The Gaspard Monge Program for Optimisation and operational research

Review of PGMO Projects

December 2015

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PRMO Projects

PRMO Projects

Completed

MAORI --MAthematics of Optimization foR Imaging (2012-2014)

- **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

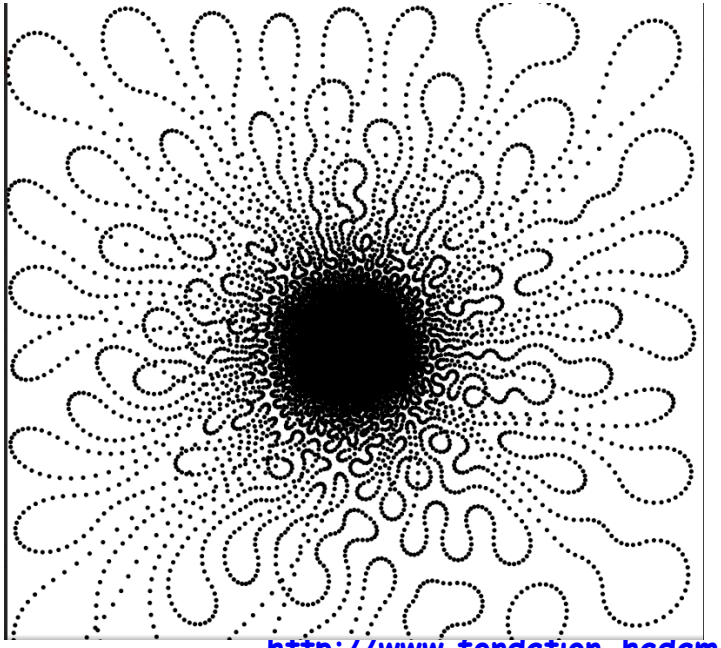
Objectives :

- Facilitates some working groups
- Organizing workshop
- Large scale optimization for imaging

MAORI --MAthematics of Optimization foR Imaging

❑ Results

- ❖Design of a non convex optimization algorithm adapted for projection on measure spaces. A sampling scheme for IRM is generated on Figure. These trajectories allow to reduce of a factor 4 acquisition time on IRM, compared to usual approaches.
- ❖Demonstration of an important theoretical results in convex optimization: A. Chambolle and C. Dossal have shown the convergence of the iterates generated by FISTA (while keeping the same speed of convergence). Until now, only the convergence of the functional values was established.



application à la génération de schémas d'échantillonnage en IRM. Ces trajectoires permettent de réduire d'un facteur 4 les temps d'acquisition sur des IRM par rapport aux approches conventionnelles

Semi-algebraic approaches to doubly sparse problems (2012-2014)

- **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)

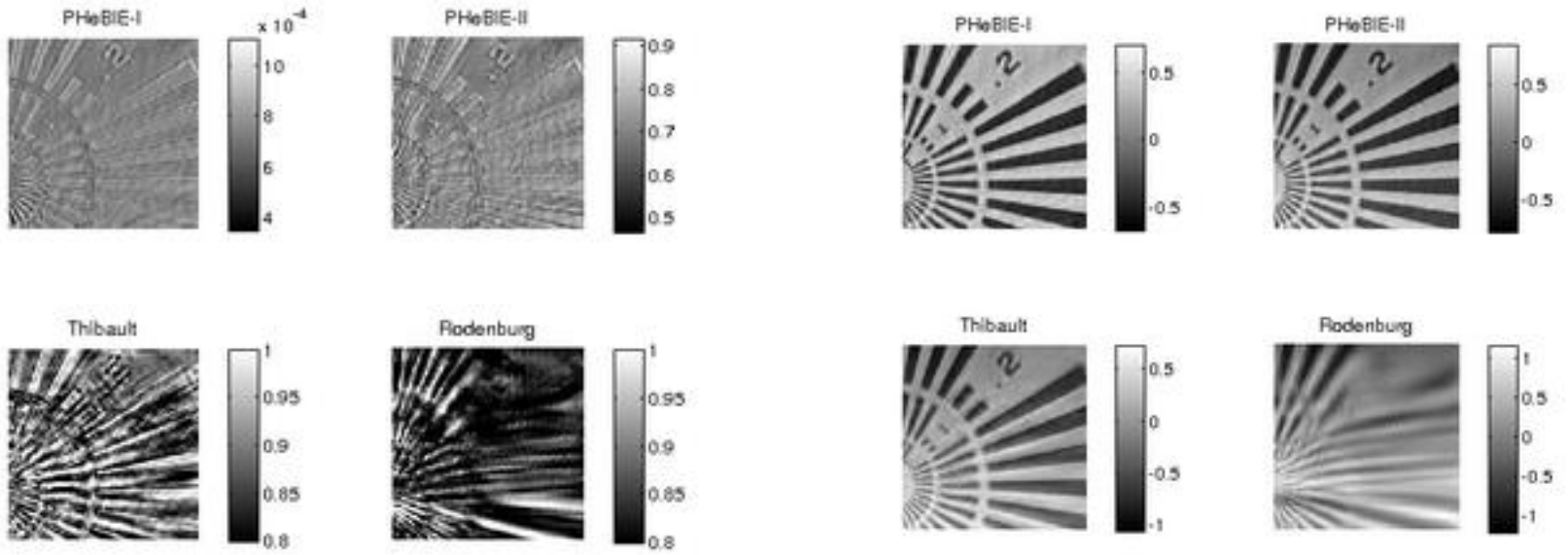
- **Context**
  - Sparse optimization, inverse problems of large size
  - Nonconvexity but semi-algebraicity

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

Semi-algebraic approaches to doubly sparse problems (2012-2014)

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

Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Discrete Trace Ratio Optimization Problem (2012-2013)

- **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

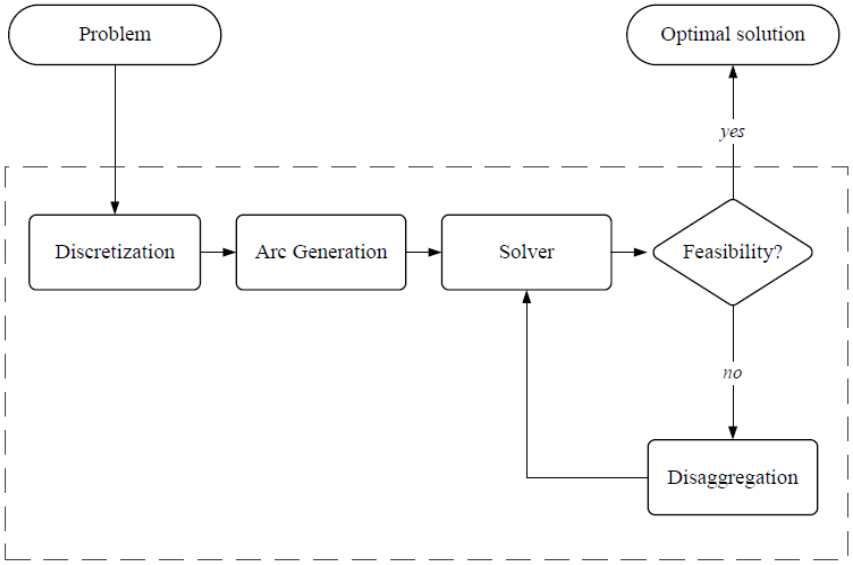
Hybrid Approaches :

- 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 (2012-2013)

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



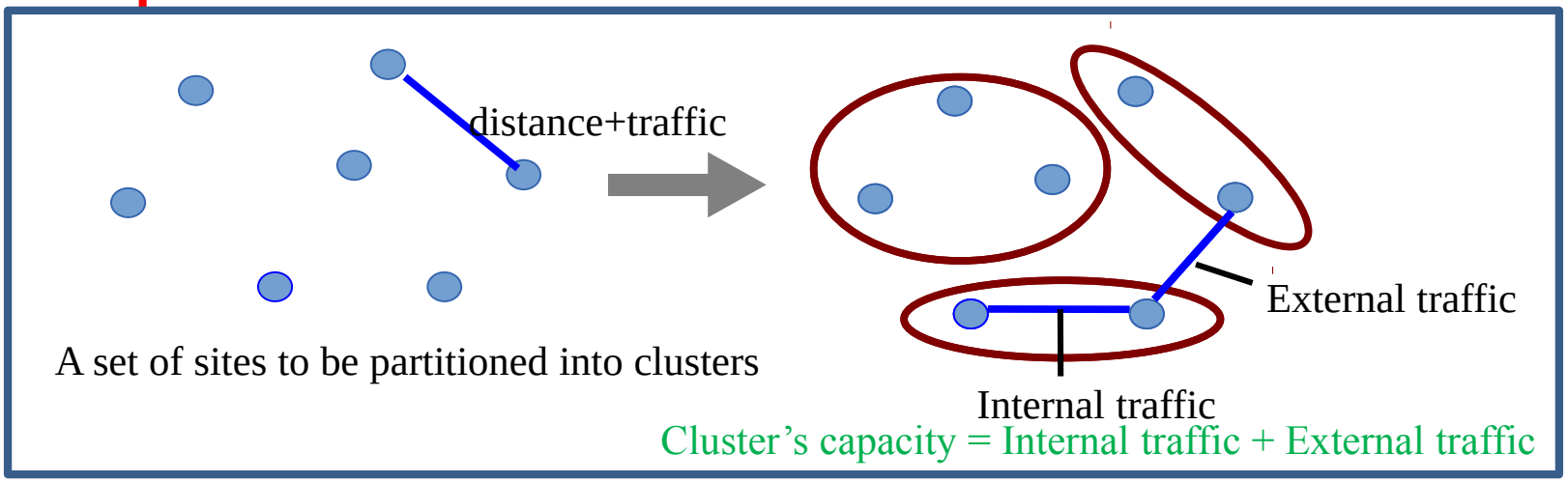
New research lines

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

Graph partitioning under capacity constraints (2012)

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 (2012)

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.

Web portal and electronic courses for the teaching of stochastic optimization (2012)

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.

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

Quadratic convex reformulation for mixed-integer quadratic programming (2013- 2014)

- **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 is done
- Comparison with other available methods and software showed the effectiveness of the method

Pastor : perturbation analysis for deterministic and stochastic optimal control problems (2013-)

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

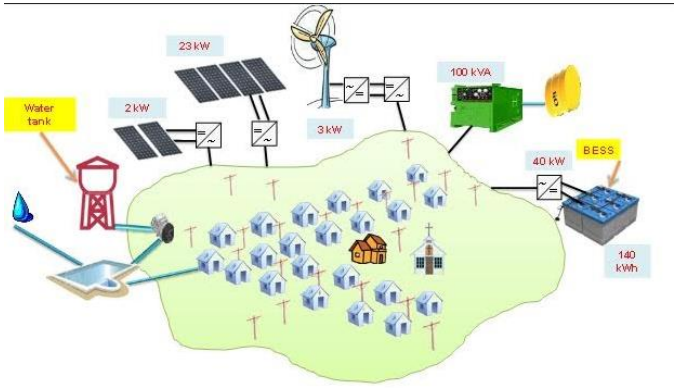
- **Context**
  - Deterministic and stochastic optimal control problems are often affected by unknown perturbations and error in measurement of the data.
  - The numerical resolution of deterministic and stochastic optimal control problems demands the implementation of recent optimization algorithms capable of dealing.with large scale systems.

- **Objectives :**
  - Stability analysis for the optimal cost and optimal solutions of deterministic and stochastic optimal control problems under some data perturbation.
  - First order algorithms for the resolution of deterministic and stochastic optimal control problems.
  - Application of the results in operations research and mathematical finance.

Pastor : perturbation analysis for deterministic and stochastic optimal control problems

Results

- Second order optimality conditions for optimal control problems involving parabolic equations.
- Sensitivity analysis for stochastic optimal control problems and for utility maximization problems in mathematical finance.
- The study of some first order algorithms to solve stochastic optimal control problems and mean field games.
- The study of dynamical models for cash management taking into account the interplay between profitability prospects and dividend policy.
- Applications of our results in numerical optimal control to the study of continuous models in micro-grid management.



Mathematical Programming based Algorithms in Non-linear Combinatorial Optimization (2013-2014)

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.

Steiner Tree Problems in Distribution Networks (2013)

- **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

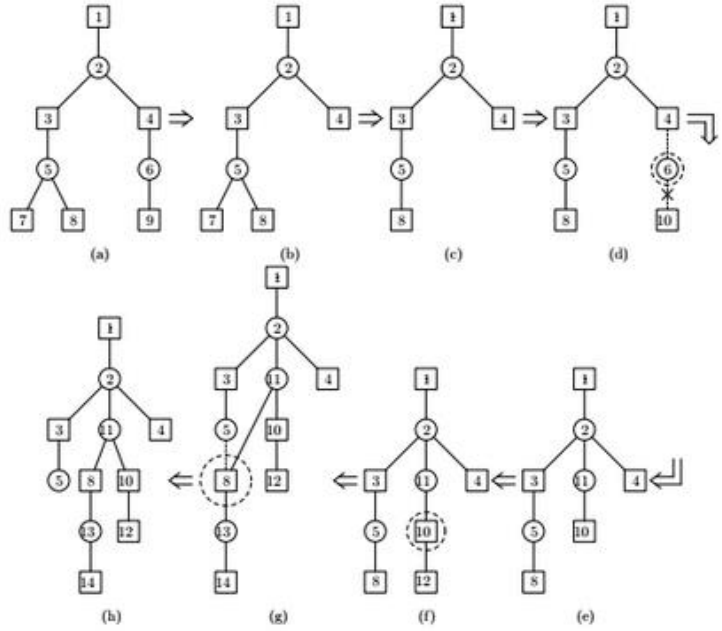


Fig. 1. Process for generating a neighboring solution for the STPRBH

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

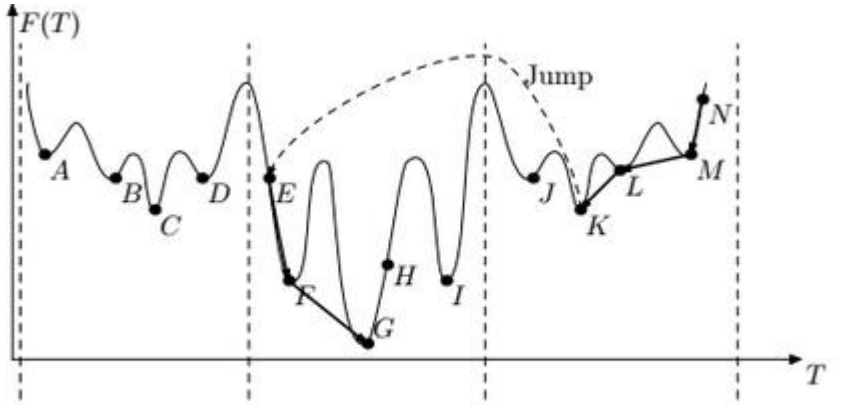


Fig. 2. Procedure of searching a high-quality feasible solution of the QMSTP

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

STORY : Stochastic and Robust Optimization and Applications (2014)

Team : L. El Ghaoui (Berkeley), D. Woodruff (UC Davis), M. Ludkowsky (U. Santa Barbara), P. Carpentier, MC. Costa (ENSTA), M. de Lara, V. Leclere, JP. Chancelier, F. Meunier (CERMICS ENPC), M. Akian, S. Gaubert (CMAP)

Context

- one team in France working on stochastic optimization (Cermics)
- one researcher in the USA working on robust optimization (El Ghaoui)
- both approaches have applications in energy management

Objectives

- making stochastic and robust optimization closer by facilitating scientific exchanges
- two workshops, one in the USA, one in France
- stress applications in energy management

Results

- the workshops have been held
- the contact is kept for future collaborations

Compact linearization techniques for chance-constrained combinatorial problems (2014)

Team : M. Minoux, VH Nguyen (LIP6 UPMC), R. Sirdey, TH Nguyen (CEA LIST)

Context

- Chance constraints programming with 0/1 decision variables.
- Could be formulated under assumptions as binary second order stochastic programs (BSOCP) or binary quadratic constraints programs (BQCP).
- Continuous relaxation for BSOCP is convex but not for BQCP

Objectives

- Showing that in branch-and-bound approaches, QCP can be prefered to SOCP.
- Numerical experiments for various applications : stochastic knapsack, stochastic graph partitionning, …

Compact linearization techniques for chance-constrained combinatorial problems (2014)

Results

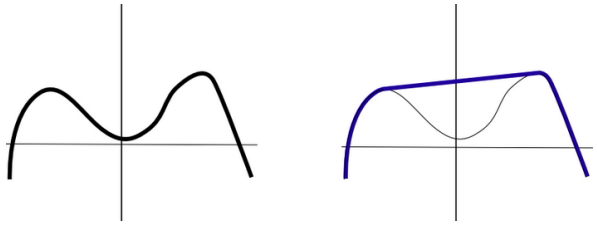
- « Compact » linearization methods for BQCP outperform SCOP in generic branch-and-bound framework as « compact » linear programs are to be solved at each
- node of the B&B tree.
- Applications to stochastic graph partitioning (Nguyen et al., to appear in Optimization Letters) and to stochastic knapsack (to be submitted).

