

Thursday, 10:30am - 12:00pm

## ■ ThA01

Marriott - Chicago A

### Approximation Algorithms for Network Design

Cluster: Approximation Algorithms

Invited Session

Chair: Cliff Stein, Columbia University, 326 S W Mudd Building, 500 W. 120th Street, New York, NY, 10027, cliff@ieor.columbia.edu

#### 1 - Traffic Grooming in Optical Networks

Lisa Zhang, Bell Labs, 600 Mountain Ave, 2A-442, Murray Hill, NJ, 07974, United States of America, ylz@research.bell-labs.com, Spyridon Antonakopoulos

Traffic grooming in optical networks offers economic advantage by aggregating low-bandwidth streams to efficiently utilize high-bandwidth media. Grooming is related to but different from buy-at-bulk network design. For example, even for the restricted special case of a line topology, grooming is APX-hard. We present results for a number of interesting special cases as well as the general case of grooming traffic streams of arbitrary bandwidth over a network of arbitrary topology.

#### 2 - Uncrossing Almost Uncrossable Setpair Families

Zeev Nutov, Open University of Israel, 108 Ravutski Street, Raanana 43107, Israel, nutov@openu.ac.il

I will present a simple method to decompose setpair families arising from the Survivable Network Design Problem (SNDP) into uncrossable families. For rooted requirements this implies the ratios  $O(k^2)$  for edge costs and  $O(k^2 \log n)$  for node costs, where  $k$  is the maximum requirement. Previous ratios were  $O(k^2 \log n)$  and  $O(k^8 \log^2 n)$ , respectively. We also obtain an  $O(k \log n)$ -approximation for the element-connectivity version with node costs.

## ■ ThA02

Marriott - Chicago B

### Complementarity Problems and Variational Inequalities in Transportation

Cluster: Complementarity Problems and Variational Inequalities

Invited Session

Chair: Siriphong Lawphongpanich, University of Florida, Dept of Industrial and Systems Engineer, 303 Weil Hall, Gainesville, FL, 32611, United States of America, lawphong@ise.ufl.edu

#### 1 - Numerical Solution Procedures for the Morning Commute Problem

Marco Nie, Assistant Professor, Northwestern University, 2145 Sheridan Road, Evanston, United States of America, y-nie@northwestern.edu, Michael Zhang

This paper discusses solution techniques for the morning commute problem that is formulated as a discrete variational inequality (VI). Two groups of non-heuristic algorithms for general VIs, namely projection-type algorithms and ascent direction algorithms, were examined. The performance of these algorithms are compared on simple instances of the morning commute problem. The implications of numerical results are discussed.

#### 2 - On the Complexity of the Minimum Tollbooth Problem

Lihui Bai, Doctor, Valparaiso University, 1909 Chapel Drive, Valparaiso, IN, 46383, United States of America, lihui.bai@valpo.edu, Siriphong Lawphongpanich, Donald Hearn

The minimum tollbooth problem considers travelers seeking the least cost routes to reach their destinations in a road network. The problem is to determine both prices and locations at which to toll in order to persuade these travelers to choose routes leading to a desired traffic distribution, e.g., one with the least congestion. The objective is to minimize the number of toll locations. In this talk, we present complexity analyses of the problem under different sets of assumptions.

#### 3 - Risk-neutral Second Best Toll Pricing

Jeff Ban, Assistant Professor, Rensselaer Polytechnic Institute, Civil and Environmental Engineering, Troy, NY, 12180, United States of America, banx@rpi.edu, Michael Ferris

We propose a risk-neutral second best toll pricing scheme to account for the possible nonuniqueness of user equilibrium solutions. The scheme is designed to optimize for the expected objective value as UE solution varies within the solution set. Such a risk-neutral scheme can be formulated as a stochastic program and solved by a simulation-based optimization algorithm. The algorithm contains three major steps: characterization of the UE solution set, random sampling over the solution set, and optimization over approximate objective functions. Numerical results are provided to illustrate the model and solution algorithm.

## ■ ThA03

Marriott - Chicago C

### Optimization Models Applied to Transmission Planning in Electricity Markets Considering Large-scale Penetration of Renewables

Cluster: Optimization in Energy Systems

Invited Session

Chair: Luiz Barroso, PSR, Praia de Botafogo 228/1701-A, Rio de Janeiro, 22250-906, Brazil, luiz@psr-inc.com

#### 1 - Cost-benefit Analysis for Optimum N-k Transmission Criteria with Wind Penetration

Rodrigo Moreno, Imperial College London, South Kensington Campus, Electrical and Electronic Dept./CAP, London, United Kingdom, rmoreno@imperial.ac.uk, Danny Pudjianto, Goran Strbac

A Cost-Benefit Analysis in the form of a Linear Programming Model is presented in order to find the optimum security constraints, named N-k, for transmission operation and planning in the presence of wind penetration. N-k rules play a key role to efficiently and securely release transfer capability to users when alleviating congestions and displacing transmission upgrades. In this framework, the model optimally balances cost of transmission investment, system operation and unsupplied demand.

#### 2 - Optimal Layout of Wind Farms in Complex Terrain

Klaus Vogstad, Head of Wind & Site, Agder Energi, Agder Energi Produksjon, Sbox 603, Kristiansand, 4606, Norway, klaus-ole.vogstad@ae.no, Raphael Chabar, Fabiano Oliveira

A new algorithm for wind park design is presented to solve the locational problem of optimal turbine layouts in complex terrain. The algorithm maximizes total energy yield subject to wind characteristics (in the form of wind energy maps), wakes effects, minimum distance between turbines and site constraints (restricted areas). Present industry standard tools rely on heuristic methods, and do not guarantee optimum. The developed algorithm, which involves MIP and guarantees global optimum, consist in an iterative method for generating minimum distance feasibility cuts. The algorithm is successfully applied and embedded in Agder Energi's in-house tools for wind power projects.

#### 3 - Optimization of the Location, Topology and Capacity of a Transmission Network: A MINLP Approach

Raphael Chabar, PUC-Rio, R. Professor Gastao Bahiana, 496 apt 502, Rio de Janeiro, RJ, 22071-030, Brazil, rchabar@gmail.com, Mario Pereira, Luiz Barroso, Alvaro Veiga, Luiz Mauricio Thomé

This work presents an optimization model for a transmission network planning considering the large-scale penetration of renewables. The problem is to define the network topology, positioning of the substations (SE), length of circuits, circuits' capacities and dimensioning of transformation equipment that result in the least cost investment plan. This involves the trade-off between using longer radial circuits with individual lower capacities connecting each generator to the main grid or shorter circuits connecting the generators to a SE and a longer high capacity circuit connecting the SE to the main grid. Transmission losses are also considered. This problem is formulated as a Mixed-Integer Non-Linear Program with linear constraints.

