1 ICCOPT-I Conference Schedule

**Monday, August 2, 2004**

<table>
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<tr>
<th>Time</th>
<th>Session</th>
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<tr>
<td>07:30-08:30</td>
<td>Registration and Breakfast</td>
<td>DCC-Great Hall</td>
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<tr>
<td>08:30-09:00</td>
<td>Opening</td>
<td>DCC-308</td>
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<td>09:00-10:00</td>
<td>Optimization in Data Mining</td>
<td>DCC-308</td>
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<td>Chair: Olvi Mangasarian</td>
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<tr>
<td>10:00-10:30</td>
<td>Break</td>
<td>DCC-Great Hall</td>
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<td>10:30-12:30</td>
<td>MM 1 Chair: Freund</td>
<td>DCC-318</td>
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<td></td>
<td><strong>Theory of Interior Point Methods</strong></td>
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<td>10:30 – Behavioral Measures and Computation</td>
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<td>of SDPLIB Problems, <em>Freund</em>, Ordóñez, Toh</td>
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<td>11:00 – On Two Measures of Problem Complexity</td>
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<td>and their Explanatory Value for the Performance of SeDuMi on Second-Order Cone Problems, <em>Cai</em>, Freund, Toh</td>
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<td>11:30 – A new notion of weighted centers for semidefinite programming, <em>Chua</em></td>
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<td>12:00 – Improving Performance of Interior Point Methods Using Conditioning Information, <em>Vera</em>, Palominos</td>
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<td>10:30-12:30</td>
<td>MM 2 Chair: Parrilo</td>
<td>DCC-324</td>
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<td><strong>Sum of Squares Optimization and Applications</strong></td>
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<td>10:30 – Optimal semi-parametric bounds for European rainbow options, <em>Pena</em>, Zuluaga</td>
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<td>11:00 – Pricing a class of exotic options via moments and SDP relaxations, <em>Lasserre</em>, Prieto-Rumeau, Zervos</td>
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<td>11:30 – Symmetries in semidefinite programming, and how to exploit them, <em>Parrilo</em></td>
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<td>12:00 – Hyperbolic Polynomials, <em>Güler</em>, Schevchenko</td>
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10:30-12:30 MM 3 Chair: Kelley

**Applications**

10:30 – A New Asynchronous Parallel Pattern Search, **Kolda**
11:00 – Refining TRPOD – Trust Region Methods applied to Proper Orthogonal Decomposition, **Sachs**
11:30 – Low Thrust Trajectory Optimization using Sparse Nonlinear Programming, **Betts**
12:00 – Global Optimization of Computationally Expensive Functions Including Applications to Partial Differential Equations, **Shoemaker**, Regis, Mugunthan

10:30-12:30 MM 4 Chair: Bennett

**Mathematical Programming in Machine Learning**

10:30 – The $\nu$-Trick for Image Reconstruction, **R"atsch**, Tsuda
11:00 – Kernel methods, classification and optimization: learning the kernel using SDP, QCQP and beyond, **Lanckriet**
11:30 – Extracting Features From Data For A Given Learning Task, **Bennett**, Momma, Xiang
12:00 – Minimum Sum-of-Squares Clustering, **Xia**, Peng

10:30-12:30 MM 5 Chair: de Miguel

**Equilibrium Constraints**

10:30 – Global Convergence of SQP Methods Applied to Mathematical Programs with Equilibrium Constraints, **Anitescu**
11:00 – A Primal-Dual Interior Point Method for Stochastic Mathematical Programs with Complementarity Constraints, **Shanbhag**, Murray, Saunders
11:30 – Parameter Estimation in Metabolic Flux Balance Models for Batch Fermentation–Formulation & Solution using Differential Variational Inequalities (DVIs), **Ragunathan**, Biegler
12:00 - An interior-point method for MPECs based on strictly feasible relaxations, **de Miguel**, Friedlander, Nogales, Scholtes

10:30-12:30 MM 6 Chair: Levy

**Theory of Nonlinear Programming**

10:30 – On Regularity Conditions in Generalized Semi-Infinite Programming, **R"uckmann**
11:00 – Conditioning Well-Behaved Functions, **R. Zhang**
11:30 – Discretization of stochastic programs, **Pennanen**
12:00 – One-Size-Fits-All Convergence Analysis For Numerical Optimization, **Levy**

12:30-02:00 Lunch
Monday Afternoon Sessions

02:00-04:00 MA 1 Chair: Ulbrich

**Filter Methods**

02:00 – Recent progress in filter methods for nonlinear equations, unconstrained and bound constrained optimization problems, **Toint**

02:30 – A multidimensional filter trust-region method for mixed complementarity problems, **Ulbrich**

03:00 – Filters in direct search methods, **Audet**, Dennis

03:30 – LOQO: An Infeasible Interior-Point Algorithm for Nonlinear Programming, **Benson**, Griva, A. Sen, Shanno, Vanderbei

02:00-04:00 MA 2 Chair: Kolda

**Pattern Search**

02:00 – Generating set search for nonlinear programming, **Torczon**, Kolda, R.M. Lewis

02:30 – Decreasing the computation time for Generalized Pattern Search optimization algorithms by using adaptive precision cost function evaluations, **Wetter**, Polak

03:00 – An adaptive restart implementation of the DIRECT algorithm, **Finkel**, Kelley

03:30 – Second-Order Behavior of Pattern Search, **Abramson**

02:00-04:00 MA 3 Chair: Reemtsen

**Optimization for Radiation Therapy Treatment Planning**

02:00 – Sampling Issues for Optimization in Radiotherapy, **Ferris**, Einarsson, Z. Jiang, Shepard

02:30 – Integrating treatment plan design and delivery for IMRT, **Romeijn**, Ahuja, Dempsey, A. Kumar, Logdberg

03:00 – Experiences in Formulating and Solving Radiotherapy Treatment Planning Problems as Optimization Problems, **Olafsson**, S.J. Wright

03:30 – The solution of optimization problems for IMRT and IMPT treatment planning, M. Alber, **Reemtsen**

02:00-04:00 MA 4 Chair: Iyengar

**Algorithms for Nonlinear Programming I**

02:00 – Effective use of Negative Curvature directions for large scale unconstrained optimization problems, **Fasano**, Lucidi

02:30 – Comparing solvers for the optimization of noisy problems, **Morales**

03:00 – An Inexact Newton Interior-Point Algorithm for Nonnegative Constrained Minimization, **Velasquez**, Argaez, Saenz

03:30 – An active set method for SOCPs with a single cone constraint, Erdogan, **Iyengar**
02:00-04:00 MA 5 Chair: Leibfritz
Nonlinear and Linear Semidefinite Programming — Theory, Applications, and Algorithms
02:00 – COMPlib: COnstrained Matrix-optimization Problem library – a collection of test examples for nonlinear semidefinite programs, control system design and related problems, Leibfritz
02:30 – Large-scale semidefinite programming in electronic structure calculation, Fukuda, Z. Zhao, Braams, Overton, Percus
03:00 – Robust mean-squared error estimation of multiple signals in linear systems affected by model and noise uncertainties, Beck, Ben-Tal, Eldar
03:30 – A Unifying Framework for Several Cutting Plane Methods for Semidefinite Programming, Mitchell, Krishnan

02:00-04:00 MA 6 Chair: Potra
Interior Point Methods
02:00 – A corrector-predictor interior point method for sufficient linear complementarity problems in a wide neighborhood of the central path, Potra
02:30 – Implementation of Self-Regular Interior Point Methods, Zhu, Romanko, Terlaky, Wang
03:00 – A new class of incomplete LDL preconditioners for interior-point algorithms, Golovashkin, Kearney
03:30 The Dual Cone for the Derivative of the Non-Negative Orthant, Zinchenko

04:00-04:30 Break
04:30-05:20 MS Robust Optimization in Robust Control
Carsten Scherer
Chair: Ben-Tal
04:30-05:20 MS Stochastic programming, How difficult is it?
Alexander Shapiro
Chair: S. Sen

05:20-05:30 Break
05:30-06:45 MC Cyber Infrastructure Panel Discussion
Chairs: Moré and S.J. Wright
Panelists: Fourer, Linderoth, Lougee-Heimer, S. Sen, Tovey, M.H. Wright
## Tuesday, August, 3, 2004

<table>
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<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
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<tbody>
<tr>
<td>07:30-08:15</td>
<td>Breakfast</td>
<td>DCC-Great Hall</td>
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<td>08:15-09:00</td>
<td>Photo session</td>
<td>DCC-Great Hall</td>
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<td>09:00-10:00</td>
<td><strong>Young Researcher Competition</strong> DCC-330</td>
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<td>Chair: Luo</td>
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<td>09:00 –</td>
<td>Polynomial Convergence of Interior-Point Algorithms on Symmetric Cones, <strong>Rangarajan</strong></td>
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<td>09:30 –</td>
<td>Experimental Results with KNOSSOS, <strong>Friedlander</strong>, Saunders</td>
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<td>09:00-10:00</td>
<td><strong>Young Researcher Competition</strong> DCC-337</td>
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<td>Chair: S. Zhang</td>
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<td>09:00 –</td>
<td>Fastest mixing Markov chain on a graph, <strong>Xiao</strong>, Boyd, Diaconis</td>
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<td>09:30 –</td>
<td>Computation of robust stability measures for discrete systems, <strong>Mengi</strong>, Overton</td>
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<td>(The winner is unable to attend, so this presentation is cancelled.)</td>
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<td>10:00-10:30</td>
<td>Break</td>
<td>DCC-Great Hall</td>
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<td>10:30-12:30</td>
<td><strong>Bilevel Programs and Equilibrium Constraints</strong> DCC-324</td>
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<td>Chair: Ecker</td>
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<td>10:30 –</td>
<td>Solving bilevel linear programming problems using multiple objective programming, <strong>Ecker</strong>, Glackin, Kupferschmid, J. H. Song</td>
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<td>11:00 –</td>
<td>M-Stationarity as a First-Order Optimality Condition Under MPEC-ACQ for Mathematical Programs with Equilibrium Constraints, <strong>Flegel</strong>, Kanzow</td>
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<td>11:30 –</td>
<td>Solving MPCCs with Interior Methods, <strong>Lopez-Calva</strong>, Leyffer, Nocedal</td>
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<td>12:00 –</td>
<td>Dynamic Slope Scaling Procedure and Lagrangian Relaxation with Subproblem Approximation, <strong>Lawphongpanich</strong></td>
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<td>10:30-12:30</td>
<td><strong>Optimization Related to Matrix Valued Functions</strong> DCC-236</td>
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<td>Chair: Sun</td>
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<td>10:30 –</td>
<td>A Robust Gradient Sampling Algorithm for Nonsmooth, Nonconvex Optimization, <strong>Burke</strong>, A.S. Lewis, Overton</td>
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<td>11:00 –</td>
<td>Normal maps on Symmetric cones, <strong>Gowda</strong></td>
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<td>11:30 –</td>
<td>Smoothing approximations for eigenvalues of symmetric matrices and nonsmooth matrix valued functions, <strong>Sun</strong></td>
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<td>12:00 -</td>
<td>On a Homogeneous Model for Nonlinear Complementarity Problems over Symmetric Cones, <strong>Yoshise</strong></td>
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10:30-12:30 TM 3 Chair: Wets DCC-330

**Stochastic Optimization**
10:30 – An Stochastic Optimization- Noncooperative Game Problem: Electricity Market model, **Jofre**
11:00 – Risk-averse stochastic optimization: stochastic dominance constraints, **Dentcheva**, Ruzsyczynski
11:30 – Risk-averse stochastic optimization: semi-infinite chance constraints, **Ruzsyczynski**, Dentcheva
12:00 – A Primal-Dual Scenario Tree Generation Algorithm for Dynamic Stochastic Programming, **Casey**, S. Sen

10:30–12:30 TM 4 Chair: Terlaky DCC-239

**Interior Point and Ellipsoid Methods**
10:30 – Working set strategies for interior point linear programming with many constraints, Wossner, **Tits**, Absil
11:00 – A Self-Regular Proximity Based Adaptive Large-Update IPM for Linear optimization, **Terlaky**, Salahi
11:30 A New Conjugate Gradient-Based Algorithm Modified for Use with Ellipsoid Preconditioners, **O’Neal**, Monteiro, Nemirovski
12:00 – Convergence Analysis of an Inexact Interior-Point Quadratic Programming Algorithm, **Lu**, Monteiro, O’Neal

10:30-12:30 TM 5 Chair: Luo DCC-337

**Optimization Techniques in Digital Communications and Signal Processing**
10:30 – Geometric Programming for Communication Systems, **Chiang**
11:00 – Duality Methods in the Optimization of Orthogonal Frequency-Division Multiplex (OFDM) Communication Systems, **Yu**
11:30 – Robust Rayleigh Quotient Maximization with Applications in Signal Processing, **Kim**, Luo
12:00 – Optimal Multi-user Spectrum Management for Digital Subscriber Lines, **Luo**

10:30-12:30 TM 6 Chair: Wolkowicz DCC-318

**Conic Optimization**
10:30 – Differentiating Spectral Functions, **Sendov**
11:00 – Invariance and Efficiency in Convex Representations, **Tunçel**, Chua
11:30 – “Cone-Free” Primal-Dual Path-Following and Potential-Reduction Polynomial Time Interior-Point Methods, **Nemirovski**, Tunçel
12:00 – Cone Preserving Maps, **Wolkowicz**
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<th>Speaker(s)</th>
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<tr>
<td>12:30-02:00</td>
<td>Lunch</td>
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<td>Self-Serve Downtown</td>
<td>Restaurants</td>
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<td><strong>Tuesday Afternoon Sessions</strong></td>
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<td>02:00-03:00</td>
<td>TP Optimization and Economic Equilibrium</td>
<td>DCC-308</td>
<td>R. Tyrell <strong>Rockafellar</strong></td>
<td>Mitchell</td>
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<td>03:00-03:30</td>
<td>Break</td>
<td>DCC-Great Hall</td>
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<td>03:30-04:20</td>
<td>TS MPECs: For a Fistful of Dollars</td>
<td>DCC-330</td>
<td>Sven <strong>Leyffer</strong></td>
<td>Ralph</td>
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<td>03:30-04:20</td>
<td>Complex Values in Optimization:</td>
<td>DCC-337</td>
<td>Shuzhong <strong>Zhang</strong></td>
<td>Luo</td>
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<td>04:20-04:45</td>
<td>Break</td>
<td>DCC-Great Hall</td>
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<td>04:45-06:15</td>
<td>TA 1 Equilibrium Problems with Equilibrium Constraints</td>
<td>DCC-330</td>
<td><strong>Mordukhovich</strong></td>
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<td>04:45-06:15</td>
<td>TA 2 Interior Point Methods for Nonlinear Programming</td>
<td>DCC-337</td>
<td><strong>Wächter</strong></td>
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<td>04:45-06:15</td>
<td>TA 3 COIN-OR</td>
<td>DCC-318</td>
<td><strong>Lougee-Heimer</strong></td>
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<td>04:45-06:15</td>
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<td><strong>Waltz</strong>, Byrd, Nocedal</td>
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<td>05:15 – On Stability of Equilibrium Constraints, <strong>Outrata</strong>, Henrion</td>
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<td>05:45 – Equilibrium Problems with equilibrium constraints via multiobjective optimization, <strong>Mordukhovich</strong></td>
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<td>04:45-06:15</td>
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<td><strong>Gill</strong>, Kroyan</td>
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<td>05:15 – Trust-Search Methods for Large-Scale Optimization, <strong>Gill</strong>, Kroyan</td>
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<td>05:45 – An Interior-point L1-penalty Method for Nonlinear Optimization, <strong>Orban</strong>, Gould, Toint</td>
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<td>04:45-06:15</td>
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<td><strong>Ralphs</strong></td>
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<td>05:15 – NLPAPI—a programming interface to nonlinear programming problems and solvers, <strong>Henderson</strong></td>
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<td>05:45 – From interpolation to regression in derivative free optimization, <strong>Scheinberg</strong></td>
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04:45-06:15 TA 4  Chair: Gasimov  DCC-239
Algorithms for Nonlinear Programming II
04:45 – Regularization and Resolution of Monotone Variational Inequalities with Operators Given by Hypomonotone Approximations, Butnariu, Y. Alber, Ryazantseva
05:15 – Global Optimization Methods and Classes of Test Functions, Kvasov, Sergeyev
05:45 – The Modified Subgradient Algorithm Based on Feasible Dual Values and Solving the Quadratic Assignment Problems, Gasimov, Rubinov, Üstün

04:45-06:15 TA 5  Chair: Romanko  DCC-236
Solutions of Nonlinear Programs
04:45 – Isolated minimizer in set-valued optimization, Crespi, Ginchev, Rocca
05:15 – Parametric Convex Quadratic Optimization; Simultaneous Parameterization of the Objective Function and Right-Hand-Side Vectors, Romanko, Hadigheh, Terlaky
05:45 – Isolated minimizers, proper efficiency and stability for $C^{0,1}$ constrained vector optimization problems, Rocca, Ginchev, Guerraggio

