The Gaspard Monge Program for Optimisation and operational research

2012-2013 Review

PGMO Days
October 3, 2013

Grégoire Allaire
Sandrine Charousset

Agenda

- FMJH and PGMO : organisation, main research topics
- Invited Professors
- Scientific events
- Review of 2012 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

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http://www.fondation-hadamard.fr/PGMO

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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)
    - 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 : Grégoire Allaire

« 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, …

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Governance

Steering Commitee

- Florian de Vuyst (ENS Cachan)
- Stéphane Gaubert (INRIA)
- Hans Rugh (FMJH, Paris-Sud)
- Eric Lunéville (ENSTA)
- Bertrand Maury (Paris-Sud)

Executive Board

- Grégoire Allaire (Coordinator of PGMO, 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

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Invited Professors 2012-2013

- **PGMO proposes 6 months (separable) of invited professor each year :**
  - **Research project**
  - **Optimization teaching (6h/Month, PhD level)**
- **2012 : Giuseppe Buttazzo (Univ. Pisa)**
  - **invited by Université Paris-Sud (Math dept.) , 1 month**
  - **« Topics in Shape Optimization »**
- **2013 : Laurent El Gahoui (Univ Berkeley)**
  - **invited by Ecole Polytechnique (CMAP) , 1 month**
  - **« Robust Data Approximation for Large-Scale Convex Programs »**

Scientific Events

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The first PGMO Conference (Sept. 2012)

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ROADEF 2013 : 2 PGMO Sessions

Session S40 : Optimisation pour le management d'énergies

(Salle C002, Chairs : Sandrine Charousset et Grégoire Allaire)

Optimisation robuste d'un parc autonome de production d'électricité

(Alain Billionnet, Marie-Christine Costa, Pierre-Louis Poirion)

Nous étudions l'optimisation de la conception d'un système hybride possédant des panneaux photovoltaïques, des éoliennes, des batteries et un générateur à diesel. Le comportement du vent et du soleil, ainsi que la demande des clients, étant aléatoires, nous chercherons une solution robuste permettant de répondre à la demande pour chaque période, tout en minimisant le coût du pire scénario associé au parc choisi. Pour résoudre le problème robuste, qui se modélise par un programme en deux étapes, nous étudions un problème dit de recours, et montrons que nous pouvons obtenir une solution optimale de ce problème en temps polynomial grâce à un algorithme de programmation dynamique. Nous résolvons alors le problème robuste par une méthode de génération de contraintes.

Optimality for Tough Combinatorial Hydro Valley Problems

(Wim van Ackooij, Claudia D'Ambrosio, Grace Doukopoulos, Antonio Frangioni, Claudio Gentile, Frederic Roupin, Tomas Simovic)

In this talk we will present the project "Optimality for Tough Combinatorial Hydro Valley Problems", funded by the Jacques Hadamard Mathematical Foundation in the context of the Gaspard Monge Program for Optimization. The aim of the project is to study a crucial problem in energy management: the Unit Commitment sub-problem dedicated to hydro valley management. One employs optimization methods to take decisions on the production schedule in the short/medium term for a hydro valley composed of different and connected reservoirs. When continuous, such a problem is easily solved to optimality by any current LP solver. However, the introduction of combinatorial elements leads to far tougher hydro valley problems. This is especially true for some of the larger French Hydro valleys.

Résolution d'un problème d'écoulement de puissance optimal en régime alternatif (AC-OPF) avec prise en compte de l'arrêt-démarrage des groupes de production

(Manuel Ruiz, Alexandre Marié, Pierre Girardeau)

Le problème d'écoulement de puissance optimal en régime alternatif (AC-OPF) consiste à déterminer, sur la base de prévisions de consommation, un plan de fonctionnement d'un réseau électrique satisfaisant les contraintes de sécurité liées au transport de l'énergie tout en minimisant un critère économique. Dans cette présentation, nous nous focalisons sur la modélisation de l'arrêt ou du démarrage des groupes de production. Afin de résoudre ce problème MINLP fortement non convexe, nous proposons des formulations utilisant des contraintes de complémentarité. Les résultats obtenus sur des jeux de données réalistes de grande taille seront présentés. Les tests sont effectués avec Knitro 8.1 qui implémente une méthode de points intérieurs pour les problèmes non linéaires.

Une modélisation LocalSolver pour le placement des assemblages combustibles en piscine

(Jean-Yves Lucas, Didier Marcel, Thierry Benoist, Frédéric Gardi, Romain Megel)

Le combustible présent dans le cœur d'un réacteur nucléaire est constitué de nombreuses unités élémentaires appelées « assemblages combustible ». Lors des arrêts pour rechargement, ces assemblages sont déchargés du réacteur et placés dans la piscine de refroidissement afin qu'un robot effectue des opérations de "permutation de grappes". L'ordre de parcours étant fixé, il convient donc de placer les assemblages dans la piscine de façon à minimiser le trajet du robot. Nous étudions ici la résolution de ce problème par LocalSolver, solveur de programmation mathématique basé sur la recherche locale.

Session S52 : Optimisation pour le management d'énergies

(Salle C002, Chairs : Sandrine Charousset et Grégoire Allaire)

Un jeu d'ordonnancement avec minimisation d'énergie

(Christoph Dürr, Lukasz Jeż, Oscar C. Vasquez)

VNS based heuristic for solving Unit Commitment problem

(Raca Todosijević, Marko Mladenović, Saïd Hanafi, Igor Crevits)

Centrale de pilotage PEGASE de gestion d'une batterie couplée à un moyen de production intermittent

(David Defossez, Julien Merano, Ala Ben Abbes, Stéphane Lascaud)

A completely positive representation of 0-1 Linear Programs with Joint Probabilistic Constraints

(Jianqiang Cheng, Abdel Lisser)

Sur quelques modèles de marchés de l'électricité : limites et reformulations

(Didier Aussel, Michal Červinka, Matthieu Marechal, Rachana Gupta)

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PGMO seminars

11 seminars with 23 talks :

- Dany Ralph (University of Cambridge), "Risk aversion in capacity equilibria", joint work with Yves Smeers (Université de Louvain)
- Miroslav Pistek (Académie des sciences de Pragues) & Didier Aussel (Université de Perpignan), "An analytical approach of one producer best response to other producers bids estimates in electricity market"
- Nordine MAZEGHRANE & Sébastien Lepaul (EDF R&D) "Modeling the coal market"
- Nadia Oudjane (EDF R&D) " Un autre point de vue sur le Lagrangien augmenté pour la gestion de production électrique au court-terme "
- Claude Lemaréchal (INRIA Grenoble) " Duality for Unit-Commitment Primal Heuristics Noisy Oracle "

- Nicolas Beldiceanu (Ecole des Mines de nantes) " Description de contraintes par des méta-données et application à des problèmes d'apprentissage "

PGMO seminars

- **Nicolas Beldiceanu (Ecole des Mines de nantes) " Résolution de problèmes d'ordonnancement cumulatif de grande taille "**
- **Andrew Phillpott (University of Auckland, New Zealand " Modelling water shortage risks in electricity markets with hydroelectric reservoirs "**
- **Pauline Sarrabezolles (CERMICS Ecole des Ponts) " Programmation linéaire colorée : bases, polytopes et algorithmes "**
- **Nabil Mustafa (LIGM, ESIEE), "Local-search techniques for geometric optimization problems"**

- **Jean-Christophe Alais (EDF R&D et CERMICS) "Méthodes de décomposition en optimisation stochastique : application à la gestion d'une vallée hydraulique"**
- **Zheng QU (CMAP, Ecole Polytechnique), "Méthodes max-plus en programmation dynamique approchée"**

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PGMO seminars

- Bernardo Pagnoncelli and Tito Homem-de-Mello, "Tutorial on stochastic programming: from two stage to multistage risk averse stochastic programming"
- Francisco Silva (Université de Limoges), joint work with J. Frédéric Bonnans (Inria & Ecole Polytechnique), "A glimpse on mean field games and its applications"
- Alejandro Jofré (CMM and DIM, Universidad de Chile), joint work with Nicolas Figueroa, "Optimal mechanism-pricing rules for electricity market"

- Mohammed Bellalij (université de Valenciennes): "The trace ratio optimization problem for dimensionality reduction"
- Saïd Hanafi (université de Valenciennes): "Hybrid Approaches for 0-1 Mixed Integer Program"
- Nadia Oudjane (EDF R&D) : "Méthodes de particules en interaction pour les problèmes d'arrêt optimal et applications à la valorisation de centrales électriques«