## ■ ThA04

Marriott - Denver

### Combinatorial Optimization G

Contributed Session

Chair: Dennis Egbers, Technische Universitaet Braunschweig, Pockelsstr. 14, Braunschweig, 38106, Germany, dennis.egbers@tu-bs.de

#### 1 - An Adaptive LNS Algorithm for the Resource-constrained Project Scheduling Problem

Laurent Flindt Muller, University of Copenhagen, Universitetsparken 1, København, 2100, Denmark, laurent@diku.dk

We present an application of the Adaptive Large Neighborhood Search (ALNS) framework to the Resource-constrained Project Scheduling Problem (RCPSp). The ALNS framework was first proposed by Pisinger and Ropke and can be described as a large neighborhood search algorithm with an adaptive layer, where a set of destroy/repair neighborhoods compete to modify the current solution in each iteration of the algorithm. To the best knowledge of the author this is the first application of the ALNS framework to the RCPSp. Experiments performed on the well-known j30, j60 and j120 benchmark instances show that the proposed algorithm is competitive and confirms the strength of the ALNS framework previously reported for the Vehicle Routing Problem.

#### 2 - Minimizing the Makespan in Resource Constrained Project Scheduling with Feeding Precedence Relations

Lucio Bianco, Professor, University of Roma Tor Vergata, Via del Politecnico 1, Roma, 00133, Italy, bianco@disp.uniroma2.it, Massimiliano Caramia

We study an extension of the Resource-Constrained Project Scheduling Problem (RCPSp) with minimum makespan objective by introducing as precedence constraints the so called Feeding Precedences (FP). A new mathematical formulation of the RCPSp with FP and a branch and bound algorithm have been developed. Also a computational experimentation on randomly generated instances has been provided.

#### 3 - Optimal Shift Schedules for Hospitals

Dennis Egbers, Technische Universitaet Braunschweig, Pockelsstr. 14, Braunschweig, 38106, Germany, dennis.egbers@tu-bs.de

Creating cost-efficient shift schedules satisfying demands of patients and employees is an important task for health care institutions. The Nurse Scheduling Problem (NSP) formulates this task mathematically, giving the possibility to apply optimization methods. Hard restrictions include demand, legal regulations and labour agreements while other constraints to be considered are wishes of the staff and regular working hours. We present a general model for NSP and algorithms developed in cooperation with a company engaged in this business. Exact solution methods and heuristics (partly relaxation based) will be proposed. For real data we compare these approaches to solve the NSP both in reasonable time as with results with sufficient quality.

## ■ ThA05

Marriott - Houston

### Combinatorial Optimization N

Contributed Session

Chair: Elisabeth Guenther, TU Berlin, Strasse des 17. Juni 136, Berlin, Germany, eguenth@math.TU-Berlin.DE

#### 1 - Partition Problems: Optimality and Clustering

Uriel G. Rothblum, Prof., Technion, Technion City, Haif, 32000, Israel, rothblum@ie.technion.ac.il

Partition problems constitute a large class of combinatorial optimization problems. Of particular interest are problems where it is possible to restrict attention to solutions that exhibit clustering properties, facilitating the solution of the partition problem in polynomial time. The talk will introduce a classification of partition problem and survey of numerous approaches to solve such problems by focusing on partitions that exhibit clustering properties.

#### 2 - The Time-cost Tradeoff Curves in Cyclic Networks

Stephan Held, Post Doc, Bonn University, Lennestr. 2, Bonn, 53129, Germany, held@or.uni-bonn.de

We present a new algorithm for computing time-cost tradeoff curves in activity-on-edge networks that contain cycles. Instead of a single project duration time, as in the acyclic time-cost tradeoff problem, the worst slack on a certain subset of edges is to be maximized. Starting with a cheapest solution we compute the support points of the piecewise-linear curve one-by-one. Combining minimum cost flow and the parametric shortest path algorithms, we achieve a strongly polynomial running time for proceeding from one support point to the next. Finally, we present the overall speed in practice on VLSI-instances with millions of vertices and edges.

#### 3 - Scheduling Generally Malleable Jobs with Precedence Constraints of Bounded Width

Elisabeth Guenther, TU Berlin, Strasse des 17. Juni 136, Berlin, Germany, eguenth@math.TU-Berlin.DE, Felix Koenig, Nicole Megow

We consider a generalization of a well-studied makespan minimization problem where malleable jobs (the processing time of each job depends on the number of allotted processors) have to be scheduled on identical parallel processors. We present an FPTAS for the NP-hard special case of precedence constraints of bounded width and give an  $O(\log n)$ -approximation for the general case. This also leads to results for related problems like bin scheduling and strip packing.

## ■ ThA06

Marriott - Kansas City

### SDP Relaxations for Sensor Network Localization

Cluster: Conic Programming  
Invited Session

Chair: Sunyoung Kim, Professor, Ewha W. University, 11-1 Dahyun dong, Seoul, 120-750, Korea, Republic of, skim@ewha.ac.kr

Co-Chair: Masakazu Kojima, Tokyo Institute of Technology, Dept of Math & Comp Sci, 2-12-1-W8-29 Oh-Okayama Meguro, Tokyo, Japan, kojima@is.titech.ac.jp

#### 1 - A Unified Theorem on Semidefinite Programming Rank Reduction and its Applications

Yinyu Ye, Stanford University, Dept of MS&E, Stanford, CA, 94305, United States of America, yinyu-ye@stanford.edu, Dongdong Ge, Jiawei Zhang, Anthony So

We present a unified theorem on semidefinite programming solution rank reduction that provides a unified treatment of and generalizes several well-known results in the literature. We also illustrate its applications on semidefinite programming (SDP) based model and method for the position estimation problem in Euclidean distance geometry such as graph realization and wireless sensor network localization.

#### 2 - Measurement Sparsification and Chordal Decomposition for Sensor Network Localization

Anthony So, The Chinese University of Hong Kong, Dept of Sys Engr & Engr Mgmt, Shatin, NT, Hong Kong - ROC, manchoso@se.cuhk.edu.hk, Dongdong Ge, Zhisu Zhu, Yinyu Ye

We consider sensor network localization with sparse and local edge-distance measurements. We develop a necessary and sufficient condition on the localizability of the graph using only a small number of edge-distance measurements. Using that condition, we develop a more efficient semidefinite programming (SDP) method for the localization problem and prove that it is guaranteed to find the same localization as the original SDP relaxation problem.

#### 3 - Exploiting Sparsity in SDP Relaxation for Sensor Network Localization

Sunyoung Kim, Professor, Ewha W. University, 11-1 Dahyun dong, Seoul, 120-750, Korea, Republic of, skim@ewha.ac.kr

We derive a sparse variant of Biswas-Ye's full SDP relaxation (FSDP) for sensor network localization problem using the sparsity of the problem. It is shown to be equivalent to FSDP. Numerical experiments with the sparse SDP relaxation, FSDP, and the sparse variant of FSDP exhibit that the sparse variant of FSDP outperforms all the other SDP relaxations in speed.