04:45-06:15 TA 6  Chair: Anjos  DCC-324
Combinatorial Optimization
04:45 – Solving the Quadratic Knapsack Problem by using Modified Subgradient Algorithm, Saraç, Sipahioglu
05:15 – A Semidefinite Optimization Approach for the Single-Row Layout Problem with Unequal Dimensions, Anjos, Kennings, Vannelli
05:45 – Semidefinite programming strengthenings of Lovász theta number applied to graph coloring and stable set problems, Djukanović, Rendl

06:15-07:00  Walk to Captain JP Cruise Line
07:00-07:30  Board Captain JP Cruise Line
07:30-10:30  Conference Banquet-Captain JP Cruise Line
**Wednesday, August, 4, 2004**

**Wednesday Morning Sessions**

08:30-09:30 WP  Solving Very Large-Scale Convex Problems: A Return to Subgradient-Type Methods  
Aharon Ben-Tal  
Chair: Pang  
DCC-308

09:30-10:00  Break  
DCC-Great Hall

10:00-11:30 WM 1  Chair: Perakis  
Complementarity and Variational Inequalities  
10:00 – Off-Central Paths in Interior Point Method for Monotone Semidefinite Linear Complementarity Problem, Sim, G. Zhao  
10:30 – The “Price of Anarchy” under Nonlinear and Asymmetric Costs, Perakis  
11:00 – Automorphism invariance of P and GUS properties of linear transformations on Euclidean Jordan algebras, Sznajder

10:00-12:00 WM 2  Chair: Toh  
Numerical Methods for Conic Programs  
10:00 – Computational Enhancements in Low-Rank Semidefinite Programming, Burer  
10:30 – Parallel Implementation for SemiDefinite Programming with Positive Definite Matrix Completion, Yamashita  
11:00 – Solving second order cone programming via the augmented systems, Toh  
11:30 – Solving Image Restoration Problems as Second-Order Cone Programs, Goldfarb, Yin, Osher

10:00-12:00 WM 3  Chair: Polyak  
Algorithms for Nonlinear Programming III  
10:00 – Extraproximal method for equilibrium and game programming problems, Antipin  
10:30 – On using perturbation to solve Linear Complementarity Problems, Adler, Verma  
11:00 – A primal-dual method for solving nonlinear optimization problems with both inequality constraints and equations, Griva, Polyak, Shanno, Vanderbei  
11:30 – Primal-Dual method for convex optimization based on Lagrangian Transformation, Polyak
10:00-12:00 WM 4 Chair: Krishnan

Cutting Plane and Column Generation Methods
10:00 – The P-Median Problem Solved by Semi-Lagrangian Relaxation, Beltran, C. Tadonki, Vial
10:30 – Towards a practical simplex-like method for conic programming, Krishnan, Pataki, Terlaky
11:00 – A matrix generation approach for eigenvalue optimization, Oskoorouchi
11:30 – Solving large scale linear multicommodity flow problems with an active set strategy and Proximal-ACCPM, Babonneau, du Merle, Vial

10:00-12:00 WM 5 Chair: Gill

Large-Scale Nonlinear Programming
10:00 – Large-scale nonlinear optimization: what counts? M.H. Wright
10:30 – Adaptive Barrier Parameter Strategies for Nonlinear Programming, Wächter, Byrd, Nocedal, Waltz
11:00 – Iterative Methods for Systems Arising in Interior Methods, Griffin, Forsgren, Gill
11:30 – Solving Optimization Problems for Protein Structure Prediction, Byrd, Eskow, L. Jiang, Schnabel

12:00-01:30 Lunch
### Wednesday Afternoon Sessions

<table>
<thead>
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<th>Time</th>
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<th>Title</th>
<th>Location</th>
<th>Chair</th>
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<tr>
<td>01:30-02:20</td>
<td>WS</td>
<td>Second-order Cone Programming Relaxation for Nonconvex Optimization</td>
<td>DCC-330</td>
<td>Paul Tseng, Chair: Tunçel</td>
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<td>01:30-02:20</td>
<td>WS</td>
<td>Complete search for constrained global optimization</td>
<td>DCC-337</td>
<td>Arnold Neumaier, Chair: Tits</td>
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<tr>
<td>02:20-02:45</td>
<td></td>
<td>Break</td>
<td>DCC-Great Hall</td>
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<td>02:45-04:15</td>
<td>WA 1</td>
<td>Chair: Sahinidis</td>
<td>DCC-337</td>
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<td><strong>Global Optimization</strong></td>
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<td>02:45</td>
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<td>On strengthening polyhedral relaxations for nonconvex mathematical programs, Sahinidis, Tawarmalani</td>
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<td>03:15</td>
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<td>A Branch-and Bound Method for Solving Quadratic Bilevel Program, Yershov</td>
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<td>03:45</td>
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<td>When to Use Evolutionary Algorithms as General Problem Solvers? Maaranen</td>
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<td>02:45-04:15</td>
<td>WA 2</td>
<td>Chair: Mifflin</td>
<td>DCC-330</td>
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<td><strong>Nonlinear Programming</strong></td>
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<td>02:45</td>
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<td>A superlinearly convergent VU-algorithm for convex minimization, Mifflin, Sagastizabal</td>
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<td>03:15</td>
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<td>A Parallel Radial Basis Function Method for Global Optimization, Regis, Shoemaker, Mugunthan</td>
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<td>03:45</td>
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<td>Minimal coercivity conditions and exceptional families of elements in quasi-monotone variational inequalities, Schaible, Bianchi, Hadjisavvas</td>
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<td><strong>Uncertainty and Sampling</strong></td>
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<td>Stochastic programming with linear decision rules, Thénié, Vial</td>
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<td>03:15</td>
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<td>Application of conic programming to the statistical design of experiments, S.E. Wright</td>
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<td>03:45</td>
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<td>Optimal bidding in electricity markets under uncertainty: A review, Anderson</td>
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Financial Optimization
02:45 – Optimal Semi-Static Hedging of Barrier Options in Heston’s Stochastic Volatility Model, Maruhn
03:15 – Nonlinear Discrete Programming for solving the combinatorial and continuous index plus alpha fund optimization, Nakagawa, Kai, Tabata, James
03:45 – Robust Portfolio Management, Erdogan, Goldfarb, Iyengar

Logistics and Other Applications
02:45 – Impulse Noise Removal by Median-type Noise Detector and Edge-preserving Regularization, Chan, Ho, Nikolova
03:15 – Optimizing Preventive Maintenance Schedules, Bartholomew-Biggs, Christianson, Zuo
03:45 – Determining an Optimal Fleet Mix and Schedule — Multiple Sources and Destinations, and the Option of Leasing Transshipment Depots, Al-Yakoob, Sherali

Differential Variational Systems and Applications
02:45 – Computing Optimal Controls for Friction Problems, Stewart, Anitescu
03:15 – On Linear Complementarity Systems with the P-Property, Shen, Pang
03:45 – Time-Stepping Models for Boundary Value Problems in Frictional Multibody Dynamics and Design, P. Song, V. Kumar, Pang

Closing Remarks
2 ABSTRACTS

MA = Monday afternoon  MM = Monday morning
MP = Monday plenary   MS = Monday semi-plenary
MC = Monday cyber infrastructure panel
TA = Tuesday afternoon  TM = Tuesday morning
TP = Tuesday plenary   TS = Tuesday semi-plenary
TY = Tuesday young researcher competition
WA = Wednesday afternoon  WM = Wednesday morning
WP = Wednesday plenary  WS = Wednesday semi-plenary

Speaker names are listed first. Abstracts alphabetized by name of speaker.

MA 2 SECOND-ORDER BEHAVIOR OF PATTERN SEARCH

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Previous analyses of pattern search algorithms for unconstrained and linearly constrained minimization have focused on proving convergence of a subsequence of iterates to a limit point satisfying either directional or first-order necessary conditions for optimality, depending on the smoothness of the objective function near the limit point. Given certain algorithmic choices and sufficient smoothness of the objective function, we can also prove some limited directional second-order results. Although not as strong as classical second-order necessary conditions, these results are stronger than the first order conditions that many gradient-based methods are able to satisfy. Under fairly mild conditions, we can eliminate from consideration all strict local maximizers and an entire class of saddle points.

WM 3 ON USING PERTURBATION TO SOLVE LINEAR COMPLEMENTARITY PROBLEMS

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We consider a variety of perturbations of the coefficient matrix of the Linear Complementarity problem (LCP). We characterize the subset of \( P_0 \) LCPs which have the property that the unique solution of the perturbed problem converges to a solution of the original unperturbed problem as the perturbation’s size tends to zero. Further, it is shown that the LCPs with column sufficient matrix and a bounded feasible region belong to this class. As an implication, it is shown that the LCP problem with \( P \) matrix can be solved in polynomial time if and only if the LCP with column sufficient matrices can.
Determining an Optimal Fleet Mix and Schedules — Multiple Sources and Destinations, and the Option of Leasing Transshipment Depots

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This paper explores models and algorithms for a storage replenishment scheduling transportation problem. Scheduling transportation problems have been widely addressed in the literature, stemming from the desire of organizations to improve efficiency and achieve cost-effectiveness. The specific problem considered in this paper is concerned with generating schedules to transport a product from multiple sources to various destinations based on a stream of demand and storage information at the destinations. The leasing of temporary transshipment storage depots is a strategic decision that can be exploited to enhance efficiency and cost effectiveness. Many oil companies face this problem, wherein a company controls a fleet of (oil tankers/trucks) and it needs to transport a product (crude oil/gasoline) to customers (storage facilities/gas stations) based on agreed upon contracts. A mixed-integer programming model for the problem is constructed in this paper. The resulting mathematical formulation is rather complex to solve, mainly due to the overwhelming size and combinational content for a typical demand contract scenario. Accordingly, an aggregate model that retains the salient essential features of the problem is formulated. The latter model is computationally far more tractable than the initial model, and specialized rolling horizon heuristics are developed to solve it. The proposed heuristics enable us to generate solutions for practical sized problems that cannot be handled by directly solving even the aggregate model. The initial and aggregate formulations are solved using CPLEX-7.5-MIP for a number of relatively small-sized test cases. For larger problem instances, the aggregate formulation is solved using CPLEX-7.5-MIP in concert with the developed rolling horizon heuristics, and related results are reported.

Optimal bidding in electricity markets under uncertainty: A review

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This paper reviews recent work by Anderson, Philpott and Xu showing how a participant in an electricity market can use market distribution functions to find optimal bids when there is uncertainty in demand and in other participant bids. The strengths
of this approach are (a) its concise treatment of the stochastic elements of the problem; (b) the inclusion of more real aspects of the problem than other approaches (for example contracts, non-smooth cost functions, and possible undercutting behaviour); (c) its strong theoretical foundations in continuous optimisation. However it has two significant limitations: (a) it can be cumbersome when dealing with networks; (b) it does not naturally lead to equilibrium formulations of the marketplace.

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**MM 5 Global Convergence of SQP Methods Applied to Mathematical Programs with Equilibrium Constraints**

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We show that, for the mixed P parametric variational inequalities, a class of problems that is slightly stronger than the one studied in the monograph of Luo, Pang and Ralph, the elastic mode algorithm converges globally to a C-stationary point. If the accumulation point satisfies stronger assumptions, then we prove that the point is an M-stationary point. We show that several instances of the obstacle problem satisfies our assumptions and we present preliminary numerical results of our algorithm.

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**TA 6 A Semidefinite Optimization Approach for the Single-Row Layout Problem with Unequal Dimensions**

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The facility layout problem is concerned with the arrangement of a given number of rectangular facilities so as to minimize the total cost associated with the (known or projected) interactions between them. We consider the one-dimensional space allocation problem (ODSAP), also known as the linear single-row facility layout problem, which consists in finding an optimal linear placement of facilities with varying dimensions on a straight line. We construct a semidefinite programming (SDP) relaxation providing a lower bound on the optimal value of the ODSAP. To the best of our knowledge, this is the first non-trivial global lower bound for the ODSAP in the published literature. This SDP approach implicitly takes into account the natural symmetry of the problem and, unlike other algorithms in the literature, does not require the use of any explicit symmetry-breaking constraints. Furthermore, the structure of the SDP relaxation suggests a simple heuristic procedure which extracts a feasible solution to the ODSAP from the optimal matrix solution to the SDP relaxation. Computational results show
that this heuristic yields a solution which is consistently within a few percentage points of the global optimal solution.

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**WM 3 EXTRAPROXIMAL METHOD FOR EQUILIBRIUM AND GAME PROGRAMMING PROBLEMS**

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We present the extraproximal approach for solving of equilibrium and game problems. Functional constraints of both types problems depend on parameters, i.e. they are coupled. In the well known proximal point method a given equilibrium problem is brought to a sequence of regularized equilibrium subproblems, such method is implicit. In the extraproximal approach, which is explicit, the given problem is brought to sequence of iterative steps, where it needs to solve two optimization problems of the same type. If given equilibrium or two-person game problem has a coupled constraints, then the extraproximal method consists of iterations in primal and dual variables. In this case in each iteration it is necessary to solve a pair of optimization problems as in primal and dual variables. The case is possible when each iteration in primal variables (solution of two optimization problems) can be replaced to iteration in which an equilibrium problem is decided, herewith the step in dual variable do not change (two optimization problems). Such process can be named as extraproximal method in dual variables. It is implicit in primal variables and explicit in dual ones. And at last, the case is possible when in each iteration of process one solves a regularized equilibrium or game auxiliary problem. The scheme of such method to within details coincides with well known proximal point method.  
At presence of convexity in optimization variables and condition of nonlinear positive semi-definiteness the convergence of all kinds extraproximal methods to equilibrium or game solutions is proved.

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**MA 1 FILTERS IN DIRECT SEARCH METHODS**

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Filter and pattern search methods have recently been combined to handle black-box constrained optimization problems. Under adequate search strategies, the method has been shown useful on some real applications. Theoretical convergence results, which are based on the Clarke calculus, are shown to be closely tied to local differentiability of the functions. However, these convergence results depend heavily on a finite set of
directions. We illustrate the limitations of these results on a simple convex optimization problem. We also show how the new Mesh Adaptive Pattern Search (MADS) algorithm may overcome this limitation, and ensures convergence result in a dense set of directions in the contingent cone.

WM 4 Solving large scale linear multicommodity flow problems with an active set strategy and Proximal-ACPPM

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We propose to solve the linear multicommodity flow problem using a partial Lagrangian relaxation. The relaxation is restricted to the set of arcs that are likely to be saturated at the optimum. This set is itself approximated by an active set strategy. The partial Lagrangian dual is solved with Proximal-ACCPM, a variant of the analytic center cutting plane method. The new approach is tested on a collection of problems, some of them of huge size.

WA 5 Optimizing Preventive Maintenance Schedules

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This paper deals with the preventive maintenance (PM) of a system. It uses a model (Lin, Zuo, and Yam 2001) based on the “effective age” of the system which is reduced whenever PM occurs. An optimal schedule is one which minimizes an average cost over the system’s lifetime and it involves determining n, the number of times PM takes place and also the time intervals between each occurrence. The optimization problem can be solved by performing unconstrained minimizations to determine the time intervals for each of a number of values of n. An alternative approach proposed in this paper is to use global optimization to calculate the time intervals and the number of PMs simultaneously. The paper will also consider the need for additional constraints in the optimal PM problem, the use of automatic differentiation to compute gradients and Hessians of the model and the extension of the problem to deal with the case when parts of the system are non-maintainable.
MA 5 Robust mean-squared error estimation of multiple signals in linear systems affected by model and noise uncertainties

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We consider the problem of estimating by a linear estimator $N$ unobservable input vectors, undergoing the same linear transformation. We assume that both the matrix representing the linear transformation, and the covariance matrices of the zero-mean noise vectors are uncertain, and are only known to belong to some deterministic uncertainty sets. We show that the optimal robust mean-squared error estimator has a special form represented by an elementary block circulant matrix, and moreover when the uncertainty sets are ellipsoidal-like, the problem of finding the optimal estimator matrix can be reduced to solving an explicit semidefinite programming problem, whose size is independent of $N$.

WM 4 The p-Median Problem Solved by Semi-Lagrangian Relaxation

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Lagrangian relaxation is commonly used in combinatorial optimization to generate lower bounds for a minimization problem. We propose a modified Lagrangian relaxation which used in combinatorial optimization generates not only a lower bound but an optimal solution. We call this new procedure semi-Lagrangian relaxation. This new concept is illustrated by solving large-scale instances of the p-median problem.