PGMO seminars

- **Olivier klopfenstein (EDF R&D) et Laurent Pfeiffer (Ecole Polytechnique) : "Contrôle Stochastique Optimal pour la gestion Actif-Passif"**
- **Anes Dallagi et Tomas Simovic (EDF R&D) : "Optimisation des actifs hydrauliques d'EDF : besoins métiers, méthodes actuelles et perspectives"**
- **Claudia D'Ambrosio (LIX-Ecole Polytechnique) : "Optimality for tough combinatorial hydro-valleys problems"**
- **R. Sirdey (CEA LIST) "Partitionnement stochastique de réseaux de processus"**
- **V.H. Nguyen (LIP6) "Solutions exactes pour un problème de partitionnement de graphes avec contraintes de capacité"**

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First Workshop on Optimization for Imaging and Signal Processing (18-20 Nov. 2013)

First Workshop on Optimization for Image and Signal Processing

Date: 18, 19 and 20 November 2013
Location: Polytechnique (Palaiseau, France) – Auditorium Pierre Faure
Registration: free ! `http://www.lss.supelec.fr/MaoriWorkshop/`

Invited speakers:

- Karteek Alahari (Inria)
- Alexandre d Aspremont (Polytechnique)
- Hedy Attouch (Université de Montpellier)
- Silvia Bonettini (Università di Ferrara)
- Coralia Cartis (University of Edimburgh)
- Patrick Louis Combettes (Université Pierre et Marie Curie)
- Daniel Cremers (Technical University of Munich)
- Michel Defrise (Université Libre de Bruxelles)
- Christine De Mol (Université Libre de Bruxelles)
- Jérôme Idier (Ecole Centrale Nantes)
- Russell Luke (University of Göttingen)
- Julien Mairal (Inria)
- Said Moussaoui (Ecole Centrale Nantes)
- Maks Ovsjanikov (Polytechnique)
- Aleksandra Pizurica (Ghent University)
- Thomas Pock (Graz University of Technology)
- Gabriele Steidl (Technische Universität Kaiserslautern)
- Marc Teboulle (Tel-Aviv University)
- Dimitri Van De Ville (EPFL)
- Silvia Villa (Istituto Italiano di Tecnologia)
- Isao Yamada (Tokyo Institue of Technology)
- Luca Zanni (University of Modena and Reggio Emilia)

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Research Projects

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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 Saclay laboratories (uppermost)

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

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2012 Projects

21 projects

- **On PRMO :**
  - 1 project about teaching
  - 2 research network projects
  - 5 research projects
- **On IROE**
  - 2 project about Unit-Commitment
  - 3 projects dealing with optimisation under uncertainties
  - 3 projects about optimising hydro-valleys
  - 2 projects about scheduling of outages for thermal plants
  - 1 project about economic equilibriums
  - 1 project about asset-liability management
  - 1 project about the design of nuclear cores

PRMO Projects

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Web portal and electronic courses for the teaching of stochastic optimization

Team : P. Carpentier (ENSTA) , JP Chancellier, M. De Lara (CERMICS)

Objectives : POCEOS is aimed at learning good ways of developing electronic training material

Main achievements

3 courses were videod and the video edition was made by a technician from Ecole des Ponts

- Optimisation et contrôle (21 h), J.-P. Chancelier, P. Carpentier, M. De Lara, Ecole des Ponts 2nd year
- Optimisation pour la gestion durable des ressources naturelles (24h), M. De Lara, Ecole des Ponts 1st year
- Stochastic Control for the Management of Renewable Energies (15h), J.-P. Chancelier, P. Carpentier, M. De Lara, CIRM school

Web portal and electronic courses for the teaching of stochastic optimization

Perspectives

- Video introductory "trailers" for each course.
- Then, put the courses on internet.

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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)

Main features

- **Context**: Stochastic optimization is, by nature, at the crossroads between disciplines. LASON is an effort to bring Chilean and French researchers in the field to join forces and try to solve challenging problems in the area

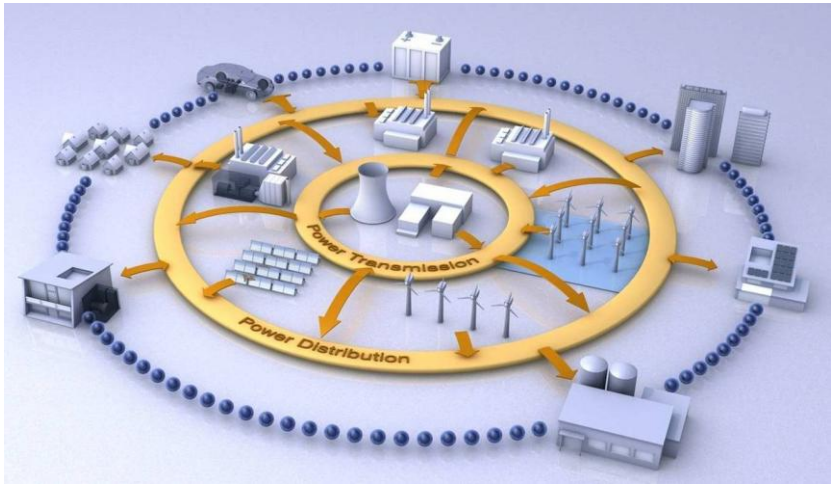
- **Objectives** : Cover a large spectrum of methods to handle various applications of optimization especially relevant for both countries: hydroelectricity, smart grids, forestry management...

  - **Stochastic Programming**
    - **How to model uncertainty?**
  - **The inclusion of risk**
    - **Which risk measure?**
    - **How to solve the resulting problem?**

Latin America Stochastic Optimization Network (LASON)

Problems we plan to attack

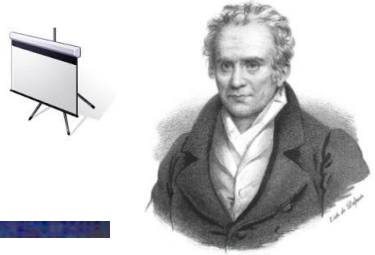
- Optimizing an aggregator of residential users
- Optimizing a micro-generation mix
- Electric cars management



Perspectives and goals

- One meeting in December 2013
  - Discuss the problem
  - Strength the ties of the network
- One PhD student in Chile working on the project
- Another meeting for 2014

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)

Goals

- **Bring together a group of researchers** and foster collaborations to develop and study efficient algorithms for imaging optimization problems.
- **Organize regular meetings** between participants (seminars, working groups, workshops, etc.)

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MAORI --MAthematics of Optimization foR Imaging

Results :

- 4 "MAORI" meetings
- 1 three days international workshop in November 2013
- Several working groups on:
  - **Accelerated algorithms for high dimensional problems** (Active set, incremental methods, etc.)
  - **Pertubation analysis of optimization problem** (Risk estimation, sensitivity analysis, parameter selection)
  - **Splitting methods for non-smooth and non-convex problems** (Structured non-smooth problems, convergence guarentees)

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- Isao Yamada (Tokyo Institue of Technology)
- Luca Zanni (University of Modena and Reggio Emilia)

Colourful Linear Programming: geometric, combinatorial, and algorithmic aspects

- **Team :** A. Deza (McMaster University), F. Meunier ,P. Sarrabezolles (Ecole des Ponts et Chaussées)

- **Context:** **Input** : $S_1, \ldots, S_k \subseteq \mathbb{R}^d$ and $p \in \mathbb{R}^d$. Each S_i is identified with a color.
Task : Decide whether there exists $T \subseteq \bigcup_{i=1}^{k} S_i$ such that $|T \cap S_i| = 1$ for all i (rainbow) and $p \in \mathrm{conv}(T)$, and if there is one, find it.

Such a T is a *rainbow simplex* containing p.

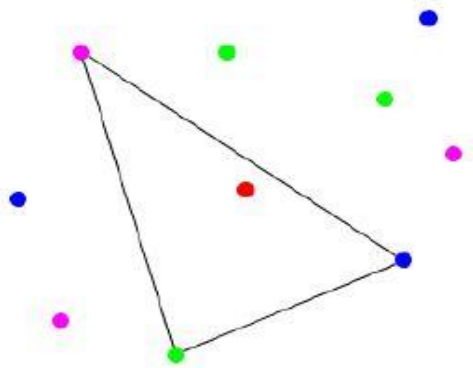

FIGURE : a rainbow triangle

* Has been defined in 1997 by Bárány and Onn.
* Is considered since then as an important challenge in mathematical programming.
* Generalizes the usual linear programming.