NOUGAT : Non-Unique Optimization and Game Theory (2014)

Team : V. Perchet (Univ Paris Diderot), G. Vigeral (Lamsade Dauphine), R. Laraki (Ecole Polytechnique & CNRS)

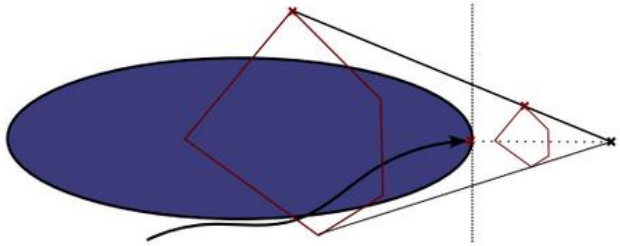
Context

- Stochastic Games and/or with incomplete information and/or with Uncertainty
- Main tool: Blackwell Approachability



Objectives

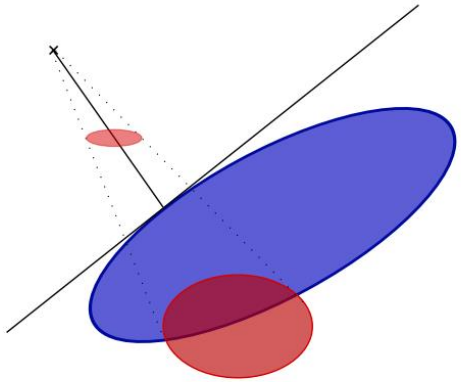
- Construct Optimal strategies with incomplete info (stochastic of with uncertainties)
- Algorithms to compute robust Nash equilibria



NOUGAT : Non-Unique Optimization and Game Theory (2014)

Results

- Necessary/sufficient conditions for approachability in subclass of absorbing games
- Algorithms to compute equilibria for 2 players



PRMO Projects

Ongoing

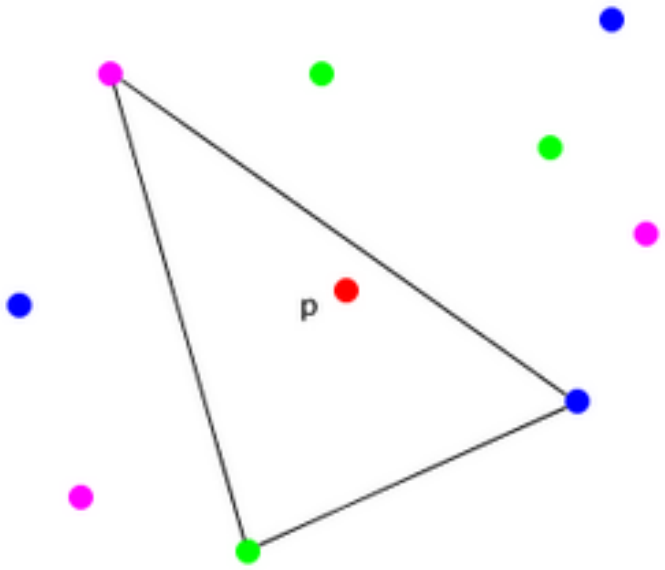
Colourful Linear Programming: geometric, combinatorial, and algorithmic aspects (2012-)

- **Team :** F. Meunier, P. Sarrabezolles (CERMICS ENPC), A Deza (McMaster University)
- **Context**
  - colorful linear programming is a generalization of linear programming
  - its complexity is not completely understood
  - It has applications in discrete geometry and discrete optimization
- **Objectives :**
  - a better understanding of its properties, and especially its complexity
  - counting the number of colorful bases

Colourful Linear Programming: geometric, combinatorial, and algorithmic aspects

Results

- Generalization of linear complementarity programming
- better understanding of its complexity and its relations with the PPAD, PLS, and NP classes
- proof of the colorful simplicial depth conjecture
- new efficient algorithm for a special case



Tropical Methods in Optimization (2012-)

- **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

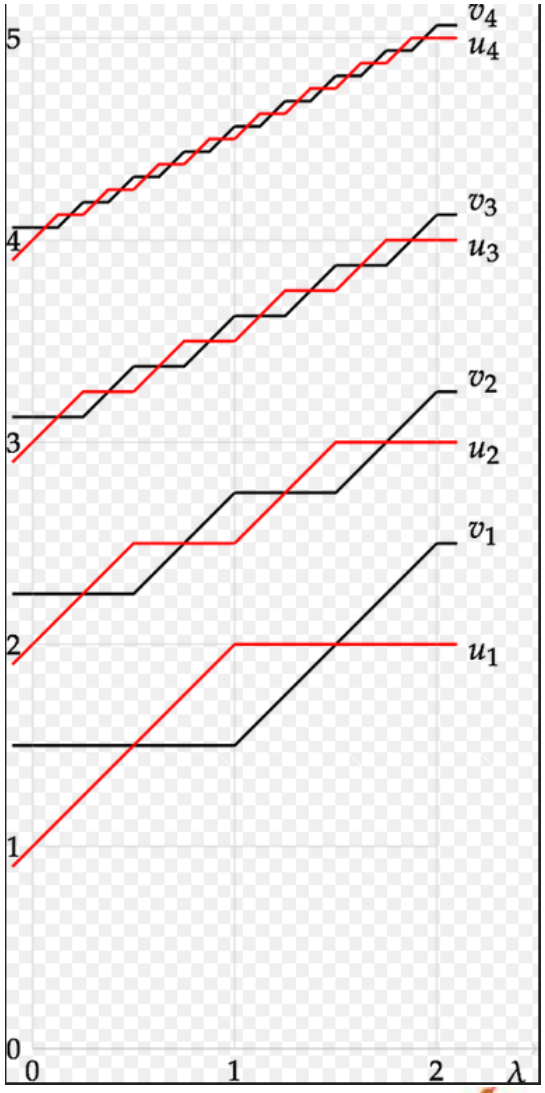
Tropical Methods in Optimization

Results

- a family of LPs where the central path has exponential curvature -> disprove the continuous Hirsch conjecture
- Tropical methods to analyze the performance of timed systems involving priorities -> application to the analysis of the new organization of emergency call centers, handling 17-18-112 calls in Paris area (collaboration with Préfecture de Police de Paris and Brigade de sapeurs-pompiers de Paris)
- new (maxplus based) numerical method to attenuate the curse of dimensionality + complexity estimates

New research lines (in progress)

- Tropicalization of semidefinite programming
- 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



Polynomial Optimisation (2013-)

- **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 inverse problems in particular
- **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

- 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.
  - Aproximation of semi-algebraic sets defined with quantifiers

New research lines

- Efficient implementation of the new hierarchy (Sparsity, point-evaluation, etc.)

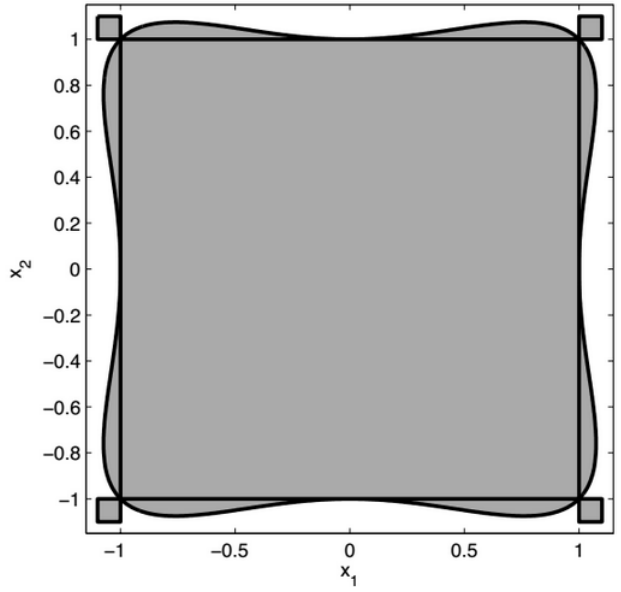


Fig : Degree 4

Global derivative free optimization with sparse grids (2013-)

- **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

Vehicles sharing systems: modelling, analysis and optimisation (2013-)

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

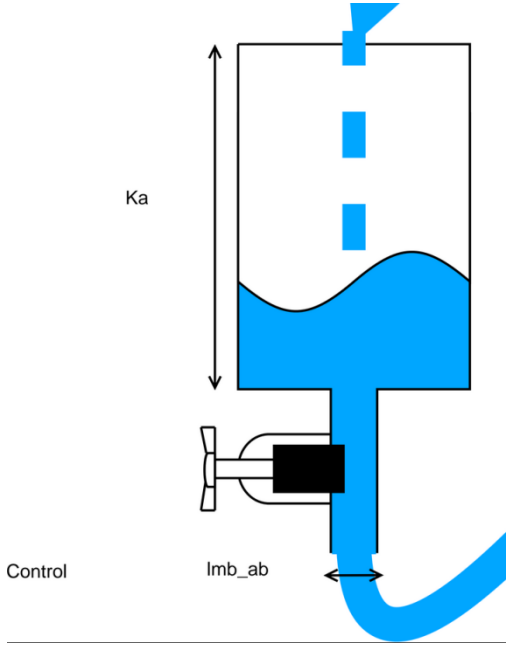
- **Context**
  - Bike/car business models: from ownership to (short-term) rental ?
  - One way rental systems are inefficient without regulation !

- **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

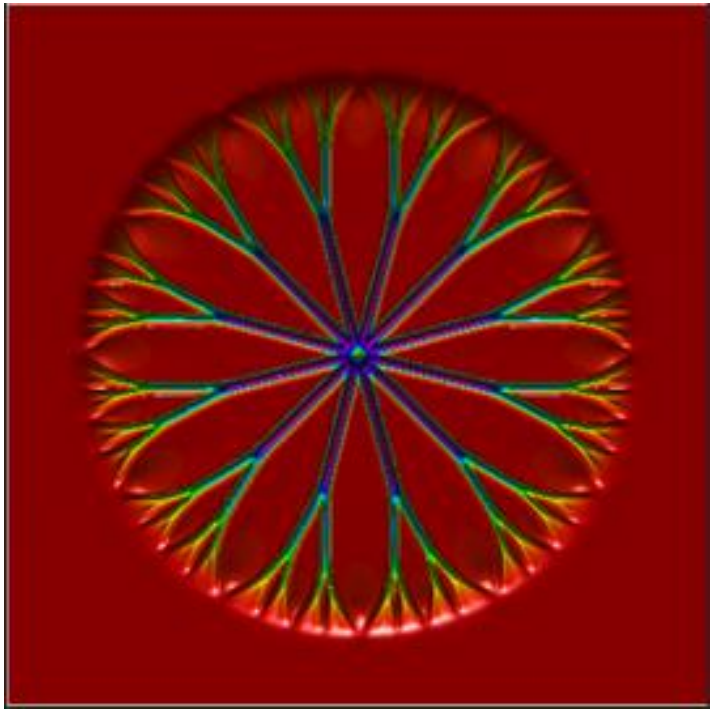


New research lines

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

Continuous Approximation Methods for optimal networks (MACRO) (2013-2014)

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

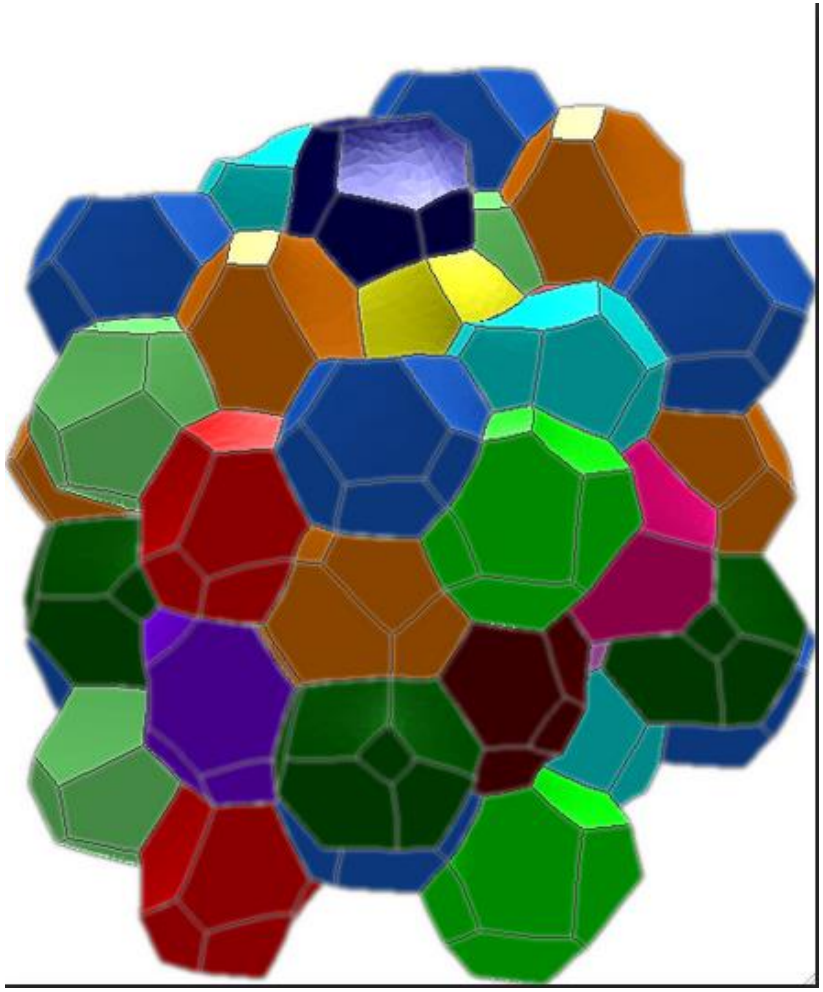
Continuous Approximation Methods for optimal networks (MACRO)