MM 4 Extracting features from data for a given learning task

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Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, New York 12180

The problem of constructing orthogonal features targeted to specific learning tasks, as defined by a given loss function and data set, is solved using boosted latent analysis (BLA). The method produces an inference function and orthogonal features that are
suitable for data visualization, dimensionality reduction, and improving generalization. For least squares loss, BLA reduces to partial least squares (PLS). PLS has been previously shown to be a conjugate gradient method. In PLS and BLA, the conjugate directions form valuable features as well as good search directions. For other loss functions, BLA corresponds to a nonlinear conjugate method in which the search directions are forced to be conjugate with respect to the data. The method is illustrated on bioinformatic and cheminformatic applications.

MA 1 LOQO: AN INFEASIBLE INTERIOR-POINT ALGORITHM FOR NONLINEAR PROGRAMMING

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In this talk, we will outline the recent changes to LOQO, an infeasible interior-point algorithm for solving nonlinear programming problems. Of particular note will be the discussion of the filter method used in LOQO and the handling of unbounded Lagrange multipliers. Extensive numerical results will be provided.

WP SOLVING VERY LARGE-SCALE CONVEX PROBLEMS: A RETURN TO SUBGRADIENT-TYPE METHODS

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Application of optimization to problems in medical imaging, shape design of mechanical structures, or relaxations of hard combinatorial problems, give rise to convex mathematical programs of a very large-scale ($10^5$–$10^7$ variables). This fact rules out the use of most of the sophisticated methods, such as Interior Point, since the number of arithmetic operations required in a single iteration is already prohibitively large. Moreover,
classical requirements from a good algorithm, such as (asymptotic) rate of convergence, quadratic termination and high accuracy, are somewhat irrelevant for very large-scale problems. Instead, a reasonable algorithm should have

(i) a computational effort per iteration which is at most linear in the design dimension
(ii) the potential to obtain medium-accuracy solutions
(iii) an error reduction factor which is essentially independent of the problem dimension.

The first requirement (i), more or less, implies that the algorithm can use and manipulate only first-order information (function values and subgradients). Within such first-order methods, we present a family of algorithms which achieve the second and third goals (ii) and (iii). These algorithms are in a sense optimal and the essence of their success is the possibility of adjusting a particular algorithm in the family to the geometry of the feasible set.

MM 3 Low Thrust Trajectory Optimization using Sparse Nonlinear Programming

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WM 2 Computational Enhancements in Low-Rank Semidefinite Programming

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We present computational enhancements of the “low-rank” semidefinite programming algorithm based on the truncated Newton method. Also detailed are strategies for preconditioning the Newton system. Computational results demonstrate improved accuracy and robustness of the algorithm.

TM 2 A Robust Gradient Sampling Algorithm for Nonsmooth, Nonconvex Optimization

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Let $f : \mathbb{R}^n \to \mathbb{R}$ be nonconvex, continuous, and continuously differentiable on an open dense subset of $\mathbb{R}^n$ where its gradient is easily computed. We present a practical, robust algorithm to locally minimize such functions based on gradient sampling. We present both an outline of our convergence theory and numerical results for a variety of interesting problems that have not, to our knowledge, been solved previously.

**TA 4 Regularization and Resolution of Monotone Variational Inequalities with Operators Given by Hypomonotone Approximations.**

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Let $X$ be a reflexive, smooth, strictly convex Banach space and let $A : X \to 2^{X^*}$ be a monotone operator which is demiclosed and convex valued on the interior of its domain. Let $\Omega$ be a nonempty, closed, convex subset of Int(Dom $A$) and let $f \in X^*$. We consider the variational inequality

$$\langle Ax - f, y - x \rangle \geq 0, \quad \forall y \in \Omega.$$  \hspace{1cm} (1)

By a solution of the variational inequality (1) we mean a vector $x^* \in \Omega$ such that, for some $\xi^* \in Ax^*$, we have

$$\langle \xi^* - f, y - x^* \rangle \geq 0, \quad \forall y \in \Omega.$$  \hspace{1cm} (2)

We denote by $S(A, f, \Omega)$ the set of solutions of (1). We assume that the problem data $A, f$ and $\Omega$ are given by sequences of approximations $\{A_k\}_{k \in \mathbb{N}}, \{f^k\}_{k \in \mathbb{N}}$ and $\{\Omega_k\}_{k \in \mathbb{N}}$, respectively.

The problem of finding a solution of (1) may be ill-posed in the sense that either $S(A, f, \Omega)$ is not a singleton and/or small perturbations of the problem data lead to relatively large perturbations of the solution set. In such situations, solving variational inequalities

$$\langle A_kx - f^k, y - x \rangle \geq 0, \quad \forall y \in \Omega_k$$  \hspace{1cm} (3)

instead of (1) makes little sense because the problem of finding solutions of (3) can be as ill-posed as the original problem and its solutions may be far from the set $S(A, f, \Omega)$.

The aim of presentation is two folds. First we show a stability result for the Tikhonov-Browder operatorial regularization method. The basic idea of the Tikhonov-Browder regularization scheme consists of associating to the variational inequality (1) the per-
turbed regularized variational inequalities

\[
\langle (A_k + \alpha_k J) x - f^k, y - x \rangle \geq 0, \forall y \in \Omega_k,
\]

where \( J \) is the normalized duality mapping and \( \{\alpha_k\}_{k \in \mathbb{N}} \) is a sequence of positive real numbers (regularization parameters) such that \( \lim_{k \to \infty} \alpha_k = 0 \). It is known that, under various conditions concerning the original and the approximative data, the Tikhonov-Browder regularization method is stable, that is, each variational inequality (4) has a unique solution \( x^k \) and that the sequence \( \{x^k\}_{k \in \mathbb{N}} \) converges weakly, and sometimes strongly, to a solution of (1). However, the stability results we are aware of are proved under the assumption that the approximating operators \( A_k \) preserve the basic continuity and monotonicity features of the operator \( A \) involved in the original variational inequality (1). In this paper we consider the situation in which, by contrast to \( A \), the operators \( A_k \) may fail to be monotone, although they are required to satisfy a less demanding property which we call "strong hypomonotonicity".

Second, we use the stability properties of the Tikhonov-Browder regularization method in order to establish convergence of an algorithm for finding solutions of the variational inequality (1) by using in computations the approximative data only. The algorithm we consider is an iterative procedure defined by

\[
z^{n+1} = \Pi_{\Omega_{p(n+1)}} J^* \left[ J z^n - \varepsilon_{p(n)} \left( \chi^n + \alpha_{p(n)} J z^n - f^{p(n)} \right) \right],
\]

where \( z^0 \), the positive integers \( p(n) \) and the positive relaxation parameters \( \varepsilon_{p(n)} \) are chosen according to specific rules, \( \chi^n \in A_{p(n)} z^n \), \( J^* \) is the normalized duality mapping of the space \( X^* \) and \( \Pi_{\Omega_{p(n+1)}} \) is the Bregman projection associated with the set \( \Omega_{p(n+1)} \). We show that if the variational inequality (1) has solutions and if the operators \( A_k \) are strongly hypomonotone and satisfy certain conditions concerning their proximity to \( A \), then the sequence \( \{z^k\}_{k \in \mathbb{N}} \) generated by the algorithm and the sequence \( \{x^k\}_{k \in \mathbb{N}} \) defined above have the same limit, namely, the minimal norm solution of (1).
on protein targets where structural information from similar proteins is unavailable. The method makes use of random sampling, secondary structure predictions, subspace minimization, and a lot of unconstrained local optimization. In this talk we focus on a preconditioned limited memory quasi-Newton method we have recently developed for the unconstrained local optimization phase. We use automatic differentiation to compute the second derivative of the bonded terms in the energy, which form a banded Hessian. Special care has to be taken in making sure the preconditioner is positive definite. So far this approach has resulted in significant speed-ups in solution time, and this can be enhanced by decreasing the frequency with which the preconditioner is computed.

**MM 1** On Two Measures of Problem Complexity and their Explanatory Value for the Performance of SeDuMi on Second-Order Cone Problems

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Herein we evaluate the practical relevance of two measures of conic convex problem complexity as applied to second-order cone problems solved using SeDuMi. The first measure we evaluate is Renegar’s data-based condition measure $C(d)$, and the second measure is the simple geometric measure of solution size $R_\varepsilon := \max(\|x^*_\varepsilon\|, \|s^*_\varepsilon\|)$ where $x^*$ ($s^*$) is the largest $\varepsilon$-optimal primal (dual) solution among the cone variables $x$ ($s$), respectively. We constructed a set of 60 second-order cone test problems with widely distributed values of $C(d)$ and $R_\varepsilon$ and solved these problems using SeDuMi. For each problem instance in the test set, we also computed estimates of $C(d)$ using Peña’s method and computed $R_\varepsilon$ directly. Our computational experience indicates a very strong correlation ($R^2 \approx 0.80$) between SeDuMi iteration counts and either of these measures. We develop an associated mathematical analysis that explains the strong correlation between SeDuMi iteration counts and the solution size $R_\varepsilon$.

**TM 3** Scenario Generation for Dynamic Multistage Linear-Quadratic Programs

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Dynamic formulations of stochastic programs are becoming increasingly popular. In these models one adopts a control theory perspective by making a distinction between state and control. The resulting problem often has nice properties such as convexity and decomposability. However, even with these helpful structural properties a significant hurdle remains: explosion of the scenario tree. This problem results from discretizing the (generally continuous) stochastic process which models the evolution of chance model parameters. We present in this talk an algorithm for generating a sequence of epi-convergent approximations to a dynamic multistage linear-quadratic program by producing a sequence of manageable scenario trees. The key idea is to start with a small tree (usually just one scenario) and then use “prolongations” to generate a new scenario. The algorithm also produces a policy rather than just the first stage decision. This policy is the stochastic programming analog of a feedback law. Numerical examples will be given.

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**WA 5 Impulse Noise Removal by Median-type Noise Detector and Edge-preserving Regularization**

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**Chung-Wa Ho** cwho@math.cuhk.edu.hk  
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**Mila Nikolova** nikolova@cmla.ens-cachan.fr  
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In this talk, we propose a two-phase scheme for impulse noise removal. In the first phase, an adaptive median filter is used to identify pixels which are likely to be contaminated by noise (noise candidates). In the second phase, the image is restored using a specialized regularization method that applies only to those selected noise candidates. This phase is equivalent to solving a minimization problem over the noise candidate set. In terms of edge preservation and noise suppression, our restored images show a significant improvement compared to those restored by using just nonlinear filters or regularization methods only. Our scheme can remove salt-and-pepper-noise with noise level as high as 90%.

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**TM 5 Geometric Programming for Communication Systems**

**Mung Chiang** chiangm@Princeton.edu  
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Geometric Programming (GP) was invented by Duffin, Peterson and Zener in the 1960s and found applications in chemical and mechanical engineering problems throughout
the 60s and 70s. Since mid-90s, very efficient interior-point algorithms have been used to solve large-scale GPs. Over the last 5 years, GP have found a variety of surprising applications in electrical engineering. This talk overviews some of the applications of GP to the analysis and design of communication systems, presenting recent results on how, and why, GP can be used for communication systems, and how problems in communication systems further lead to new research in GP. We will present how GP solves basic information-theoretic problems of channel capacity and rate distortion, a suite of network resource allocation problems including power control in wireless networks and performance optimization in simple queuing systems, and distributed rate allocation through some TCP congestion control protocols.

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**MM 1 A NEW NOTION OF WEIGHTED CENTERS FOR SEMIDEFINITE PROGRAMMING**

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The notion of weighted centers is essential in V-space interior-point algorithms for linear programming. Although there were some successes in generalizing this notion to semidefinite programming via weighted center equations, we still do not have a generalization that preserves two important properties — 1) each choice of weights uniquely determines a pair of primal-dual weighted centers, and 2) the set of all primal-dual weighted centers completely fills up the relative interior of the primal-dual feasible region. We present a new notion of weighted centers for semidefinite programming that possesses both uniqueness and completeness. Furthermore, under strict complementarity, these weighted centers converge to weighted centers of optimal faces. When this convergence result is applied to homogeneous cone programming, it can be shown that the central paths defined by a certain class of optimal barriers for homogeneous cones converge to analytic centers of optimal faces in the presence of strictly complementary solutions.

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**TA 5 ISOLATED MINIMIZER IN SET-VALUED OPTIMIZATION**

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Set-valued optimization arises quite naturally in the topic of duality for vector optimization (see e.g. D.T. Luc Theory of vector optimization., 1989) as well as in several applications, when the data of a single-valued problem are not exactly known. We can consider this field as the ultimate extension of optimization problems involving a
set-valued objective function. It is, therefore, quite natural to extend the most widely known notions of solutions from vector-optimization to set-valued optimization. Besides the well-known notions of efficient and weakly efficient minimizers, we also propose definitions of proper minimizers and isolated minimizers for an unconstrained problem with set-valued objective function. We assume that these are dependent on the order induced by a closed and convex cone. After some remarks to argument the definitions presented, we discuss first-order necessary optimality conditions for weak minimizer and sufficient optimality conditions for isolated ones. Here comes one of the motivations for introducing the new concept of isolated minimizers, that is it allows us to prove also the reversal of sufficient optimality conditions. Such a problem has been dealt in I. Ginchev, A. Guerraggio and M. Rocca, in a forthcoming paper, with regard to vector optimization problems. Our main tools are a generalized Dini derivative (contingent derivative) and scalarization based on the oriented distance function introduced by Hiriart-Urruty. Finally, we give some extension of these results toward constrained set-valued optimization problems.

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**TM 3 Risk-averse stochastic optimization: stochastic dominance constraints**

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We introduce a new stochastic optimization model with stochastic dominance constraints. It is a new decision model under uncertainty involving comparison of random outcomes dependent on the decisions to stochastic reference points. We develop necessary and sufficient conditions of optimality and duality theory for these models. Furthermore, we show that the Lagrange multipliers corresponding to dominance constraints are concave non-decreasing utility functions. The analysis demonstrates that the expected utility approach is dual to the new one. Next, we develop a theory of splitting for these models, and specialized decomposition methods. The results are illustrated on a portfolio optimization problem.

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**TA 6 Semidefinite programming strengthenings of Lovász theta number applied to graph coloring and stable set problems**

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Semidefinite programming formulation of Lovász theta number does not give only one of the best polynomial simultaneous bounds on the chromatic number and clique number of a graph but also leads to heuristics for graph coloring and extracting large cliques (or equivalently stable sets). This semidefinite programming formulation can be tightened toward either number by adding several types of cutting planes. Adding all valid cutting planes is compared versus adding only a few crucial ones.

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**TM 1 Solving bilevel linear programming problems using multiple objective programming**

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We present an algorithm for solving bilevel linear programming problems that uses simplex algorithm pivots. Computational results using well know test problems are presented comparing our approach with the Bard and Moore algorithm.

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**WA 4 Robust Portfolio Management**

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In this talk we will present robust models for index tracking and active portfolio management, — two basic strategies adopted by fund managers. We show that these models allow one to impose additional side constraints such as bounds on the portfolio holdings, beta-constraints, limits on cash exposure, etc. Each portfolio in this strategy is computed by solving a second order cone program.

We will also report the performance of the robust strategy in tracking and outperforming the S&P 500 index. We find that the robust strategy is able to track the index with a significantly smaller number of assets than the non-robust mean-variance index tracking strategy. The robust active portfolio management strategy significantly outperforms the S&P 500 in tests on data from 1994–2003.
MA 4 Effective use of Negative Curvature directions for large scale unconstrained optimization problems

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In this paper we are concerned with efficiently solving the large scale unconstrained optimization problem $\min_{x \in \mathbb{R}^n} f(x)$, by means of iterative methods, which converge towards second-order stationary points. Algorithms for the convergence to second order points require a deep knowledge on $f(x)$; in particular, the method in hand should be able to retrieve second order information on $f(x)$. Gould et al. (2000) proved that the Lanczos process may be successfully employed for detecting the second order local information on $f(x)$. Furthermore, the alternate use of the Newton direction and a suitable negative curvature direction of the Hessian matrix, was assessed as a winning strategy.

In this paper we assume that $n$ is large and $\nabla^2 f(x)$ is dense; then, we propose an effective algorithm which both exploits the second order local information on $f(x)$ (on the guideline of Gould et al.) and avoids large storage. We prove that the use of suitable CG-type algorithms can supply “iterative factorizations” of the Hessian matrix, which are used within a large scale unconstrained minimization algorithm. In particular, our proposal considers a Truncated Newton scheme based on a CG-like algorithm: in each outer iteration, the method iteratively calculates a pair of vectors, which both ensure the super-linear rate of convergence and the convergence to second order stationary points. We report several numerical results which support theoretical conclusions.