Colourful Linear Programming: geometric, combinatorial, and algorithmic aspects

Objectives :

- To determine the complexity of various special cases.
- To propose efficient algorithms.
- To count the number of solutions.

Results obtained so far:

* Complexity of the case $k = d + 1$ colors, asked in 1997 by Bárány and Onn : PPAD-hard since it contains Nash equilibria in bimatrix games. *(Article in preparation)*
* Theorem : If $k = d + 1$ and $p \in \bigcap_{i=1}^{d+1} \text{conv } S_i$, then there exists at least $\frac{1}{2}d^2 + \frac{7}{2}d - 8$ rainbow simplices which contains p. *(Article to appear in SIAM Journal on Discrete Mathematics)*

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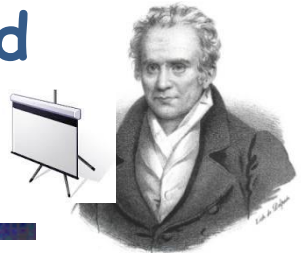
Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Discrete Trace Ratio Optimization Problem

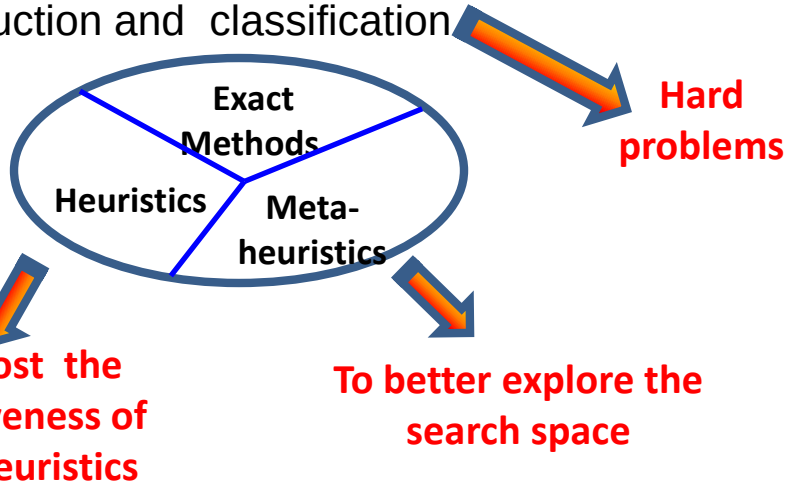


Team : F. Glover, M. Guignard, Y. Saad, S. Hanafi, I. Crévits, C. Wilbaut, M. Vasquez (LAMIH), N. Mladenovic, M. Bellalij, F. Baghery, I. Massa-Turpin (Université Valenciennes)

Main Objective : Extend to discrete formulation the results obtained from the continuous case to solve the relaxed trace-ratio optimization problem

Context :

- **Trace-Ratio**
  - High dimensional data arises from many modern applications of data mining
  - Statistical approaches for dimensionality reduction and classification
- **Hybrid approaches**
  - Combining



  - Using mathematical properties

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

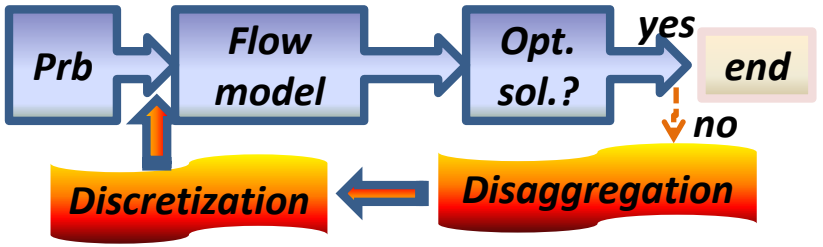
Results :

Methodological level

- Enhancements and generalization of the Iterative Disaggregation Algorithm (IDA).
- Hybrid Approaches combining Variable Neighborhood Search (VNS) with mathematical programming.
- Important advances concerning the formulation of cellular manufacturing problems.

Application level

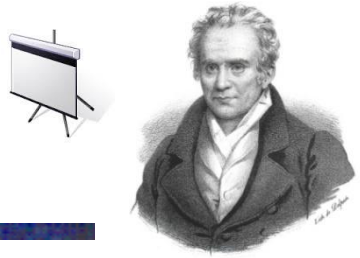
- Generalized transportation problems
- Resource allocation problems



Scientific Publications and Outreach

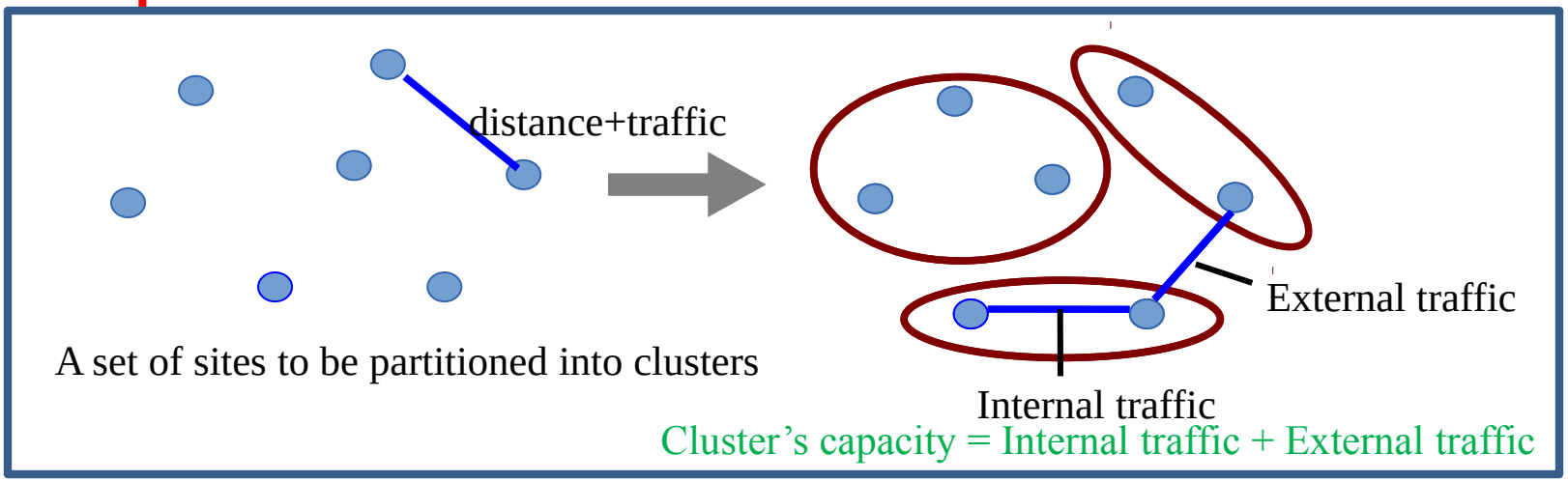
- Organization of conference : « Interdisciplinary meeting about Optimization », RIO2012. Université de Valenciennes.
- Chapters (2), Papers (10) : EJOR, COR, JOH, SIAM, Conferences (15) : EURO, MeCVNS, ROADEF, Best Paper Awards (2).

Graph partitioning under capacity constraints



Team : M. MINOUX, V. Hung NGUYEN (LIP6), P. BONAMI, (CNRS)

The problem :



- Capacity constraint: The capacity of the clusters is bounded by a constant C.
- Objective function: Minimizing the cost (which is a combination of distance and traffic) of the inter-connection between clusters.
- Applications: SONET/SDH Optical network design, Parallel computing on massively parallel computers, …
- Models: Formulated under different forms as an binary (non-convex) quadratic program.
- PGMO project: Conception, implementation and comparison of convexification/linearization techniques for solving exactly these binary quadratic models.

Graph partitioning under capacity constraints

Realizations

- Reinforcement of **Fortet's linearization technique** by the RLT (Reformulation & Linearization Technique) order 1.
- Implementation of the **linearization by projection** technique.
- **New method of linearization** based on Sherali & Smith (2007) technique. Reinforcement by involving capacity constraints in the computation of linearization parameters.

Results

- Systematic comparisons of numerical results on various methods of convexification/linearization applied to the models.
- Computation time of exact solutions is reduced in average by a factor of 10 in compared to the best known method.
- Somewhat a rarely observed case study where having choice among several equivalent integer models, the tightest (in term of continuous relaxation) is not the most efficient to be integrated in Branch-and-bound algorithms.

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)

Main Problem : Find “doubly sparse" solutions of large overdetermined linear systems.