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

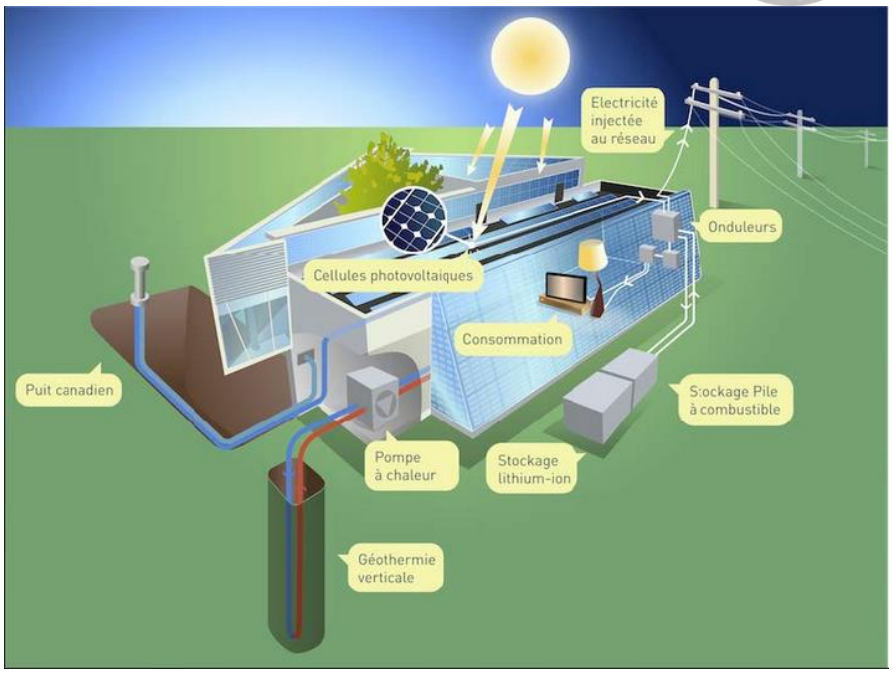


Combinatorial Optimization with Multiple Resources and Energy Contraints (

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

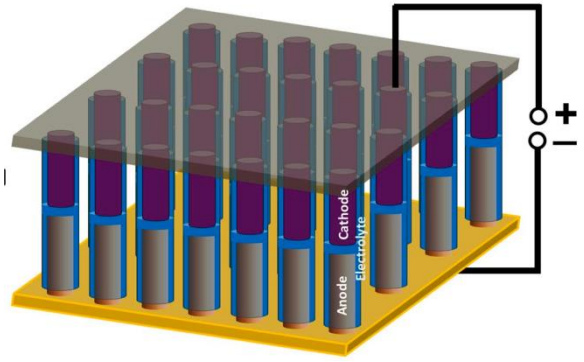
Context

- Energy considerations are becoming paramount in the resolution of real-world applications.
- Pre-existing studies : multiple energy sources and non-linear efficiency functions, but generally no scheduling.
- Previous work on scheduling under energy constraints only assumed linear (and even identical) energy efficiency functions,
- Phase 1 focused on scheduling with non reversible energy sources with piecwise linear efficiency functions
- Phase 2 introduces reversible energy sources



Objectives :

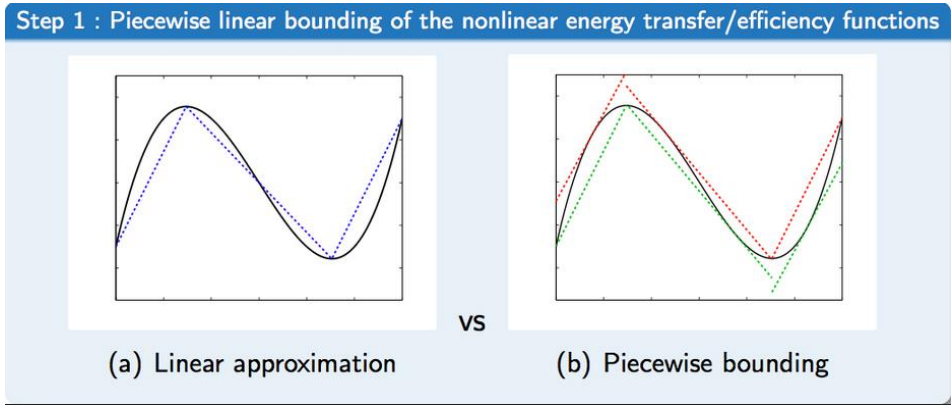
- Address the (combinatorial) optimization challenge of integrating energy sources constraints (physical, technological and performance characteristics) in deterministic (scheduling) models.
- Solve explicitly and in an integrated fashion the resulting energy resource allocation problems and energy-consuming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



Combinatorial Optimization with Multiple Resources and Energy Contraints (2013-)

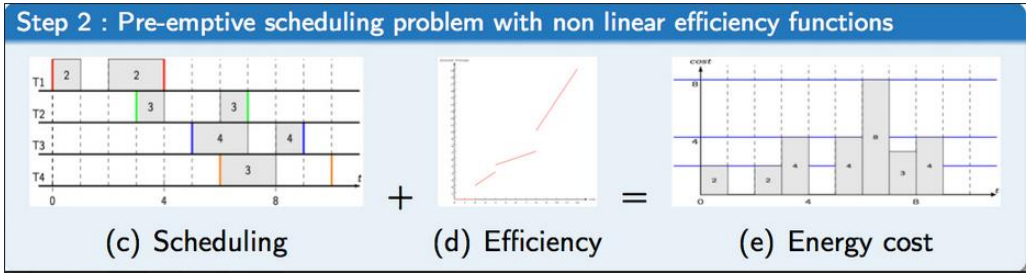
❑ Results

- ❖ Proof of concept with real-world data from Electrical engineering researchers
- ❖ Study of complexity and aggregability for general and particular cases / classes of efficiency functions
- ❖ Design of efficient bounding procedures and decomposition-based solution methods
- ❖ Analysis of the impact of reversible energy sources and the strong connection of the resulting problems with lot sizing



❑ New research lines

- ❖ extention of the bounding methods to handle general efficiency functions for reversible energy sources
- ❖ combine mathematical and constraint programming to solve exactly the problem with reversible energy sources



Adjustable robust optimisation applied to network design problems (2013-)

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

- Combinatorial robust otpimization are hard.
- Budgeted uncertainty introduced by Bertsimas and Sim (2003) yields easier problems.

Objectives :

Extend the results of BS to other problems

- Shortest path problems
- Scheduling problems
- Lot-sizing problems

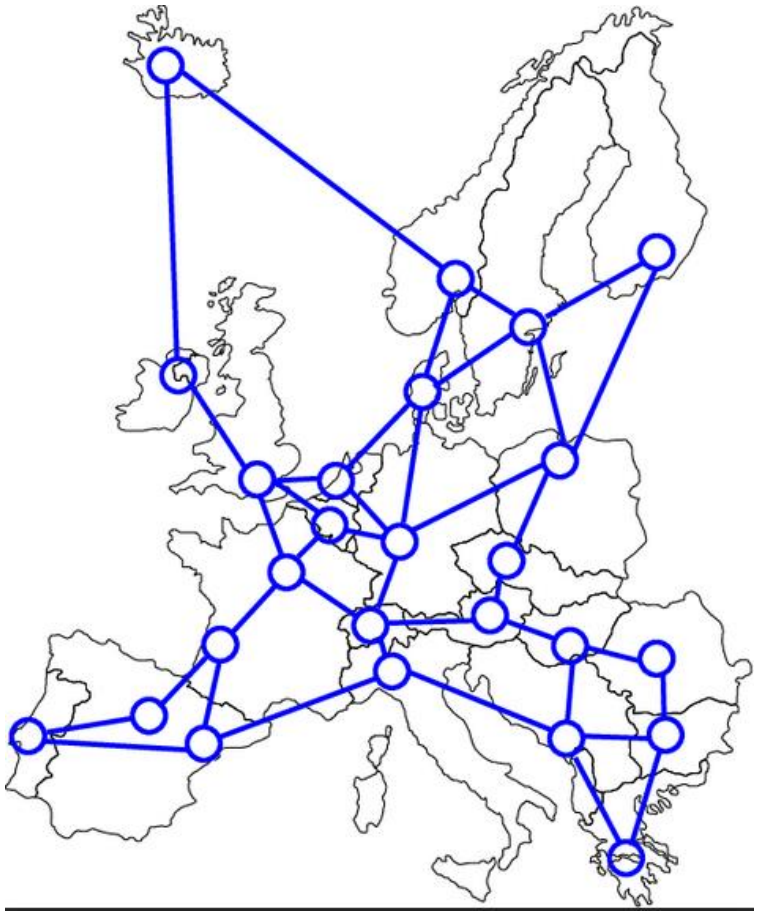
Adjustable robust optimisation applied to network design problems

❑ Results

- ❖ abel-setting algorithm for the robust capacity constrained shortest path problem
- ❖ NP-hardness proof of the robust shortest path with time windows
- ❖ preliminary results on robust scheduling

❑ New research lines

- ❖ Developping ad-hoc algorithms, including dynamic programming.



Towards the design of efficient local search based on fitness landscape analysis (2014 -)

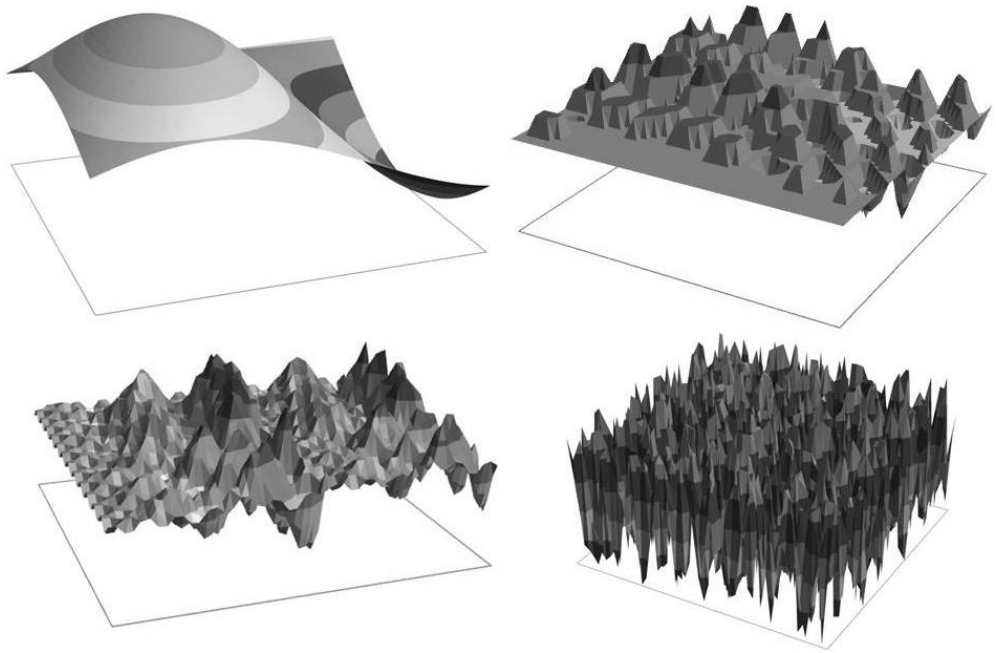
Team : M. Basseur, A. Goeffon, JK. Hao (Univ Angers), A. Lefooghe (Univ. Lille1 / INRIA)

Context

- Local Search for combinatorial optimisation
- Fitness landscape analysis

Objectives

- Design of alternative moving criterions
- Evaluate the attainability of global optima
- Incorporate results in metaheuristics for scheduling problems



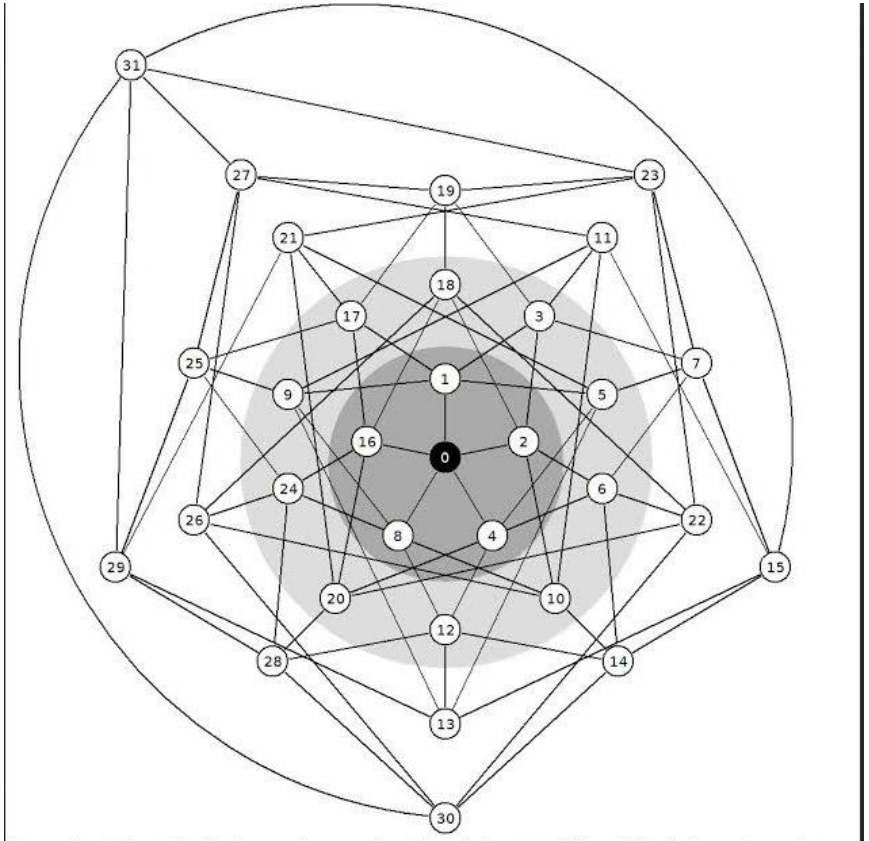
Towards the design of efficient local search based on fitness landscape analysis

Results

- Analysis of neighborhood search moving criteria
- Experiments on artificial landscapes and scheduling problems

New research lines

- Design of efficient advanced local search
- Extension to the multiobjective case



Hypercube of dimension 5 where vertex are placed in order to respect the relation between hamming distance and euclidian distance thanks to the solution « 00000 ».
We aim at moving efficiently in the "moving area" thanks to the information provided by the "vision area".
Landscapes derived from real-world problems are of dimension ranging froms hundreds to thousands.

Optibio : New challenges in the optimal control of bioprocesses (2014-)

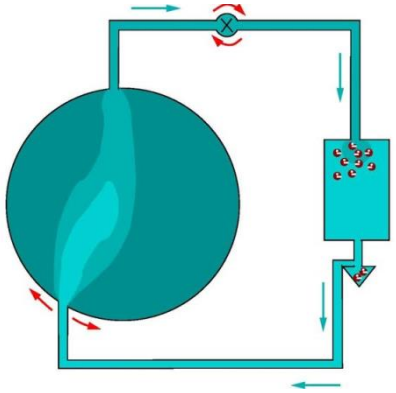
Team : T. Bayen, J. Harmand, A. rapaport (Univ Montpellier), F. Silva (Univ. Limoges), P. Martinon, F. Mairet (INRIA)

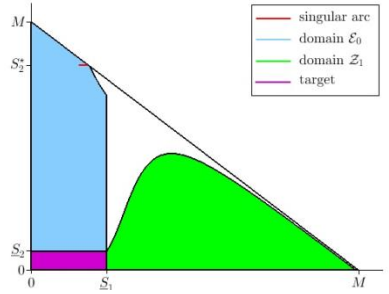
Context

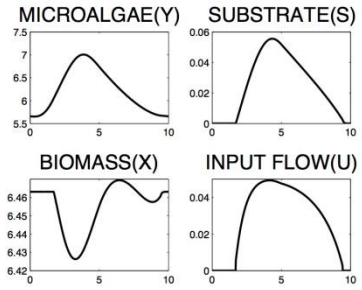
- Sustainable development
- Conversion of solar energy into bio-bas production
- New optimization problems from the modeling of these processes.