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MA 3 Sampling Issues for Optimization in Radiotherapy

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A variety of optimization problems arise in radiation treatment planning. These problems typically involve large amounts of data, derived from simulations of patient anatomy and the properties of the delivery device. We investigate a three phase approach for the solution of these optimization problems, based on sampling the underlying data. As a particular example, we show how the approach determines optimal beam angles, wedge orientations and delivery intensities in several 3D conformal radiation therapy patient examples, and show the applicability of the approach to a large
collection of radiation treatment problems. The use of importance sampling in this context will be outlined and general conclusions for design of sampling procedures in this context will be given.

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**MA 2** AN ADAPTIVE RESTART IMPLEMENTATION OF THE DIRECT ALGORITHM

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DIRECT, a global optimization algorithm, can be an effective tool when trying to solve medium-sized, noisy, "black-box" optimization problems with multiple local minima. The algorithm does not use derivative information about the objective function; instead, it relies on the iteration history to determine future sampling locations. In this talk, we describe DIRECT, and present some vulnerabilities we have discovered about the algorithm. A modified version of DIRECT is suggested, and test results are presented.

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**TM 1** M-STATIONARITY AS A FIRST-ORDER OPTIMALITY CONDITION UNDER MPEC-ACQ FOR MATHEMATICAL PROGRAMS WITH EQUILIBRIUM CONSTRAINTS

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Mathematical programs with equilibrium constraints are optimization problems which violate most of the standard constraint qualifications. Hence the usual Karush-Kuhn-Tucker conditions cannot be viewed as first order optimality conditions unless relatively strong assumptions are satisfied. This observation has lead to a number of weaker first order conditions, with M-stationarity being the strongest among these weaker conditions. We are able to show that M-stationarity is a first order optimality condition under a very weak Abadie-type constraint qualification, using a fairly simple and direct method of proof. Jane Ye first obtained this result using a less direct proof. In the talk, we put M-stationarity and MPEC-ACQ in perspective, demonstrating why this result is so important.

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**MM 1** BEHAVIORAL MEASURES AND COMPUTATION OF SDPLIB PROBLEMS

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When solving SDP problems using an infeasible-interior-point algorithm such as SDPT3, one observes variability in the number of iterations needed to attain approximate solutions. In this study we explore several possible explanations for this observed variability, such as (i) the level of primal and/or dual degeneracy of the optimal solutions of the problem instances, (ii) the (Renegar-) condition measure of the problem instances, and/or (iii) geometric measures of the problem instances related to the norms of optimal solutions. Using the SDPLIB problems as a test set, we report on the extent to which these or other behavioral measures of problem instances explain and/or account for the number of iterations needed to solve an SDP problem.

**Experimental Results with KNOSSOS**

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KNOSSOS is a Fortran 90 solver for large-scale constrained optimization. For nonlinear constraints it implements a stabilized LCL (sLCL) method in which linearly constrained subproblems are solved with gradually increasing accuracy. (Each subproblem minimizes an augmented Lagrangian subject to elastic linearized constraints.) The sLCL approach permits the use of existing linearly constrained solvers. KNOSSOS currently uses MINOS or SNOPT. We present numerical results on the CUTER and COPS test sets.

**Large-scale semidefinite programming in electronic structure calculation**

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The electronic structure problem we are investigating consists in determining the ground state energy of an N-electron system subject to a given external potential. It is one of the fundamental problems in quantum chemistry. It was known since the 1960s that one could obtain a lower bound for the ground state energy by solving a semidefinite program, however this approach faded away due to its great computational difficult.

Recently, with the advance of numerical semidefinite programming computation, the electronic structure calculation through the Reduced Density Matrix method has reinvigorated, and it seems a very promising approach since it gives better accuracy for the ground state energy than familiar approximations based on wavefunction for small molecules. At the same time, it is a very challenging problem because the semidefinite programs which arise here are huge-scale and they require about 7-8 digits of accuracy for the objective function values.

One of the key issues to solve this problem is to choose an appropriate formulation as a semidefinite program. Also since this problem is unusually large, it requires parallel computation, careful memory management, check points, etc. Several topics are under consideration now to solve larger problems like the conjugate gradient method, the cutting plane method, exploration of the problem structure, and handling with numerical errors.

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**TA 4 The Modified Subgradient Algorithm Based on Feasible Dual Values and Solving the Quadratic Assignment Problems**

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We study the Modified Subgradient (MSG) algorithm based on sharp augmented Lagrangian duality. This algorithm has been introduced for solving the sharp augmented Lagrangian dual problems constructed for nonconvex optimization problems. This approach guarantees a zero duality gap property and does not use any penalty parameter. The other advantage of the MSG algorithm is that it generates a strictly increasing sequence of dual values converging to the optimal value. To update stepsize parameters, at each iteration it uses an unconstrained global minimum of the augmented
Lagrangian. In this study we generalize it and present updating formulas based on solutions of a simple constraint satisfaction problem for the augmented Lagrangian and proof the convergence theorems. The new algorithm allows us to find global minimums for a wide class of nonconvex optimization problems by using different techniques for solving inequalities. To demonstrate the performance of the new algorithm we apply it to solve the well-known quadratic assignment test problems and present the obtained results. The comparison of computational times for the proposed and the earlier used methods on many test problems demonstrates a high performance of the new algorithm.

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**TA 2 Trust-Search Methods for Large-Scale Optimization**

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Recent research on interior methods has re-emphasized the role of sequential unconstrained optimization for the solution of very large nonconvex problems. However, existing line-search and trust-region methods for unconstrained optimization may get into difficulty near points at which the Hessian is singular. In such cases, line-search methods may require many iterations to converge, and trust-region methods may require many iterations to solve the constrained subproblem. A new class of methods is proposed that combines the best features of trust-region and line-search methods. These “trust-search” methods maintain the rapid convergence associated with trust-region methods while solving the subproblem at a cost comparable to that of a line-search method. This work is joint with Julia Kroyan.

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**WM 2 Solving Image Restoration Problems as Second-Order Cone Programs**

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We show how second-order cone programming can be used to solve image restoration problems based on the total variation minimization framework of Rudin, Osher and Fatemi as well as several other models. We describe nested dissection and domain decomposition techniques that enable these large problems (the number of variable and constraints are in the millions) to be solved efficiently. A new iterative refinement approach that produces improved images will also be described and computational results presented.
MA 6 A new class of incomplete LDL preconditioners for interior-point algorithms

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In this paper we present a new class of incomplete LDL preconditioners: a combination of an approximate minimum degree ordering heuristic with modified LDL factorization for interior-point algorithms. Computational experiments on NETLIB and QPLIB public domain problems sets (for linear and convex quadratic programming) are reported and demonstrate that the PLDL-Krylov scheme for solving indefinite KKT systems is often superior to the classical direct Cholesky factorization approach. Interior-point algorithm convergence (complexity) analysis for the permuted LDL preconditioner, and its incomplete flavor PLDL(k) is also presented.

TM 2 Normal maps on Symmetric cones

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In this talk, we describe some necessary and sufficient conditions for a normal map, defined with respect to a symmetric cone in a Euclidean Jordan algebra and a linear transformation, to have the (Lipschitzian) homeomorphism property.

WM 5 Iterative Methods for Systems Arising in Interior Methods

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In the context of interior-point methods for large-scale optimization, the solutions of very large linear systems are needed. As the problem size increases, the direct factorization of these systems becomes prohibitively expensive, creating a bottleneck within the interior-point algorithm. Possible alternative approaches are parallel factorization and/or the use of iterative methods. Two issues complicate the formulation of efficient
iterative methods. First, in order to retain second-order convergence near a point of optimality, an increasingly accurate solution is needed. Second, the linear systems become increasingly ill-conditioned as the iterations proceed. These difficulties imply that an effective preconditioner is vital for efficiency. This talk will focus on preconditioned iterative methods in the context of a specific interior-point method. A preconditioner will be discussed that eliminates the ill-conditioning and becomes increasingly effective as a solution is approached. Numerical results will be provided.

**WM 3**

A primal-dual method for solving nonlinear optimization problems with both inequality constraints and equations

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We consider a primal-dual method for solving nonlinear optimization problems with both inequality constraints and equations. We prove global convergence, establish 1.5-Q-superlinear rate of convergence under the standard second order optimality conditions and provide numerical results corroborating the theory.

**MM 2**

Hyperbolic Polynomials

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Homogeneous cones have a rich automorphism group (symmetry structure) which has been used by Vinberg in early 1960s to provide an algebraic classification for them – although a rough one. The same symmetry structure is also ideally suited to develop several classes interior point methods on these cones, extending some of the algorithms developed for symmetric cone programming (SDP and quadratic cone programming) to these cones. Homogeneous cones include symmetric ones as a subclass, but the vast majority of homogeneous cones are not symmetric. For this reason, new ideas and methods are needed to carry out this extension. In this talk, I will elaborate on
the work my student Olena Schevchenko and I have been carrying out on homogeneous cone programming, including our work on the supply and properties of invariant barrier functions on these cones.

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**TA 3 NLPAPI—A PROGRAMMING INTERFACE TO NONLINEAR PROGRAMMING PROBLEMS AND SOLVERS**

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NLPAPI is a programming interface for stating and solving nonlinear optimization problems. It was originally written to interface LANCELOT, which is built on a file oriented problem definition called SIF, to a program which chooses transistor widths for maximum speed and/or minimum power in integrated circuit design. More recently, we have written an interface to IPOPT, which allows it to accept problems defined via NLPAPI. LANCELOT’s Group Partially Separable Problem definition represents functions as sums of compositions of scalar functions with sums of vector valued functions. Its main advantage is in computing gradients and Hessians, since the lowest level functions can depend on small subsets of the problem variables as arguments. Derivatives are much simpler, and differencing is more economical. It does however, make for a more difficult problem definition. The approach used by LANCELOT is to create a file based problem definition language which allows the user to provide FORTRAN source code for the basic nonlinear functions, and to indicate how to build the optimization problem from these functions. The file is parsed and used to generate source code which is linked to a main program. By contrast, NLPAPI allows the basic nonlinear functions to be subroutines, and the user can use a full programming language (Fortran/C/C++) to define the combinations. This is (to some) a much more natural way to program, and allows the possibility of dynamic changes to the problem and multiple problems. I will describe the design and use of the NLPAPI, and give a few examples of its use. The code is available through COIN-OR (www.coin-or.org/NLPAPI), as are interfaces to LANCELOT and IPOPT.

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**MA 4 AN ACTIVE SET METHOD FOR SOCPs WITH A SINGLE CONE CONSTRAINT**

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In this talk we present an active set method for solving optimization problems of the
form

minimize \( f^T x \)
subject to \( H x = g, \ E x = 0, \)
and \( D x \succeq 0, \)

where the decision vector \( x \in \mathbb{R}^n, f \in \mathbb{R}^n, H \in \mathbb{R}^{m \times n}, g \in \mathbb{R}^m, E \in \mathbb{R}^{k \times n}, D \in \mathbb{R}^{p \times n} \)
and \( \succeq \) denotes the partial order with respect to the standard Lorentz or conic quadratic cone in \( \mathbb{R}^p. \) Such problems often arise in the context of robust optimization and trust region methods. The active set method exploits the fact that an SOCP with only a single cone constraint (and no inequality constraints) can be solved in closed form.

**TM 3 An Stochastic Optimization- Noncooperative Game Problem: Electricity Market model**

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This paper models an electricity market with generators and customers located in a network as a stochastic optimization/noncooperative two stage game problem. The generators are allowed to bid cost functions and are dispatched by a system operator who maximizes the total benefit while considering the electricity network constraints. We study different analytical properties of this model and prove that a Perfect Nash equilibrium exists and is robust by using stability concepts derived from variational analysis.

**TM 5 Robust Rayleigh Quotient Maximization with Applications in Signal Processing**

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We consider the robust Rayleigh quotient maximization problem which is to maximize the worst-case Rayleigh quotient of a pair of uncertain symmetric matrices. We show that this problem is equivalent to the problem of minimizing the largest generalized eigenvalue of a pair of symmetric matrices each of which depends on the variables representing the uncertainty, i.e., the generalized eigenvalue minimization problem, which can be solved globally and efficiently by interior-point methods. As practical applications in signal processing, we show that robust beamforming and robust channel shortening in the presence of unknown arbitrary-type mismatches of the desired signal responses can be cast as robust Rayleigh quotient maximization problems, and hence,
generalized eigenvalue minimization problems. We also address some computational
issues that arise in the applications.

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**MM 3 A NEW ASYNCHRONOUS PARALLEL PATTERN SEARCH**

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For many optimization problems arising in science and engineering, the function being
optimized depends on the results of a complex simulation. In these situations, derivative
information is often unavailable or extremely difficult to obtain. For such problems,
we propose the use of Asynchronous Parallel Pattern Search (APPS), a direct search
optimization method. APPS has been used successfully on applications ranging from
design of forging processes to transmembrane protein structure prediction to wild fire
simulation parameter identification. In this talk, we discuss a new APPS algorithm
and the associated software, APPSPACK 4.0. The new algorithm can handle bound
constraints and has an optional zero-order sufficient decrease condition. The software
can be run in serial or parallel and works with stand-alone programs or scripts for
computing the value of the objective function.

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**WM 4 TOWARDS A PRACTICAL SIMPLEX-LIKE METHOD FOR CONIC PROGRAMMING**

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Conic programming is perhaps “linear programming (LP)” for the 21st century, and
has a variety of applications in science and engineering. Other than LP, the two im-
portant subclasses of conic programming include semidefinite programming (SDP) and
second order cone programming (SOCP). Interior point methods (IPMs) and large
scale approaches like BMZ, BMPD, and spectral bundle are currently the ‘techniques
of choice’ for solving large SDP and SOCP problems. It is of great interest to devise a
theoretically solid and well working generalization of the LP simplex method for conic
problems. Some of the requirements for such a method are: 1) it should work with
iterates fully feasible for one of the primal and dual problems. 2) in the spirit of the
LP simplex method, work ”primarily” with the extreme points on the boundary of
the feasible set; e.g., in SDP this means working with low rank iterates whose ranks
are bounded above by the square root of the number of equality constraints in the
problem. 3) it should work reasonably well in practice, especially where reoptimization
after branching or the addition of constraints is concerned. While simple cutting plane
methods (like Kelley’s) for conic problems do generalize the LP simplex algorithm in
a sense, they do not meet criterion 2) above.

Extending the work of Pataki in 1996 and Krishnan-Pataki-Zhang in 2003, we devised
such an algorithm for SOCP. In this talk we present this algorithm which meets the
above requirements for a proper generalization of the simplex method for LP. The
algorithm generates a sequence of iterates with non-increasing objective values, which
are extreme points of the primal feasible region. Under a nondegeneracy assumption,
we show that the objective values of the iterates are in fact strictly decreasing. We
have implemented the method devoting special attention to doing every iteration of the
algorithm quickly; in particular we attempt to replicate the fast basis inverse updates
of the simplex method for LP. Finally, we present our computational experiences with
the algorithm.

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**TA 4 Global Optimization Methods and Classes of Test Functions**

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A wide literature is dedicated to studying numerical algorithms for solving continu-
ous global optimization problems. In these problems the objective function can be
multieextremal, non-differentiable, and “black box”. Development of efficient global op-
timization algorithms is impossible without examination of their behavior on sets of
sophisticated test problems. The lack of complete information (such as number of local
minima, their locations, attraction regions, local and global values, etc.) describing
global optimization tests taken from real-life applications creates additional difficul-
ties in verifying validity of the algorithms. That is why a significant effort is made to
custom test functions for which this kind of information is available.
In this talk, a procedure for generating three types (non-differentiable, continuously
differentiable, and twice continuously differentiable) of classes of multidimensional and
multieextremal test functions with known local and global minima is presented. The
procedure consists of defining a convex quadratic function systematically distorted by
polynomials. Each test class provided by the generator consists of 100 functions and
is defined by the following parameters: (i) problem dimension, (ii) number of local
minima, (iii) global minimum value, (iv) radius of the attraction region of the global
minimizer, (v) distance from the global minimizer to the quadratic function vertex. The
other necessary parameters are chosen randomly by the generator for each test function
of the class. A special notebook with a complete description of all functions is supplied
An important class of machine learning algorithms is formed by the kernel-based learning algorithms. These methods work by embedding the data into a Euclidean space, and then searching for linear relations among the embedded data points. These linear relations are often revealed by solving a convex optimization problem, e.g., a quadratic programming problem to train a binary support vector machine classifier. Moreover, linear relations in the embedding space generally correspond to non-linear relations between the original data points, thus giving kernel methods the power of non-linear approaches. The embedding is performed implicitly, by specifying the inner products, between each pair of images of data points in the embedding space, in the so-called kernel matrix, a symmetric and positive semidefinite matrix. Specifying this matrix amounts to specifying the geometry of the embedding space. Clearly, the choice of the kernel matrix is a crucial step to obtain good predictive performance with any kind of kernel method. For a binary classification setting with support vector machines (SVMs), I will show how the optimal kernel matrix can automatically be learned from data via semidefinite programming (SDP) techniques. Under certain assumptions, this SDP can be solved more efficiently as a QCQP, which, in turn, can be solved very efficiently by decomposition. This makes the approach applicable for practical problems of large size. I will conclude with a short example that shows the applicability of this approach to predict gene function from heterogeneous genome-wide data.