Not. Being given Θ a vector/matrix: $\|\Theta\|_0$=number of nonzero entries of Θ.

Solve $\mathcal{A}X = B$ where X is an $m \times n$ matrix with $\|X\|_0 \leq r$, rank $X \leq s$

where $\mathcal{A}$ is a linear operator on matrix spaces and B a matrix.

Applications: multitask learning, social networks, graph denoising...

A common feature at stake for this problem is the identication of few types among large populations (low-rank condition) whose characteristics are dened through a small number of features (sparsity condition).

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Semi-algebraic approaches to doubly sparse problems

2 Approaches :

- **Define an adequate piecewise-linear function promoting double sparsity.**
  - Establish theoretical efficiency along probabilistic views
  - Adapt primal-dual methods à la Chambolle-Pock to derive an efficient numerical method.

    Richard, E., Bach, F., Vert, J.-P., Intersecting singularities for multi-structured estimation, Atlanta, ICML 2013.

- **Using reformulation/relaxation techniques, our problem can be seen as an instance of « Sparse (nonnegative) matrix factorization problems »**

$$\min \left\{ \frac{1}{2}\|A - XY\|^2 : X \geq 0,\ \|X\|_0 \leq r, \quad \& \quad Y \geq 0,\ \|Y\|_0 \leq s \right\}$$

  - Design a new decomposition algorithm – “an alternating forward-backward method"
  - Establish strong theoretical properties with semi-algebraic tools

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)

Axes 1 : tropical algorithms applied to zero sum games

- Main contribution : tropical analogue of the simplex algorithm
  - solves tropical linear programs, i.e. problems of the form :

$$\begin{array}{ll} \min & \max_{1\le j\le n}(c_j + x_j) \\ \text{s.t.} & \max(\max_{1\le j\le n}(a_{ij}^+ + x_j), b_i^+) \ge \max(\max_{1\le j\le n}(a_{ij}^- + x_j), b_i^-) \\ & x \in (\mathbb{R}\cup\{-\infty\})^n \end{array}$$

  - pivoting is done by a combinatorial algorithm, in linear time
  - traces the path followed by the classical simplex algorithm on a corresponding LP over real Puiseux series
- Application : connection between two notoriously open problems :
  - in optimization, is there a pivoting rule such that the simplex algorithm is strongly polynomial? (in particular, polynomial nb of pivots)
  - in AGT, can mean payoff games be solved in polynomial time?

Theorem ***If there exists a strongly polynomial classical simplex algorithm equipped with a combinatorial pivoting rule, then mean payoff games can be solved in strongly polynomial complexity.***

Joint work with Michael Joswig (TU Berlin).

Tropical Methods in Optimization

Axes 2 : attenuation of the curse of dimensionality in dynamic programmming

- Main contribution : Max-plus algorithm to approximate the value function (thesis of Zheng Qu):
  - solves first order HJB PDE

$$0 = -H(x, \nabla V) \sim -\max_{m \in \mathcal{M}} H^m(x, \nabla V), \qquad H^m \text{ linear quadratic Hamiltonian}$$

  - V is approximated by a supremum of quadratic forms.
  - randomized algorithm reduces the backsubstitution error at random witness points, through a Riccati ODE (curse of dimensionality free).

Solution of a dimension 15 instance of quantum control problem on SU(4) from James et al., in 4 hours on a single core

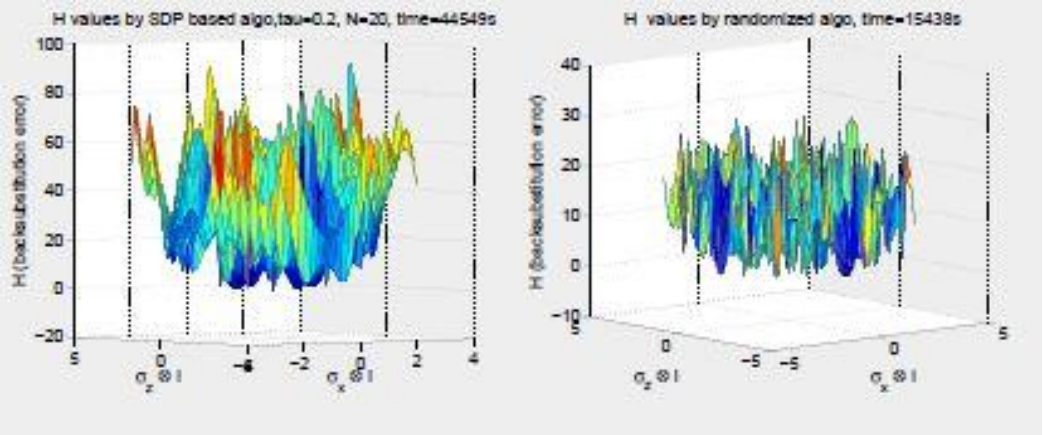

Figure : Backsubstitution error: McEaneaney's SDP based algorithm in 44549 seconds (left) versus the new (witness) algorithm in 15438 seconds (right). Error visualized on the plane span $\{\sigma_x \otimes I, \sigma_z \otimes I\}$ in the Lie algebra of SU(4).

IROE Projects

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Energy Management main optimization problems

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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

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

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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

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

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

IROE Projects

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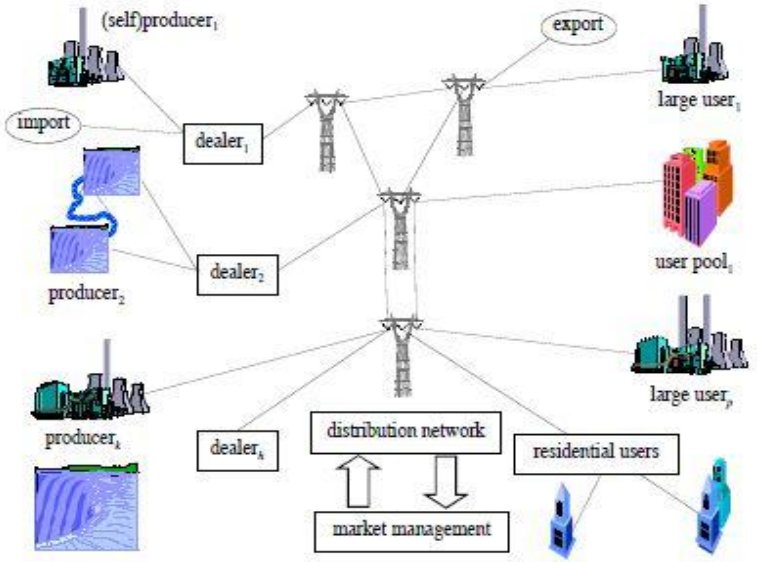
Consistent Dual Signals and Optimal Primal Solutions

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

Managing the electrical system requires decomposition

- many actors (thermal + nuclear + hydro + sun + wind, consumption, network . . .)
- complex contraints (technical, physical, economical, legal . . .)
- nasty optimization problems (large-scale, nonlinear, mixed-integer, stochastic . . .)
- electricity cannot be stored ⇒ quick decisions (real-time . . .)



- Very many problems in this setting have the very general form

$$\min \left\{ f(x) = \sum_i f_i(x_i) \ : \ \sum_i A_i x_i = b \,,\ x = [x_i] \in X = \prod_i X_i \right\}$$

e.g. Hydro-Thermal Unit Commitment problem (i = unit)

- Decomposition: relax linking constraints, solve subproblems ($x_i \in X_i$)

Consistent Dual Signals and Optimal Primal Solutions

Objectives and proposed approaches :

- The main issue: construct a feasible solution $x \in X$
- Current Approach:
  - Dual Phase: find optimal Lagrangian multipliers ($f(x) + \lambda^*(b - \sum_i A_i x_i)$ maximum when x_i minimum)
  - Primal Phase: use the obtained information to construct $x \in X$ (Augmented Lagrangian, auxiliary problem principle, ...)
- Many issues: subproblems difficult to solve exactly, slow convergence of dual phase, corrupted dual signals, convergence of primal phase not well understood, primal solutions not good enough and unstable to small data changes, ...
- Proposed approaches:
  - Primal Heuristics during the Dual Phase using combinatorial methods
  - Improvements in the Primal Phase: stabilize the primal phase to produce better primal solutions and consistent dual signals
  - Better (Primal and) Dual Phase: improve convergence by using inexact information, improve handling of information, warm-start, exploit structure, ...