## ■ ThA07

Marriott - Chicago D

### Integer and Mixed Integer Programming G

Contributed Session

Chair: Robert Nauss, Professor, University of Missouri-St. Louis, 209 CCB, 1 University Blvd., St. Louis, MO, 63121, United States of America, robert\_nauss@umsl.edu

#### 1 - Characterization of 0/1/-1 Facets of the Hop Constrained Path Polytope by Dynamic Programming

Ruediger Stephan, ZIB, Takustrasse 7, Berlin, Germany, stephan@math.tu-berlin.de

We present a dynamic programming based polyhedral approach for the hop constrained shortest path problem defined on a directed graph. We show that many facet defining inequalities with coefficients 0, 1, or -1 for the polytope associated with this problem can be classified by means of the well-known Bellman equations.

**2 - Practical Mixed Integer Kriging Models**

Joseph Simonis, The Boeing Co., P.O. Box 3707 MC 7L-21,  
Seattle, WA, 98124, United States of America,  
joseph.p.simonis@boeing.com, Paul Frank, Andrew Booker

Many optimization problems require the evaluation of computationally expensive functions. In practice, the expensive function evaluations are sometimes replaced by "cheaper" evaluations on surrogate models. We are interested in models that accurately approximate responses when design variables are a mixture of continuous and categorical types. This talk examines the use of mixed-integer Kriging models as surrogates; focusing on the steps of efficiently building and updating the models.

**3 - Solving Hard Single Source Capacitated Facility Location Problems**

Robert Nauss, Professor, University of Missouri-St. Louis, 209  
CCB, 1 University Blvd., St. Louis, MO, 63121,  
United States of America, robert\_nauss@umsl.edu

We investigate solving hard instances of SSCFLP that take CPLEX over 8hrs to solve. A property of SSCFLP is that by fixing all facility variables, the remaining problem of binary assignment variables is a generalized assignment problem. We capitalize on this by using projection. After certain relaxation tightenings and a heuristic to generate a good feasible solution, we generate a list of GAP problems that must be solved in order to ensure that an optimal solution to the SSCFLP is found.

**ThA08**

Marriott - Chicago E

**Branch-and-Price I**

Cluster: Integer and Mixed Integer Programming  
Invited Session

Chair: Marco Luebbecke, TU Berlin, Institute of mathematics,  
Strasse des 17. Juni 136, Berlin, 10623, Germany,  
m.luebbecke@math.tu-berlin.de

**1 - Stronger Bounds by Enforcing Complete Solution Properties in Column Generation Subproblems**

Ricardo Fukasawa, Assistant Professor, University of Waterloo,  
Waterloo, Ontario, Canada, Artur Pessoa

Column generation is usually applied in a way that the subproblems correspond to parts of a solution; e.g., in the BPP, the knapsack subproblems yield possible fillings of a single bin, in the VRP, subproblems correspond to a single route. The proposed approach consists in associating the subproblems to complete solutions, while enforcing some global properties (not valid for solution parts) without increasing the pricing complexity. Computational results on classical problems are given.

**2 - A Branch-and-cut-and-price Approach for a Two-level Hierarchical Location Problem**

Alberto Ceselli, Assistant Professor, DTI - University of Milan,  
Via Bramante, 65, Crema, CR, 26013, Italy,  
alberto.ceselli@unimi.it, Bernardetta Addis, Giuliana Carello

In many telecommunication networks a given set of client nodes must be served by different sets of facilities, which must be located and dimensioned in designing the network. We provide a compact and an extended formulation for that problem and we design an exact branch-and-cut-and-price optimization algorithm. We test our approach on a set of instances derived from the facility location literature.

**3 - Review and Classification of Branching Schemes for Branch-and-price**

Francois Vanderbeck, Professor, University Bordeaux 1 & INRIA,  
Institut de Mathématiques de Bordeaux, 351, cours de la  
Libération, Talence, 33405, France, fv@math.u-bordeaux1.fr,  
Sophie Michel

Developing a branch-and-price algorithm requires an ad-hoc branching scheme. One must consider the impact of the branching scheme on the pricing procedure. The paper reviews the schemes that have been proposed in an application specific context. They can be classified into branching on original variables, auxiliary variables (arising from an extended formulation) or on constraints. Another distinction is whether branching is implemented in the master or the subproblem. The review is complete by direct numerical comparisons between alternative schemes on some standard problems.

**ThA09**

Marriott - Chicago F

**Branching Strategies for Mixed Integer Programming**

Cluster: Integer and Mixed Integer Programming  
Invited Session

Chair: Emilie Danna, IBM, 1195 W Fremont Avenue, Sunnyvale, CA,  
94087, United States of America, edanna@us.ibm.com

**1 - To Branch or To Cut**

Ashutosh Mahajan, Doctor, Argonne National Lab, MCS Division,  
Bldg 221, 9700 S Cass Avenue, Chicago, IL, 60439,  
United States of America, asm4@lehigh.edu, Ted Ralphs

Given a valid disjunction for a Mixed Integer Program (MIP), one can either use it for branching or for generating valid inequalities (VIs). Even though considerable research has gone in to identifying disjunctions useful for solving a MIP, little attention has been paid to whether to use these for branching or for generating VIs. In this talk, we present computational results from several experiments performed towards understanding this question and also discuss some theoretical results.

**2 - Bilevel Branching**

Ted Ralphs, Associate Professor, Lehigh University, Industrial and  
Systems Engineering, 200 West Packer Avenue, Bethlehem, PA,  
18015, United States of America, ted@lehigh.edu, Andrea Lodi,  
Stefano Smriglio, Fabrizio Rossi

We describe a new branching strategy for binary integer programs in which fixing variables to 1 results in a significant change in the bound obtained by solving the LP relaxation, whereas fixing to 0 has little or no impact. In such cases, branching on variables can be ineffective. The new strategy involves simultaneously branching on a set of variables chosen by solving a bilevel program. Computational results show that this strategy can be effective for combinatorial problems.

**3 - Using Infeasible Nodes to Select Branching Variables**

Emilie Danna, IBM, 1195 W Fremont Avenue, Sunnyvale,  
CA, 94087, United States of America, edanna@us.ibm.com,  
Andrea Lodi

In mixed integer programming, the choice of the branching variable is traditionally based on the history of changes in objective value caused by branching. This pseudocost strategy does not take into account branching decisions that create an infeasible child node. In this presentation, we describe how to integrate infeasible nodes into the branching variable selection. We discuss several alternatives and we show with computational experiments that our approach improves on the state of the art.