We present a new methodology for the numerical pricing of a class of exotic derivatives such as Asian or barrier options when the underlying asset price dynamics are modelled by a geometric Brownian motion or a number of mean-reverting processes of interest. This methodology identifies derivative prices with infinite-dimensional linear program-
ming problems involving the moments of appropriate measures, and then develops suitable finite-dimensional relaxations that take the form of semi-definite programs indexed by the number of moments involved. By maximising or minimising appropriate criteria, monotone sequences of both upper and lower bounds are obtained. Numerical investigation shows that very good results are obtained with only a small number of moments. Theoretical convergence results are also established.

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**TM 1 Dynamic Slope Scaling Procedure and Lagrangian Relaxation with Subproblem Approximation**

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The dynamic slope scaling procedure (DSSP) is an efficient heuristic algorithm that provides good solutions to the fixed-charge transportation or network flow problem. In this paper, we formulate the fixed-charge problem as a mathematical programming problem with complementarity constraints and show that DSSP is equivalent to a Lagrangian relaxation technique in which the subproblem is solved approximately. Instead of using subgradients of the Lagrangian function, the technique relies on the Karush-Kuhn-Tucker multipliers of the fixed-charge problem in an attempt to find an improved solution.

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**MA 5 COMPl_lib : CONSTRAINED MATRIX-OPTIMIZATION PROBLEM LIBRARY – A COLLECTION OF TEST EXAMPLES FOR NONLINEAR SEMIDEFINITE PROGRAMS, CONTROL SYSTEM DESIGN AND RELATED PROBLEMS**

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We present a collection of test examples which can be used for testing and comparing algorithms for nonlinear semidefinite programs (NSDPs), bilinear matrix inequality (BMI) and related problems. The examples in COMPl_lib are drawn from a variety of control systems engineering applications (including PDE-based models). Currently, COMPl_lib contains a total of 124 examples coded in standard MATLAB matrix format. From the COMPl_lib data it is possible to formulate several constrained matrix optimization problems, for example, NSDPs, BMIs and other related matrix problems. In particular, COMPl_lib may serve as a useful benchmark tool for NSDP (including BMI) and other matrix optimization problem (including linear SDP) solvers. As a byproduct, COMPl_lib can be also used as a test environment for parts of control design procedures, for example, model reduction algorithms and Riccati equation solvers.

In this talk we provide a short overlook of all test examples in COMPl_lib 1.0 and discuss some PDE-based models which are currently implemented in COMPl_lib. Then, we state some NSDP, BMI and SDP formulations which can be built by the COMPl_lib
Finally, it is hoped that COMPlib will stimulate the development of improved software for the solution of constrained matrix optimization problems, in particular, algorithms for solving (large) NSDPs.

**MM 6 One-Size-Fits-All Convergence Analysis For Numerical Optimization**

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A generic algorithm for solving inclusions is presented and shown to cover many numerical optimization methods (including generalized quasi-Newton methods, proximal point algorithms, penalty/barrier methods, trust region methods, interior point methods, and a generalized primal SQP method). Convergence of the generic algorithm is related to a nonsingularity condition and a generalized Taylor approximation condition. Connections to existing results are made and new possibilities are exposed.

**TS MPECs: For a Fistful of Dollars**

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An exciting new nonlinear modeling paradigm is mathematical programs with equilibrium constraints (MPEC). Problems of this type arise in many engineering and economic applications and cover diverse areas such as the design of structures involving friction, elasto-hydrodynamic lubrication, taxation models, the modeling of competition in deregulated electricity markets, and transportation network design. An attractive and cheap way to solve MPECs is to reformulate them as nonlinear programming (NLP) problems and apply a standard NLP solver. Until recently, this approach had been regarded as numerically unsafe. We survey recent advances in the implementation and theory of NLP solvers for MPECs. Both active set approaches and interior point techniques are considered. We discuss future challenges and open questions.

**TM 1 Solving MPCCs with Interior Methods**

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We study an algorithmic framework for solving a L1-penalty reformulation of Mathematical Programs with Complementarity Constraints (MPCC) with interior methods. The preservation of first and second order conditions under this reformulation is proved, from which standard results on speed of convergence and distance to the solution for interior methods follow. Convergence of the inexact barrier scheme to strongly-stationary points is proved under standard assumptions. We show that the regularization and the penalty approaches are equivalent within the framework of interior methods. An updating strategy for the penalty parameter is proposed, which is suitable for a more general class of NLP algorithms. Extensive numerical results on an extended MacMPEC collection demonstrate the efficiency and robustness of this approach.

TM 4 CONVERGENCE ANALYSIS OF AN INEXACT INTERIOR-POINT QUADRATIC PROGRAMMING ALGORITHM

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In this paper, we extend our results in a previous paper to convex quadratic programming, where the quadratic matrix $Q$ has a known factorization $Q = VV^T$. We build a new equation, the augmented normal equation (ANE), to determine the search directions at each step. In addition, we show that we can solve the ANE to sufficient accuracy using an iterative solver, and that the number of iterations required is bounded by $n$ and a condition number which depends on a matrix containing $A$ and $V$. We then give a method to spread out the error from the ANE so that we retain polynomial convergence in the number of “outer” iterations. Finally, we show that the number of “outer” iterations in our algorithm is bounded by $O(n^2 \log \epsilon^{-1})$, where $n$ is the number of columns of $A$.

TM 5 OPTIMAL MULTI-USER SPECTRUM MANAGEMENT FOR DIGITAL SUBSCRIBER LINES

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We formulate the problem of multi-user spectrum management for digital subscriber lines (DSL) as a nonlinear complementarity problem (NCP). We study conditions under which the resulting NCP belongs to the class $P_0$ and its solution is B-regular. The NCP...
formulation makes it possible to use the Newton type smoothing methods to efficiently compute a Nash equilibrium solution. In our computer simulations, the smoothing method appears much more robust to the presence of strong interference than the existing Iterative Water-filling method. We also present a reformulation of this problem as a linear complementarity problem and use it to establish the linear convergence of the Iterative Water-filling method for the case where the multi-user interferences are symmetric. This is joint work with Nobuo Yamashita of Kyoto University and Jong-Shi Pang of Rensselaer Polytechnic Institute.

WA 1 WHEN TO USE EVOLUTIONARY ALGORITHMS AS GENERAL PROBLEM SOLVERS?

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In optimization, evolutionary algorithms do not exploit problem-specific information such as convexity, differentiability, number of local minima, number of variables, etc. Therefore, evolutionary algorithms are seldom the most effective methods for any specific problem. The strength of the evolutionary algorithms is that they are able to solve a wide range of optimization problems, which is an appealing property and has made them as popular as they are today. In this paper, we compare the general problem solving abilities of an evolutionary algorithm, two multistart methods and a hybrid combining an evolutionary algorithm and a local search. We study whether we can find some guidelines when to use evolutionary algorithms and when local search based methods may be preferable. We test the performance of the methods numerically using a large set of test problems from the literature.

MP OPTIMIZATION IN DATA MINING

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Optimization plays a significant role in data mining: the process of analyzing data in order to extract useful patterns and relations such as clusters and classes. Clustering, a major branch of unsupervised machine learning, is amenable to a fruitful application of optimization theory. This leads to effective algorithms such as the k-median clustering algorithm and the suppression of irrelevant features of the data. Classification on the other hand, a mainstay of supervised machine learning and data mining, is an extremely rich field of application for optimization theory and its algorithms. Support vector machines (SVMs) constitute the core of modern classification theory. SVMs have been extensively used in the last decade, even though they were introduced some forty years ago. Through the use of nonlinear kernel functions, SVMs are powerful tools not only in classification theory but also in function approximation as well as nonconvex
function optimization. Kernels allow the introduction of complex nonlinear structures into classifiers and nonlinear function approximation by using linear programming only. Topics such as the above will be presented as well as applications to medicine and bioinformatics.

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**WA 4** Optimal Semi-Static Hedging of Barrier Options in Heston’s Stochastic Volatility Model

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Optimization problems governed by stochastic differential equations have various applications in finance. As financial market data changes very quickly, fast numerical algorithms are required. During the talk we consider a nested sample average approximation method for the solution of the corresponding optimization problems and present some numerical results. As an example, we introduce the problem of optimal semi-static hedging of barrier options in Heston’s stochastic volatility model by liquidly traded standard options. The obtained hedging strategies are compared to other hedging approaches found in the literature.

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**TY 2** Computation of robust stability measures for discrete systems

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**WA 2** A superlinearly convergent VU-algorithm for convex minimization

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This talk describes a globally and superlinearly convergent algorithm for minimizing a convex function. The method requires only one subgradient value with each function evaluation and so is useful for decomposition applications. It is most efficient for functions having primal-dual gradient (pdg) structure. This C² substructure differs from that of a fully amenable function, because the pdg class contains maximum eigenvalue functions and other “infinitely-defined” functions. This structure is defined at a point and linked to a VU-space decomposition there depending on the function’s subdifferential. Under a strong transversality assumption there exists a C² primal track and
a $C^1$ dual track, respectively, leading to a minimizing point and a zero subgradient. If the function has a strong minimizer then the primal track is a “fast track” with the property that the proximal point of any point near the minimizer is on this track. This is important because a proximal point can be approximated with any desired accuracy via a bundle method subprocedure that collects subgradients for constructing a V(or cutting-plane)-model of the function. Also, explicit knowledge of any existing pdg structure is not needed for such a construction. Our rapidly convergent algorithm exploits structural properties by approximating a corresponding primal-dual track via “U-Newton-steps” alternating with “V-steps”. Each V-step and a “U-gradient” for defining its U-step successor is produced by a subroutine terminating with a convex combination of bundled subgradients having a zero approximate V-component.

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**MM 5** An interior-point method for MPECs based on strictly feasible relaxations,

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An interior-point method for solving mathematical programs with equilibrium constraints (MPECs) is proposed. At each iteration of the algorithm, a single primal-dual step is computed from each subproblem of a sequence. Each subproblem is defined as a relaxation of the MPEC with a nonempty strictly feasible region. In contrast to previous approaches, the proposed relaxation scheme preserves the nonempty strict feasibility of each subproblem even in the limit. Local and superlinear convergence of the algorithm is proved even with a less restrictive strict complementarity condition than the standard one. Moreover, mechanisms for inducing global convergence in practice are proposed. Numerical results on the MacMPEC test problem set demonstrate the fast-local convergence properties of the algorithm.

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**MA 5** A Unifying Framework for Several Cutting Plane Methods for Semidefinite Programming

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Cutting plane methods provide the means to solve large scale semidefinite programs (SDP) cheaply and quickly. They can also conceivably be employed for the purposes of re-optimization after branching, or the addition of cutting planes. We give a survey of various cutting plane approaches for SDP in this paper. These cutting plane approaches arise from various perspectives, and include techniques based on interior point cutting plane approaches, non-differentiable optimization, and finally an approach which mimics the simplex method for linear programming (LP). We present an accessible introduction to various cutting plane approaches that have appeared in the literature. We place these methods in a unifying framework which illustrates how each approach arises as a natural enhancement of a primordial LP cutting plane scheme based on a semi-infinite formulation of the SDP.

MA 4 Comparing solvers for the optimization of noisy problems

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In this talk we compare different software packages designed to solve unconstrained optimization problems in which the objective function has noise. In our comparison we use a subset of the CUTE collection in which gaussian noise has been added to the objective function.

TA 1 Equilibrium Problems with equilibrium constrains via multiobjective optimization

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We discuss a new class of optimization-related problems called Equilibrium Problems with Equilibrium Constraints (EPECs). One may treat them as two-level hierarchical problems, which involve equilibria at both lower and upper levels. Such problems naturally appear in various applications providing an equilibrium counterpart (at the upper level) of Mathematical Programs with Equilibrium Constraints (MPECs). This talk presents a unified approach to both EPECs and MPECs from the viewpoint of multiobjective optimization subject to equilibrium constraints. The problems of this type are intrinsically nonsmooth and require the use of generalized differentiation for their analysis and applications. We obtain necessary optimality conditions for EPECs in finite-dimensional spaces based on advanced generalized differential tools of variational analysis.
MC Cyber Infrastructure Panel Discussion

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WA 4 Nonlinear Discrete Programming for solving the combinatorial and continuous index plus alpha fund optimization

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An improved surrogate constraints (ISC) method for optimally solving large-scale separable nonlinear integer programming problems with multiple constraints has been presented by Nakagawa in 2003. We address the non-separable non-convex optimization problem that chooses the type and quantity of m index stocks from n original stocks
\((m < n)\) in order to minimize the variance between the return from the \(n\) original stocks and the \(m\) chosen stocks, while also maintaining a higher mean rate of return. A high quality solution was found to the problem of choosing 50 stocks from the 225 Japanese Nikkei stocks using data from April 1995 to March 1998. The second order moment error from the Nikkei 225 of the solution was just 0.0000148. The present method can also be easily applied to the index plus alpha fund problem.

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**TM 6 “Cone-Free” Primal-Dual Path-Following and Potential-Reduction Polynomial Time Interior-Point Methods**

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We present a framework for designing and analyzing primal-dual interior-point methods for convex optimization. We assume that a self-concordant barrier for the convex domain of interest and the Legendre transformation of the barrier are both available to us. We directly apply the theory and techniques of interior-point methods to the given good formulation of the problem (as is, without a conic reformulation) using the very usual primal central path concept and a less usual version of a dual path concept. We show that many of the advantages of the primal-dual interior-point techniques are available to us in this framework and therefore, they are not intrinsically tied to the conic reformulation and the logarithmic homogeneity of the underlying barrier function.

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**WS Complete search for constrained global optimization**

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Theoretical tools for the reliable solution of global optimization problems have continuously improved over the years. While, in the past, stochastic approaches of limited reliability were indispensable for all global problems of significant size, complete search techniques can now handle reliably many large problems. Successful strategies require the intelligent combination of convex analysis, constraint propagation, and interval techniques in a branch and bound approach and the careful handling of rounding error issues. Moreover, techniques from semidefinite programming have shown high promise. There are now several powerful packages on the market exploiting these tools.

The lecture discusses complete search techniques for the solution of global optimization problems, covering the most successful methods, important software, and benchmarking results.
MA 3 EXPERIENCES IN FORMULATING AND SOLVING RADIOTherAPY TREATMENT PLANNING PROBLEMS AS OPTIMIZATION PROBLEMS

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Optimization has become an important tool in treatment planning for cancer radiation therapy. It may be used to determine beam weights, beam directions, and appropriate use of beam modifiers such as wedges and blocks, with the aim of delivering a specified dose to the tumor while sparing nearby critical structures and normal tissue. The effectiveness of a given dose distribution can be measured by “physical” objectives and constraints (which compare the delivered dose explicitly to the dose prescribed by the physician at each “voxel” in the patient’s body) or “biological” functions (which attempt to relate the given dose distribution to the probability of tumor control, the probably of normal tissue complications, and so on). Linear programming formulations are a core computation in many approaches to treatment planning involving physical functions, but such formulations often require a surprisingly large amount of time to solve. The choices of formulation, algorithm, and pivot rule that perform best from a computational viewpoint are sometimes not obvious, and the default choices made by standard software packages are sometimes poor. We consider several linear programming formulations of the treatment planning problem and compare the performance of variants of simplex and interior-point methods on these formulations. In the second part of the talk, we consider nonlinear optimization formulations of the treatment planning problem that uses a biological objective function based on equivalent uniform dose (EUD). We discuss the characteristics of this optimization problem and compare different techniques for solving it.

TM 4 A NEW CONJUGATE GRADIENT-BASED ALGORITHM MODIFIED FOR USE WITH ELLIPSOID PRECONDITIONERS

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The conjugate gradient (CG) algorithm is well-known to have excellent theoretical properties for solving linear systems of equations where the matrix is positive definite.
However, for extremely ill-conditioned systems the CG algorithm performs poorly in practice. In this talk, we discuss an adaptive preconditioning procedure which improves the practical performance of the CG algorithm on extremely ill-conditioned systems. The adaptive preconditioners employed are based on results from the Ellipsoid Method. We require that the initial matrix have all eigenvalues greater than or equal to one. We present both theoretical and computational results comparing our algorithm with the standard CG method.