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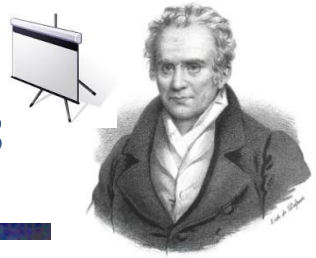
Learning Constraints for Reducing Combinatorics



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

Objectives : Identify Plant Specific Constraints based on pas production planning reports

- Large part of model are plant specific constraints
- This determines how a plant can be scheduled
- Big differences between different types of plants (nuclear, thermal, hydro)
- Different parameter values for each plant (even if same type)
- Ignore at the moment:
  - Matching demand (+ handling of reserves)
  - Minimizing cost
  - Seasonal/weather effects (especially hydro)

Learning Constraints for Reducing Combinatorics

Overview :

CLUSTERING TIME SERIES
(to learn stronger constraints)

↓

LEARNING CONSTRAINTS
- Functional dependency constraints
- Constraints without functional dependency
- Binary constraints (on consecutive periods)
- Variable partitions generator (find breakpoints)

↓

LEARNING DOMAINS
- For each period
- For each functional dependency parameter

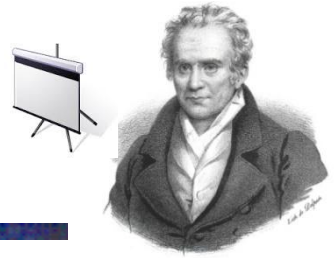
↓

SEARCH
(generate similar time series)

Results :

- Not easy
- Interaction of global constraints not modelled
- Many possible redundant constraints
- Best so far
  - Domains: Set for power output, range for parameters
  - Binary constraints help
  - Search: Input order, most used in samples

Stochastic Optimization for Unit-Commitment problems

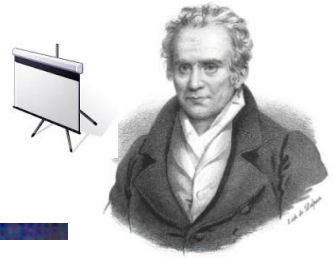


Team : R. Henrion (Weierstrass Berlin), M. Minoux (LIP6),W. van Ackooij (EDF)

Main features

- **Objectives** : **Solve optimization problems Under uncertainty, with particular attention to efficient numerical treatment, by using decomposition methods**
  - ***Investigate uncertainty in linear systems wherein either the matrix or the right hand side can be uncertain. (assuming that laws of uncertainty are known (for the moment))***
- **Illustrative example** : **network problem with random nodal injections following Gaussian uncertainty. The decision vector is related to the capacity of the arcs. (!! non-differentiability !!).**

Stochastic Optimization for Unit-Commitment problems



Achievements

- **The practical implications of the conditions Under which differentiability can be shown to hold were inevtigated. A formula for a sub-gradient in other points was derived.**

  [Submitted paper: On a completion of the Henrion-Möller-Prékopa Gradient formula for Gaussian Distribution Functions]

- **Decomposition methods for unit-commitment problems with coupling joint chance constraints**

  [submitted paper : Decomposition Approaches for Block-Structured Chance-Constrained Programs with Application to Hydro-Thermal Unit-Commitment]

- **More efficient algorithms for solving joint chance constrained problems have been obtained.**

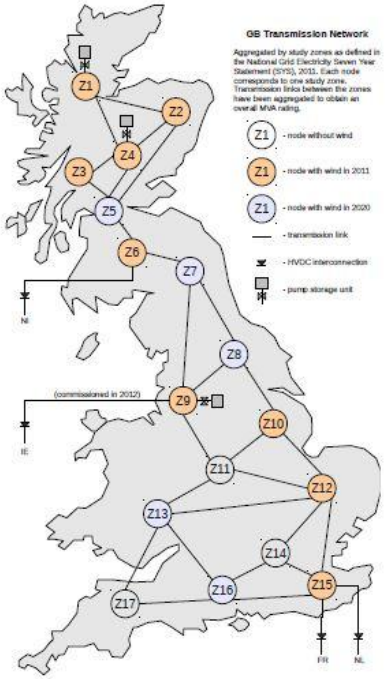
  [Submitted paper: Constrained Bundle Methods for Upper Inexact Oracles with Application to Joint Chance Constrained Energy Problems]

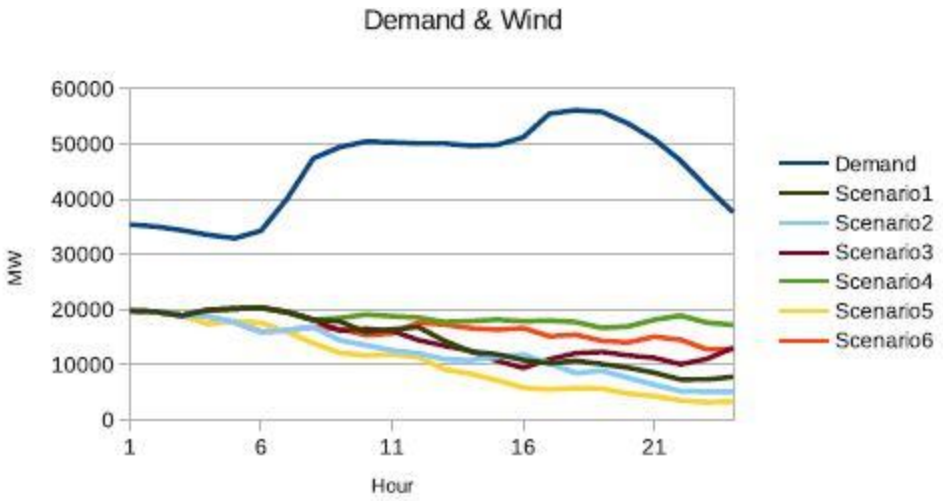
A Stochastic Programming Approach to Finding Robust Reference Schedules for the Unit Commitment problem

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?**





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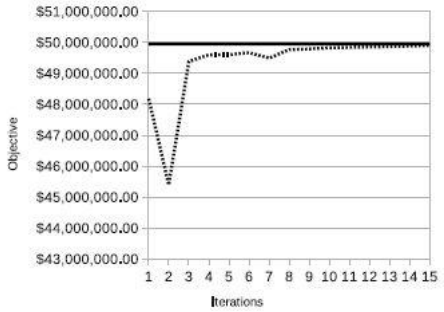
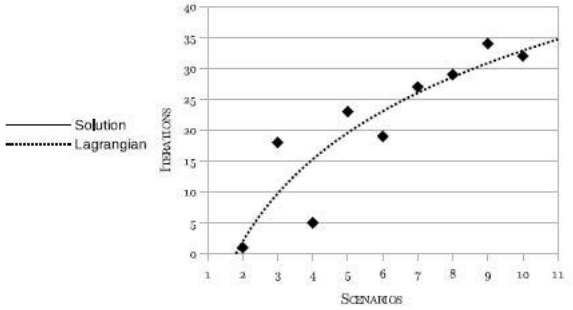
A Stochastic Programming Approach to Finding Robust Reference Schedules for the Unit Commitment problem

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**





Perspectives:

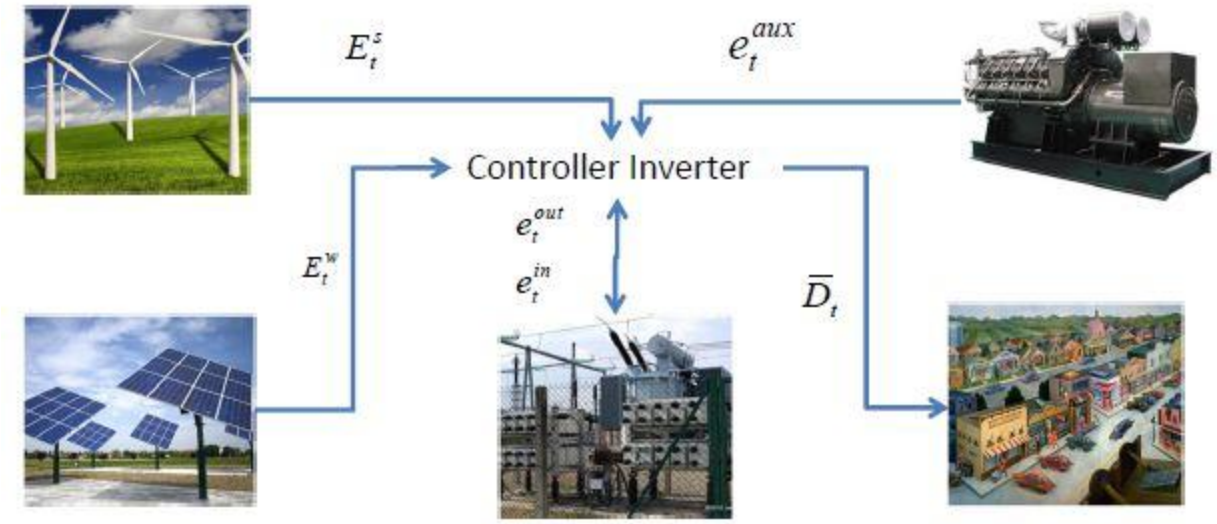
- **When is stochastic planning superior to deterministic planning?**
- **How high can the Expected Value of Perfect Information and Value of the Stochastic Solution be?**
- **In cases with larger wind to demand ratio solving a single scenario problem becomes harder. What can be done?**
- **Different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

