Banff International Research Station
for Mathematical Innovation and Discovery

The BIRS Workshop 06w5081,

Optimization and Engineering Applications

November 11 to November 16, 2006

MEALS

Breakfast (Continental): 7:00 – 9:00 am, Donald Cameron Hall, Sunday – Thursday
*Lunch (Buffet): 11:30 am – 1:30 pm, Donald Cameron Hall, Sunday – Thursday
*Dinner (Buffet): 5:30 – 7:30 pm, Donald Cameron Hall, Saturday – Wednesday
Coffee Breaks: As per daily schedule, 2nd floor lounge, Corbett Hall
***Please remember to scan your meal card at the host/hostess station in the dining room for each breakfast, lunch and dinner.**

MEETING ROOMS

All lectures will be held in Max Bell 159 (Max Bell Building accessible by bridge on 2nd floor of Corbett Hall). Hours: 6 am – 12 midnight. LCD projector, overhead projectors and blackboards are available for presentations. *Please note that the meeting space designated for BIRS is the lower level of Max Bell, Rooms 155-159. Please respect that all other space has been contracted to other Banff Centre guests, including any Food and Beverage in those areas.*

SCHEDULE

Saturday

16:00 Check-in begins (Front Desk – Professional Development Centre - open 24 hours)
Lecture rooms available after 16:00 (if desired)
17:30-19:30 Buffet Dinner, Donald Cameron Hall
20:00 Informal Get Together in 2nd floor lounge, Corbett Hal
Beverages and small assortment of snacks available on a cash honour-system.

Sunday

7:00-8:45 Breakfast
8:45-9:00 Introduction and Welcome to BIRS by BIRS Station Manager, Max Bell 159
9:00-10.00 **J. Betts:** Planning a Trip to the Moon? ... And Back?
10.00-10.30 Coffee Break, 2nd floor lounge, Corbett Hall
10.30-11.30 **J. Moré:** Derivative-free methods for simulation-based optimization problems
11:30-13:30 Lunch
13:30-14:00 **D. Goldfarb***:* Total variation based image restoration by second-order cone programming and min-cuts
14:00-14:30 **A. d'Aspermont:** Smooth semidefinite optimization and applications
14:30-15:00 **J. Martins:** Multidisciplinary Optimization: Current Status and Future Directions
15.00-15:30 **G. Savard:** Pricing a segmented market subject to congestion
15:30-16:00 Coffee Break, 2nd floor lounge, Corbett Hall – to END no later than 4 pm.
16:00-17:30 Panel Discussion: **Where we need breakthroughs? What is the next breakthrough?**
Panel: Don Goldfarb, Yuri Nesterov, Tom Marlin, János Pintér, Robert Vanderbei
Moderator: Tamás Terlaky
17:30-19:30 Dinner

20:00- Panel Discussion Continued

Monday

7:00-9:00 Breakfast
9:00-10.00 **A. Conn:** An initial algorithmic framework for convex mixed integer nonlinear programs
10.00-10.30 Coffee Break, 2nd floor lounge, Corbett Hall
10.30-11.30 **C. Viswesvariah:** Challenges in Statistical Timing and Optimization of Integrated Circuits
11:30-13:30 Lunch
13:00-13:45 Guided Tour of The Banff Centre; meet in the 2nd floor lounge, Corbett Hall
13:45-14:00 Group Photo; meet on the front steps of Corbett Hall
14:00-15:00 **M.C. Ferris:** Optimization of Noisy Functions: Application to Simulations
15:00-15:30 Coffee Break, 2nd floor lounge, Corbett Hall
15:30-16:00 **M. Anjos:** Finding Nash Equilibria in Electricity Markets: An AC-Network Approach
16.00-16:30 **A. Ozgadlar:** Differential Topology for the uniqueness of equilibrium in network control models
16:30-17:30 Panel Discussion: **What engineers need?**
What Optimizers need to know about engineering?
Panel: Tom Luo, Tom Marlin, Joaquim Martins, Jorge Moré, Chandu Viswesvariah, Laleh Behjat
Moderator: Robert Vanderbei
17:30-19:30 Dinner
20:00- Panel Discussion Continued

Tuesday

7:00-9:00 Breakfast
9:00-9.35 **R.M. Freund:** On Efficient Randomized Methods for Convex Optimization
9.35-10.00 **N. Krislock:** The Nonsymmetric Semidefinite Least Squares Problem and Compliance Matrix Estimation
10.00-10.30 Coffee Break, 2nd floor lounge, Corbett Hall
10.30-11.05 **F. Jarre:** An augmented primal-dual method for linear conic minimization
10.05-10.25 **K. Kostina**: Model Based Design of Optimal Experiments for Parameter Estimation and Its Applications