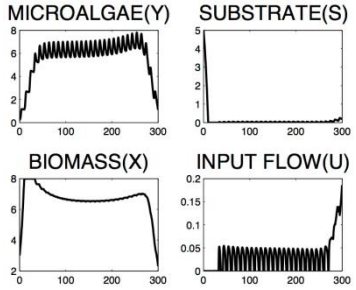
Objectives

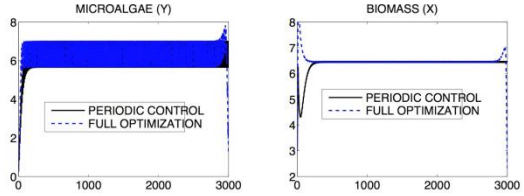
- Develop new mathematical methods in order to improve control strategies of such processes.
- Contribute to the development of new control strategies (that could be transferred to transfered specialists in industrial biotechnologies).
- Optimize the anaerobic digestion to convert solar energy into methane (bio gas)











Optibio : New challenges in the optimal control of bioprocesses (2014-)

Results

- Regularization method for minimizing the time crisis function (About Moreau-Yosida regularization of the minimal time crisis problem, published online, Journal of Convex Analysis, vol. 23, 2016).
- Study of optimal periodic control strategies (also work in progress)

New research lines

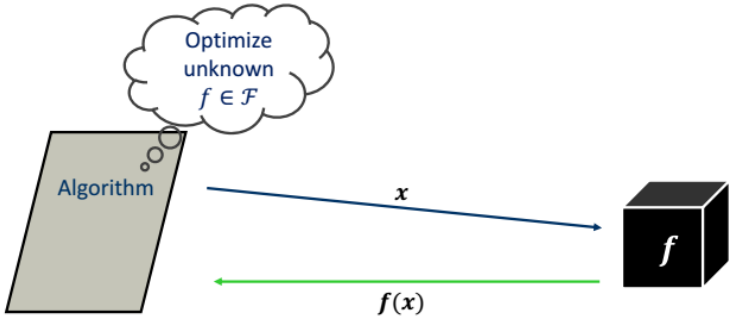
- Develop periodic strategies optimizing the time crisis function
- Develop singular control laws to optimize the selection of species of micro-algae (for solar conversion into bio bas)

Towards a Complexity Theory for black-Box Optimisation (2014-)

Team : A. Auger, N. Hansen (INRIA, LRI Orsay), D. Brockhoff (INRIA), B. Doerr (LIX), C. Doerr (CNRS LIP6), T. Kotzing (U. Jena), J. Lengler (ETH Zurich), J. Rowe (U. Birmingham)

Context

- Black-Box Optimization (unknown optimization goal)
- Limits of Heuristic Search
- Theoretical Evaluation



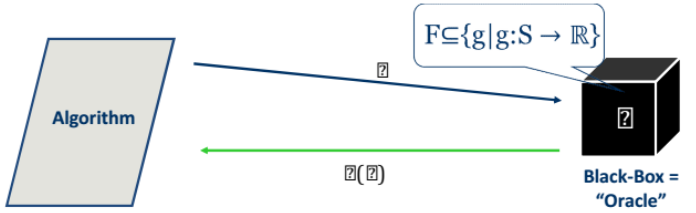
Objectives

- Development of a Complexity Theory for Black-Box Optimization
- Measuring the influence of parameter choices
- Understanding Limits of General-Purpose Heuristics

Towards a Complexity Theory for black-Box Optimisation (2014-)

❑ Results

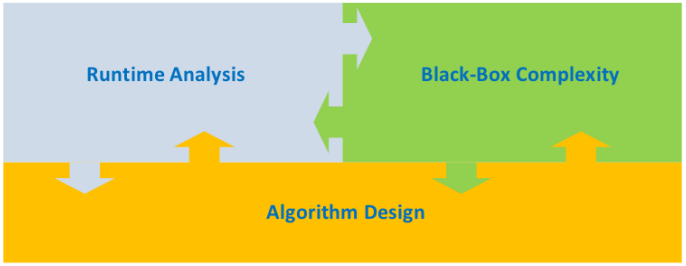
- ❖ Elitist Black-Box Model introduced
- ❖ New Complexity Measure: Monte Carlo vs. Las Vegas Black-Box Complexity
- ❖ Analysis of Combined Complexity Models (Ranking-Based + Memory-Restricted Algorithms)



Algorithm knows search space and possibly some features of but cannot access target function other than by querying search points ∈

❑ New research lines

- ❖ Further analysis of elitist and combined ranking-based + memory-restricted models
- ❖ Other optimization problems
- ❖ Precise bounds for classic problems in black-box theory



Our Goal: Using insights from algorithm analysis and complexity theory for designing new search heuristics.

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

Copositive Optimization under uncertainties (CO2U) (2014 -)

Team : A. Lisser, C. Gicquel (LRI Orsay), I. Bomze (U.. Vienne), JC. Gilbert (INRIA)

Context

- Study new methods for solving optimization problems under uncertainty using copositive programming.
- Reformulations of hard optimization problems as co(mpletely) positive problems.
- Applications to energy problems with extension to more general

Objectives

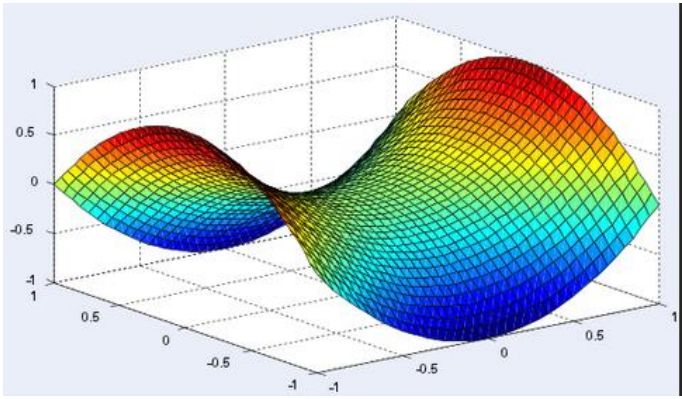
- Set up the theory and methodology for solving deterministic copositive optimization problems.
- Feasibility of solving chance constrained optimization problems using copositive programming.
- Study the potential of such methods for solving industrial problems, e.g., energy plannig problems.

QPLIB2014 : a Library of Quadratic Programming Instances (2014-)

Team : F. Furini (Univ Dauphine), E. Traversi (Univ Paris 13)

Context

- Quadratic programming problems have received an increasing amount of attention in recent years.
- Important applications: energy production, process networks optimization, computational geometry, finance.
- A library specifically conceived for QP does not exist yet.



Objectives

- Define a standard test set for QP, i.e. a library of quadratic programming instances.
- Useful to compare the performance of different generic quadratic optimization software.
- Useful to evaluate the computational performance of newly developed algorithms and solution techniques

QPLIB2014 : a Library of Quadratic Programming Instances (2014-)

Research lines

- Study efficient co(ompletely) positive reformulations for solving hard optimization problems.
- Applications to hard deterministic optimization problems.
- Study of the possibility to extend these approaches to chance constrained problems and applications to energy problems.

Efficient exact algorithms for Graph Partitionning Problems (2014-)

Team : R. Mahjoub, F. Furini, D. Cornaz (Lamsade, Dauphine), M. Lacroix (LIPN Paris 13), S. Martin (LCOMS, Univ Lorraine)

Context

- Graph partitioning (GP) : a fundamental problem with applications in many areas. particularly in parallel computing, scheduling in multi-processor systems, data analysis and risk management of energy and social networks.

Objectives

- design powerful techniques from polyhedral combinatorics and mathematical programming to solve to optimality
- exploit the global combinatorial structure of the underlying problem, which needs a deep investigation of the associated polyhedron.
- general and exact methods that efficiently solve large-sized GP problems.

Efficient exact algorithms for Graph Partitionning Problems (2014-

Results

- Development of a polyhedral analysis of the mathematical formulation
- Development of an extended formulation of the problem
- Study and comparison of a branch-and-price algorithm based on column generation
- Resolution of large sized and real-world VSP instances

New research lines

- Development of a Branch-and-cut-and-price algorithm.
- Combining the strength of branch-and-cut and branch-and-price algorithms
- Study of more effective separation and pricing procedures
- Study of further variants of vertex separator problem

COGLED : Convergence of gradient-like and evolutionary dynamics (2014 -)

Team : S. Sorin, J Kwon (UPMC), J. Bolte, T. Nguyen (Gremaq Toulouse)

Context

- Evolutionary dynamics, potential and dissipative games
- Gradient systems, Hessian Riemannian metrics, Lyapounov functions
- Behavior of gradient-like systems under semi-algebraic assumptions

Objectives

- Analyze gradient systems with degenerate metrics
- Selection of equilibria for dissipative or potential games
- Underlying geometric/strategic structure of evolutionary dynamics

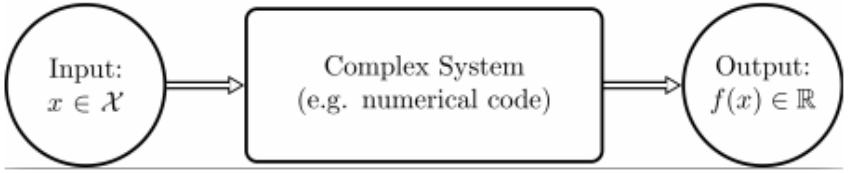
COGLED : Convergence of gradient-like and evolutionary dynamics (2014 -)

Research lines

- Algebraic properties of the dynamics and trajectories with finite length
- Generalize KL inequality

Active Learning, Links with Optimisation (2014 -)

Team : N. Vayatis, E. Contat, C. Labourdette, C. Malherbe (CMLA ENS Cachan), V. Perchet, M. Mougeot (Paris Diderot)



Context

- Sequential optimization of non-convex black-box functions
- Evaluating the function is expensive
- Gaussian process or non-parametric function spaces

Objectives

- Adapt to complex input spaces
- Provide theoretical guarantees
- Design practical and flexible algorithm

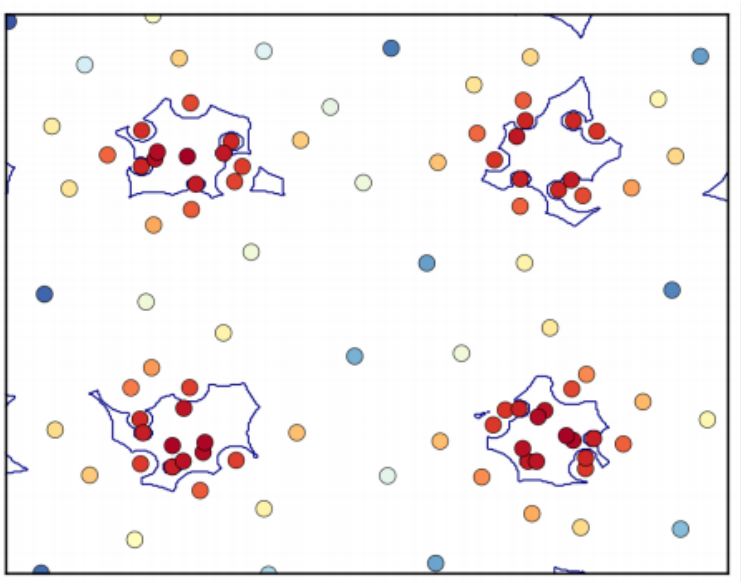


Figure 1: Optimization via active learning of level sets

Active Learning, Links with Optimisation

Results

- Theorem and proofs for the speed of convergence
- Synthetic empirical assessments
- Good results on a real setting: placement of 40 Wave Energy Converters (WEC) to optimize the global energy production

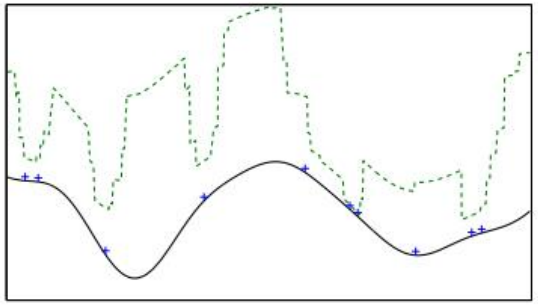


Figure 2: Upper confidence bound via chaining

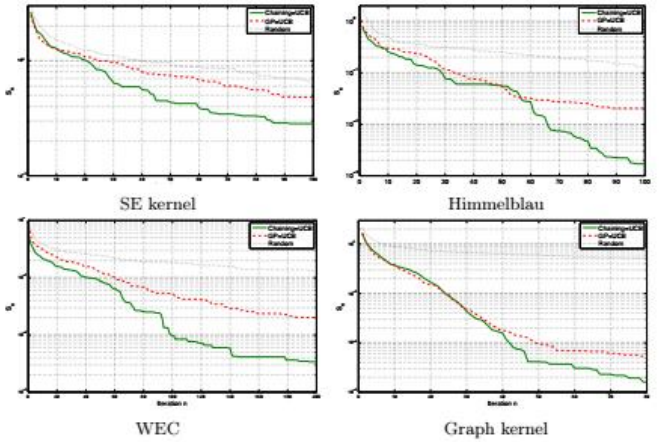


Figure 3: Convergence of the simple regret S_T with respect to the iteration (lower is better)

LMG – Limit game : asymptotic analysis of two person zero-sum dynamic games (2014-)

Team : G. Vigeral (Ceremade), S. Sorin (UPMC)

Context

- zero-sum dynamic games
- discrete time and continuous time analysis
- large number of interactions: vanishing weight versus vanishing durations

Objectives

- classification of dynamic games: dissipative properties
- limit of values and viscosity solutions
- asymptotic optimal strategies and limit game

LMG – Limit game : asymptotic analysis of two person zero-sum dynamic games (2014-)

Results

- Link with non expansive operators (iterates and generators)
- convergence via comparison theorems

New research lines

- Games with signals
- Construction of a limit game

State-Constrained Stochastic Optimal Control Problems and Applications (2014-)

- **Team :** H. Zidani, F. Russo, D. Lefevre, A. Picarelli, I. Laachir (ENSTA)

Context

- Stochastic Control problems under state constraints
- In Stochastic Analysis there are modern tool based on replacements of Itô formulae for non regular functions of the state process, based on Fukushima-Dirichlet decomposition

Objectives

- Developing new theoretical and numeriacl tools for analyzing the Hamilton-Jacobi approach
- Establish verification theorems

PRMO Projects

New

Search and Surveillance Games: Theory, Algorithms and Applications (2015-)

- **Team :** Spyros Angelopoulos, Christoph Dûrr, Marc Renault (LIP6 DESIR), Thomas Lidbetter, Katerina Papadiki (London School of Economics)

Context

- Search games: A mobile Searcher that must locate a Hider
- Surveillance games: A Patroller that guards an area against an Attacker
- Problems at the intersection of OR and TCS

Objectives

- Search with stochastic detection and search with delay
- Algorithmic issues in patrolling games

Stochastic Control under State Constraints (2015-)

❑ **Team :** *Piernicola BETTIOL*, *Rainer BUCKDAHN* (*Université de Bretagne Occidentale*)

❑ Context

"Neighbouring Feasible Trajectories' (NFT) results

- ❖ are well developed for deterministic control systems;
- ❖ constitute important analytical tools in state constrained optimization.

❑ Objectives

- ❖ to study NFT type theorems for Stochastic Control Systems with State Constraints;
- ❖ to extend to deterministic and stochastic differential games;
- ❖ to investigate necessary and sufficient optimality conditions for stochastic constrained control problems.

SPARC : Sparse variational classification by proximal splitting (2015-)

Team :

Combettes, P. L. (Paris 6) , Perchet, V. (Paris 7), Barlaud,M, Fillatre L. (Université Nice Sophia Antipolis)

Context

- Context: Large-scale classification problems arising in biology
- Challenge: the growth of the high-throughput technologies has resulted in an exponential growth in the harvested data with respect to both dimensionality and sample size.
- Task: select relevant features for supervised classification and the classical independence assumption on the features is typically not fulfilled.
- Areas of interaction: optimization, statistics, machine learning

Objectives

- Develop advanced optimization techniques to deal with large-scale classification problems arising in biology.
- Strategy: 1) select/eliminate features via sparsity promoting techniques.
  2) Combine with online learning & optimization techniques (fast and robust)
- We aim at bringing state-of-the art proximal optimization tools to solve this problem.