**TA 2** An Interior-point L₁-penalty Method for Nonlinear Optimization

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A mixed interior/exterior-point method for nonlinear programming is described, that handles constraints by an L₁-penalty function. A suitable decomposition of the penalty terms and embedding of the problem into a higher-dimensional setting leads to an equivalent, surprisingly regular, reformulation as a smooth penalty problem only involving inequality constraints. The resulting problem may then be tackled using interior-point techniques as finding a strictly feasible initial point is trivial. The reformulation relaxes the shape of the constraints, promoting larger steps and easing the nonlinearity of the strictly feasible set in the neighbourhood of a solution. Under the Mangasarian–Fromovitz constraint qualification, exactness of the penalty function eliminates the need to drive the corresponding penalty parameter to infinity. Global and fast local convergence of the proposed scheme are established and practical aspects of the method are discussed.

**WM 4** A Matrix Generation Approach for Eigenvalue Optimization

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An extension of a column generation technique to eigenvalue optimization is presented. In our approach we utilize the method of analytic center to obtain the query points in each iteration. A restricted master problem in the primal space, corresponding to the relaxed dual problem, is formed. At each step of the algorithm, an oracle is called to return the necessary columns to update the restricted master. Since eigenvalue
optimization yields to a nonpolyhedral model, at some query points the oracle generates matrices, rather than traditional columns. In this case, we update the restricted master problem by enlarging the matrix variable by a block-diagonal element. Computational experience of implementing the algorithm on randomly generated problems is reported.

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**TA 1** ON STABILITY OF EQUILIBRIUM CONSTRAINTS

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The contribution concentrates on calmness of a special constraint structure, frequently arising in a number of parameter-dependent equilibrium problems. This property is ensured by new qualification conditions, which enables to weaken some statements of the generalized differential calculus. In particular, this result may be used in the computation of the limiting normal cone to the considered constraint system and in the computation of coderivatives of equilibrium maps. In this way, one obtains a new criterion ensuring the Aubin property of these maps.

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**MM 2** SYMMETRIES IN SEMIDEFINITE PROGRAMMING, AND HOW TO EXPLOIT THEM

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Semidefinite programming (SDP) techniques have been extremely successful in many practical engineering design questions. In several of these applications, the problem structure is invariant under the action of some symmetry group, and this property is naturally inherited by the underlying optimization. A natural question, therefore, is how to exploit this information for faster, better conditioned, and more reliable algorithms. To this effect, we study the associative algebra associated with a given SDP, and show the striking advantages of a careful use of symmetries. The results are motivated and illustrated through applications of SDP and sum of squares techniques from networked control theory, analysis and design of Markov chains, and quantum information theory.

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**MM 2** OPTIMAL SEMI-PARAMETRIC BOUNDS FOR EUROPEAN RAINBOW OPTIONS

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We consider the problem of computing the best upper and lower semi-parametric bounds on the expected payoff of a European "rainbow" option; that is, an option whose payoff depends on the price of various underlying asset prices. In practice, these bounds are used to obtain information about option prices under incomplete market conditions, or to approximate options prices that are difficult to compute exactly. We show how sum-of-squares techniques can be used to either prove the optimality or improve the best known semi-parametric bounds for European options on the maximum of several assets. In addition, we show that these same techniques can be applied to a wide variety of European rainbow options.

**MM 6 Discretization of stochastic programs**

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In many stochastic optimization problems in practice, the uncertain factors are best modeled as random variables with an infinite support. This is the case, for example, in many financial planning problems, where the most successful models of financial data are econometric models with continuous distributions. The resulting optimization problems can rarely be solved directly, so numerical techniques are required. This talk presents discretization approaches that are based on modern techniques of high-dimensional numerical integration.

**WM 1 The “Price of Anarchy” under Nonlinear and Asymmetric Costs**

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In this talk we characterize the inefficiency between user and system optimal solutions (also referred to as the “price of anarchy”) , when costs are non-separable, asymmetric and nonlinear, generalizing earlier work that under separable costs. The generalization in this work models traffic equilibria, competitive multi-period pricing and competitive supply chains. The bounds established in this talk are tight and explicitly account for the degree of asymmetry and nonlinearity of the cost functions. We also introduce an alternate proof method for providing bounds that uses ideas from semidefinite optimization. Finally, in the context of multi-period pricing our analysis establishes that user and system optimal solutions coincide.

**WM 3 Primal-Dual method for convex optimization based on Lagrangian Transformation**

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A class of strictly concave functions with particular properties is used to transform terms of the Classical Lagrangian associated with the constraints of a given constrained optimization problem. The transformation is scaled by a vector of positive scaling parameters, one for each constraint. The Lagrangian Transformation (LT) leads to LT multiplier method. Each step of the LT method alternates the unconstrained minimization of LT in primal space followed by both Lagrange multipliers and scaling parameters update. One step of the LT method can be replaced by solving a Primal-Dual system of nonlinear equations. We will show the key role of the Primal-Dual system in the computational process. Newton method for solving the Primal-Dual system leads to the Primal-Dual LT method. Global convergence of the Primal-Dual LT with asymptotic quadratic rate will be discussed and numerical results that corroborate the theory will be presented.

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**MA 6**

**A CORRECTOR-PREDICTOR INTERIOR POINT METHOD FOR SUFFICIENT LINEAR COMPLEMENTARITY PROBLEMS IN A WIDE NEIGHBORHOOD OF THE CENTRAL PATH**

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The most efficient interior point methods for linear complementarity problems produce a sequence of iterates in a wide neighborhood of the central path that converges to an optimal solution. Most of the algorithms studied in the literature are of predictor-corrector type. It turns out that it may be advantageous to first take a corrector step and then a predictor step. In this way we work with only one neighborhood of the central path instead of two. Moreover, the algorithm does not depend on the handicap of the sufficient linear complementarity problem. Also, in case of wide neighborhoods we can design the corrector step in such a way that both the proximity to the central path and the duality gap are improved. The resulting algorithm has optimal computational complexity and is superlinearly convergent even on degenerate problems. Initial numerical experiments show that it compares favorably with existing algorithms.

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**MM 5**

**PARAMETER ESTIMATION IN METABOLIC FLUX BALANCE MODELS FOR BATCH FERMENTATION—FORMULATION & SOLUTION USING DIFFERENTIAL VARIATIONAL INEQUALITIES (DVIs)**

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In this work we present a framework for predicting fermentation operations by mod-
eling the interaction between metabolism and growth. The governing equations for the system are metabolite evolution differential equations, Linear Program (LP) modeling cell metabolism and piecewise smooth functions modeling the links modifying cell metabolism. We propose an equivalent formulation using Differential Variational Inequalities (DVIs). Discretization of the system and reformulation of the VIs using optimality conditions converts the DVI to a Mathematical Program with Complementarity Constraints (MPCC). Here we describe an interior point algorithm for solving the MPCC. Encouraging numerical results are presented in estimating model parameters to model prediction and data obtained from fermentation using cultures of Saccharomyces cerevisiae.

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**TA 1 Sensitivity of EPEC solutions**

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An EPEC, equilibrium program with equilibrium constraints, is a kind of bilevel game. When complementarity constraints define the lower level, for example the (upper-level) players’ strategies are parameters in a lower-level nonlinear complementarity problem, we have an EPCC. Though ”EPEC” and ”EPCC” are recent terms, these kinds of models are already familiar in electricity markets, and are appearing in other areas such as revenue management.

The usual game-theoretic solution concept is a Nash equilibrium, i.e. a list of strategies such that no player has any incentive to change its strategy. On one hand, existence of Nash equilibria does not seem to be guaranteed for EPECs, even in cases that appear to be similar to ”good” cases in single-level games. On the other hard, it is often possible to find an equilibrium for a specific problem. Given an equilibrium of an EPCC, our goal is to understand what might happen if the EPCC is perturbed slightly.

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**TA 3 The Computational Infrastructure for OR Project: COIN-OR**

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The COIN-OR (www.coin-or.org) initiative is a consortium of researchers in both industry and academia interested in the development of interoperable, open source software tools for operations research. The goals of the project include supporting and promoting such development by hosting a software repository, facilitating the establishment of interface standards, and providing for software what the open literature provides for theory. This talk will be a brief introduction to the COIN-OR project and the open
source development model, as well as an overview of the optimization software tools currently available in the repository.

**TY 1**

**Polynomial Convergence of Interior-Point Algorithms on Symmetric Cones**

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Conic programs are optimization problems where a linear function is minimized over the intersection of an affine space and a closed convex cone. An interior-point algorithm for conic programs over symmetric cones derived from associative algebras is presented. This setting naturally generalises semidefinite programming. In the process, a Lyapunov-type lemma is established in this framework. The algorithms start at an initial point that is in the interior of the cone but not necessarily in the affine space. The difficulty of analysing such infeasible-interior-point methods compared to methods that start at a feasible point is highlighted. The iterates are restricted to a wide neighborhood of the central path, inside of the cone. A polynomial convergence result for the algorithm is presented.

**MM 4**

**The $\nu$-Trick for Image Reconstruction**

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A common way of image denoising is to project a noisy image to the subspace of admissible images made for instance by PCA. However, a major drawback of this method is that all pixels are updated by the projection, even when only a few pixels are corrupted by noise or occlusion. We propose a new method to identify the noisy pixels by $\ell_1$-norm penalization and update the identified pixels only. The identification and updating of noisy pixels are formulated as a single linear program. The application of the well-known $\nu$-trick is particularly useful in this context as it allows the specification of the fraction of pixels to be updated. Moreover, we extend the linear program to be able to exploit prior knowledge that occlusions often appear in contiguous blocks (e.g. sunglasses on faces). The basic idea is to penalize boundary points and interior points of the occluded area differently. We are able to show the $\nu$-property also for this extended LP leading a method which is easy to use. Experimental results impressively demonstrate the power of our approach.

**MA 3**

**The solution of optimization problems for IMRT and IMPT treat-**
Different approaches to the computation of beam intensity profiles for Intensity Modulated Radiation Therapy (IMRT) treatment planning in cancer treatment lead to various types of large-scale optimization problems where, in the past, the majority of these have been continuous linear, mixed-integer linear, or simple-bound-constrained least-squares type problems. In this talk we suggest an optimization model for IMRT which includes the (logarithmic) Tumor Control Probability (TCP) as objective function and, among others, Equivalent Uniform Dose (EUD) and Partial Volume (PV) constraints, which recently have come into the focus of interest. In comparison to simplified replacements of these constraints which have been employed, the direct implementation of such functions leads to large-scale nonlinear optimization problems with a nonempty feasible set, which are solved by a Lagrangian barrier-penalty type algorithm. In the typical situation of clinical practice where normal tissue dose tolerances are set too restrictively initially and therefore an obtained solution does not provide a required tumor dose, a sensitivity analysis is applied to arrive at an altered problem, which is usually solved rapidly by use of the previously obtained solution as a starting point. Finally we show that treatment planning for Intensity Modulated Proton Therapy (IMPT), which has recently met with increasing interest, leads to optimization problems which are similar to those for IMRT, but have a significantly larger number of variables (30 to 50 thousand). We especially apply again a TCP objective and EUD and PV constraints and demonstrate that the resulting problems can be solved by the algorithm mentioned above. Case examples for both IMRT and IMPT are presented.

WA 2 A Parallel Radial Basis Function Method for Global Optimization

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We develop a parallel global optimization method for computationally expensive functions that is based on the radial basis function (RBF) method by Gutmann (2001). Here, we assume that the time to evaluate the expensive function is constant, which is a fairly reasonable assumption in practice. The RBF method by Gutmann requires a guess t of the global minimum value of the expensive function in each iteration, and
the next point for function evaluation is chosen to be the point $y$ that minimizes the
bumpiness of the RBF model that interpolates previously evaluated data points and the
additional data point $(y,t)$. To keep all processors busy, we modify this RBF method
so that it generates as many candidate evaluation points as there are processors. We
show good speedups for the resulting parallel RBF method on several test problems
for global optimization. We also show promising results on a real application involv-
ing the detoxification of groundwater contaminated by chlorinated ethenes, where the
simulation time is approximately 2.5 hours.

**TA 5 Isolated minimizers, proper efficiency and stability for $C^{0,1}$ con-
strained vector optimization problems**

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In this paper we consider the vector optimization problem

$$\min_C f(x), \quad g(x) \in -K,$$

where $f : \mathbb{R}^n \to \mathbb{R}^m$ and $g : \mathbb{R}^n \to \mathbb{R}^p$ are $C^{0,1}$ functions and $C \subset \mathbb{R}^m$ and $K \subset \mathbb{R}^p$
are closed convex cones. We give several notions of solutions (efficiency concepts),
among them the notion of a properly efficient point ($p$-minimizer) of order $k$ and the
notion of an isolated minimizer of order $k$. We show that each isolated minimizer
of order $k \geq 1$ is a $p$-minimizer of order $k$. The possible reversal of this statement
in the case $k = 1$ is the main subject of the investigation. For this study we apply
some first order necessary and sufficient conditions in terms of Dini derivatives. We
show that the given optimality conditions are important to solve the posed problem,
and a satisfactory solution leads to two approaches toward efficiency concepts, called
respectively sense I and sense II concepts. Relations between sense I and sense II
isolated minimizers and $p$-minimizers are obtained. In particular, we are concerned in
the stability properties of the $p$-minimizers and the isolated minimizers. By stability,
we mean that they still remain the same type of solutions under small perturbations
of the problem data. We show that the $p$-minimizers are stable under perturbations
of the cones, while the isolated minimizers are stable under perturbations both of the
cones and the functions in the data set. Further, we show that the sense I concepts are
stable under perturbations of the objective data, while the sense II concepts are stable
under perturbations both of the objective and the constraints.

**TP Optimization and Economic Equilibrium**

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In the classical models of economic equilibrium, going back to Arrow and Debreu in the 1950’s, consumers of goods maximize utility while producers of goods maximize profits, subject to constraints on production capabilities, consumption feasibilities, and trade budgets that are tied to initial endowments. This would reduce optimization pure and simple if the market prices were known in advance, but they aren’t. The key issue, in fact, is that of determining prices for which the resulting optimization will create a balance between supply and demand.

Most of the attention in the economics literature has been devoted to establishing existence of such prices, which isn’t so simple and tends to require assumptions that are either unpleasantly restrictive or next to impossible to verify. Interest in approaching equilibrium computationally has been increasing, however. Economists working on the matter have mainly tried reducing everything to the solution of large-scale systems of nonlinear equations in which inequality constraints are ignored or suppressed. Optimization methodology, in its current highly advanced state, should be able to offer much more effective approaches, both conceptually and numerically. This talk will survey the subject and explain some of the progress that has recently been made.

**TA 5** Parametric Convex Quadratic Optimization; Simultaneous Parameterization of the Objective Function and Right-Hand-Side Vectors

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We present an IPM and optimal partition based technique and provide a polynomial time algorithm for conducting sensitivity and parametric analysis of Convex Quadratic Optimization problems. The novelty of our results is that we allow simultaneous variation in the coefficient vector of the linear term of the objective function and in the right-hand side vector of the constraints. The best known application of parametric quadratic programming is the financial portfolio selection problem, however it has numerous engineering applications too.

**MA 3** Integrating treatment plan design and delivery for IMRT

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We consider the problem of radiation therapy treatment planning for cancer patients using a technique called intensity modulated radiation therapy (IMRT). In IMRT, the patient is irradiated from several different directions. From each direction, one or more irregularly shaped radiation beams of uniform intensity are used to deliver the treatment. We formulate the problem of designing a treatment plan for IMRT that determines an optimal set of such shapes (called apertures) and their corresponding intensities as a convex optimization problem. This is in contrast with established two-stage approaches where, in the first phase, a somewhat idealized so-called fluence map is determined, which then in a second phase is approximated by a deliverable treatment plan stated in terms of apertures and corresponding intensities. Our integrated approach further allows us to take into account several other delivery aspects explicitly. In particular, we will account for radiation leakage, which occurs due to the fact that it is not possible to perfectly block part of a radiation beam to form an aperture. In addition, we will investigate the trade-off between treatment time and quality by imposing a limit on the total time the radiation beam is on during treatment. We develop a column generation approach to solving the optimization problem, and show that the associated pricing problem can be solved in polynomial time while incorporating several different equipment-specific constraints on the aperture shapes.

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**MM 6 On Regularity Conditions in Generalized Semi-Infinite Programming**

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The paper deals with the class (GSIP) of generalized semi-infinite programming problems where the index set of the inequality constraints depends on the decision vector and all appearing functions are assumed to be continuously differentiable. We introduce an extension of the Kuhn-Tucker constraint qualification (which is based on the existence of a tangential continuously differentiable arc) to the class (GSIP), prove a corresponding Karush-Kuhn-Tucker theorem and discuss its assumptions. Finally, we present several examples which illustrate for (GSIP) some interrelations between the considered extensions of the Mangasarian-Fromovitz constraint qualification, the Abadie constraint qualification and the Kuhn-Tucker constraint qualification.
Risk-averse stochastic optimization: semi-infinite chance constraints

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We discuss stochastic optimization problems with continuum of chance constraints arising in the context of stochastic dominance of first order. This type of constraints, frequently called stochastic ordering constraints, has been introduced in statistics and further applied and developed in economics. We develop first order necessary and sufficient conditions of optimality for these models. We show that the Lagrange multipliers corresponding to dominance constraints are piecewise constant non-decreasing utility functions. We also show that the convexification of stochastic ordering relation is equivalent to second order stochastic dominance relation. The model represents a new approach to decisions under uncertainty in which random outcomes dependent on our decisions are compared with stochastic reference points. The analysis demonstrates that the expected utility approach is dual to the new one.