11:30-13:30 Lunch
Free Afternoon
17:30-19:30 Dinner
20:00- Free Discussions

Wednesday

7:00-9:00 Breakfast
9:00-10.00 **Z-Q. Luo** and S. Zhang**:** Optimization in Resource Management: Complexity, Lyapunov Theorem and Approximation
10.00-10.30 Coffee Break, 2nd floor lounge, Corbett Hall
10.30-11.00 Z-Q. Luo and **S. Zhang:** Optimization in Resource Management: Complexity, Lyapunov Theorem and Approximation
11.00-11.30 **D. Gao: C**anonical Duality Theory and Applications in Global Optimization
11:30-13:30 Lunch
13:30-14:30 **H. Wolkowicz:** Semidefinite Relaxations for Anchored Graph Realization and Sensor Localization
14:30-15:00 **J. Nie:** SOS methods for sensor network localization
15.00-15:30 **J.D. Pintér:** Global Optimization in Practice: State-of-the-Art and Perspectives
15:30-16:00 Coffee Break, 2nd floor lounge, Corbett Hall
16:00-17:30 Panel Discussion: **Optimization Software**
Panel: Andrew Conn, Jorge Moré, János Pintér, Imre Pólik, Kim Toh, Robert Vanderbei
Moderator: Tamás Terlaky
17:30-19:30 Dinner
20.00- Discussion: Where can we be complacent?

Thursday

7:00-9:00 Breakfast
9:00-10.00 **P. Tseng:** p-order cone relaxation for sensor network localization
10.00-10.30 Coffee Break, 2nd floor lounge, Corbett Hall
10.30-11.00 **H. Zhang:** Approximation Algorithms for Routing in VLSI Design and Multicast Networks
11.00-11.30 **M. Duer:** Solving Copositive Programs through Linear Approximations
11:30-13:30 Lunch

Checkout by 12 noon.

** 5-day workshops are welcome to use the BIRS facilities (2nd Floor Lounge, Max Bell Meeting Rooms, Reading Room) until 3 pm on Thursday, although participants are still required to checkout of the guest rooms by 12 noon. **

Abstracts to follow (if desired) in alphabetical order by last name of speaker.

Banff International Research Station

for Mathematical Innovation and Discovery

Optimization and Engineering Applications

November 11 to November 16, 2006

ABSTRACTS

(in alphabetic order by speaker surname)

Speaker: **M. Anjos** (U. Waterloo)
Title: Finding Nash Equilibria in Electricity Markets: An AC-Network Approach*
Abstract:
Using an AC transmission network, oligopolistic competition in power markets is formulated as a Nonlinear Programming (NLP) problem, and characterized by a multileader single-follower game. The follower is composed of a set of competitive suppliers, demands and the system operator, while the leaders are the dominant suppliers. The transmission network is modeled with a detailed nonlinear system. This approach allows one to capture the strategic behavior of suppliers regarding not only active but also reactive power. With this setting, the impact of voltage and apparent power flow constraints can be easily explored. Based on a three-node system, an illustrative study case is used to highlight the features of the formulation. A larger system is also used to describe computational issues.
*This is joint work with G. Bautista and A. Vannelli.

Speaker: **A. d'Aspermont** (Princeton U.)
Title: Smooth semidefinite optimization and applicationsAbstract:
Abstract:
We describe an application of Nesterov's optimal first-order method on large scale semidefinite optimization problems arising in multivariate statistics. The method's key numerical step involves computing a matrix exponential, and we show that this can be done very efficiently for favorable matrix spectrum structures.

Speaker: **John T. Betts** (Boeing)
Title: Planning a Trip to the Moon? ... And Back?
Abstract:
Designing an optimal trajectory to the moon and back leads to an extremely challenging optimal control problem. This presentation will describe the practical and computational issues associated with the solution of these problems, including treatment of the underlying nonlinear boundary value problem, and nonlinear programming algorithm.