Combinatorial optimization/Optimization and uncertainties (2015-)

- **Team :** Rosa Figueiredo, Philippe Michelon , Vincent Labatut (UAPV – LIA), Sébastien Destercke (CNRS, UTC – Heudiasyc), Martine Labbé (ULB – DI), Yuri Frota (UFF - Computaçao)

Context

- Signed graphs to model social networks
- Evaluate balance on signed networks
- Community detection on signed networks

Objectives

- Extraction of real-world signed networks in different time points
- Identification and solution of balanced-related optimization problems
- Model aiming at generating realistic signed networks

New research lines

- Combining Operations Research with Complex Networks Analysis and Information Fusion

Optimization under probabilistic contraints of complex systems – Application to the anchoring of offshore wind-turbines (2015-)

- **Team :** Rüdiger Schultz (Universität Duisburh-Essen), Garnier Josselin (LPMA- ParisVII), Munoz Zuniga Miguel, Guiton Martin, Poirette Yann, Delphine Sinoquet (IFPEN), van Ackooij Wim (EDF R&D)

Context

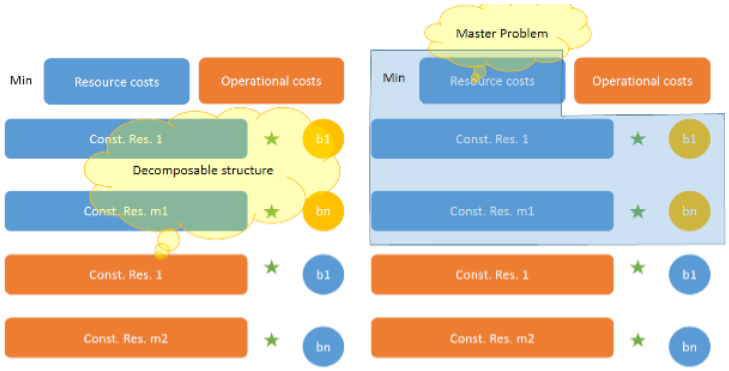
- Design floating wind turbine systems
- Environmental constraints: winds and waves, in normal and extreme conditions
- Multicriteria (masses, costs)

Objectives

- Take into account uncertainties
- Optimize under probabilistic contraints
- Combine MINLP optimization and reliability techniques

BENMIP: A Generic Bender Decomposition - based (Mixed) Integer Programming Solver (2015-)

- **Team :** Bernard Fortz (Universite libre de Bruxelles) , Shahin Gelareh, Frédéric Semet, Maxime Ogier (Lab. CRIStAL)



Context

- Mixed Integer Programming
- Large Scale Combinatorial Optimization
- Primal/Resource-based Decomposition

Objectives

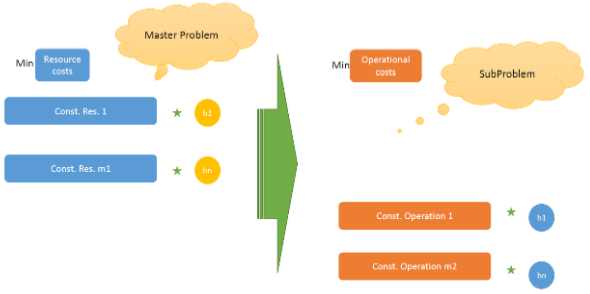
- Automated resource-based decomposition in mixed integer programming models
- An open source decomposition-based black-box MIP solver

Results

- An initial (basic) prototype of the open-source library
- Benchmarking on MIPs of large scale

New research lines

- Automated identification of sub-structures
- Robustnesss in Combinatorial Optimization



Stochastic Optimization for Planning Remanufacturing Activities in Reverse Supply Chains (2015-)

Team : Celine Gicquel, Dominique Quadri (LRI – UPSUD), Safia Kedad Sidhoum (LIP6 – UPMC)

Context

- Transition to a circular economy
- Closed-loop supply chain management
- Remanufacturing of end-of-life industrial products

Objectives

- Optimizing the aggregate planning of remanufacturing activities
- Coordinating disassembly and reassembly for a multi-product system
- Main challenge: uncertainty on the quantity and quality of end-of-life returned products

Research lines

- Development of a 2-stage stochastic programming approach
- Extension to a multi-stage stochastic programming approach

Strategic design optimization problem under stochastic user equilibrium constraints (2015-)

❑ **Team :** Yezekael Hayel (LIA – UAPV), Dominique Quadri, Steve Martin (LRI – UPSUD)

❑ Context

- ❖ Discrete choice model, control and Queueing games
- ❖ Bilevel mathematical programming with Stochastic user equilibrium,
- ❖ Application to capacity management of urban charging stations for Electrical Vehicles

❑ Objectives

- ❖ combine mathematical programming with game theoretic solution concept
- ❖ develop tools to solve this optimization problem and to obtain insights for the application

Optimal control of partial differential equations using parameterizing manifolds, model reduction, and dynamic programming (2015-)

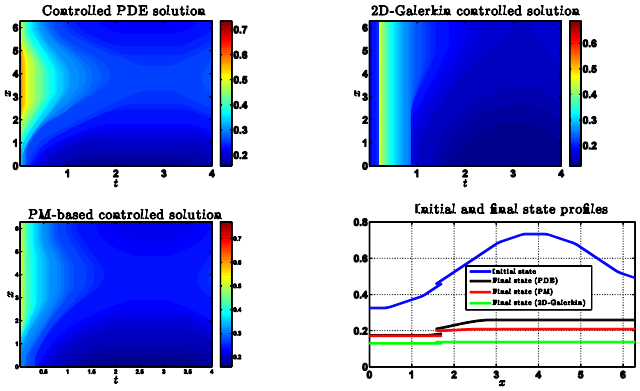
❑ **Team :** Frédéric Bonnans, Axel Kroener (Ecole Polytechnique), Mickael Chekroun (UCLA), Martin Gubisch (University of Konstanz), Karl Kunisch (RICAM), Hasnaa Zidani (ENSTA, Paris–Tech)

❑Context

- ❖Optimal control of partial differential equations
- ❖Model reduction and parameterizing manifolds
- ❖Dynamic programming

❑Objectives

- ❖Reduced-order suboptimal closed-loop control of nonlinear PDEs
- ❖Suboptimal sparse control based on parameterizing manifolds



❑Results

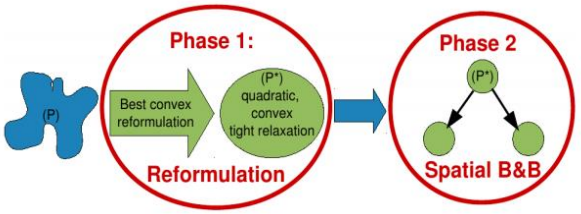
- ❖ Numerical results of the PM-HJB approach

❑New research lines

- ❖Theoretical analysis for reduced-order suboptimal sparse control
- ❖Reduced-order closed-loop control in climate modelling

Global solution of mixed-integer polynomial optimization problems through quadratic reformulation (2015-)

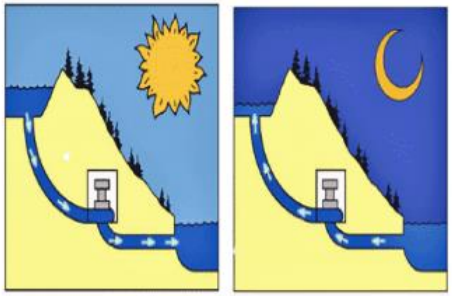
- **Team :** Amelie Lambert, Sourour Elloumi (CEDRIC), Claudia D'Ambrosio (LIX)



❑ Context

- ❖ Mixed-integer non linear optimization : minimization of a non linear function subject to non linear constraints
- ❖ Formulation general enough to formulate a large number of problems.
- ❖ Existing method MIQCR dedicated to quadratic optimization based on quadratic convex reformulation

Application 1:
The hydro unit commitment problem



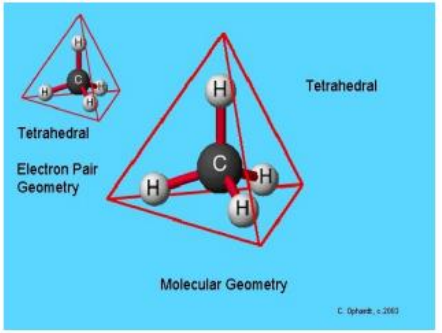
Daytime: Water flows downhill through turbines, producing electricity

Nightime: Water pumped uphill to reservoir for tomorrow's use

❑ Objectives

- ❖ Extend the ideas of MIQCR method to the case of (P)
- ❖ Evaluate the new method through two applications having trilinear and quadrilinear terms :

Application 2:
The distance geometry problem



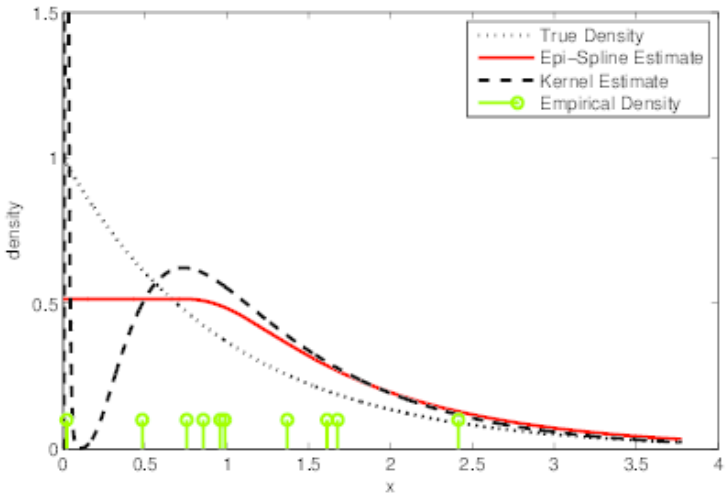
http://www.fondation-hadamard.fr/PGMO

Solar Forecasting with Epi-Splines (2015-)

- **Team :** V. Leclere (CERMICS ENPC), Johannes Royset, (Naval Post-Graduate School), Robert Bassett, PhD Student, Roger Wets, (UC Davis), Pierre Carpentier (UMA, ENSTA)

❑ Context

- ❖ Incorporate knowledge / beliefs about the random phenomena in the estimation of probability distributions.
- ❖ Can help overcome lack of reliable data.
- ❖ Promising results already exist



❑ Objectives

- ❖ Apply Epi-spline forecasting to larger problems.
- ❖ Use density estimation to model the extra volatility in renewable energy markets.
- ❖ Continue to develop software for academic and industrial use.

Generalized framework for robust approximated approach to chance-constrained optimization problems (2015-)

Team : D. Nace, J. Carlier, A. Jouglet, D. Savourey (Heudiasyc, UTC), R. Sirdey, O.Stan (CEA), N. Kaciroti (Univ. Michigan), A. Fundo (U.Polytech Tirana)

Context

- starting point (Journal of Heuristics, Stan et al. 2014)
- applied to problem of graph partitioning with application to multi-core architecture

Objectives

- generalizing the approach to robust optimization programs
- adapting to main known metaheuristics
- look at other real-life meaningful applications.

Research lines and methodology

- Based on the scenario approach
- Combining sampling with heuristics
- Using statistical hypotheses testing theory
- Leveraging existing heuristics on determinist case

How Randomness Helps in Scheduling Problems (2015-)

- **Team :** F. Pascual, C. Doerr (LIP6 UPMC), Thang Nguyen Kim (IBISC Evry), Nicole Megow (Technische Universität Berlin, Germany), Krzysztof Rzadca (University of Warsaw, Poland)

❑ Context

- ❖ Scheduling problems
- ❖ Environment dealing selfish agents (algorithmic game theory)
- ❖ Environment dealing dynamic data (online algorithms)

❑ Objectives

- ❖ Performance of randomized algorithms for scheduling problems
- ❖ How randomization improves the performance of a truthful algorithm
- ❖ How randomization improves the performance of an online algorithm

❑ Research Lines

- ❖ Analyses of the random list scheduling algorithm
- ❖ Performance of randomized coordination mechanisms

Paris-London network on stochastics and optimization in renewable energy (2015-)

- **Team :** T. Pennanen (King's College London), Anes Dallagi, (EDF Energy R&D UK Centre, London), Jean-Philippe Chancelier, (Cermics, Ecole des Ponts ParisTech)

❑ Context

- ❖ power production and trading
- ❖ renewable energy and storages

❑ Objectives

- ❖ optimization of production and trading
- ❖ pricing of power contracts via optimal production and trading

❑ Research Lines

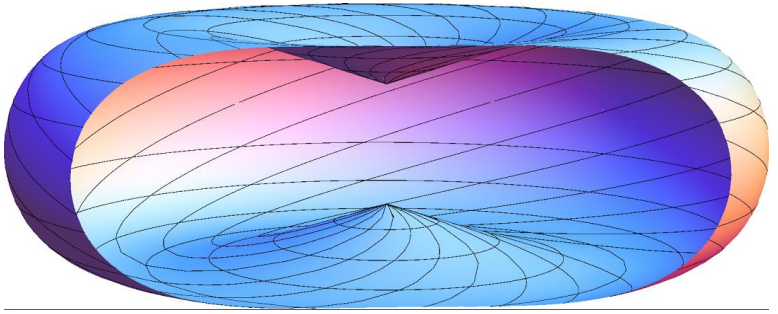
- ❖ stochastic modelling of physical and market risk factors
- ❖ application of modern techniques of convex stochastic optimization

Geometric Optimal Control (2015-)

Team : Ugo Boscain, Yacine Chitour, Frédéric Jean, Paolo Mason, Mario Sigalotti, Luca Rizzi

Context

- frontiers of sub-Riemannian geometry: sub-Riemannian random walks and curvature
- biomimetic algorithms in image processing
- chattering and Fuller phenomena in optimal control

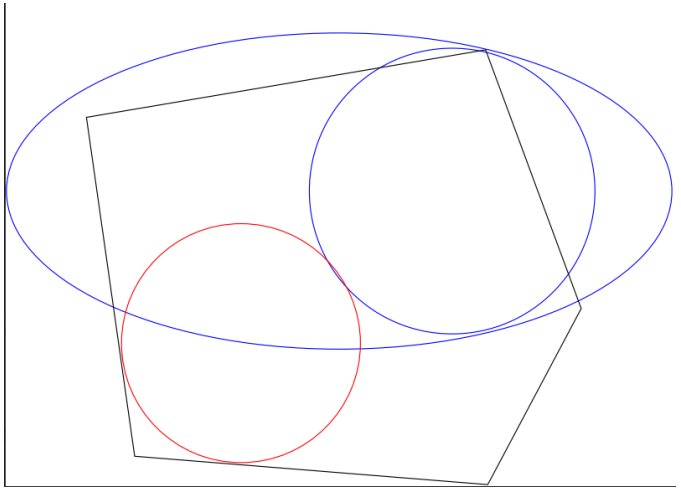


Objectives

- understanding hypoelliptic diffiusion via random walks
- development of an intrinsic theory of curvature in sub-Riemannian geometry
- a new sub-Riemannian paradigm for image processing
- description of the ugliest stable singularities for bang-bang optimal controls

Covering Balls Techniques (COBALT) for nonconvex optimization (2015-)

- **Team :** Ider Tseveendorj, Guillaume Guerard (PRISM, UVSQ, University Paris Saclay), Dominique Fortin (INRIA, Rocquencourt), Bazarragchaa Barsbold (National University of Mongolia, Ulaanbaatar, Mongolia), Bukharov (Russian Academy of Sciences).

