MLADENOVIC, C. WILBAUT (Univ. Valenciennes), B. JARBOUI (Univ. Sfax, Tunisia), N. MLADENOVIC (Univ. Brunel, UK)

❑ Context

Unit commitment

- Academic problem
- Additional pratical constraints

❑ Objectives

Hybrid Approach

- Variable Neighborhood Search
- Convex Analysis

Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Environmental Unit Commitment Problem (HACE)

PGMO
Programme Gaspard Monge pour l'optimisation et la recherche opérationnelle

❑Results

- ❖ Best know solutions

❑Remaining work

- ❖ Hydrolic Valley
- ❖ Implementation of efficient local search
- ❖ Comparison with Branch and Bound

Optimization of Hydroelectric Valleys

The problem

On the long-terme horizon : compute coordinated strategies for interconnected reservoirs
On the shorrt-terme horizon : deal with operational constraints and compute feasible schedules

Operational difficulties

- Calculate water values for complex valleys, dealing with numerous constraints
- Short calculation time for large scale MILP
- Strong Feasability requirements

Scientific difficulties

- Stochastic optimisation where dimension of the state ~50
- Joint probability constraints
- Solve huge MILP quickly

Hydro-electric scheduling under uncertainty

- **Team :** A. Philpott, W. Faisal , A. Downward (Electric Power Optimization Center, University of Auckland, New Zealand), A. Kerr (Meridian Energy, New Zealand), F. Bonnans (CMAP – INRIA), A. Dallagi (EDF)

Context

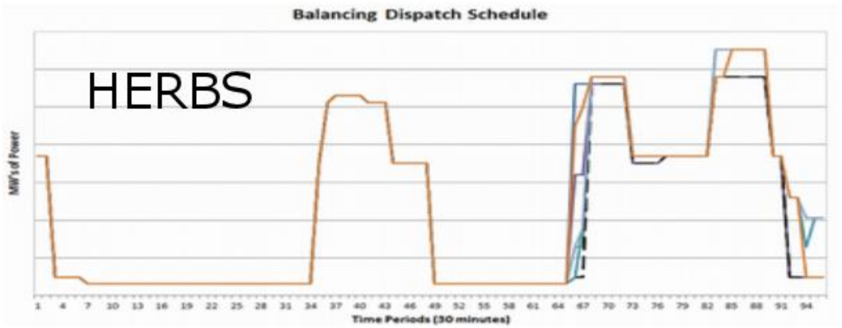
- River chains in New Zealand and France can benefit from scheduling models to deal with inflows and price uncertainty.
- Policies come from multistage stochastic control problems with binary variables to account for :
  - Unit commitment
  - Head effects
  - Price-setting behaviour

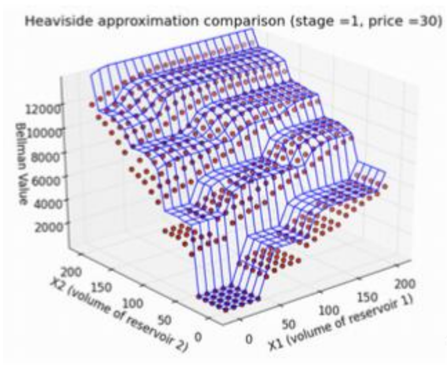
Objectives

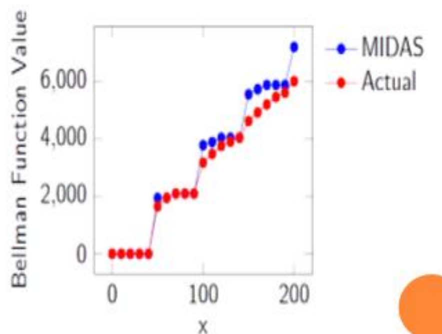
- Build next generation of stochastic dynamic programming models for daily optimization of river chains;
- Incorporate price uncertainty into SDDP models over short term;
- Investigate models for including head effects in short-term scheduling;
- Develop new methods for SDP based on mixed integer programming

❑Results

- Pilot models developed in OPL Studio and Cplex.
- HERO (Hydro Electric River Optimizer)
  - Designed for Waitaki river system in New Zealand
  - Calibrated to historical inflow data
- HERBS (Hydro Electric River Bidding System)
  - Designed for computing EDF river chain bids into French balancing market
- MIDAS (Mixed Integer Dynamic Approximation Scheme)
  - Pilot MIP model for nonconvex Bellman functions
  - MIDAS results outperform convexified SDDP







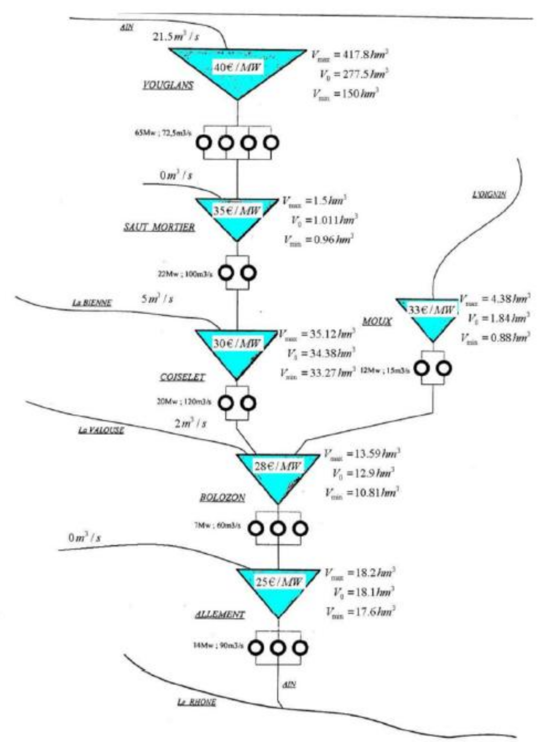
MIDAS

Optimality for tough combinatorial Hydro-valleys problems

❑Team : C. D'Ambrosio (CNRS, Ecole Polytechnique), F. Roupin, (Univ. Paris XIII), C. Gentile (IASI, CNR, Italia), G. Doukopoulos, W van Ackooij (EDF), Y Sahraoui (PHD, EDF), R. Taktak (postdoc)