Speaker: **A.R. Conn** (IBM Research)
Title: An initial algorithmic framework for convex mixed integer nonlinear programs*
Abstract:
In my opinion mixed integer nonlinear programming is an area of ever increasing importance and applications that is significantly under researched --- no doubt because it presents many difficult challenges. I will present a basic hybrid framework for convex mixed-integer nonlinear programming. In one extreme case, the method becomes the branch-and-bound approach, where a nonlinear optimization problem is solved in each node of the enumeration tree, and in the other extreme it reduces to the polyhedral outer approximation algorithm, which alternates between the solution of a nonlinear optimization problem and a mixed-integer linear program. Numerical results are presented, using an open source software implementation available on http://www.coin-or.org. This work results from an on-going research collaboration between IBM and CMU.
*This is a joint work with: P. Bonami, L.T. Biegler, A. Wächter, G. Cornuéjols, I.E. Grossmann, C.D. Laird, J. Lee, A. Lodi, F. Margot, N. Sawaya

Speaker: **M. Duer** (T.U. Darmstadt)
Title: Solving Copositive Programs through Linear Approximations*
Abstract:
Optimization over convex cones has become increasingly popular in recent years, the most prominent cones being the positive semidefinite cone and the second order cone. Semidefinite programming provides good and efficiently computable relaxations for several hard combinatorial and quadratic problems. However, it is known that these bounds may be improved by solving optimization problems over the copositive cone. The price of this gain in quality is an jump in complexity, as copositive programs are NP-hard. In this talk, we propose new polyhedral approximations of the cone of copositive matrices which we show to be exact in the limit. This gives rise to necessary as well as sufficient criteria for copositivity, and it can also be used to approximate copositive programs. We present an algorithm resulting from this approach, and conclude by presenting preliminary numerical results.
*This is joint work with Stefan Bundfuss.

Speaker: **M.C. Ferris** (U. Wisconsin)
Title: Optimization of Noisy Functions: Application to Simulations*
Abstract:
In many real-world optimization problems, the objective function may come from a simulation evaluation so that it is (a) subject to various levels of noise, (b) not neccesarily differentiable, and (c) computationally hard to evaluate.

We propose a two-phase approach for optimization of such functions. Phase I uses classification tools to facilitate the global search process. By learning a surrogate from existing data the approach identifies promising regions for optimization. Additional features of the method are: (a) more reliable predictions obtained using a voting scheme combining the options of multiple classifiers, (b) a data pre-processing step that copes with imbalanced training data and (c) a nonparametric statistical method to determine regions for multistart optimizations.

Phase II is a collection of local trust region derivative free optimizations. Our methods apply Bayesian techniques to guide appropriate sampling strategies, while simultaneously enhancing algorithmic efficiency to obtain solutions of a desired accuracy. The statistically accurate scheme determines the number of simulation runs, and guarantees the global convergence of the algorithm.

We present results on two practical simulations: a Wisconsin breast cancer simulation and the robust design for a floating sleeve coaxial antenna for hepatic microwave ablation. The use of resampling of particular organ structures in this context will be outlined. Particular emphasis will be on general principles that are applicable to large classes of treatment planning problems. Specific ex-

amples will also be detailed showing enormous increase in speed of planning, without detriment to the quality of solutions found.
*This is a joint work Geng Deng.

Speaker: **R.M. Freund** (MIT)
Title: On Efficient Randomized Methods for Convex Optimization
Abstract:
Randomized methods for convex optimization rely on stochastic processes and random number/vector generation as part of the algorithm and/or its analysis. In this talk we will discuss some recent developments in randomization-based algorithms for convex optimization from both a theoretical and practical point of view. We will show some interesting parallels between one randomization-based method and interior-point methods, and will forecast some possible trends both in theory and practice and pose some pertinent research questions.

Speaker: **D.Y. Gao** (Virginia Tech)
Title: **C**anonical Duality Theory and Applications in Global Optimization
Abstract:
This paper presents a canonical (i.e., strong) duality theory for solving nonconvex programming problems subjected to box constraints. It is proved that the dual problems are either concave maximization, or convex minimization problems. Both global and local extrema of the constrained nonconvex problems can be identified by triality theory proposed by the author. Applications to nonconvex integer programming and Boolean least squares problem are discussed. Examples are illustrated. A conjecture on NP-hard problems is proposed.