**ThA10**

Marriott - Chicago G

**Developments and Applications of Global Optimization in Chemical Engineering**

Cluster: Global Optimization  
Invited Session

Chair: Angelo Lucia, Professor, University of Rhode Island, Chemical  
Engineering Dept., Kingston, RI, 02881, lucia@egr.uri.edu

**1 - Large Scale Dynamics of Phase Transitions**

Rajeswar Gattupalli, Senior R&D Scientist, UOP LLC, 25 E  
Algonquin Road, Des Plaines, IL, 60017, United States of America,  
Rajeswar.Gattupalli@UOP.com, Angelo Lucia, Sam LeBlanc

In this work, a novel probing procedure is used within the terrain/funneling method of global optimization to find stationary points on the potential energy landscape for all-atom representations of n-alkane molecules and to quantify liquid-solid (or rotator-low ordered temperature) phase transitions. Numerical results for tetracosane are presented.

**2 - Role of Random Numbers in Global Optimization**

Urmila Diwekar, President, Vishwamitra Research Institute,  
368 56th Street, Clarendon Hills, IL, 60514,  
US Minor Outlying Islands, urmila@vri-custom.org

Random numbers play an important role in global optimization based on probabilistic methods. This paper exploits uniformity properties of random number to design new global optimization algorithms based on simulated annealing (SA) and genetic algorithms (GA). These algorithms are further extended for optimization under uncertainty. These new variants of SA and GA are found to be extremely efficient compared to traditional SA and GA.



### 3 - A Hybrid Sequential Niche Algorithm for Multimodal Optimization Problems

Jeonghwa Moon, Graduate Student, University of Illinois-Chicago, 851 S. Morgan St. - 218 SEO, Chicago, 60607, United States of America, jmoon8@uic.edu, Andreas Linninger

Detection of multiple solutions is important because multimodal objective functions are common in engineering and physics. In this talk, we will present a novel hybrid algorithm for locating all solutions in multimodal problems. This algorithm combines a sequential niche technique with deterministic local optimization to detect all extrema efficiently. We will show the efficiency and robustness of our algorithm with several examples in engineering designs.

## ■ ThA11

Marriott - Chicago H

### Robust Optimization in Finance

Cluster: Robust Optimization

Invited Session

Chair: Aurelie Thiele, Assistant Professor, Lehigh University, 200 W Packer Ave, Bethlehem, PA, 18015, United States of America, aurelie.thiele@lehigh.edu

#### 1 - Log-robust Portfolio Management

Aurelie Thiele, Assistant Professor, Lehigh University, 200 W Packer Ave, Bethlehem, PA, 18015, United States of America, aurelie.thiele@lehigh.edu, Ban Kawan

We present a robust optimization approach to portfolio management under uncertainty that (i) builds upon the well-established Lognormal model for stock prices while addressing its limitations, and (ii) incorporates the imperfect knowledge on the true distribution of the uncertainty drivers in an intuitive manner. We derive theoretical insights into the optimal asset allocation and the degree of diversification in the portfolio, in the cases with and without short sales.

#### 2 - Worst-case Value-at-risk of Non-linear Portfolios

Steve Zymler, Mr, Imperial College London, 180 Queen's Gate, South Kensington Campus, London, SW7 2AZ, United Kingdom, sz02@doc.ic.ac.uk, Berc Rustem, Daniel Kuhn

Models which aim to minimize the Value-at-Risk of a portfolio assume that the distribution of the underlying risk factors is known precisely. When the distributional assumptions do not hold, the calculated risk may be grossly underestimated. We will give an overview of Worst-Case VaR (WCVaR), which aims to overcome this modeling risk. We extend WCVaR for portfolios which are quadratic functions of the risk factors, and show how it can be used to minimize the WCVaR of derivative portfolios.

#### 3 - Tractable Robust Expected Utility and Risk Models for Portfolio Optimization

Joline Uichanco, PhD Candidate, MIT, 77 Massachusetts Avenue, Cambridge, MA, United States of America, uichanco@mit.edu, Karthik Natarajan, Melvyn Sim

We derive exact and approximate optimal trading strategies for a robust or maximin expected utility model where the distributions of the random returns are practically characterized. The investor's utility is modeled as a piecewise-linear concave function. We also provide connections of our results with robust or ambiguous convex risk measures, in which the investor minimizes his worst case risk under distributional ambiguity.

## ■ ThA12

Marriott - Los Angeles

### Optimal Design with PDE Constraints

Cluster: PDE-constrained Optimization

Invited Session

Chair: Eldad Haber, Emory University, 400 Dowman Drive, E414, 30322, United States of America, haber@mathcs.emory.edu

#### 1 - Optimal Experimental Design for Large-scale Non-linear Ill-posed Problems

Lior Horesh, IBM, Watson Research Center, Yorktown Heights, NY, United States of America, lhoresh@us.ibm.com, Eldad Haber, Luis Tenorio

Many theoretical and practical problems in science involve acquisition of data via an indirect observation of a model. The observed data are determined by the physical properties of the model sought, the physical governing laws, but also by the experimental settings. The experimental setup can be controlled by the experimentalist, and evidently a proper experimental design can substantially

improve the obtained results. Optimal experimental design for ill-posed problems was seldom tackled. In this study we propose a generic numerical and statistically sound optimal experimental design methodology for non-linear, ill-posed problems. We present the utilization of this approach for large-scale, non-linear electromagnetic inversion problems.

#### 2 - Optimal Experimental Design for the Surveillance of the Glucose Metabolism

Matthias Conrad, Emory University, 400 Dowman Drive, E429, Atlanta, GA, 30322, United States of America, conrad@mathcs.emory.edu, Eldad Haber

The glucose metabolism is a tight regulated system providing energy in humans. Dysfunctions in the glucose metabolism may lead to pathologies like obesity or diabetes. Establishing mathematical algorithms for control and optimal design is therefore essential in imbalanced glucose metabolisms. We will present new combined computational methods for ODE systems, optimization, parameter estimation, and optimal design to target this problem. The goal is to monitor the glucose metabolism via mathematical optimal control and to design minimal invasive methods.

#### 3 - Optimum Experimental Design for Nonlinear Differential Equation Models

Stefan Körkel, Head of a Junior Research Group, IWR, Heidelberg University, Im Neuenheimer Feld 368, Heidelberg, D-69120, Germany, Stefan.Koerkel@iwr.uni-heidelberg.de

This talk deals with optimum experimental design for parameter estimation in the validation process of nonlinear differential equation models. Numerical methods for this class of non-standard optimal control problems are discussed including a new multiple shooting formulation and tailored methods for automatic derivative evaluation. A new online experimental design approach is presented applied to an example from chemical engineering.