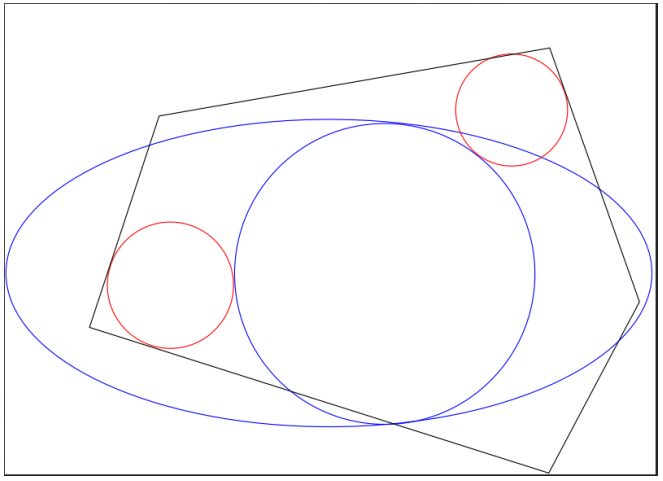


❑ Context

- ❖ nonlinear separation for nonconvex optimization instead of linear separation
- ❖ use of spherical sets for the separation instead of hyperplanes

❑ Objectives

- ❖ an algorithm combining local search and the improvement of local solutions
- ❖ convergence issues of the algorithm for convex maximization
- ❖ global optimality condition checking



IROE Projects

IROE Projects

Completed

Nash equilibria for the valuation of offers in the management of daily production : the point of view of the producer (2012-2014)

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

Context

- Electricity pay-as-bid market with linear and quadratic bids
- Point of view of producer and ISO

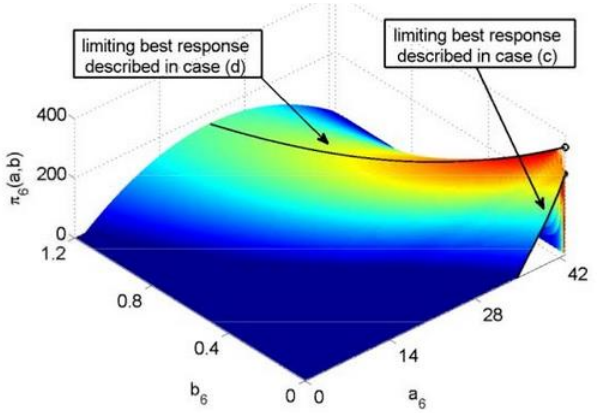
Objectives

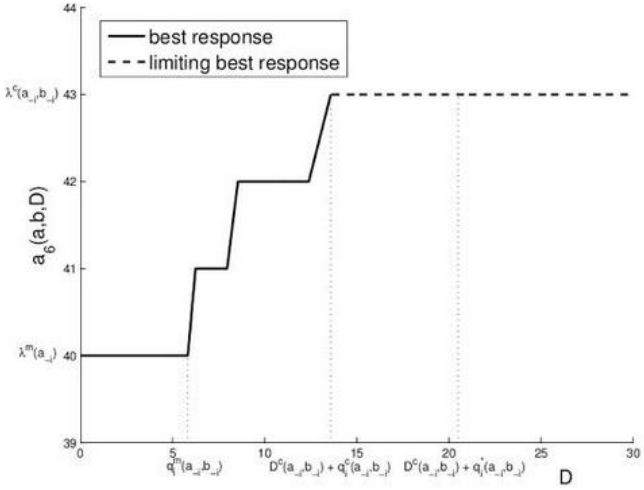
- Analysis of the best response of producer
- Evaluation of Nash equilibrium of the market

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

Results

- Complete analytic description of the best response of the producer
- Only linear bids provide (exact) best response
- Quadratic bids can provide only approximate best response
- Existence and explicit formulae of the set of Nash equilibrium of yje market





Remaining work

- Analysis of stability of the obtained Nash equilibrium of the market

Optimality for tough combinatorial Hydro-valleys problems (2013-2014)

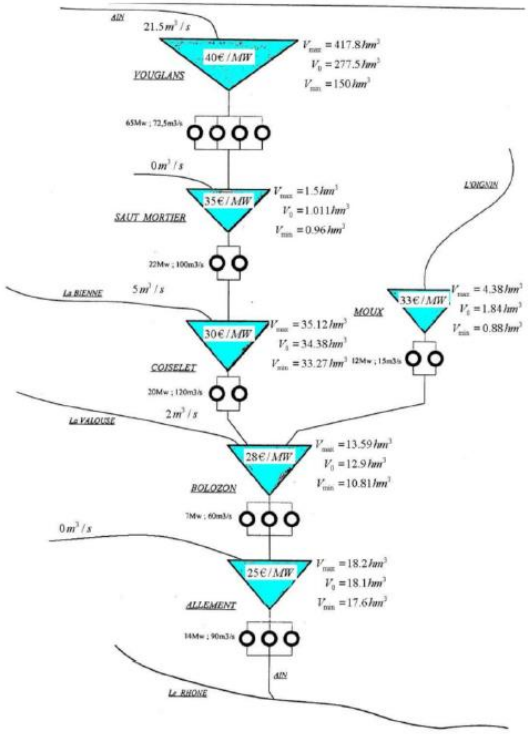
Team : C. D'Ambrosio (CNRS, Ecole Polytechnique), F. Roupin, (Univ. Paris XIII), C. Gentile (IASI, CNR, Italia), G. Doukopoulos, W van Ackooij (EDF), Y Sahraoui (PHD, EDF), R. Taktak (postdoc)

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



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

Stochastic Nuclear Outage problems with chance constraints (2012-2014)

- **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 (2012-2014)

❑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

Hydro-electric scheduling under uncertainty (2012-2014)

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

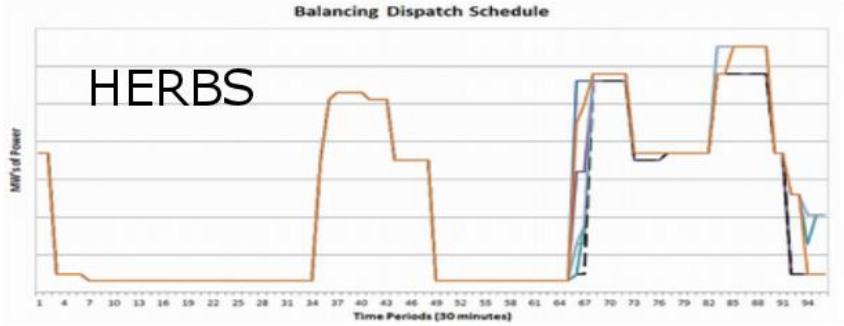
Objectives

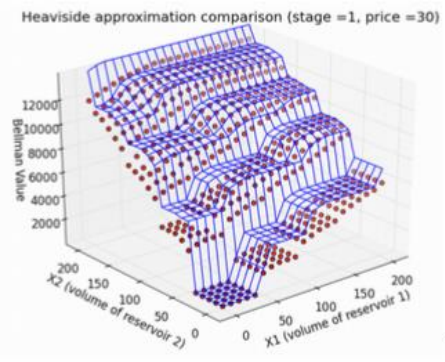
- Build next generation of stochastic dynamic programming models for daily optimization of river chains;
- Incorporate price uncertainty into SDDP models over short term;
- Investigate models for including head effects in short-term scheduling;
- Develop new methods for SDP based on mixed integer programming

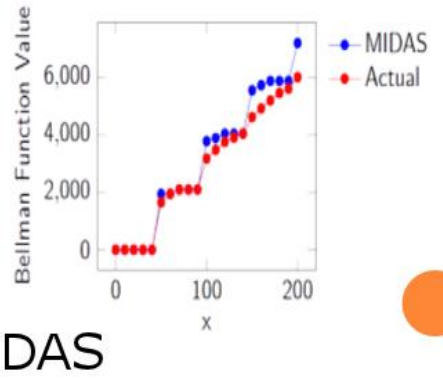
Hydro-electric scheduling under uncertainty

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





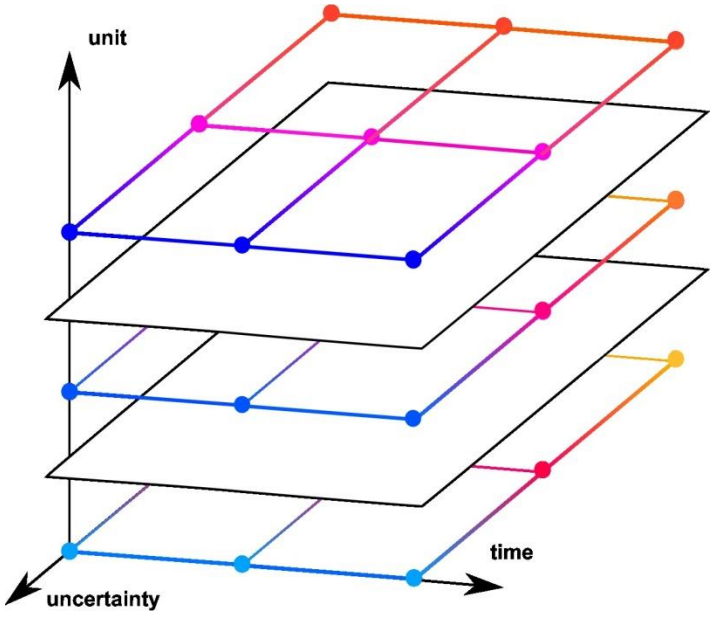


MIDAS

Decomposition/coordination methods in stochastic optimal control (2012)

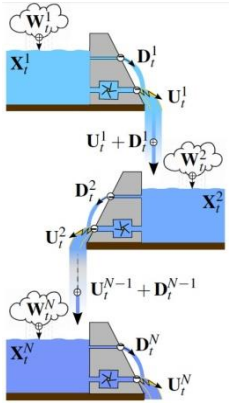
Team : P. Carpentier (ENSTA), M. De Lara, J-Ph. Chancelier, V. Leclère (CERMICS)

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).

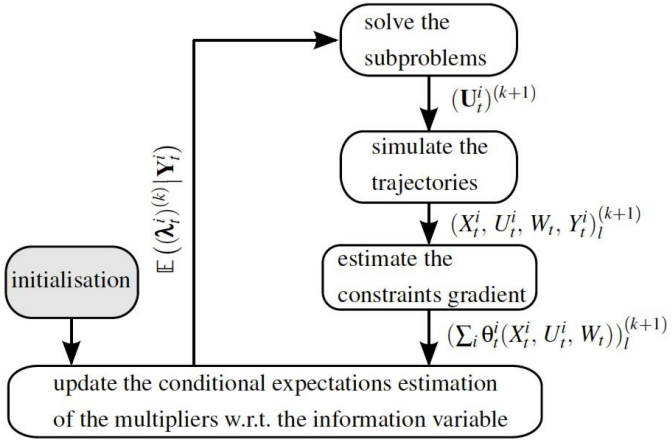


Fig. 3: DADP algorithm flowchart

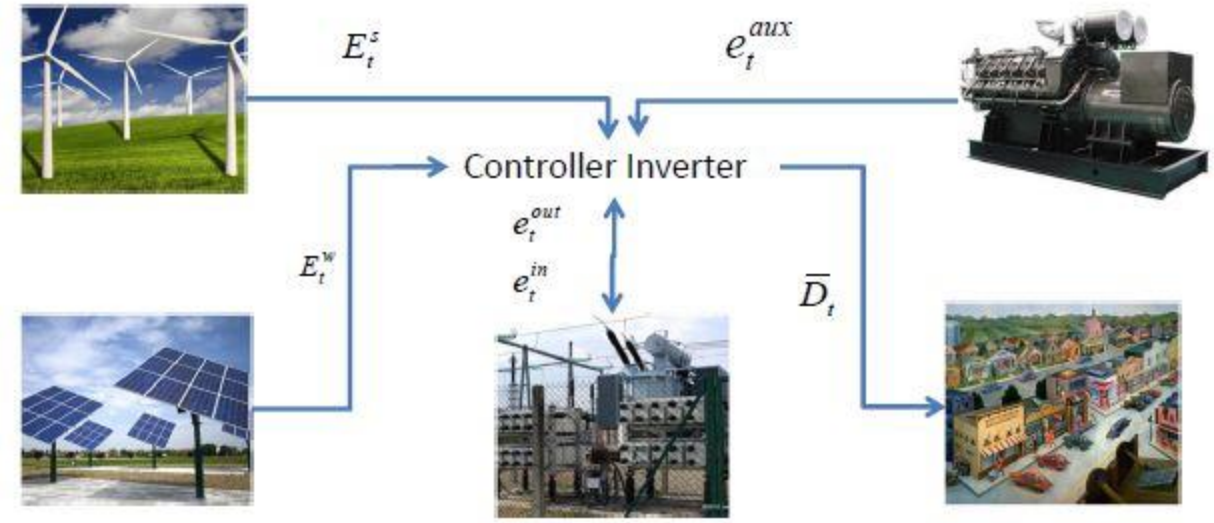
Perspectives: apply the method to more general optimization problems (smart grids): new PGMO project “SmartGrid” starting in 2014

Robust optimal sizing of an hybrid energy stand-alone system (2012)

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

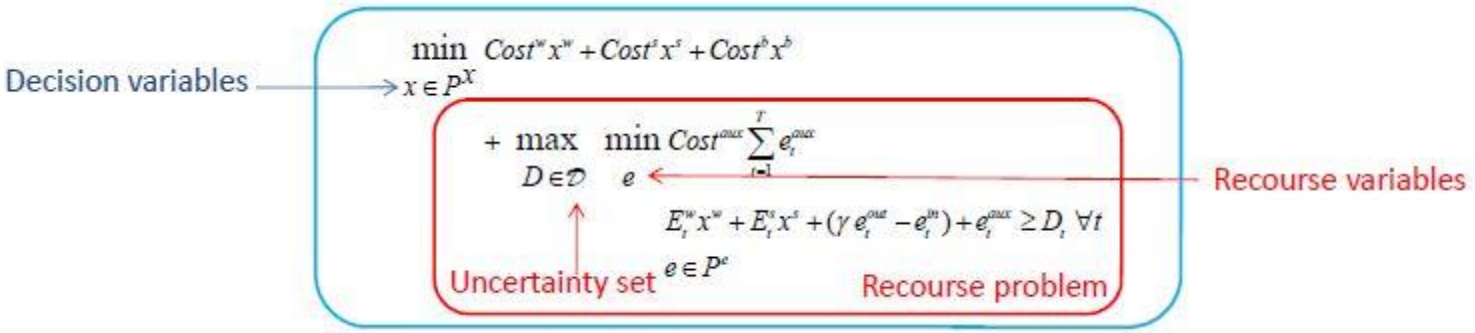
Objectives

- 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.



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.

Optimal stochastic control for asset-liability management (2012)

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

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

- 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: $\mathbb{P}[A_T/L_T \geq 1] \geq z$.