Speaker: **D. Goldfarb** (Columbia U.)
Title: Total variation based image restoration by second-order cone programming and min-cuts*
Abstract:
The traditional approach for solving total variation based image restoration problems is based on solving partial differential equations. We describe here how to formulate and solve these problems either by interior-pont algorithms for second-order cone programs or by parametric max flow algorithms.
*This is joint work with Wotao Yin at Rice University

Speaker: **F. Jarre** (U. Düsseldorf)
Title: An augmented primal-dual method for linear conic minimization*
Abstract:
We present a new iterative method for solving linear minimization problems over convex cones.
The problem is reformulated as an unconstrained problem of minimizing a differentiable convex function. The method does not use any homotopy parameter but solves the primal-dual problem in one
step using a nonlinear conjugate gradient type approach. Some approaches for preconditioning of the algorithm will be illustrated with numerical examples.
*This is a joint work with F. Rendl

Speaker: **N. Krislock (U. Waterloo)**
Title: The Nonsymmetric Semidefinite Least Squares Problem and Compliance Matrix Estimation
Abstract:
An important step in the process of making an interactive computer model of a deformable object is to estimate the compliance matrix at various points on the object. This estimation is accomplished by taking experimental measurements of the object and computing the least squares solution of a linear matrix equation of the form $AX = B$. For such a compliance matrix X, it is required that $\frac{1}{2}(X+X^T)$ be positive semidefinite, otherwise the computer model may respond to the user touching some contact point by pulling the user's hand further in the direction of the touch. Adding this constraint to the least squares problem we get the nonsymmetric semidefinite
least squares NS-SDLS
minimize \|A X - B\|_F
subject to 0.5 (X + X^T) \succeq 0
When the matrix A has linearly independent columns, the solution of the NS-SDLS problem exists and is unique. We will provide the Karush-Kuhn-Tucker equations which characterize this solution and show how these equations can be stated as a semidefinite linear complementarity problem. Finally, we will discuss how interior-point methods can be used for the numerical solution of the NS-SDLS problem.

Speaker: **K. Kostina** (U. Heidelberg)
Title: Model Based Design of Optimal Experiments for Parameter Estimation and Its Applications
Abstract:

Speaker: **Z.Q. Luo (U. Minnesota) and S. Zhang** (Chinese University, Hong Kong)
Title: Optimization in Resource Management: Complexity, Lyapunov Theorem and Approximation
Abstract:
We consider a class of nonconvex optimization problems arising from resource (e.g., spectrum) management in multiuser communication. For the discretized version of this problem, we characterize its computational complexity under various practical settings and study the structure of its global optimal solutions. It is shown that this discretized nonconvex optimization problem is NP-hard in general and has a positive duality gap. Surprisingly this duality gap disappears asymptotically as the size of discretization step decreases to zero, thanks to a hidden convexity that can be uncovered by the Lyapunov Theorem in functional analysis. Based on this asymptotic zero duality result and a agrangian dual relaxation, we present, for any positive ϵ, a polynomial time approximation scheme to compute an ϵ-optimal solution for the continuous version of the resource management problem. Finally, we also establish a general minimax theorem for a game theoretic formulation under the continuous framework.

Speaker: **J. Moré** (Argonne National Lab.)
Title: Derivative-free methods for simulation-based optimization problems*
Abstract:
We give a brief overview of the current state of the art of derivative-free methods that emphasizes the viewpoint that the performance of derivative-free methods should be measured when there is a constraint on the computational budget, that is, when there is a (small) limit on the number of function evaluations. We discuss how this viewpoint is appropriate for simulation-based optimization problems, and outline current research on new algorithms for this class of optimization problems.
*This is a joint work with S. Wild.

Speaker: **J. Martins** (U. Toronto)
Title: Multidisciplinary Optimization: Current Status and Future Directions
Abstract:
The objective of this talk is to present an overview multidisciplinary design optimization (MDO), with emphasis on the most significant challenges currently faced by academia and industry in its utilization. All current MDO architectures will be described and a unified mathematical framework for describing these architecture will be proposed. On the more applied side, a new software package that uses these ideas to automatically implement the various MDO architectures will be presented, together with results obtained in the solution of a suite of test problems. The suite itself represents another important focus of the current research and includes scalable problems in order to investigate how the relative merits of each MDO architecture vary. Finally, future research directions will be identified and discussed.

Speaker: **J. Nie** (IMA, Univ. of Minn.)
Title: SOS methods for sensor network localization
Abstract:
We formulate the sensor network localization problem as finding the global minimizer of a quartic polynomial. Then sum of squares (SOS) relaxations can be applied to solve it. However, the general SOS relaxations are too expensive for practical problems. Exploiting special features of this polynomial, we propose a new Structured SOS relaxation. It works well for large scale problems. At each step of interior-point methods solving the resulting SOS relaxation, the computational cost is O(n^3). When distances have errors and localization is unique, we show that the sensor location given by this SOS relaxation is accurate within a constant factor of the distance error under some technical assumptions.