Refining TRPOD – Trust Region Methods applied to Proper Orthogonal Decomposition

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Proper Orthogonal Decomposition (POD) can lead to powerful reduced order models in various problems of fluid flow. A large scale complex optimization problem with PDEs is substituted by a reduced order model of smaller dimension. The resulting small scale optimization problem is solved and the model is updated using a trust region strategy. In the new approach, the original optimization problem is replaced by a sequence of small to mid and large scale optimization problems with ODEs. The management of the refinement of the reduced order models is carried out using trust region ideas. This results in superior numerical results over common adaptive strategies in the contexts of PODs.

On strengthening polyhedral relaxations for nonconvex mathematical programs

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Because nonlinear programs are harder to solve and associated with more numerical issues than linear programs, we have recently developed polyhedral relaxations of nonconvex mathematical programs and implemented them in the global optimization package BARON. In particular, after transforming a given nonconvex program into a partially separable equivalent, we apply a sandwich algorithm to construct a polyhedral approximation of the nonlinear convex envelopes of univariate functions of the separable program, thus obtaining a polyhedral relaxation of the original program. In this talk, we describe methodology that takes advantage of special structures of a nonconvex mathematical program in order to strengthen these polyhedral relaxations. In particular, two avenues are explored:

1. In the tradition of modeling languages for optimization, a single model is passed to a solver for solution. We extend BARON’s modeling language in order to facilitate the communication of problem-specific relaxation information from the modeler to the branch-and-bound solver. This effectively results into two models being passed from the modeling language to the solver. Important application areas involve: RLT constraints, first-order optimality constraints, and problem-specific constraints. In all cases, nonlinear constraints are provided only to the relaxation constructor in order to strengthen the lower bounding step of the algorithm without complicating the local search process.

2. We implement a cutting plane generation scheme that significantly reduces the relaxation gap of an initial LP relaxation by constructing supporting hyperplanes of the nonlinear convex envelopes of nonconvex functions at the solution of the LP relaxation in a repetitive function. The procedure is applied at every node of the branch-and-bound algorithm. Extensive computational results with BARON are presented and demonstrate that the proposed techniques reduce relaxation gaps and expedite the search process, often by several orders of magnitude.

There are two journal papers related to this material. A paper related to item (1) above has been accepted for publication in JOGO. A paper related to (2) above is currently being written for the special issue of Mathematical Programming B edited by Moré and Leyffer. It will be available at http://archimedes.scs.uiuc.edu as soon as it is completed.
In this study we examine the performance of modified subgradient algorithm to solve the 0-1 quadratic knapsack problem (QKP). Firstly, zero-one nonlinear problem is converted into continuous nonlinear problem by adding only one constraint and not adding new variables. For solving the continuous QKP we construct dual problem with “zero duality gap” by using the augmented Lagrangian function, then for solving dual problem modified subgradient method proposed by Gasimov is used. Finally computational results for some test problems are presented.

**WA 2 MINIMAL COERCIVITY CONDITIONS AND EXCEPTIONAL FAMILIES OF ELEMENTS IN QUASIMONOTONE VARIATIONAL INEQUALITIES**

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A coercivity condition is usually assumed in variational inequalities over a noncompact domain to guarantee the existence of a solution. We derive minimal, i.e., necessary coercivity conditions for pseudomonotone and quasimonotone variational inequalities to have a nonempty, possibly unbounded solution set. Similarly, a minimal coercivity condition is derived for quasimonotone variational inequalities to have nonempty, bounded solution set, hereby complementing recent studies for the pseudomonotone case. Finally, for quasimonotone complementary problems previous existence results involving so-called exceptional families of elements are strengthened by considerably weakening assumptions in the literature.

**TA 3 FROM INTERPOLATION TO REGRESSION IN DERIVATIVE FREE OPTIMIZATION**

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Derivative free optimization is a branch of nonlinear optimization that addresses problems where derivatives of the objective function and, possibly, constraints are unavailable. The objective function is typically approximated by a low degree polynomial (linear and quadratic). Extensive theory has been developed for the case of polynomial interpolation. It is critical for the convergence of derivative free methods to maintain good quality of the interpolation set. We will extend these notions to the case of least square regression approximation of the objective function. We will show how the the-
ory can be applied in this case and discuss advantages and disadvantages of regression vs. interpolation. DFO software is available through COIN-OR (www.coin-or.org).

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**MS Robust Optimization in Robust Control**

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Have you ever realized that you act as a highly optimized control system when you ride a bicycle? In trying to design a biking robot one encounters all fundamental issues of control: stabilization to keep the bike upright, trajectory following to use the bike as a means of transportation, and disturbance suppression to handle wind gusts. These multiple objectives should of course be robustly achieved under diverse circumstances, such as changing loads or a quickly varying velocity.

On the basis of this example we will discuss various aspects of recently developed techniques for optimization based analysis and synthesis of controllers. We will put particular emphasis on the crucial role of linear semi-definite programming and robust optimization in modern control algorithms.

Robust linear matrix inequalities with rational dependence on uncertainties can be identified as a unifying generic framework for control purposes. In the technical part of the presentation we will reveal how to construct computationally tractable relaxations that can be complemented by numerically verifiable tests for when the relaxations do not involve any conservatism. Based on novel sum-of-squares representations of positive definite polynomial matrices on semi-algebraic sets we will finally compose relaxation families that can be shown to be asymptotically exact.

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**TM 6 Differentiating Spectral Functions**

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A function $F$ on the space of $n \times n$ symmetric matrices is called *spectral* if it depends only on the eigenvalues of its argument, that is $F(A) = F(UAU^T)$ for every orthogonal $U$ and every $A$ in its domain. We are interested in the derivatives of these functions with respect to the argument $A$. Explicit formulae for the gradient and the Hessian are given in Lewis (1994) and Lewis-Sendov (2000). These formulae appear quite different from each other and this obstructs attempts to generalize them. The questions that we address in this talk are about the common features in these formulae. We propose a language that seems to describe well the higher-order derivatives of the spectral functions. It is based on a generalization of the Hadamard product between two matrices to a (tensor-valued) product between $k$ matrices, for $k \geq 1$.  

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In particular, we present a compact formula for the \( k \)-th derivative of the operator-valued function \( f(A) \), where \( f \) is a function on a scalar argument, see Chapter V in Bhatia’s 1997 book.

**MM 5 A Primal-Dual Interior Point Method for Stochastic Mathematical Programs with Complementarity Constraints**

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We discuss a primal-dual interior point method to solve two-stage stochastic programs with complementarity constraints (SMPCCs). These problems include stochastic non-linear programs and MPCCs amongst others. We shall provide motivation for such problems from the realm of electricity pricing under various assumptions of competition and uncertainty. To cope with the computational burden, we propose a scenario-based decomposition scheme to obtain primal and dual steps. Local and global convergence theory is discussed for the proposed method. We discuss some preliminary results on an extension of the existing QPECGEN testproblem set to stochastic QPECs. Some examples from the area of electricity markets shall also be discussed.

**MS Stochastic programming, How difficult is it?**

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In an abstract framework stochastic programming problems are often formulated as optimization of the expected value of the considered objective function with respect to the involved random parameters. There are several conceptual questions and technical difficulties related to such a formulation which we discuss in this talk. In order to evaluate the expected value we need to assume an explicit form of the probability distributions of the random parameters. In applications these distributions are never known exactly and, even worse, in many cases are given by a subjective judgement. Why do we optimize the expected value, i.e., why do we want to optimize our decisions on average? How can we measure an involved risk? Even if we are satisfied with a formulated model we still need to solve it numerically. Evaluation of the expected values typically requires calculations of multivariate integrals. This motivates the question: can realistic stochastic programming problems be solved numerically with a reasonable accuracy?

**WA 6 On Linear Complementarity Systems with the P-Property**
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This talk addresses non-Zenoness, bounds of the number of mode switchings and local observability for a class of linear complementarity systems (LCS), i.e. the LCS satisfying the $P$-property. This class of LCS arises from mechanical systems with elastic unilateral constraints and constrained optimal control problems or differentiable Nash games. Using notions from systems theory and results from LCP theory, we propose an expansion based approach to prove non-Zenoness of the LCS. Combining the techniques of Brunovsky and Sussmann, we also show boundedness of the number of mode switchings in any finite time. Finally, local observability of the LCS is studied. These addressed issues provide a theoretical foundation for further study of fundamental properties of complementarity systems in robotics and dynamic optimization.

MM 3 Global Optimization of Computationally Expensive Functions Including Applications to Partial Differential Equations

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We present a new strategy for the constrained global optimization of computationally expensive black box functions using response surface models and apply it to nonconvex applications that take up to 3 hours for one simulation. A response surface model is a multivariate approximation of a continuous function, which is used as a surrogate model for optimization in situations where function evaluations are computationally expensive. We assume that the derivatives of the computationally expensive (“costly”) function are not available because they are either too expensive or impossible to compute accurately.

Prior global optimization methods that utilize response surface models were limited to box-constrained problems, but our CORS(Constrained Optimization using Response Surfaces) method can easily incorporate general nonlinear constraints. In the proposed method, the next point for costly function evaluation is chosen to be the one that minimizes the current response surface model subject to the given constraints and to additional constraints that the next costly function evaluation point be of some distance from previously evaluated points, which is a global optimization problem. However, because the optimization is done on the response surface (which can be computed very quickly), we can afford to use multistart gradient methods. We do not compute the derivatives of the computationally expensive function. After each evaluation of the
costly function, the response surface is updated.
The distance requirement is allowed to cycle, starting from a high value (global search) and ending with a low value (local search). The purpose of the distance constraint is to drive the method towards unexplored regions of the domain and to prevent the premature convergence of the method to some point which may not even be a local minimizer of the costly function.

A proof shows that the CORS method can be shown to converge to the global minimizer of any continuous function on a compact set regardless of the response surface model that is used. We will present implementations of the CORS method that utilize a radial basis function model (CORS-RBF) applied to the box-constrained Dixon-Szegö test functions and to a simple nonlinearly constrained test function. The results indicate that the CORS-RBF algorithms at least as good as existing global optimization algorithms for costly functions on the box-constrained global optimization test problems. The results also show that the CORS-RBF algorithms is better than other algorithms for constrained global optimization on the nonlinearly constrained test global optimization test problem.

We also applied a radial basis function algorithm to a complex system of nonlinear partial differential equations (PDE) describing the detoxification of groundwater containing toxic chlorinated ethenes, which represents a widespread and serious environmental pollution problem. There were two examples for this application: a) a sample PDE problem that takes 8 minutes for a single simulation and b) a realistic field application that requires 3 hours for a single simulation. The field application was for a TCE plume at a naval air station in Alameda, California. Each evaluation of the objective function requires a simulation. Based on ten trials of 100 function evaluations on the sample PDE problem, our radial basis functions (RBF) response surface methods had the solutions with the lowest mean and smallest deviations in comparison to all other methods considered including FMINCON (MATLAB’s gradient based method), Genetic Algorithm (heuristic) and a different global optimization method using RBF approximation suggested by Gutmann (2001). The results for the large 3-hour simulation model indicated that our RBF method also performed significantly better that the other methods considered including the Gutmann RBF and FMINCON.

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**WA 6 Time-Stepping Models for Boundary Value Problems in Frictional Multibody Dynamics and Design**

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We present a fully implicit time-stepping model for multibody systems with fri-
tional contacts. Using a viscoelastic model for the contact forces, and formulating the Coulomb friction as a quadratic program, we are able to unify the dynamics of all types of contact states with the same set of equations with nonlinear complementarity conditions. We explain how this model lends itself to the solution of boundary value problems. We show the numerical implementation and the results of using this model for planning manipulation and part reorienting tasks.

WA 6 COMPUTING OPTIMAL CONTROLS FOR FRICTION PROBLEMS

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Optimal control problems with Coulomb friction arise in relation to mechanical design and control problems. Controls are known to exist, but there is no equivalent to the Pontryagin maximum principle for these problems because the right-hand side is discontinuous in the state variable. The strategy of discretizing in time and then optimizing the discrete-time system fails for these problems as the computed gradients have $O(1)$ errors in them, even if fully implicit time discretizations are used. We have used a smoothing approach which computes accurate gradients provided the step-size $h$ and the smoothing parameter $\sigma$ go to zero, and $h/\sigma \to 0$. This has been used for a minimum-time type problem for a crude model of a racing car which can slip sideways.

TM 2 SMOOTHING APPROXIMATIONS FOR EIGENVALUES OF SYMMETRIC MATRICES AND NONSMOOTH MATRIX VALUED FUNCTIONS

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This talk is divided into two parts. The first part introduces ways to compute smoothing functions for approximating eigenvalues of symmetric matrices. The obtained smoothing functions are proved to be strongly semismooth. The second part is about the differential properties of a class of smoothing functions for nonsmooth matrix valued functions.

WM 1 AUTOMORPHISM INVARIANCE OF P AND GUS PROPERTIES OF LINEAR TRANSFORMATIONS ON EUCLIDEAN JORDAN ALGEBRAS

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Generalizing the P-property of a matrix, recently Gowda, Sznajder, and Tao introduced
and studied P and Globally Uniquely Solvable (GUS) properties for linear transformations defined on Euclidean Jordan algebras. In this talk, we describe the invariance of these properties under automorphisms of the algebra and of the symmetric cone. By using the concept of a principal subtransformation, we introduce and describe ultra and super P properties for a linear transformation on an Euclidean Jordan algebra.

**TM 4 A Self-Regular Proximity Based Adaptive Large-Update IPM for Linear optimization**

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Primal-Dual Interior-Point Methods (IPMs) have shown their power in solving large classes of optimization problems. However, there is still a gap between the practical behavior of these algorithms and their theoretical worst-case complexity results with respect to the update strategies of the duality gap parameter in the algorithm. The so-called small-update IPMs enjoy the best known theoretical worst-case iteration bound but their performance in computational practice is poor, while the so-called large-update IPMs have superior practical performance but with relatively weaker theoretical results. This gap was reduced by Peng, Roos, and Terlaky who introduced a new family of Self-Regular (SR) proximity functions based IPMs.

In this talk we discuss an adaptive single step large-update IPM for a class of SR-proximities. At each step our algorithm chooses the target value adaptively and the update is a large update. The new algorithm does not do any inner iterations, unlike other large update methods. An $O\left(qn^{q+\frac{q+1}{2}}\log\frac{2}{\epsilon}\right)$ worst-case iteration bound of the algorithm is established, where $q$ is the barrier degree of the SR-proximity. For a special choice of $q$ the best complexity for large-update IPMs is established.

**WA 3 Stochastic Programming with Linear Decision Rules**

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Multistage decision problems under uncertainty is a fundamental management paradigm. Unless those problems have a special structure (e.g., one-dimensional state space) they cannot be solved by the current computational tools. In particular, with more than three stages, stochastic programming is limited by the explosion of the event tree. We propose an approach based on linear decision rules. The idea is not new in management (Holt et al., 1960) but it has never been applied in a stochastic programming context. Linear decision rules dramatically reduce the state space, as it replaces the indepen-
dent decisions at each stage by a policy defined at the initial stage. Using oracle-based programming, it is possible to solve problems with several stages and a huge number of scenarios to represent the stochastic evolution. We show on an example in supply chain management, that a model based on linear decision rules yields solution that are comparable with the exact approach of stochastic programming, but a much smaller computational cost.

---

**TM 4 Working set strategies for interior point linear programming with many constraints**

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It is now well established that, especially on large linear programming problems, the simplex method typically takes up a number of iterations considerably larger than recent interior-points methods in order to reach a solution. On the other hand, at each iteration, the size of the linear system of equations solved by the former can be significantly lower than that of the linear system solved by the latter.

The approach proposed in this paper can be thought of as a simple-minded attempt at a compromise between the two extremes: viewed from the dual framework standpoint, it makes use of interior-point search directions computed by solving a reduced-size Newton-KKT system, where only constraints in a "critical set", updated at each iteration, are taken into account. Two algorithms are considered. Promising numerical results are reported on randomly generated problems. Global and local quadratic convergence are proved in the case of one of them (of the primal-dual affine scaling type).

---

**WM 2 Solving second order cone programming via the augmented systems**

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The standard normal equation based implementation of interior-point methods for second order cone programming encounters stability problems in the computation of search directions when the barrier parameter is small. Based on the eigenvalue decomposition of the $(1, 1)$ block of the augmented equation, a reduced augmented equation approach is proposed to overcome the stability problems. Numerical experiments on randomly generated problems and problems in the DIMACS library show that the new approach is more stable than the normal equation based approach, even if the latter uses the
product-form Cholesky factorization.