Robust optimal sizing of an hybrid energy stand-alone system

Team : A. BILLIONNET (ENSIIE/Cedric) , M.Ch. COSTA, P.L. POIRION (ENSTA/Cedric)

Objectives

- **How to determine the optimal number of photovoltaic panels, wind turbines and batteries while minimizing the total cost of investment and use?**
- **The data are uncertain and the underlying probability distribution is assumed not to be known, which needs to search for a robust solution.**



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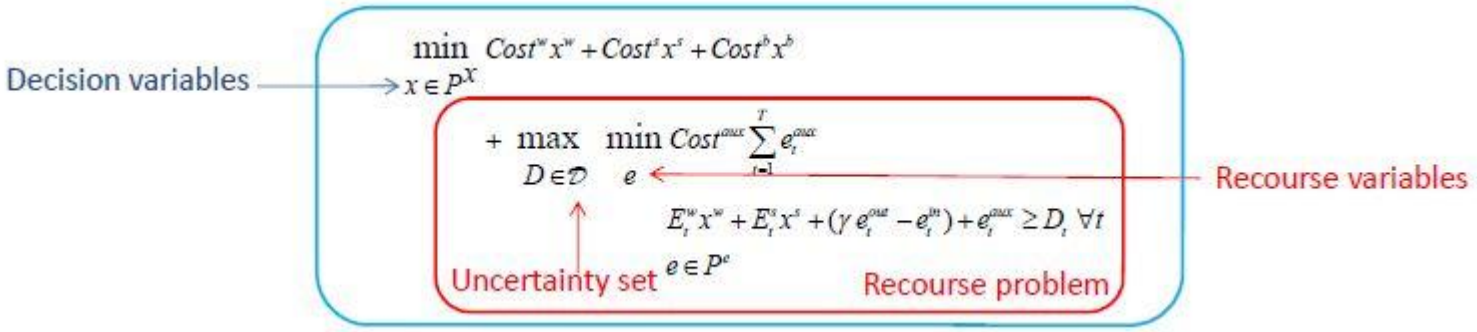
Robust optimal sizing of an hybrid energy stand-alone system

Model : A 2-Stage robust problem



Results

- **Complexity**: The problem without uncertainty is NP-difficult when the number of integer variables is not fixed. Nevertheless the recourse problem can be solvable in polynomialy time by using dynamic programming.
- **Solving Approach**: Exact approach based on linearization, dualization and a constraint generation algorithm.
- **Computational Results**: Real data from Homer web site. Tested instances with severaluncertainty levels, for up to 8670 time periods, in less than two minutes.
- **Generalization of our approach** : it can be applied to general mixed integer problem with continuous recourse variables even if the usual full recourse property is not verified.

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, T. Simovic, W van Ackooij, Y Sahraoui (EDF), postdoc (to hire)

Context : Hard MILP to solve in short time

More accurate model

- **To decide : water flow at each plant, pumped and spilled water (plus dependent variables).**
- **To satisfy : physical constraints, pumping vs. generating, operational constraints, safety constraints.**
- **Integrality of certain variables so as to model important aspects.**

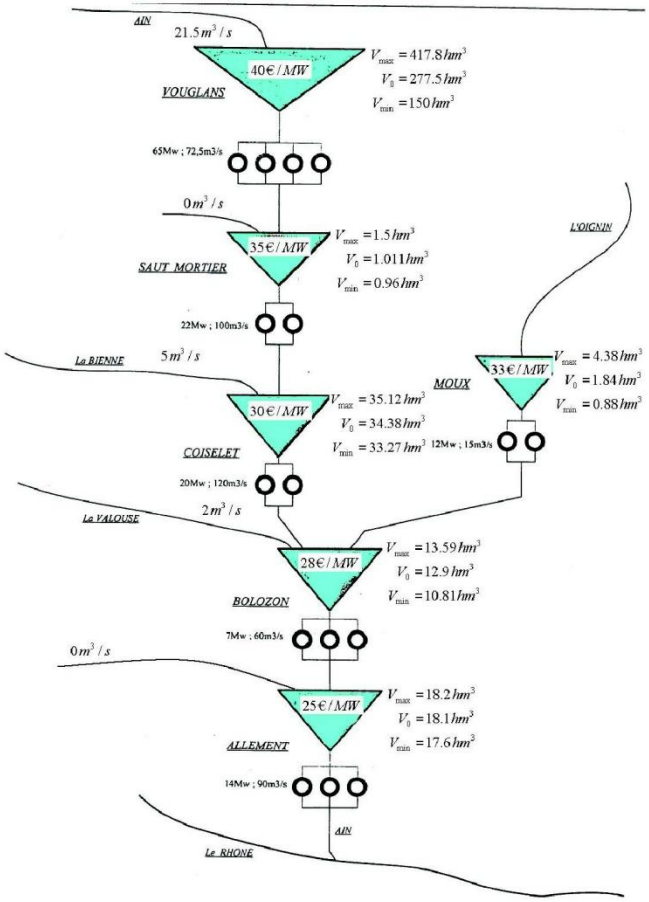
Optimality for tough combinatorial Hydro-valleys problems

Objective : speed up the resolution

Research lines :

- **Reformulations:** relaxation, approximation, decomposition
- **Heuristics:** constructive, local search.

Aim : relax some model assumptions and generalize it

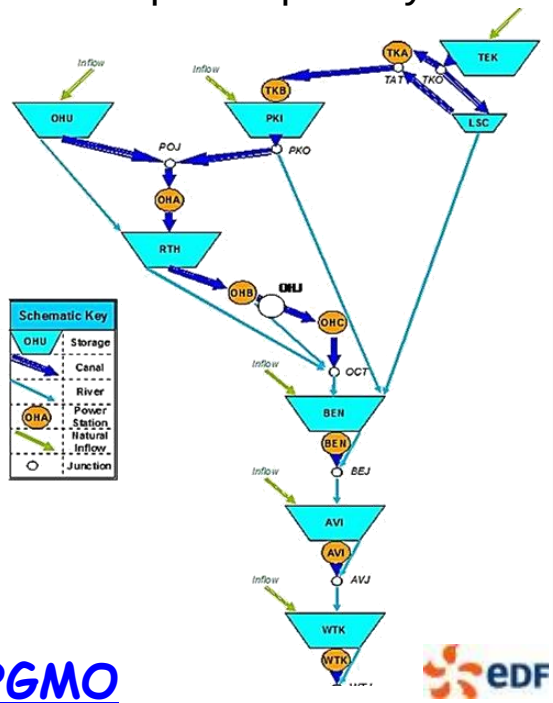


Hydro-electric scheduling under uncertainty

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)

Main features

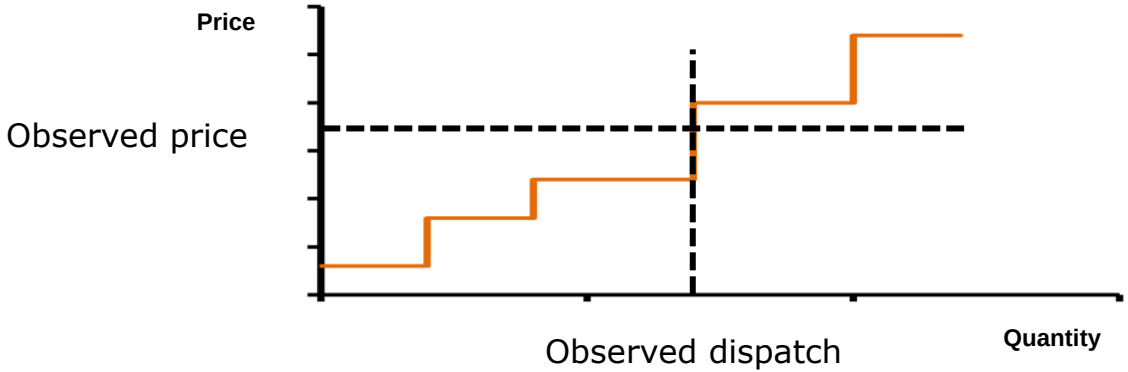
- **Objective : Develop optimisation models that efficiently schedule hydroelectricity stations on river chains** : scheduling hydro stations in the short term to respond optimally to uncertainties such as inflows, demand and electricity price.
- **Applications : in France and New Zealand**
- **Research focus areas**
  - Price uncertainty and offer optimisation
  - Reservoir head effects
  - Unit commitment