## ■ ThA13

Marriott - Miami

### Robust and Multi-Criteria Models in Energy

Cluster: Optimization in Energy Systems

Invited Session

Chair: Christiano Lyra, Professor, University of Campinas - UNICAMP, Av. Albert Einstein 400 (CP 6101), Cidade Universitaria, Campinas, SP, 13083-852, Brazil, christiano@pq.cnpq.br

#### 1 - Robust Optimization Applied to the French Unit-commitment Problem

Sinda Ben Salem, PhD Student, EDF R&D and Ecole Centrale Paris, 1 Avenue General de Gaulle, Clamart, France, sinda.ben-salem@edf.fr, Ala Ben Abbes, Michel Minoux, Gerald Vignal

This work concerns a robust optimization approach to the unit-commitment problems for the French daily electricity production. Our aim is to minimize production costs with an uncertain electricity demand, supposed to be specified by a given polyhedral uncertainty set. We formulate the problem in terms of minimizing a convex nonsmooth function, which is achieved via a proximal algorithm. Numerical results will be reported, showing that the proposed approach appears to be promising.

#### 2 - Robust Pricing in Electricity Markets with a Variable Demand

Eugene Zak, AREVA-TECH, 10865 Wilshire Road NE, Redmond, WA, 98072, United States of America, eugene.zak@areva-ta.com, Kwok Cheung

Clearing prices in a linear dispatch problem come from a dual solution. The situation is getting more complicated when a power demand is not constant but depends on current prices. Following Bulavskii [Soviet Math. Dokl., Vol 23 (1981), No. 2] a corresponding primal-dual model incorporates both primal and dual variables. Under linearity assumption for the demand-price function with a semi-definite matrix a resultant quadratic program yields stable prices and optimal levels of the demand.

#### 3 - Hierarchical Multiple Criteria Optimization of Maintenance Procedures on Power Distribution Networks

Christiano Lyra, Professor, University of Campinas - UNICAMP, Av. Albert Einstein 400 (CP 6101), Cidade Universitaria, Campinas, SP, 13083-852, Brazil, christiano@pq.cnpq.br, Celso Cavellucci, Jose Gonzalez, Fabio Usberti

Utilities must supply energy with reliability levels above minimum values. This work represents the relationship between maintenance and reliability with a mathematical model which allows formulating a multiple criteria optimization problem to unveil the best compromise for maintenance activities. The problem is solved for all local networks with two objective functions: maintenance costs and network reliability. Local solutions are coordinated to give global solutions for the whole company.

LATE CANCELLATION

## ■ ThA15

Gleacher Center - 100

### Approximation and Dynamics

Cluster: Stochastic Optimization

Invited Session

Chair: Silvia Vogel, Professor, Technische Universität Ilmenau, Postfach 100565, Ilmenau, 98684, Germany, Silvia.Vogel@tu-ilmenau.de

#### 1 - Dynamic Portfolio Optimization with Bounded Shortfall Risks

Ralf Wunderlich, Professor, Zwickau University of Applied Sciences, Mathematics Group, PSF 201037, Zwickau, D-08056, Germany, ralf.wunderlich@fh-zwickau.de

We consider the optimal selection of portfolios for utility maximizing investors under joint budget and shortfall risk constraints. The shortfall risk is measured in terms of the expected loss. Stock returns satisfy a stochastic differential equation with an unobservable drift process leading to a market model with partial information. Using martingale method we first find the optimal level of terminal wealth. Then, under general conditions on the corresponding drift process we provide the optimal trading strategy using Malliavin calculus. For a hidden Markov model (HMM) for the drift we present numerical results.

#### 2 - Approximation of Multistage Stochastic Programs

##### Via Scenario Trees

Holger Heitsch, Humboldt-University Berlin, Unter den Linden 6, Berlin, 10099, Germany, heitsch@math.hu-berlin.de, Werner Roemisch

Recent stability results for multistage stochastic programs state that for consistent approximation schemes we have to consider approximations with respect to two different types of distances namely a distribution and a information (or filtration) distance. We take up the latter issue and present a general framework for scenario tree construction and reduction in multistage stochastic programming models.

#### 3 - Universal Confidence Sets for Constrained Decision Problems

Silvia Vogel, Professor, Technische Universität Ilmenau, Postfach 100565, Ilmenau, 98684, Germany, Silvia.Vogel@tu-ilmenau.de

We will consider universal confidence sets, i.e. sequences of random sets which converge to the true constraint set or solution set and have the property that for each  $n$  the true set is covered at least with a prescribed probability. In addition to suitable convergence assumptions for the objective functions and the constraint functions the approach requires knowledge about certain characteristics of the unknown true decision problem. We will explain how estimates for these characteristics can be incorporated.

## ■ ThA16

Gleacher Center - 200

### Stochastic Optimization D

Contributed Session

Chair: Olga Myndyuk, Graduate Student, Rutgers University, RUTCOR, 640 Bartholomew Road, Piscataway, NJ, 08854, United States of America, olgamyn@eden.rutgers.edu

#### 1 - On the Certainty Equivalent and Probability Dependent Utility Function of CVaR based Preferences

Alexandre Street, Assistant Professor, Pontifical Catholic University of Rio de Janeiro, Marques de Sao Vicente Str., 225, Cardeal Leme Build., 4th Floor - DEE, Rio de Janeiro, RJ, 22451-900, Brazil, street@ele.puc-rio.br

The Conditional Value-at-Risk (CVaR) has been paving the way for an enormous number of applications in risk management problems. This work aims to introduce the characterization of the associated Certainty Equivalent (CE) and Utility Function (UF) of two types of well known decision agents: CVaR maximizers and CVaR constrained maximizers. A discussion on the need of time consistency in multistage stochastic decision will be provided based on a coherent usage of the CVaR utility.

#### 2 - Corporate Asset Liability Management (ALM) via Stochastic Programming

Davi Valladão, PhD Student, PUC-Rio, Guimarães Rosa 203/2003, Rua Marquês de São Vicente, 225, Gávea, Rio de Janeiro, 22793620, Brazil, davimv@ele.puc-rio.br, Alvaro Veiga, Alexandre Street

ALM is the practice of managing a business so that decisions taken with respect to assets and liabilities are coordinated, in order to achieve financial objectives, given a tolerance to risk. For a corporation, the main financial objective is to increase de value for the stockholders and the main risk is to bankrupt. In this paper we discuss a linear stochastic programming model to select projects and fundings of a corporation.

#### 3 - Probabilistic Programming with Uniformly Distributed Random Variable

Olga Myndyuk, Graduate Student, Rutgers University, RUTCOR, 640 Bartholomew Road, Piscataway, NJ, 08854, United States of America, olgamyn@eden.rutgers.edu

We assume that in the underlying LP the vector on the right hand side has multivariate uniform distribution in a convex set. We solve the probabilistic constrained stochastic programming problem by the supporting hyperplane and the logarithmic barrier methods. The combination of these methods provide us with lower and upper bounds for the optimum values. The problem to calculate the volumes of convex polyhedra will also be discussed. Numerical results will be presented.