---

**MA 1** RECENT PROGRESS IN FILTER METHODS FOR NONLINEAR EQUATIONS, UNCONSTRAINED AND BOUND CONSTRAINED OPTIMIZATION PROBLEMS

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The talk will focus on introducing some recent developments of filter-trust-region methods for problems for which the restoration phase (a common feature of filter methods so far) does not make immediate sense. The talk will describe how this difficulty can be circumvented for the problem of finding a feasible point for a set of nonlinear constraints (including the case of systems of nonlinear equations) and for the unconstrained minimization problem. Results will be discussed indicating that the new methods appear to be very efficient and reliable. Recent research in applying the filter ideas to interior point methods (in the context of bound constrained problems) will also be discussed.

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**MA 2** GENERATING SET SEARCH FOR NONLINEAR PROGRAMMING

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Generating Set Search (GSS) defines a class of direct search methods that rely on a set of generators for the cone of feasible descent directions. Using this observation leads to a unifying framework that lends itself to a variety of convergence results. Stationarity results for derivative-free GSS methods optimization will be the focus of this talk.

Appropriately chosen measures of stationarity will be shown to be of the same order as the step length at an identifiable subset of the iterations. Thus, even in the absence of explicit knowledge of the derivatives of the objective function, there is information about stationarity. These results help clarify the fundamental geometrical ideas underlying several classes of direct search algorithms. In addition, these results validate a practical stopping criterion for such algorithms and lead to local convergence results.

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**WS** SECOND-ORDER CONE PROGRAMMING RELAXATION FOR NONCONVEX OPTI-
A popular approach to solving difficult nonconvex optimization problem is to approximate the problem by a convex programming relaxation. A classical example is the approximation of an integer program by its linear programming relaxation. In the past 10 years, semidefinite programming relaxation has become popular due to its higher accuracy of approximation. However, semidefinite programs, which are like linear programs but with nonnegativity constraints replaced by nonnegativity of the eigenvalues of the variables (viewed as a symmetric real matrix), are considerably harder to solve than linear programs. Second-order cone programs are between linear programs and semidefinite programs in structural complexity, and efficient interior-point methods have been developed for its solution. [A second-order cone is the epigraph of the Euclidean norm.] In this talk, we survey recent work on approximating nonconvex optimization problems by second-order cone programming relaxation. These problems typically involve Euclidean norm, such as ad hoc wireless sensor network localization and, more generally, Euclidean geometry optimization.

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Many optimization problems can be “converted” to semidefinite optimization problems. In particular, every homogeneous cone can be expressed as the intersection of the cone of symmetric positive semidefinite matrices and a linear subspace. Some other convex cones can be dealt with in a similar way using linear maps, linear projections and the positive semidefiniteness requirements. In this talk, I will focus on two lines of investigations:

1. Ways of evaluating the quality of representations from a theoretical viewpoint.
2. Ways of utilizing the representations as theoretical tools in establishing original facts about more complicated cones.

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We propose a multidimensional filter globalization technique for the solution of non-
linear complementarity problems based on trust-region methods. The filter is used to weaken the acceptance test for trial steps in a nonmonotone trust region method. The method is shown to converge globally. If (possibly inexact) semismooth Newton steps are used as candidates for the trial step computation, the method is q-superlinearly or q-quadratically convergent to regular solutions. Numerical results are presented that demonstrate the efficiency of the approach.

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**MA 4** An Inexact Newton Interior-Point Algorithm for Nonnegative Constrained Minimization

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We present a primal-dual interior point algorithm that uses trust region globalization strategy, a quasicentral path, and a new merit function for solving nonnegative constrained problems. Numerical results on large scale problems are reported.

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**MM 1** Improving Performance of Interior Point Methods Using Conditioning Information

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Condition numbers in optimization have been the subject of research in recent years, and connections with complexity and numerical properties of optimization algorithms have been established. In particular, theoretical analysis predicts that the condition number of an optimization problem affects the computational effort of interior point methods for finding an approximate solution to the problem. This predictions have been also observed in computational experiments. As is well known in numerical analysis, reducing the condition number can improve the performance of algorithms and numerical properties. The natural question, then, is whether a similar effect can be expected for optimization algorithms. In this work we show how the information obtained from the computation of the condition measure of a linear program can be used to improve the condition number. This improvement is shown to have effects in the running time of an interior point algorithm. We show different computational results using CPLEX barrier procedure as a solver in a series of randomly generated instances, as well as some of the instances form the NETLIB set.
**WM 5 Adaptive Barrier Parameter Strategies for Nonlinear Programming**

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The effectiveness of interior methods is largely dependent on the strategy for updating the barrier parameter. In the past, efficient updating procedures have been developed and analyzed for interior methods within the context of linear and convex programming. In this presentation we examine various adaptive choices of the barrier parameter within interior algorithms for general nonlinear nonconvex optimization. A framework for enforcing global convergence is presented. The practical performance of the approaches is demonstrated on numerical results using the IPOPT and KNITRO software packages.

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**TA 2 Advances in Interior-Point Methods for Nonlinear Optimization**

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We will discuss recent algorithmic advances implemented in the KNITRO interior-point software package. Particular attention will be paid to issues of infeasibility detection and optimal active-set identification via crossover techniques. Numerical results will be presented.

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**MA 2 Decreasing the Computation Time for Generalized Pattern Search optimization algorithms by using adaptive precision cost function evaluations**

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We are interested in solving optimization problems in which evaluating the cost function requires the numerical solution of a system of differential algebraic equations that needs to be numerically solved using iterative solvers. We assume that the cost function is smooth in the design parameters, but that its numerical approximations, defined on the numerical approximate solutions of the differential algebraic equations, are discontinuous in the design parameters, and hence derivatives are not available. For such problems, we developed adaptive simulation-precision control subprocedures for Generalized Pattern Search (GPS) optimization algorithms that adaptively control the precision of the approximating cost functions in the course of the optimization.

We present our adaptive simulation-precision control subprocedures for GPS algorithms. We show that our adaptive precision optimization algorithms provably construct sequences of iterates with stationary accumulation points, even though they only use function values of the discontinuous approximating cost functions. We show numerical experiments in which our adaptive simulation-precision control subprocedure reduced the computation time from five days to one day, making optimization fast enough to be applicable for the design of building envelope and energy systems.

---

**TM 6 Cone Preserving Maps**

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We study cone preserving maps for the: Semidefinite Cone; Euclidean Distance Matrix Cone; and Second Order Cone. These maps help in transforming problems from one cone to the other and can be used in algorithmic approaches.

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**WM 5 Large-scale nonlinear optimization: what counts?**

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In recent years, researchers have worked on a variety of methods—for example, SQP, interior-point, and SLP—for nonconvex nonlinearly constrained optimization. This talk will consider several questions associated with some of the proposed methods, motivated by the wish to understand which features really count and why—which are theoretically equivalent, which matter the most in practice, which are interconnected in non-obvious ways, and which are most effective for which kinds of problems. The topics to be considered will include the treatment of indefiniteness, the inclusion of equality constraints, and the approximate solution of subproblems.

---

**WA 3 Application of conic programming to the statistical design of ex-**
The problem of experimental design is to choose points at which samples will be drawn in order to produce good statistical estimates at a reasonable cost. Such problems are typically formulated as the minimization of some measure of the statistical variability subject to resource constraints. Although convex analysis has played a key role in the theoretical study of "design criteria", the computational methods of convex optimization have seldom been used. In this talk, we describe how the standard experimental design criteria can be formulated in terms of conic programming (linear, second-order cone, and semidefinite). This provides a new source of easily generated, scalable test problems. It also provides new challenges for algorithm and software development, including the need for preprocessing and for quickly re-solving problems after minor changes to the data.

MM 4 Minimum Sum-of-Squares Clustering

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The minimum sum-of-squares clustering problem is shown to be a concave continuous program. Modifying Tuy’s cutting plane method we are able to find its global minimum in a finite number of steps. Numerical examples confirm that this method can find a better solution than that by the popular k-means algorithm.

TY 2 Fastest mixing Markov chain on a graph

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We consider a symmetric random walk on a connected graph, where each edge is labeled with the probability of transition between the two adjacent vertices. The associated Markov chain has a uniform equilibrium distribution; the rate of convergence to this distribution, i.e., the mixing rate of the Markov chain, is determined by the second largest (in magnitude) eigenvalue of the transition matrix. In this paper we address
the problem of assigning probabilities to the edges of the graph in such a way as to minimize the second largest magnitude eigenvalue, i.e., the problem of finding the fastest mixing Markov chain on the graph. We show that this problem can be formulated as a convex optimization problem, which can in turn be expressed as a semidefinite program (SDP). This allows us to easily compute the (globally) fastest mixing Markov chain for any graph with a modest number of edges (say, 1000), using standard SDP methods. Larger problems can be solved by exploiting various types of symmetry and structure in the problem, and far larger problems (say 100000 edges) can be solved using a subgradient method we describe. We compare the fastest mixing Markov chain to those obtained using two commonly used heuristics: the maximum-degree method, and the Metropolis-Hastings algorithm. For many of the examples considered, the fastest mixing Markov chain is substantially faster than those obtained using these heuristic methods. We derive the Lagrange dual of the fastest mixing Markov chain problem, which gives a sophisticated method for obtaining (arbitrarily good) bounds on the optimal mixing rate, as well the optimality conditions. Finally, we describe various extensions of the method, including a solution of the problem of finding the fastest mixing reversible Markov chain, on a fixed graph, with a given equilibrium distribution.

**WM 2** Parallel Implementation for SemiDefinite Programming with Positive Definite Matrix Completion

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Parallel computation plays an essential role to enhance Primal-Dual Interior-Point Methods (PD-IPM) for SemiDefinite Programings. SDPARA (SemiDefinite Programming Algorithm paRAllel version) attained very fast computation time for SDPs with many equality constraints. However, since PD-IPM involve dense matrix computations even if input data has considerable sparsity, SDPARA is not suitable for SDPs with large variable matrices. To overcome the difficulty, we incorporate positive definite matrix completion methods based on advanced graph theory into PD-IPM. The completion methods exploit the sparsity aggressively and save a lot of memory space, however, at the same time, require long computation time. Parallel computation and the completion methods complement each other’s short coming and enable us to solve extremely large SDPs with many equality constraints and large variable matrices in a short time.

**WA 1** A Branch-and Bound Method for Solving Quadratic Bilevel Program

*Maria S. Yershov*
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We consider a bilevel programming problem such that there are quadratic objective function and convex quadratic constraints at the upper level, while the lower level problem consists in minimization of convex quadratic function subject to linear constraints. The bilevel program can be reformulated as a single-level problem to find the global optimum of the upper level objective over an implicit inducible region. The inducible region is a part of the weak feasible set determined by all the explicit constraints.

For the considered problem we propose a branch-and-bound method. It shares the main idea with other methods of the class: the feasible set is partitioned into subsets, and upper and lower bounds of optimal value of the objective characterize each of the subsets. The specifics of the presented method is that the feasible set (inducible region) is partitioned implicitly on the basis of subdividing the weak feasible set. A partition element of the weak feasible set is determined by linear and convex quadratic inequalities. A corresponding subset of the inducible region constitutes its implicit part, probably disconnected and nonconvex. Upper bounds of the optimal value over a partition element are calculated through the local optimization of the objective under the condition that duality gap in the lower level problem is zero. The idea for obtaining a lower bound is approximation of a partition element by an ellipsoid.

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**TM 2 On a Homogeneous Model for Nonlinear Complementarity Problems over Symmetric Cones**

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In this talk, we propose a homogeneous model for solving monotone nonlinear complementarity problems over symmetric cones in a finite dimensional real Euclidean space. We will investigate its several properties including the existence and the limiting behavior of trajectories. Our analysis is based on the study of Monteiro and Pang (1998) for nonlinear complementarity problems over the cone of symmetric positive semidefinite matrices.

---

**TM 5 Duality Methods in the Optimization of Orthogonal Frequency-Division Multiplex (OFDM) Communication Systems**

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The design and optimization of orthogonal frequency division multiplex (OFDM) systems typically take the following form: The design objective is usually to maximize the total sum rate which is the sum of individual rates in each frequency tone. The design constraints are usually linear constraints imposed across all tones. This paper explains why dual methods are ideally suited for this class of problems. The main result is the following: Regardless of whether the objective or the constraints are convex,
the duality gap for this class of problems is always zero in the limit as the number of frequency tones goes to infinity. As the dual problem typically decouples into many smaller per-tone problems, solving the dual is much more efficient. This gives an efficient method to find the global optimum of non-convex optimization problems for the OFDM system. Multiuser optimal power allocation, optimal frequency planning, and optimal low-complexity crosstalk cancellation for vectored DSL are used to illustrate this point.

---

**MM 6 Conditioning Well-Behaved Functions**

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For a lower semicontinuous function $f$ with the set of global minimizers $S_f$ and the minimum $m_f$, a conditioner of $f$ is a nondecreasing function $\mu : \mathbb{R}^+ := [0, +\infty] \rightarrow \mathbb{R}^+$ such that

$$d(x, S_f) \leq \mu(f(x) - m_f).$$

The function $f$ is said to be well-conditioned if $\mu$ has the property that $\lim_{s \rightarrow 0} \mu(s) = 0$. In this presentation, we discuss the representations of such functions $\mu$ for convex and nonconvex functions.

---

**TS Complex Values in Optimization: Some Recent Results**

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In this talk we present some recent results in continuous optimization, where the use of the complex values plays an important role. In the first part we discuss the connection between the so-called joint numerical range and quadratic optimization. It turns out that the convexity of the joint numerical range is equivalent to the existence of a complex-valued LMI (Linear Matrix Inequalities) representation for the set. This has several interesting implications, e.g. in the description for the (joint) field of values of two complex matrices, and in the complex-valued non-convex quadratic optimization.

In the second part of the talk, we discuss the application of complex-valued SDP (Semidefinite Programming) in the max-cut and the max set-splitting problems. By studying the complex-valued SDP and the complex-valued normal distributions, the approximation algorithms and their worst case performance bounds for such problems follow in a natural and easy way.

---

**WM 1 Off-Central Paths in Interior Point Method for Monotone Semidefinite Linear Complementarity Problem**
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An interior point method defines a search direction at any interior point of the feasible region. These search directions form a direction field which in turn defines, as the unique solution of a system of ODEs, a curve passing any interior point. We call such curves off-central paths (the central path is trivial for analysis; our concern is off-central paths, so the name). We study off-central paths for monotone semidefinite linear complementarity problem (SDLCP). We show that each off-central path is a well-defined analytic curve with parameter $\mu$ ranging over $(0, \infty)$ and any accumulation point of the off-central path is a solution to SDLCP. Through a simple example we will show that the off-central paths are not analytic at $\mu = 0$ in general. On the other hand, for the same example, we can find a subset of off-central paths which are analytic at $\mu = 0$. These “nice” paths are characterized by some algebraic equations. Then, applying the predictor-corrector path-following algorithm to this example and starting from a point on any such a “nice” path, but not necessarily staying on this path, superlinear convergence can be achieved.

MA 6 IMPLEMENTATION OF SELF-REGULAR INTERIOR POINT METHODS

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Self-regular based interior point methods present a unified novel approach for solving linear optimization and conic optimization problems. In this talk, we present our experiences in developing the software package McIPM: McMaster Interior Point Methods. It uses the dynamic version of Self-Regular interior point methods and it is based on the homogeneous self-dual embedding model. McIPM can solve linear, quadratic, and second order cone optimization problems. Extensive testing on Netlib, QPlib, and DIMACS-SOCO problems shows that the Self-Regular proximity based approach allows improving the performance of interior point methods software when solving difficult conic optimization problems.

MA 6 THE DUAL CONE FOR THE DERIVATIVE OF THE NON-NEGATIVE ORTHANT

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Elementary symmetric functions (polynomials) are building blocks for hyperbolic polynomials. While one can easily construct a logarithmic self-concordant barrier (SCB)
functional for the hyperbolicity cone $K_p$ associated to an arbitrary hyperbolic polynomial $p$, little is known about the dual cone $K_{p^*}$, even when $p$ is the $k$-th derivative ($1 \leq k \leq n - 2$) in the direction $e = (1, 1, \ldots, 1)$ of the polynomial $x_1 \cdots x_n$, the standard hyperbolic polynomial for the nonnegative orthant.

For the case $k = 1$ — that is, for the polynomial $p'(x) = \Pi_{n-1}(x) = \sum_{1 \leq i \leq n} \prod_{j \neq i} x_j$ — we give an algebraic characterization of the dual cone and show how one can easily construct an SCB functional for it. We also indicate extensions of the result.
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