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

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

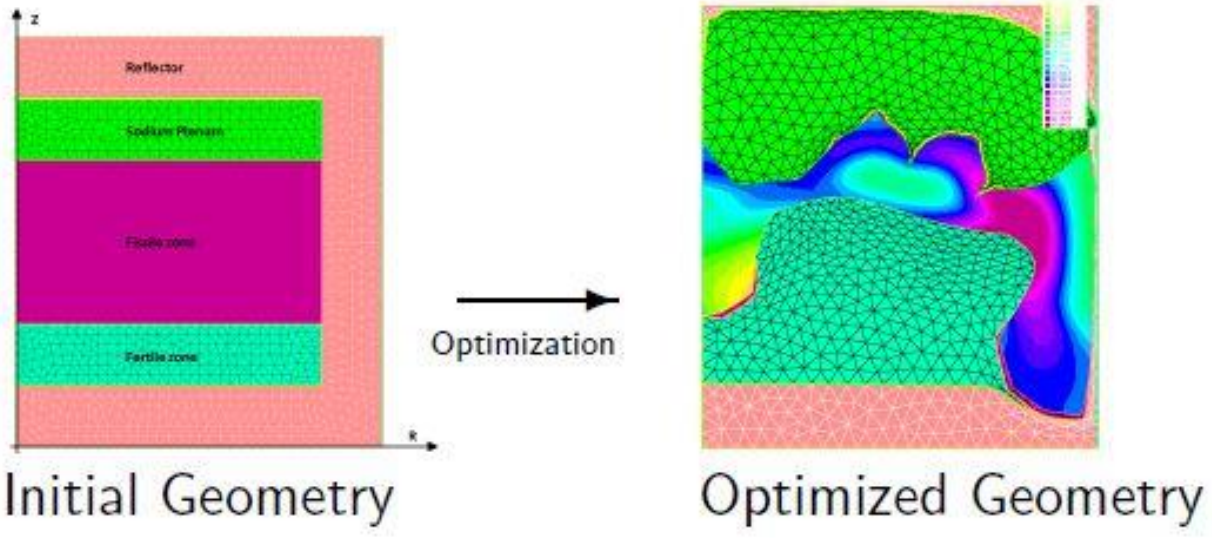
- Application to the ALM problem.

Optimization of the Core of a Sodium Fast Reactor (SFR) (2012)

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 !

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.**

Latin America Stochastic Optimization Network (LASON) (2012 2013)

- **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

- 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

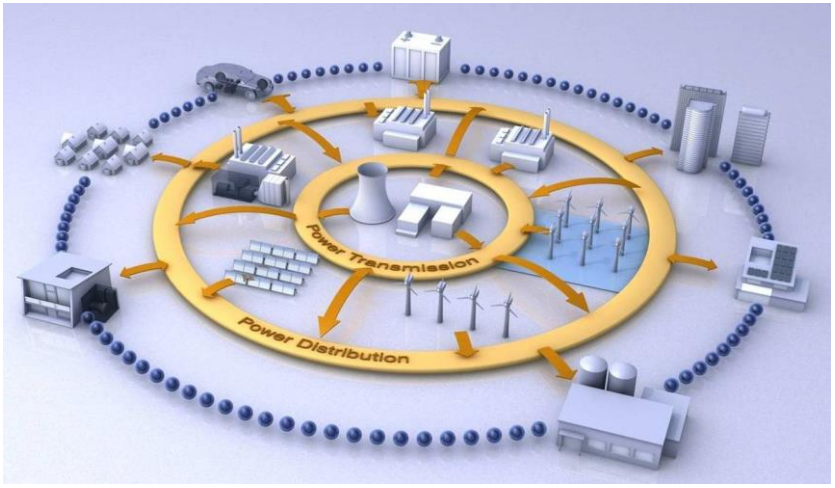
Objectives

- 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)

Results

- Problems we plan to attack:
  - **Optimizing an aggregator of residential users**
  - **Optimizing a micro-generation mix**
  - **Electric cars management**



IROE Projects

Ongoing

Stochastic Optimization for Unit-Commitment problems (2012-)

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.

Optimization of the scheduling of the Nuclear Power Plant stops (2012 -)

Team : R. Wolfler-Calvo, A. Rozenknop, C. Pira (Paris XIII), P. Bendotti, M. Porcheron (EDF)

Context

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

Objectives :

- Tackling uncertainty of stops duration
- Considering at the same time: ROBUSTNESS, STABILITY and REOPTIMIZATION on a sliding horizon

Optimization of the scheduling of the Nuclear Power Plant stops

Results

- A nested decomposition scheme with Benders approach to deal with demand scenarios, and Dantzig-Wolfe approach to decompose the sub-problem by plants

New research lines

- Validation of the methodology in a real-life case

Consistent Dual Signals and Optimal Primal Solutions (2013-)

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

- **Context :** managing the lectrical systems requires decomposition
  - Many actors: thermal, hydro, nuclear, sun, wind, consumption, network...
  - Complex constraints (technical, physical, legaj, economical…)
  - Nasty optimization problems (large-scale, non linear, mixed-integer, stochastic)
  - Electricity cannot be stored => quick decisions
  - Decomposition : relax linking constraints, solve subproblems

- **Objectives**
  - Construct a good feasible solution
  - Many issues : subproblems difficult to solve exactly, slow convergence (dual), corrupted dual signals, primal solutions not good enough

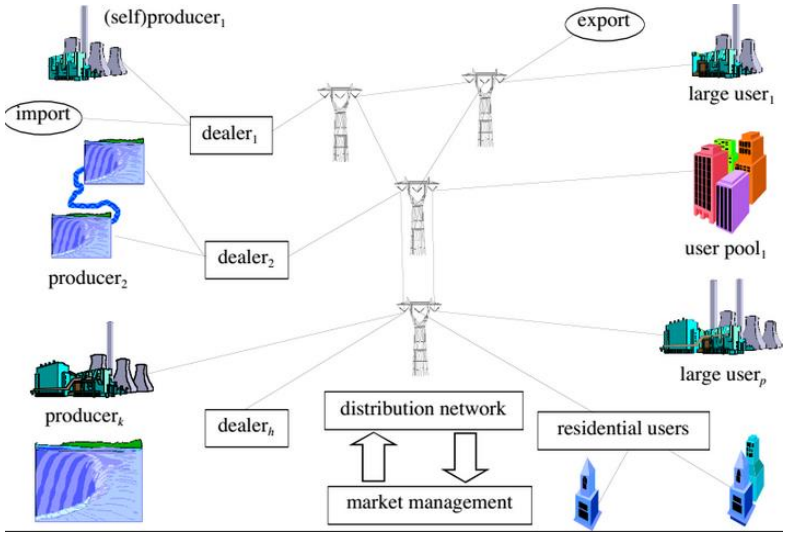
Consistent Dual Signals and Optimal Primal Solutions

Current Results

- Different MILP models of thermal (nuclear) units
- Improvements in Dynamic Programming for “academic” thermal units
- Setup of experiments for the dual phase (6= oracles, inexact info.)
- Design of new C++ structured modeling system

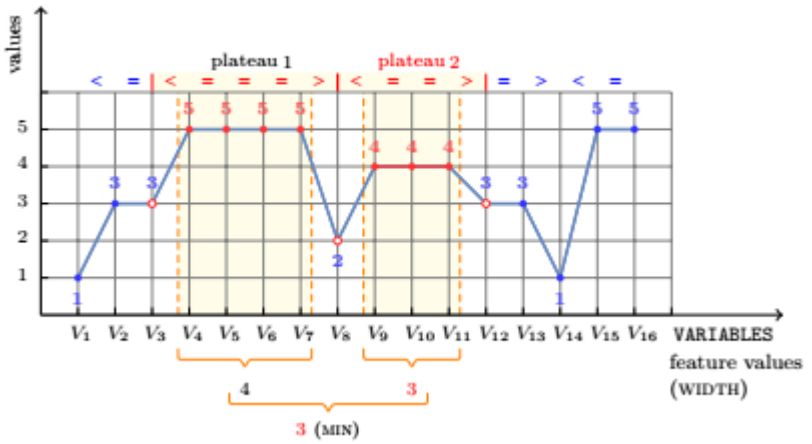
Expected Results

- Implementation of C++ structured modeling system
- Computational comparison of different MILP models of EDF UC
- Design and implementation of new DP approaches to UC
- Computational comparison of different dual stabilizations
- Primal Phase based on stabilized Lagrangian Heuristic



Learning Constraints for Reducing Combinatorics (2012-)

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



Context

- extracting time-series constraints from production data
- business rules on electricity production curves

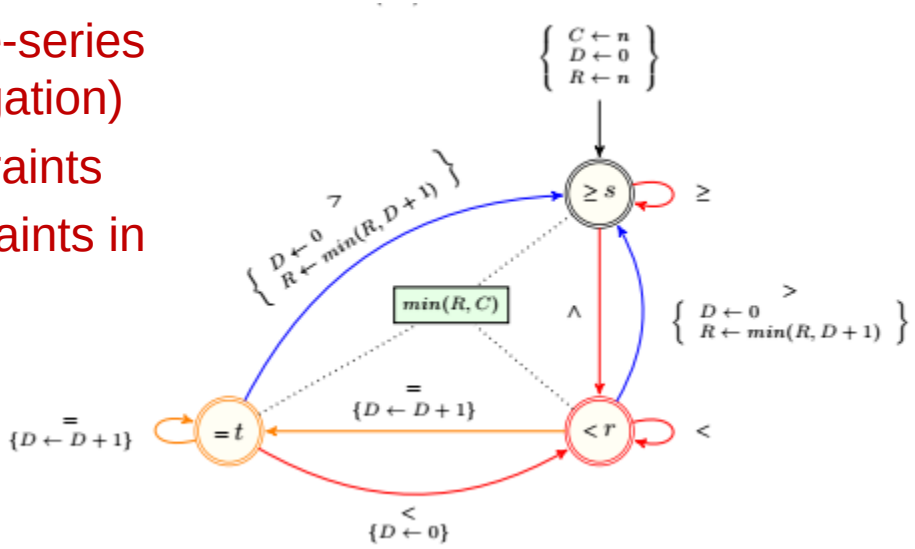
Objectives

- systematic definition of a huge variety of time-series constraints
- handling time-series constraints in mip

Learning Constraints for Reducing Combinatorics

Results

- a compositional way to define time-series constraints (pattern,feature,aggregation)
- a catalog of 659 time-series constraints
- reformulation of time-series constraints in MIP



New research lines

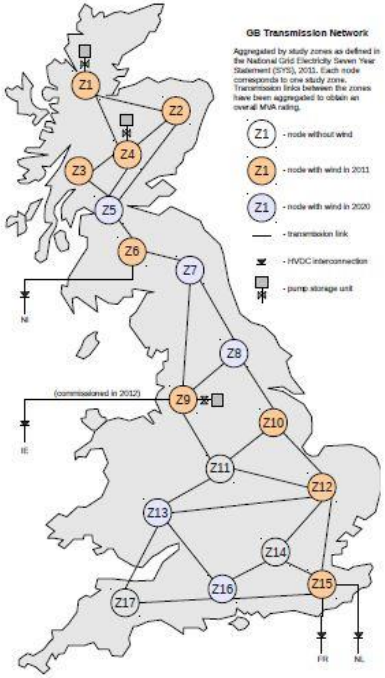
- tighter mip models based on:
- more compact automata
- generation of invariants and glue matrices

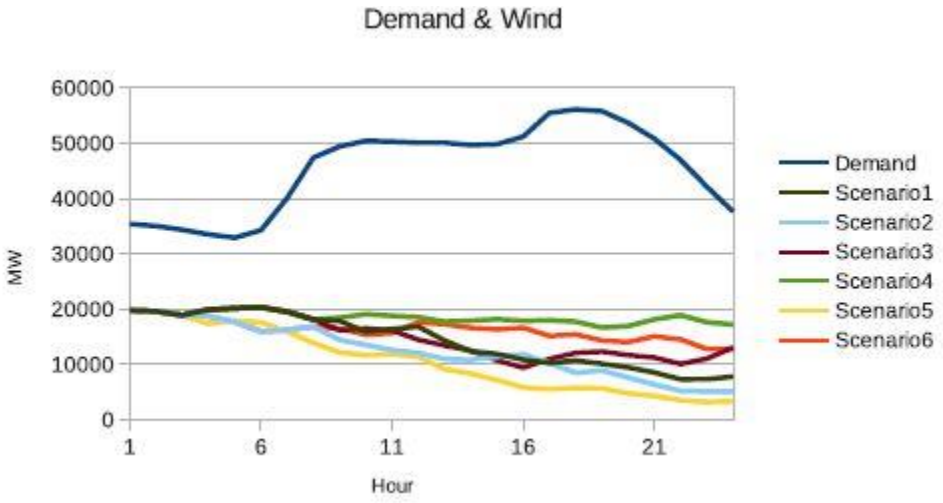
A Stochastic Programming Approach to Finding Robust Reference Schedules for the Unit Commitment problem (2012-)

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?**





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

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

Results

- Decomposition approach faster that CPLEX on the undecomposed problem, and able to solve to higher accuracy - 0.02% typical.
- No root node branching needed to achieve this tolerance.
- Primal and Dual initialization and stabilization key to success.
- The approach scales well in the number of scenarios
- In the UK model stochastic scheduling with 3 hour, 6 hour or daily schedule revisions costs respectively 0.35%, 0.65% and 1.3% more that the perfect foresight solution.
- These results used 12 carefully calibrated scenarios. Results didn't improve with more scenarios.
- The deterministic schedule with the best exogenous reserve setting were 0.09%, 0.09% and 0.29% worse than the respective stochastic cases.
- 1% corresponds to about $1m per day.

Decomposition/Coordination for smart-grids (SmartDec) (2013-)

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)

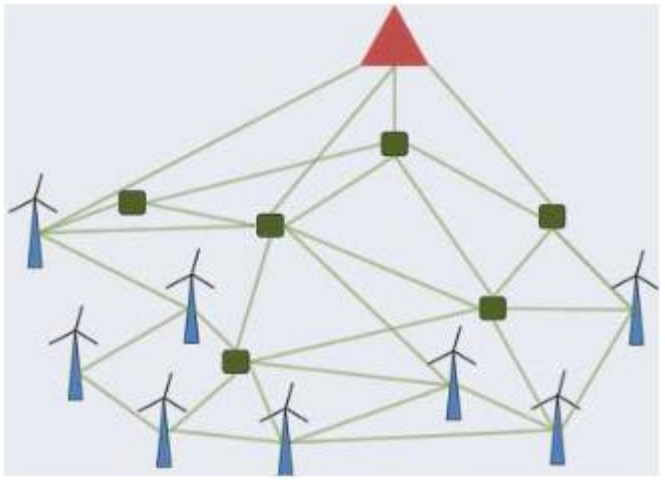
Results

- Resignation of PhD student recruited December 2014
- State of the art “decomposition methods for stochastic optimisation in energy problems”

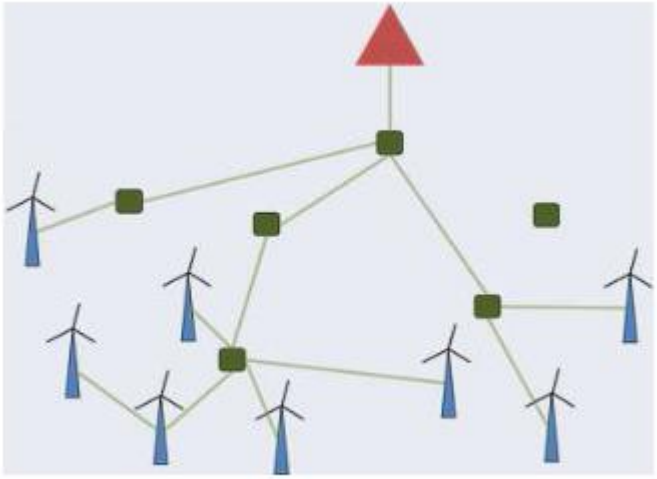
« Cabling » optimisation for Smart-Grids (2013-)

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

- **Context :** How to route the electricity from the wind turbines towards a central point (sub-station).
  - Associate a graph G=(V,E) with the problem: (V : sub-stations, wind turbines, interconnection nodes ; E : possible cable).
  - Search for a minimal-length Steiner rooted tree covering the terminal vertices and respecting the capacity constraints.