Speaker: **A. Ozgadlar** (MIT)
Title: Differential Topology for the uniqueness of equilibrium in network control models*
Abstract:
In this talk, we first present an extension of the Poincare-Hopf Theorem of index theory to generalized critical points of a function *defined* on a compact region with nonsmooth boundary, defined by a finite number of smooth inequality constraints. We use the generalized Poincare-Hopf Theorem to present
sufficient (local) conditions for the *global* uniqueness of solutions to finite-dimensional variational inequalities and the uniqueness of stationary points of optimization problems. We finally use our results to establish uniqueness of equilibria in two *recent models of communication* networks.
*This is joint work with A. Simsek and D. Acemoglu.

Speaker: **J.D. Pintér** (Pintér Consulting)
Title: Global Optimization in Practice: State-of-the-Art and Perspectives
Abstract:
Summary: Global optimization (GO) - the theory and methods of finding the best solution in multi-extremal models - has become a subject of significant interest in recent decades. The key theoretical results have been followed by software implementations, and a growing range of real-world applications. We present a concise review of these developments, with an emphasis on practical aspects, including modeling environments, software and applications.

Speaker: **G. Savard** (Ecole Polytechnique Montreal)
Title: Pricing a segmented market subject to congestion*
Abstract:

The optimal setting of prices, taxes or subsidies on goods and services can be naturally modeled as a bilevel program. Indeed, bilevel programming is an adequate framework for modeling optimization situations where a subset of decision variables is not controlled by the main optimizer (the leader), but rather by a second agent (the follower) who optimizes its own objective function with respect to this subset of variables. In this presentation we address the problem of setting profit-maximizing tolls on a congested transportation network involving several user classes. At the upper level, the firm (leader) sets tolls on a subset of arcs and strives to maximize its revenue. At the lower level, each user minimizes its generalized travel cost, expressed as a linear combination of travel time and out-of-pocket travel cost. We assume the existence of a probability density function that describes the repartition of the value of time (VOT) parameter throughout the population. This yields a bilevel optimization problem involving a bilinear objective at the upper level and a convex objective at the lower level. Since, in this formulation, lower level variables are flow densities, it follows that the lower level problem is infinite-dimensional. We devise a two-phase algorithm to solve this nonconvex problem. The first phase aims at finding a good initial solution by solving for its global optimum a discretized version of the model. The second phase implements a gradient method, starting from the initial point obtained in the initial phase.
*This is a joint work with M. Fortin, L. Brothers, P. Marcotte

Speaker: **P. Tseng** (U. Washongton)
Title: p-order cone relaxation for sensor network localization
Abstract:
Building on recent work on 2nd-order cone relaxation for sensor network localization, we discuss extensions to p-order cone relaxation when measured distances are based on p-norm instead of Euclidean norm.

Speaker: **C. Visweswariah** (IBM Research)
Title: Challenges in Statistical Timing and Optimization of Integrated Circuits
Abstract:
As transistors and wires on a chip get smaller, they are exhibiting proportionately increasing variability. This variability is changing the design methodology, and the tools and techniques used to analyze and optimize chip designs. The first part of this presentation will give an overview of our research work in statistical timing and optimization. In the second part, some mathematical problems will be formulated that, if solved, would be of tremendous utility to the design automation community.

Speaker: **H. Zhang** (McMaster U.)
Title: Approximation Algorithms for Routing in VLSI Design and Multicast Networks*
Abstract:
Given a computer chip represented as a grid graph and groups of pins as vertices to be connected, the goal of the global routing problem in VLSI design is to find one tree along the channels for each group of pins such that the number of trees crossing a channel is bounded by its capacity and the total cost (a combination of the overall tree length and the total number of bends) is minimized. Global routing is regarded as one of the hardest problems in discrete optimization due to the scales of real instances. We present a concurrent routing algorithm by mathematical programming methods in order to approach the global optimum. Our algorithm runs in a polynomial time and delivers a near-optimal solution with a provably good approximation bound for any instance. Promising numerical results for challenging benchmarks are also reported. We also show that this algorithm can be applied to a multicast routing problem in communication networks.

*This is joint work with A. Deza, C. Dickson, T. Terlaky and A. Vannelli.

Speaker: **H. Wolkowicz** (U. Waterloo)
Title: Semidefinite Relaxations for Anchored Graph Realization and Sensor Localization
Abstract:

Many applications use ad hoc wireless sensor networks for monitoring information. Typical networks include a large number of sensor nodes which gather data and communicate among themselves. The location of a subset of the sensors is known; these sensors are called anchors. From the intercommunication, we are able to establish distances between a subset of the sensors and anchors. The sensor localization problem is to find/estimate the location of all the sensors. We study several semidefinite programming relaxations for this *numerically hard* problem.