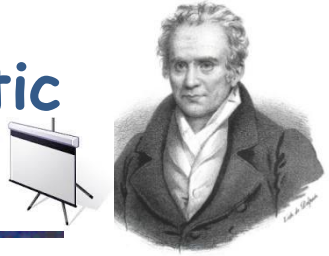
Hydro-electric scheduling under uncertainty

Progress

- **Developed a MIP model (HERCO) with convexified head effects for Waitaki river chain (shown at right).**
- **Work begun on HERBS (**Hydro Electric Reservoir Bidding System**), an offer optimisation model Price uncertainty and offer optimisation**
  - HERBS is a stochastic optimisation model to construct offer curves for hydro electric stations on a river chain.
  - Offers dispatched by random market prices.
  - HERBS integrates hydropower production and market exchange into one optimisation system (see *http://www.epoc.org.nz/workshops/ww2013/EPOC2013Wahid.pptx)*
  - France: to be used in balancing market.
  - New Zealand: to be used in wholesale spot market.

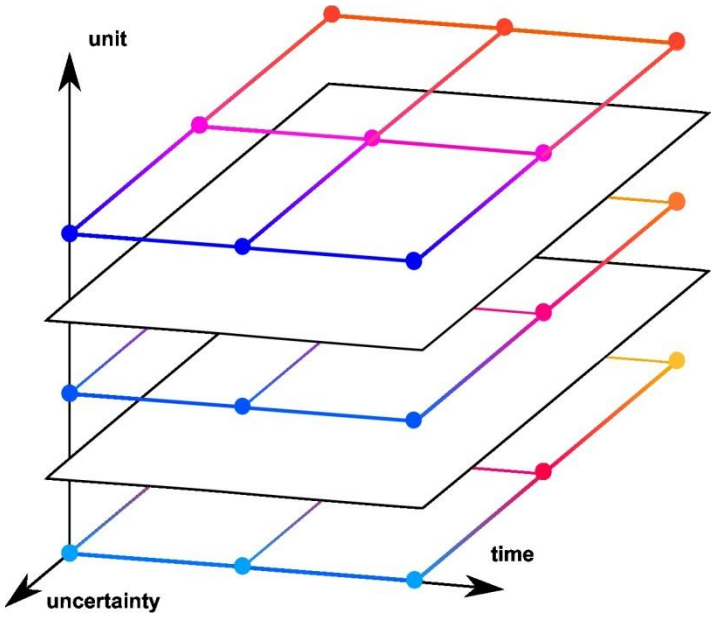


Decomposition/coordination methods in stochastic optimal control



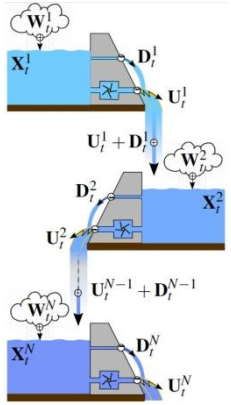
Team : P. Carpentier (ENSTA), M. De Lara, J-Ph. Chancelier, V. Leclère (CERMICS)

General Goals : apply decomposition/coordination methods to obtain strategies for large scale stochastic dynamic optimization problems. Decomposition is performed in the “space” dimension.



Decomposition/coordination methods in stochastic optimal control

Specific project : perform a systematic study in case of an hydraulic valley including three dams, and compare the true optimal solution with the solutions obtained by different flavors of the decomposition method DADP.



Results : numerical studies and comparison of all methods have been performed on a 16-core computer (PGMO grants): PhD thesis of Jean-Christophe Alais (December 2013); organization of a one-day workshop (spring 2014).

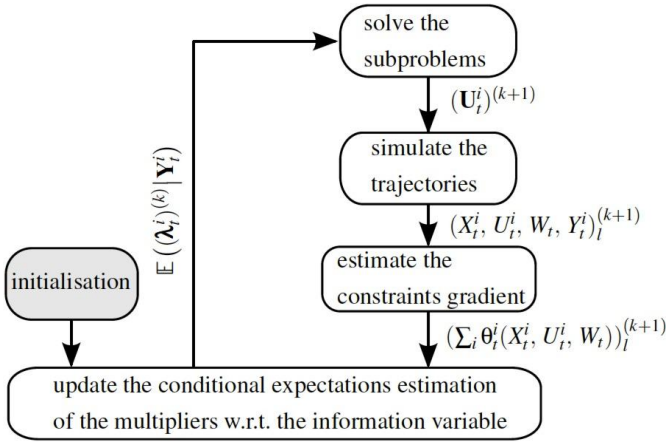
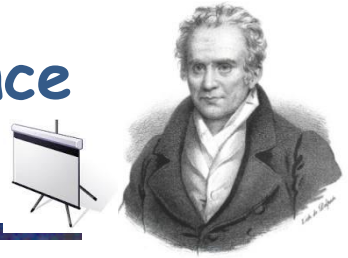


Fig. 3: DADP algorithm flowchart

Perspectives: apply the method to more general optimization problems (smart grids): new PGMO project “SmartGrid” starting in 2014

Stochastic Nuclear Outage problems with chance constraints



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

Main features

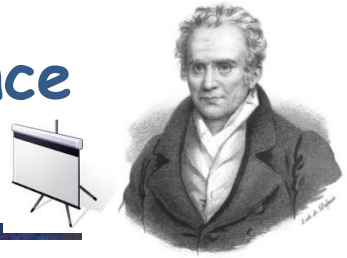
Application : planning outages for nuclear power plants

- 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.

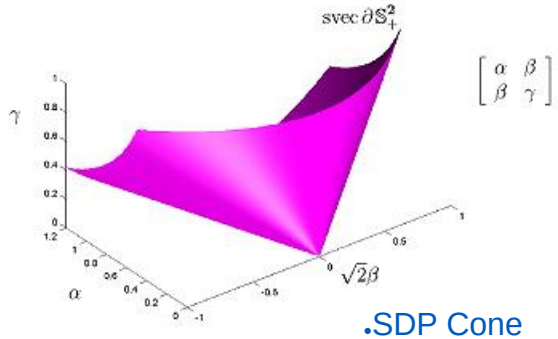
Stochastic Nuclear Outage problems with chance constraints



Results

Theoritical/algorithmic/software prototypes

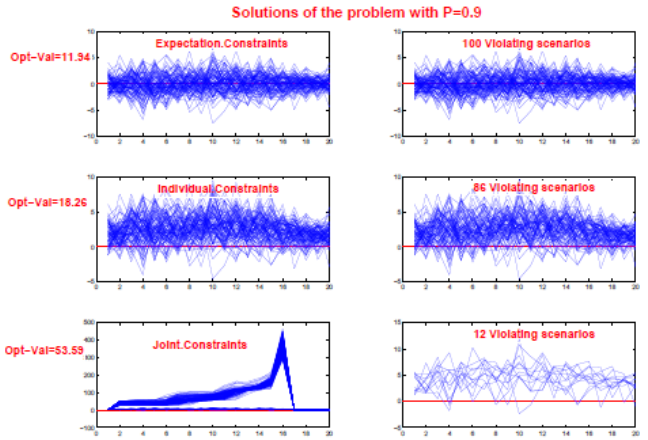
- **Individual chance constraints and binary variables**
  - SOCP reformulation + B&B
  - SDP relaxations + B&B
- **Joint chance constraints and binary variables (in progress)**
  - SDP reformulations + B&B
  - Copositive reformulations + B&B
  - Distributionally robust Reformulations
  - Convexity results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



•SDP Cone

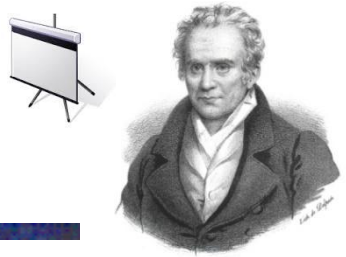
Applications to energy management problems