## ■ ThA17

Gleacher Center - 204

### Logistics and Transportation C

Contributed Session

Chair: Uwe Zimmermann, Technical University Braunschweig, Pockelsstrasse 14, Braunschweig, 38106, Germany, u.zimmermann@tu-bs.de

#### 1 - An Exact Method for the Vehicle Routing Problem with Time Windows

Roberto Roberti, PhD Student, DEIS - University of Bologna, Via Sacchi, 3, Cesena, 47521, Italy, roberto.roberti6@unibo.it, Roberto Baldacci, Aristide Mingozzi

We present an exact method for the Vehicle Routing Problem with Time Windows (VRPTW) based on the set partitioning formulation with subset-row inequalities. A valid lower bound is computed by combining different dual ascent procedures and a pricing and cut method. The final dual solution is used to generate a reduced IP problem solved using CPLEX. The proposed method solved all but one Solomon benchmark instances, outperforming the best known methods.

#### 2 - Efficient Lower and Upper Bounds for the Multi-commodity Capacitated Multi-facility Weber Problem

Temel Oncan, Galatasaray University, Ciragan Cad NO 36, Istanbul, 34357, Turkey, oncantem@yahoo.com, I. Kuban Altinel, M. Hakan Akyuz

The Capacitated Multi-facility Weber Problem is concerned with locating  $I$  capacitated facilities in the plane to satisfy the demand of  $J$  customers with the minimum total transportation cost of a single commodity. This is a non-convex optimization problem and difficult to solve. In this study, we focus on a multi-commodity extension and consider the situation where  $K$  distinct commodities are shipped to the customers subject to capacity and demand constraints. Customer locations, demands and capacities for each commodity are known a priori. We propose specially tailored Lagrangean relaxation schemes to obtain lower bounds on the MCMWP and present efficient heuristic algorithms.

#### 3 - Large-scale Vehicle Routing for Urban Waste Disposal

Uwe Zimmermann, Technical University Braunschweig, Pockelsstrasse 14, Braunschweig, 38106, Germany, u.zimmermann@tu-bs.de, Ronny Hansmann

An ongoing project with waste disposal companies aims at simultaneously planning routes and crews of collection-vehicles. We focus on the optimization of routes. We illustrate practical constraints extending classical Arc Routing. Best exact methods for Arc Routing solve instances with up to 200 demand arcs to optimality. Our street network of the German city of Bochum consists of about 15000 arcs with demand, i.e. street segments with waste to collect. Based on adequate aggregations and relaxations we present optimization approaches for finding efficient routes. We discuss computational results for real data and we compare our solutions with the routes applied in practice. We conclude with some remarks on planning routes and crews at once.

## ■ ThA18

Gleacher Center - 206

### Non-linear Combinatorial Optimization

Cluster: Nonlinear Mixed Integer Programming

Invited Session

Chair: Jesus De Loera, Professor, University of California-Davis, Dept of Mathematics, One Shields Avenue, Davis, CA, 95616, United States of America, deloera@math.ucdavis.edu

#### 1 - Optimality Certificates, N-fold IPs and Nash Equilibria

Raymond Hemmecke, Visiting Professor, Technical University Darmstadt, Dept. of Mathematics, Darmstadt, Germany, hemmecke@mail.math.uni-magdeburg.de

In this talk I present a polynomial oracle-time algorithm to minimize a separable convex function over the lattice points in a polyhedron. Applying this algorithm to structured problems, such as N-fold integer programs, even yields a polynomial time algorithm for their solution. Based on this, I present a polynomial time algorithm for finding a generalized Nash equilibrium for a family of integer programming games.

### 2 - A New SDP Approach to the Max-cut problem

Joao Gouveia, Graduate Student, University of Washington,  
Dept of Mathematics, Seattle, WA, 98195, United States of  
America, jgouveia@math.washington.edu, Monique Laurent,  
Pablo A. Parrilo, Rekha Thomas

Using sums-of-squares techniques we generalize Lovasz's theta body construction and use it to derive a new hierarchy of SDP relaxations for the Max-Cut problem, solving an open question by Laszlo Lovasz.

### 3 - A Hierarchy of Theta Bodies for Polynomial Systems

Rekha Thomas, Professor, University of Washington, Box 354350,  
Department of Mathematics, Seattle, WA, 98195, United States of  
America, thomas@math.washington.edu, Joao Gouveia,  
Pablo A. Parrilo

We extend Lovasz's theta body of a graph to a hierarchy of SDP relaxations for the convex hull of real solutions to any polynomial system. I will discuss the geometry of these relaxations.

## ■ ThA19

Gleacher Center - 208

### Nonlinear Mixed Integer Programming C

Contributed Session

Chair: Qing Wang, The World Gates, Inc., 11545Parkwoods Circle,  
Suite B-1, Alpharetta, GA, United States of America,  
qingwangtct@yahoo.com

#### 1 - An Interior Point Lagrangian Decomposition Method for Convex Programming

Ion Necoara, K.U.Leuven, Kasteelpark Arenberg 10, Electrical  
Engineering Department, Leuven-Heverlee, 3001, Belgium,  
ion.necoara@esat.kuleuven.be, Johan Suykens

We present a decomposition algorithm that incorporates the interior point method into augmented Lagrangian decomposition technique for solving large-scale separable convex problems. By adding self concordant barrier terms to the ordinary Lagrangian we prove under mild assumptions that the corresponding family of dual functions is self concordant. This makes it possible to efficiently use the Newton method for tracing the central path. We also show that the new algorithm is globally convergent.

#### 2 - The End Set and the Extent of a Convex Set, the Closedness of a Convex Cone, and Applications

Hui Hu, Northern Illinois University, Math Dept.,  
Watson Hall 333, DeKalb, IL, 60115, United States of America,  
hu@math.niu.edu, Qing Wang

This article presents new conditions that ensure the closedness of a convex cone in terms of the end set and the extent of its generator. The results significantly extend the classical condition of the same problem. The new closedness conditions are utilized to obtain a simple formula of the least global error bound and a suitable regularity condition of the set containment problem for positively homogeneous convex functions.

## ■ ThA20

Gleacher Center - 300

### Large Scale Nonlinear Programming and PDE-based Problems

Cluster: Nonlinear Programming

Invited Session

Chair: Stefan Ulbrich, Technische Universitaet Darmstadt, Fachbereich  
Mathematik, Schlossgartenstr. 7, Darmstadt, 64289, Germany,  
ulbrich@mathematik.tu-darmstadt.de

#### 1 - Optimization of Time Dependent PDEs using Model Reduction

Matthias Heinkenschloss, Rice University, CAAM Dept. - MS 134,  
Houston, TX, 77005, United States of America, heinken@rice.edu

Optimization of time dependent PDEs involve the solution of large scale systems that arise from the forward in time state PDE and the backward in time adjoint PDE. We investigate the use of model reduction techniques as a method to reduce the storage and computing time requirements that arise. We present a model reduction approach that allows the derivation of a-priori bounds for the error in the solution and we present numerical examples for shape optimization and optimal control problems.