Support network



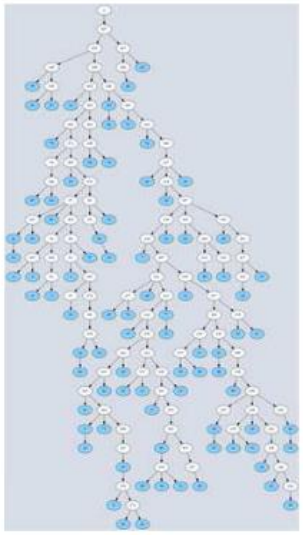
Final network

- **Objectives**
  - Complexity study
  - Solve general deterministic case
  - Study robustness : how to minimize the number of wind*turbines disconnected from the network in case of a cable breakdown (in the worst case).*

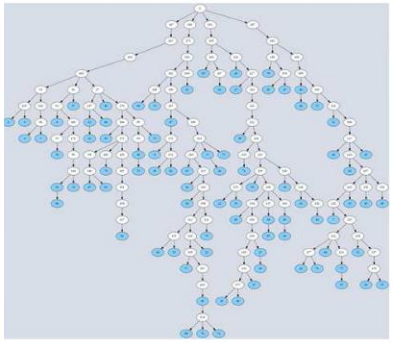
« Cabling » optimisation for Smart-Grids

Results

- A very complete presentation of the complexity of the Capacitated Steiner rooted tree problem for directed graphs, directed acyclic graphs and undirected graphs.
- Proposition of a mathematical program for the general problem, solution and tests by using CPLEX.
- Study of "what is a robust capacitated Steiner rooted tree?" Search for a robust "balanced" tree. Proposition of different objective functions, tests and comparison of the results.



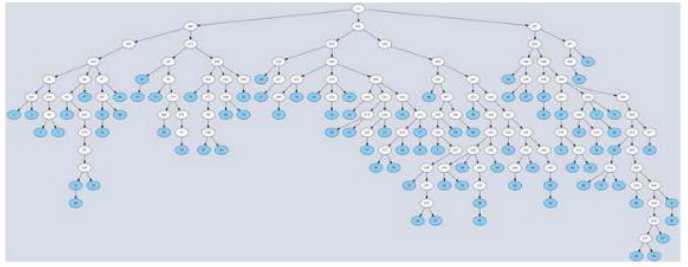
Minimum Cost solution



Robust solution

Future works

- Study other robustness approaches.
- How to protect optimal solutions of combinatorial optimization problems?
- Solving a class of min max problems with mixed integer variables.



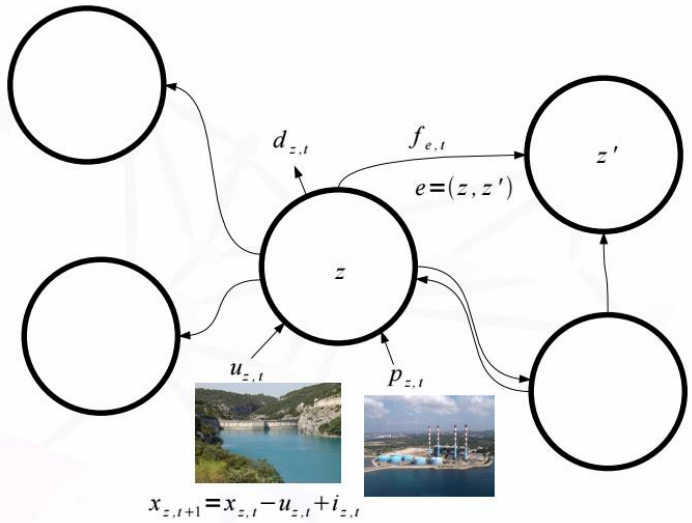
Balanced Robust solution

Proximal decomposition of Stochastic Zonal Long-Term Energy Production Planning (2013-)

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
- Coupling between Approximate Dynamic Programming and Spatial Decomposition
- Numerical testing with EDF scenarios data for 2030



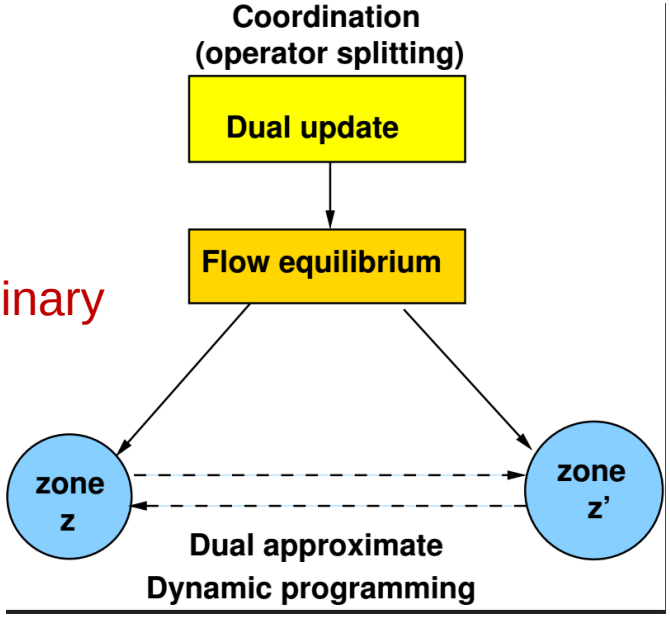
Objectives

- Apply splitting methods to the multizone model
- Decentralize the information to approximate the optimal solution by local dynamic programming
- 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
- Relax time interdependency between local production and energy flow transfer : preliminary results on stochastic large instances
- New class of primal-dual Fejer monotone algorithms



Perspectives

- Reducing the gap between spatial decomposition and multiperiod stochastic dynamic programming
- Numerical comparison of splitting methods : from Proximal Decomposition to block-coordinate iterations with random sweeping
- Submit publications to ICSP 2016 and OR scientific journal

Hybrid Approaches Combining Metaheuristics and Methods of Mathematical Analysis for Environmental Unit Commitment Problem (HACE) (2013-)

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)

Results

- Best know solutions

Remaining work

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

Learning4Opt (2014 -)

Team : E. Rachelson, A. Hait (Supaero), A. Lenoir (EDF)

Context

- Intra-daily energy production planning
- Unit-commitment problems
- Principled learning methods for the guidance of optimization engines

Objectives

- Scale down the resolution time of unit-commitment problems
- Define efficient abstractions to leverage the ability to solve intra-daily production planning problems
- Establish a general methodology in order to learn how to guide an optimization engine in the case of recurrent combinatorial optimization problems

Learning4Opt (2014 -)

Research lines

- Extract statistically relevant indicators on intra-daily energy production problems via supervized learning methods
- Explore the ability of cascades of predictors in order to perform the selection of ensembles of variables for local re-optimization
- Explore the ability of sequential decision methods (Monte-Carlo Tree Search or other Reinforcement Learning methods) to guide a Branch-and-Bound search for combinatorial problems.

Dantzig-Wolfe and Benders decompositions applied to the problem of the scheduling of the Nuclear Power Plant stops with uncertainties (2014-)

- **Team :** F. Clautiaux, B. Detienne, S. Ruslan, F. Vanderbeck (Univ. Bordeaux, INRIA), M. Porcheron, P. Bendotti, G. Petrou (EDF)

Context

- Scheduling of the Nuclear Power Plant stops with uncertainties

Objectives

- Develop algorithms using :
  - Column generation
  - Benders decomposition
  - Dantzig-Wolfe decomposition

Stochastic and Robust Optimization and Applications (2014)

Team : L. El Ghaoui (Berkeley), P. Carpentier, MC. Costa (ENSTA), M. de Lara, JP. Chancelier, V. Leclere, F. Meunier (CERMICS ENPC), R. Zorgati (EDF)

Context

- Multi-instance optimization,
- Sparse solution of optimization problem

Objectives

- "robust sketching" approach in probabilistic setting for energy management problem

Stochastic and Robust Optimization and Applications (2014)

Results

- Robust sketching approah for linear and quadratic problems
- Development of the "group sparsity" approach focusing on the weigthing of penalization
- Development of exact and heuristic rules to a-priori eliminate features in the optimization problem

Centralized versus Decentralized Energy Management in a Stochastic Setting (2014-)

- **Team :** BK. Pagnoncelli , T. Homen de Mello, R Carrasco (Univ Adolfo ibanez, Chili), P. Carpentier (ENSTA), M. de Lara, JP. Chancelier (CERMICS ENPC), S. Charousset (EDF)

Context

- Centralized versus decentralized energy management
- Stochastic elements, intermittent energy sources.
- The importance of energy storage through batteries

Objectives

- New optimization models for smart grids
- Uncertainty modelling
- Specialised multistage decomposition algorithms
-

Centralized versus Decentralized Energy Management in a Stochastic Setting (2014-)

Results

- "Stochastic Optimization in the microgrid", report by student V. Foucher
- A paper in preparation, to be submitted early 2016
- SESO workshop, Paris France (June 2015)
- Energy optimization workshop in Santiago, Chile (January 2016)

New research lines

- Inclusion of risk into the models
- Mechanism design in the context of smart grids

IROE Projects

New

Design and Pricing of Electricity Services in a Competitive Environment (2015-)

- **Team :** Luce Brotcorne (INRIA Lille) and Frédéric Semet (Ecole Centrale de Lille), S. Lepaul (EDF R&D)

❑Context

- ❖ Joint Pricing and design of energy services in a competitive environment
- ❖ Generate Revenue and encourage the customers to reduce their consumption at peak periods

❑Objectives

- ❖ Define bilevel models to take explicitly into account the strategic behaviour of consumers
- ❖ Design and implementation of ad-hoc optimization methods
- ❖ Solve the problem on real life instances
- ❖ Study the robustness of the model.

Decentralized control for renewable integration in smart-grids (2015-)

❑ Team : Ana Busic (Inria Paris-Rocquencourt), Sean Meyn (University of Florida)

❑ Context

- ❖ Integration of renewable generation (solar, wind) creates problems to the energy grid due to its intermittence and volatility
- ❖ In the absence of grid-level efficient storage, increased need for responsive fossil-fuel generators, negating the environmental benefits of renewable generation

❑ Objectives

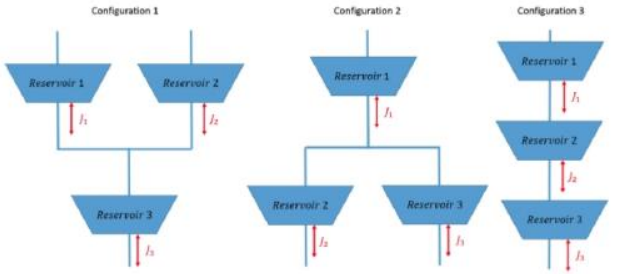
- ❖ Creating Virtual Energy Storage (VES) through direct control of flexible loads: stochastic optimization problems for local control of loads - helping the grid while respecting user QoS (Markov decision process on the local level and mean-field analysis of the aggregate)
- ❖ Investigating needs for communication and forecast (minimizing communication and computation costs while providing reliable service to the grid)
- ❖ Integrating VES with traditional generation and batteries (resource allocation optimization problems involving different time scales)

Decomposition and feasibility restoration for Cascaded Reservoir Management (2015-)

- **Team :** Claudia d'Ambrosio (LIX Ecole Polytechnique)

❑ Context

- ❖ Hard hydro unit commitment (HUC) instances
- ❖ Hydro valley decomposition
- ❖ Can be extended in a more general context



❑ Objectives

Provide effective primal heuristic :

- ❖ to deal with infeasibility of decomposition/relaxation solutions
- ❖ based on local branching
- ❖ limit the search space to be explored

Logiciels pour l'Optimisation des Réseaux Intelligents (LORI) (2015-)

- **Team :** M. de Lara, JP. Chancellier (CERMICS ENPC), P. Carpentier (ENSTA)

Context

- More and more intermittent sources make part of the energy mix
- More and more actors control energy stocks and flows on the grid
- This is a challenge for the management of energy systems

Objectives

- Make companies and academics closer to work on optimization methods
- Focus on the development of free softwares

Optimisation de tournées de techniciens avec véhicules électriques (2015-)

- **Team :** Jussien Guéret Christelle, Montoya José Alejandro (doctorant) (Université d'Angers), Mendoza Jorge, (Polytech'Tours), Villegas Juan-Guillermo (Universidad de Antioquia (Colombie)), B. Kaddour (EDF R&D)

❑ Context

- ❖ politiques d'incitation à utiliser des véhicules électriques (VE) dans de nombreux pays
- ❖ frein : contraintes techniques (autonomie limitée, longs temps de charge, ...)
- ❖ => nécessité de développer des méthodes d'optimisation de tournées incluant les spécificités des VE

❑ Objectives

- ❖ développer des techniques performantes pour résoudre le problème de tournées de techniciens avec VE
- ❖ utiliser ces méthodes pour prévoir l'impact de la transition au tout électrique

Smart Methods for the Grid(2015-)

- **Team :** Hélène Le Cadre, Philippe Colo , Sophie Demassey (MINES ParisTech), A. Papavasiliou (UCLouvain CORE), D. Barth (UVSQ), R. Zorgati, B Kaddour (EDF R&D)

- D. Barth (UVSQ), S. Charousset, R. Zorgatti, B. Kaddour (EDF) Context :

Context

- Which services should emerge in the smart grid ?
- Then, how to price them ?

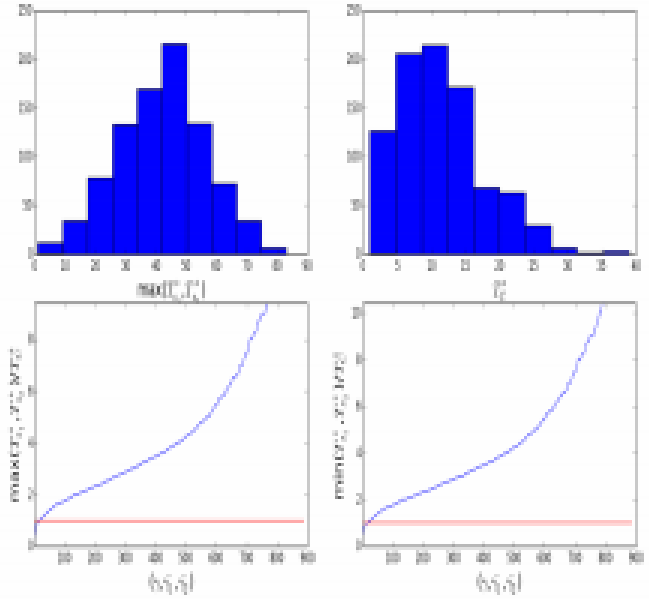
Objectives

- Building new methods to improve energy consumption and production forecasting based on smart information management
- Impact of more reactive tariff schemes/contract mechanisms following the market volatility and information exchanges
- Viability of the aggregators' business models

Smart Methods for the Grid(2015-)

Results

- Stylized modeling of the smart grid as a multi-agent system
- Quantification of the impact of biases in the forecasts on the smart grid overall performance under various information structures



Performance of learning algorithms

when all the agents integrate a grand coalition.

Nex Research Lines

- Considering more information structures
- Impact of coalition sizes and characteristics on the smart grid performance
- Models for flexibility pricing

Decentralised optimization and smart-grids (2015-)

Team : El-Ghazali Talbi (University of Lille and INRIA Lille Nord Europe), Ekaterina Alekseeva (INRIA Lille Nord) , Jean-Yves Lucas (EDF R&D)

Context

- Smart home
- Demand side energy management
- Multi-objective optimization
- Metaheuristics

Objectives

- Optimization of energy generation and distribution
- House energy management
- Home automation system monitoring appliance scheduling

Optimization & stability of stochastic unit-commitment problems (2015-)

Team : M. Théra (Univ. Limoges), C. Sagastizábal (IMPA Brazil), R. Henrion (WIAS, Berlin), A. Kruger (Federation University Australia), W. de Oliveira (Rio de Janeiro State University Brazil), W. van Ackooij (EDF R&D)

Context

- Energy management and optimal production schedule
- Renewable energy sources and uncertainty modelling
- Stochastic unit-commitment problems

Objectives

- Theoretical and numerical studies of stochastic unit-commitment problems
- Stability properties of the underlying optimization problem