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



•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)

Objectives

To enrich the problem proposed with the Challenge Roadef 2010 by modeling and inserting the following important aspects of the problem:

- **production planning of Nuclear and Hydraulic power plants must be managed together;**
- **the duration of a stop for refueling and maintenance is uncertain;**
- **a nuclear power plant can stop which has an impact on the quantity of fuel on stock;**
- **the production planning is recalculated each month.**

Modelization : main point are :

- **Robustness.**
- **Stability.**
- **Optimization.**

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Optimization of the scheduling of the Nuclear Power Plant stops

Direction of research

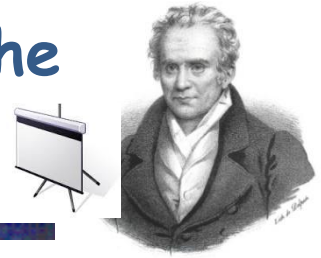
Add the Chance Constraints to the column generation approach:

- **Constraints added to the Master Problem:**
- **Pr(a production planning is successful) >= threshold =>** $\sum_i \beta_i x_{i,r} \geq \beta$
- **The Sub Problem becomes a decision tree**

Future Directions of research :

- **Improve the column generation removing the discretization of the slave**
- **Improve the way of taking into account uncertainty**
- **Insert the idea of Stability**

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, T. Simovic (EDF)

Objectives

- **Study the best response of a producer (P1) on an electricity market**
- **Evaluate the « stability » of this best response with regards to the incertainties on the strategies of the other players.**

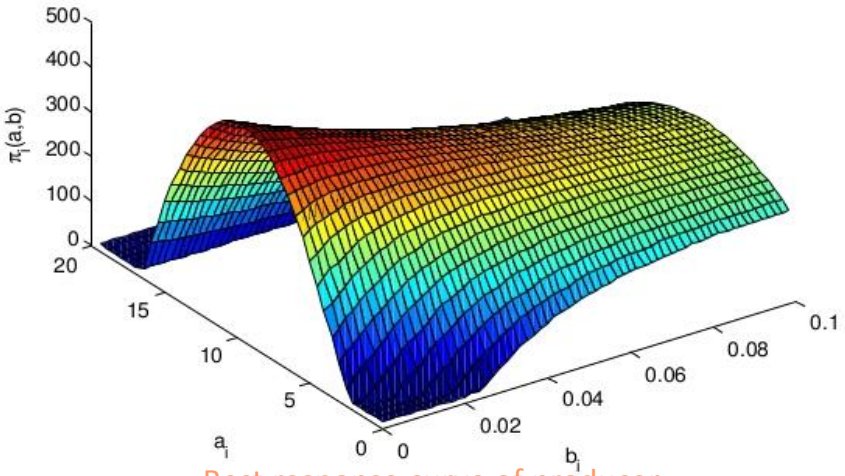
Formulation : bilevel optimization model

- **The lower level represents the minimization problem of the market regulator (ISO)**
- The **upper level problem express the maximization problem of the benefit of the corresponding producer P1**

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

Achievements

- **explicit formulation of the solution of the ISO problem and therefore a characterization, as solution of a nonlinear system, of the best response of the producer P1.**
- **Preliminary numerical tests and simulations**
- *one preprint soon submitted + two oral presentations (PGMO 13, ADGO 13 (Chile))*



Best response curve of producer

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Optimal stochastic control for asset-liability management

- **Team :** F. Bonnans (CMAP), O. Klopfenstein, K. Barty (EDF)

- **Main features**
  - **Application** : **Asset-Liability Management problems**.
  - **Model** : denote by $X^{t,x,u}$ the solution to

$$\mathrm{d}X_t = f(X_t, u_t)\,\mathrm{d}t + \sigma(X_t, u_t)\,\mathrm{d}W_t, \quad X_t = x,$$

where W is a Brownian motion, $\mathcal{U}$ the set of adapted processes in a compact U, $u \in \mathcal{U}$, and consider

$$V(t,x,z) = \operatorname*{Min}_{u\in\mathcal{U}} \mathbb{E}\left[\phi(X_T^{t,x,u})\right] \quad \text{s.t. } \mathbb{E}\left[g(X_T^{t,x,u})\right] \geq z$$

  - State variables: A_t, the value of a portfolio of risky and non-risky assets, L_t, the cost of decommissioning of nuclear power plants.
  - Constraint: $\mathbb{P}\left[A_T/L_T \geq 1\right] \geq z$.

Optimal stochastic control for asset-liability management

Contributions

- Properties of V:
  - Convexity with respect to z
  - $D_z V$ is constant along optimal trajectories
  - $V^*(t,x,\lambda)$ is the value of an unconstrained problem.
- Some EDPs:
  - For the value function V
  - For its Fenchel transform V^*
  - For the boundary of the domain of V.
- Our method: given a finite sampling Λ of $\mathbb{R}_+$, we compute

$$V(t,x,z) = V^{**}(t,x,\lambda) \approx \sup_{\lambda\in\Lambda} \{\lambda z - V^*(t,x,\lambda)\}.$$

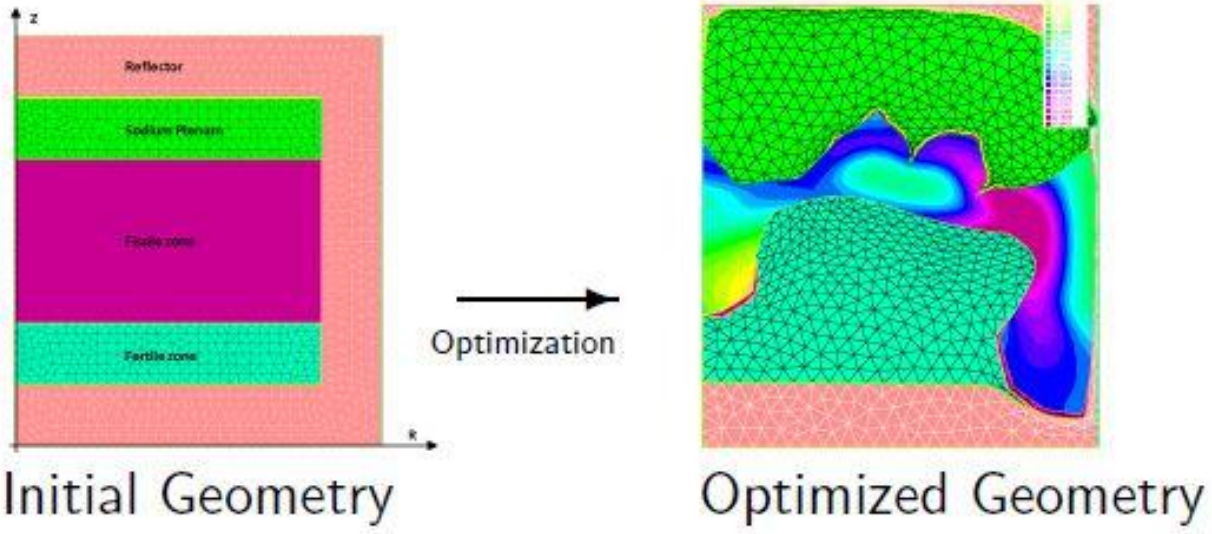
- Application to the ALM problem.

Optimization of the Core of a Sodium Fast Reactor (SFR).

Team : O. Pantz, G. Allaire (CMAP), D. Schmitt (EDF), N. Pozin (ECP)

Objective :

- **Optimize the core of a sodium cooled fast reactor with respect to its geometry and its concentration in Plutonium in order to reduce the sodium void effect (increase of reactivity in case of a decrease in sodium density).**



The optimized configuration has a negative void effect !

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Optimization of the Core of a Sodium Fast Reactor (SFR).

- **The optimization is based on parametric optimization for the concentration of plutonium and geometric optimization for the shape of the core. Both optimizations are performed using a gradient type algorithm.**
  - 1 - Define an initial shape ω of the core and an initial concentration e in plutonium.
  - 2 - Solve the flux equations (partial differential equations) and compute the reactivity and the sodium void effect.
  - 3 - Compute the sensitivity of the sodium void effect and reactivity with respect to changes in the shape ω and theconcentration.
  - 4 - Apply small perturbations to the shape and the concentration in plutonium to decrease the sodium void effect and keep a correct reactivity and go back to 2. till a local minimum is reached.

- **In the future: Integrate feasibility constraints to the algorithm.**

Thanks !

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.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.

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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
- …