#### 2 - Trust Region Methods for Reduced Order Models

Ekkehard Sachs, Universitat Trier, Trier, 54286, Germany,  
sachs@uni-trier.de

Optimization problems with PDEs lead to large scale optimization problems with demand for very efficient software. In several applications the use of reduced order models have proven to become highly efficient. We present an adaptive approach to manage the models and discuss several issues in selecting the models related to proper orthogonal decomposition (POD).

#### 3 - Inexact Null-space Iterations in Large Scale Optimization

Michael Hintermueller, Professor, Humboldt-Universitaet zu  
Berlin, Department of Mathematics, Unter den Linden 6, Berlin,  
10099, Germany, hint@math.hu-berlin.de

For a class of PDE-constrained optimization problems it is assumed that the following building blocks for a solver of the KKT-system are available: an iterative procedure for the forward as well as the adjoint equation and a (simple) preconditioner for the KKT-system, which itself has the flavor of an iterative procedure. In fact, the overall method defines an inexact null space iteration (within an SQP framework). Therefore, in general it cannot be guaranteed that a search direction provides sufficient progress toward optimality. In this talk, under suitable conditions, a convergence analysis of such inexact null space iterations is provided and a report on numerical tests is given.

## ■ ThA21

Gleacher Center - 304

### Algorithmic Game Theory for Networks

Cluster: Telecommunications and Networks

Invited Session

Chair: Stavros Kolliopoulos, National & Kapodistrian University of  
Athens, Department of Informatics, Panepistimiopolis, Ilissia, Athens,  
157 84, Greece, sgk@di.uoa.gr

#### 1 - Selfish Routing with Oblivious Users and User Preferences

George Karakostas, McMaster University, 1280 Main St. W.,  
Hamilton, ON, Canada, karakos@mcmaster.ca, Taeyon Kim,  
Anastasios Vlgas, Hao Xia

We extend the known models of selfish routing by considering users oblivious to congestion. For example, a percentage of travelers may base their route simply on the distances they observe on a map, without any concerns about the delays experienced on this route due to their fellow travelers. We also consider the selfish routing of users with individual route preferences and the problem of inducing these selfish users to follow the optimal flow pattern through taxes.

#### 2 - Utilitarian Mechanism Design for Multi-objective Optimization

Piotr Krysta, University of Liverpool, Department of Computer  
Science, Ashton Building, Ashton Street, Liverpool, L69 3BX,  
United Kingdom, P.Krysta@liverpool.ac.uk, Stefano Leonardi,  
Fabrizio Grandoni, Carmine Ventre

We study mechanism design for NP-hard multi-objective optimization problems with one objective function and secondary objectives modeled by budget constraints. Our main contribution is showing that two of the main tools for the design of approximation algorithms for multi-objective optimization problems, approximate Pareto curves and Lagrangian relaxation, can lead to truthful approximation schemes. By exploiting the first method, we devise truthful FPTASs for the multi-budgeted versions of minimum spanning tree, shortest path, maximum matching, and matroid intersection. By building on the second method, we present a universally truthful Las Vegas PTAS for minimum spanning tree with a single budget constraint, without violating the budget.

#### 3 - On the Complexity of Price Wars

Adrian Vetta, McGill University, 805 Sherbrooke St, McGill  
University, Canada, vetta@math.mcgill.ca, Nithum Thain

We consider the complexity of decision making with regards to predatory pricing in multi-market models. Specifically, we develop multi-market extensions of the classical oligopoly models of Bertrand, Cournot and Stackelberg. Using the current legal framework, we then show that it is hard for a firm to decide whether engaging in predatory behaviour will be profitable, even with complete information. On the positive side, we present approximation algorithms for this problem.



## ■ ThA22

Gleacher Center - 306

### Implementations, Software A

Contributed Session

Chair: Geraldo Veiga, RN Ciancia e Tecnologia, R. Aperana 57/404, Rio de Janeiro, 22453-900, Brazil, gveiga@gmail.com

#### 1 - Mathematical Programming with Mathematica: Forming Models, Executing Methods, and Confirming Results

James Noyes, Emeritus Professor of Computational Science, Wittenberg University, P.O. Box 190, 140 Owners Drive, Tremont City, OH, 45372, United States of America, jnoyes@wittenberg.edu

Using Mathematica 7, many types of optimization problems (UO, LP, QP, NLP, MILP, etc.) can be easily formulated and solved, often by a single command. Integrated features include: symbolic and numeric processing (e.g., partial derivatives), exact and arbitrary precision arithmetic, static vs. dynamic visualization, and user-selected vs. auto-selected hybrid solution algorithms. Performance on test problems will be investigated and code will be demonstrated that extends Mathematica's capability.

#### 2 - On the Implementation of the Primal-dual Interior-point Method for SDPs with Log-determinants

Mituhiko Fukuda, Assistant Professor, Tokyo Institute of Technology, 2-12-1-S6-5, Oh-okayama, Meguro-ku, Tokyo, 152-8550, Japan, mituhiko@is.titech.ac.jp

We incorporate new routines to adapt the general semidefinite programming (SDP) solver SDPA version 7 to solve SDPs with weighted log-determinant terms. Numerical experiments show that the current version inherits all the best features of the new SDPA.

#### 3 - Parallel Implementation of Interior Point Algorithms for Linear Programming

Geraldo Veiga, RN Ciancia e Tecnologia, R. Aperana 57/404, Rio de Janeiro, 22453-900, Brazil, gveiga@gmail.com, Fernanda Thomé, Luiz Carlos Costa Jr., Nelson Maculan

In interior point methods, the computational effort lies in solving a sequence of symmetric linear systems. We explore the parallelization of a primal-dual algorithm by incorporating linear system solvers from highly scalable parallel toolkits. Using MPI and OpenMP, we consider MUMPS, a parallel implementation of the multi-frontal method, and iterative methods from the PETSc toolkit. Computational experiments solve problems from a standard testbed and a large-scale power system planning model.

## ■ ThA23

Gleacher Center - 308

### Optimization in Machine Learning II

Cluster: Sparse Optimization

Invited Session

Chair: Kristin Bennett, Professor, Rensselaer Polytechnic Institute, Dept of Mathematical Sciences, 110 Eighth Street, Troy, NY, 12180, United States of America, bennek@rpi.edu

#### 1 - Privacy-preserving Support Vector Machine Classification via Random Kernels

Olvi Mangasarian, Professor Emeritus, University of Wisconsin, Computer Sciences Dept., 1210 West Dayton Street, Madison, WI, 53706, United States of America, olvi@cs.wisc.edu, Edward Wild

Privacy-preserving support vector machine (SVM) classifiers are proposed for vertically and horizontally partitioned data. Vertically partitioned data represent instances where distinct entities hold different groups of input space features for the same individuals, but are not willing to share their data or make it public. Horizontally partitioned data represent instances where all entities hold the same features for different groups of individuals and also are not willing to share their data or make it public. By using a random kernel formulation we are able to construct a secure privacy-preserving kernel classifier for both instances using all the data but without any entity revealing its privately held data.