❑Context

- Short-term HUC problem
- Deterministic, linear
- Head-dependent reservoirs



❑Objectives

- Satisfy complicated physical and strategic constraints
- Solve large-size of real-world instances
- Provide optimal (or near optimal) solutions

Optimality for tough combinatorial Hydro-valleys problems

❑Results

- Exhaustive survey on the HUC problem
- MILP and Lagrangian decomposition →application case : 2 and 3 reservoirs
- Graph representation and path-based formulation

❑Future works

- Column generation based heuristic and exact algorithms
- Benchmark for the deterministic HUC problem
- Multiobjective and Pareto frontier approximation
- Relaxation strengthening through cuts on special HUC problems

Centralised vs decentralised Optimization, Local optimization (smart-grids)

The problem

What is the impact of new kind of actors on the system?
Modeling of local autonomous systems?

Operational difficulties

- Modeling
- Coordination of local and global strategies
- Robust strategies for local actors

Scientific difficulties

- Stochastic decomposition
- Modeling of asynchronous dynamics

Decomposition/Coordination for smart-grids (SmartDec)

❑ Team : P. Carpentier (ENSTA), M. De Lara, J-Ph. Chancelier, V. Leclère (CERMICS)

❑ Context

- Discrete time stochastic optimal control
- Decomposition/coordination methods for large-scale systems
- Applications to specific structures (chain)

❑ Objectives

- Application to general structures (smart grid)
- Use of more elaborated techniques (Augmented Lagrangian)
- Mixing with other decomposition methods (Progressive Hedging)

Decomposition/Coordination for smart-grids (SmartDec)

❑Results

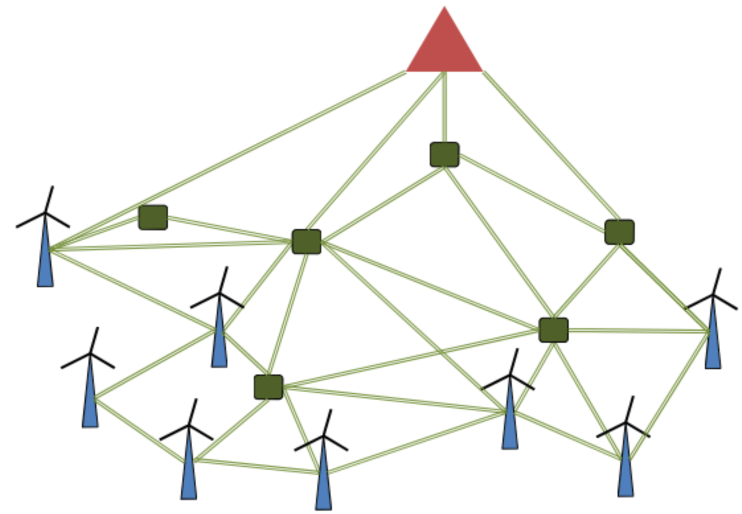
- ❖ Resignation of PhD student recruited early 2014
- ❖ New PhD thesis restarting December 1, 2014

« Cabling » optimisation for Smart-Grids

❑Team : C. Bentz (CNAM-CEDRIC), M.-C. Costa (ENSTA-Paris-Tech-CEDRIC), A. Hertz (polytechnique Montréal-GERAD), Pierre-Louis Poirion (ENSTA-X-LIX)

❑Context

- Numerous wind farms are being built on electricity networks, leading to new optimization problems such as network cabling optimisation.



❑Objectives

- Model the design optimisation of wind farm collection networks as generalized Steiner problem, study the theoretical aspects of the problem and solve it.

Results

- Complexity results:
  The feasibility problem is solvable in polynomial time if all the capacities are 1 but it NP-hard if all the capacities are 2, whatever the graph. The minimum cost problem is NP-hard even if all the cost are 1 but it can be solved in polynomial time if there are 2 terminals.
- Model and solution to the general problem: A mathematical model is proposed. Some cuts are added. Some tests have been made on real instances (using Cplex).

Future works

- Find a dynamic programming approach solving the problem in directed acyclic graphs
- Take into account some data uncertainties.

Thanks !

•Annexes

FMJH

Bringing together the mathematicians of the Saclay campus in order to form a top research community in pure and applied mathematics and their interfaces with sciences.

Members :

- Founding members : Math departments of the ENS-Cachan (CMLA), Université Paris-Sud (LMO), École Polytechnique (CMAP and CMLS), IHÉS , CNRS
- Partners : UVSQ, ENSTA ParisTech, Télécom ParisTech, CEA (IPhT), INRIA, EDF …
- The FMJH is hosted by the Fondation de Coopération Scientifique of the Paris-Saclay campus.

FMJH

Main objectives :

- Become a worldwide recognized center on the campus, highly visible and competitive for the best graduate students and mathematicians
- Promote openess and exchanges between mathematics and other disciplines and between mathematics and the economic world
- Promote a shared scientific policy, with a reactive governance,
- Develop joint research and training actions
- Contribute to break the fronteers between University, Grandes Écoles and companies
- Develop job opportunities for young mathematicians in companies
- Enhance the mathematical background of engineers
- ...