#### 2 - MetricBoost: AdaBoosting Positive Semi-definite Matrices for Metric Learning

Jinbo Bi, Scientist, Siemens Medical Solutions, 51 Valley Stream Parkway, Malvern, PA, 19355, United States of America, jinbo\_bi@yahoo.com

We study a boosting algorithm, MetricBoost, for learning a distance metric to preserve proximity relationship among objects. The problem of learning a proper distance metric arises in many applications, eg in content-based image retrieval. PSD matrices can be used to define Mahalanobis distance. We give mathematical derivation of MetricBoost which builds a Mahalanobis metric by combining rank-one matrices into a PSD matrix. We discuss the options for choosing alpha and weak models. Efficient implementations of MetricBoost are also developed to

dramatically scale it up. Computational results on benchmark data sets as well as on a real-world medical problem to identify diffused lung diseases demonstrate the effectiveness of MetricBoost.

#### 3 - SVM Cross-validation as a Bilevel Program with Unconstrained Lower Level Problems

Greg Moore, Rensselaer Polytechnic Inst, 110 8th Street, AE 301, Troy, NY, 12180, United States of America, mooreg5@rpi.edu, Kristin Bennett, Jong-Shi Pang

We formulate selection of support vector machine (SVM) hyper-parameters via cross-validation as a bilevel program. The lower level SVM problems are treated directly as convex unconstrained optimization problems. We replace the lower level problems with a nonsmooth penalty function of the optimality conditions. The resulting penalty problems are solved using successive convex function approximations with proximity control. This novel approach is scalable and generalizes well.

## ■ ThA25

Gleacher Center - 404

### Variational Analysis

Cluster: Variational Analysis

Invited Session

Chair: Shu Lu, University of North Carolina-Chapel Hill, 355 Hanes Hall CB 3260, Chapel Hill, NC, 27599, United States of America, shulu@email.unc.edu

#### 1 - Prox-regularity

Rene Poliquin, Professor, University of Alberta, Edmonton, AB, T6G2G1, Canada, rene.poliquin@ualberta.ca

A survey of prox-regularity will be given. Operations that preserve prox-regularity will be presented. New results concerning the second-order epi- and parabolic derivatives of these functions will be examined.

#### 2 - Implications of the Constant Rank Constraint Qualification

Shu Lu, University of North Carolina-Chapel Hill, 355 Hanes Hall CB 3260, Chapel Hill, NC, 27599, United States of America, shulu@email.unc.edu

This talk concerns a parametric set defined by finitely many equality and inequality constraints under the constant rank constraint qualification (CRCQ). The CRCQ generalizes both the linear independence constraint qualification (LICQ) and the polyhedral case, and is also related to the Mangasarian-Fromovitz constraint qualification (MFCQ) in a certain way. It induces some nice properties of the set defined by a fixed parameter, and some nice behavior of the set-valued map that assigns parameters to sets defined by them. Such properties are useful in analysis of variational conditions.

#### 3 - Coderivatives in Parametric Optimization in Asplund Spaces

Nhi Nguyen, Wayne State University, Department of Mathematics, Detroit, MI, 48202, United States of America, ax4667@wayne.edu

In this talk, we first develop some calculus rules for second-order partial subdifferentials of extended real-valued functions in the framework of Asplund spaces. We then apply these rules in the study of a family of parameterized optimization problems in which both cost function and constraint function are nonsmooth extended real-valued on Asplund spaces, and conduct a local sensitivity analysis for the stationary point multifunctions.

## ■ ThA28

Gleacher Center - 600

### Convex Optimization Algorithms

Cluster: Nonsmooth and Convex Optimization

Invited Session

Chair: Angelia Nedic, Assistant Professor, University of Illinois at Urbana-Champaign, 117 Transportation Building, 104 South Mathews Avenue, Urbana, IL, 61801, United States of America, angelia@illinois.edu

#### 1 - Multi-dimensional Mechanism Design: Finite Dimensional Approximations and Efficient Computation

Alexandre Belloni, Duke University, The Fuqua School of Business, 1 Towerview Drive, Durham, NC, 27708, abn5@duke.edu, Giuseppe Lopomo, Shouqiang Wang

Multi-dimensional mechanism design problems have proven difficult to solve. We consider mechanism design problems with multi-dimensional types when the seller's cost function is not separable across buyers. We transform the seller's problem into a representation that only involves 'interim' variables and eliminates the dimensionality dependence on the number of buyers. We show that the associated infinite dimensional optimization problem can be approximated arbitrarily well by a sequence of finite dimensional LPs.

**2 - Convex Optimization for Multi-task/kernel Learning**

Paul Tseng, Professor, University of Washington, Department of Mathematics, Box 354350, Seattle, WA, 98195, United States of America, tseng@math.washington.edu, Jieping Ye, Ting Kei Pong

We describe ongoing work on convex optimization arising in multi-task and multi-class discriminant kernel learning. These problems involve matrix variables and are large scale. We study primal and dual formulations, some of which involve SDP and/or nuclear/trace norm minimization, and efficient algorithms, including accelerated gradient methods. One application is gene expression pattern analysis.

**3 - Distributed Convex Optimization**

Sundhar Ram Srinivasan, University of Illinois, 1308 W. Main Street, Urbana, IL, 60801, United States of America, ssriniv5@illinois.edu, Angelia Nedic, Venugopal Veeravalli

We first consider the problem of minimizing the sum of convex functions, when each function is known only to a network agent. We briefly review two distributed algorithms that solve this problem. We then introduce a new class of objective functions that can be solved using distributed algorithms and discuss the associated algorithm. We motivate both the problems using regression. Finally, we also discuss extensions to the case when there are gradient errors, communication errors and quantization effects.

**ThA29**

Gleacher Center - 602

**Mathematical Programming Approaches in Financial Modeling**

Cluster: Finance and Economics

Invited Session

Chair: Stan Uryasev, Professor, University of Florida, ISE Department, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32611, United States of America, uryasev@ufl.edu

**1 - Implied Copula CDO Pricing Model: Entropy Approach**

Alex Veremyev, University of Florida, 303 Weil Hall, Gainesville, United States of America, averemyev@ufl.edu, Stan Uryasev, Alex Nakonechnyi, Tyrrell Rockafellar

An implied copula CDO pricing model is considered for calibrating obligor hazard rates. To find the probability distribution of the hazard rates we propose an entropy approach to the implied copula model by Hull and White. We maximize entropy with no-arbitrage constraints based on bid and ask prices of CDO tranches. To reduce the noise a new class of distributions is introduced. A case study shows that this approach has a stable performance. The MATLAB code is provided.

**2 - Risk Classification Approach through Convex Optimization**

Vladimir Bugera, Kammerdiner Consulting, 16031 N 31st Ave, Phoenix, AZ, 85053, United States of America, vladimir@bugera.com, Stan Uryasev

We consider an optimization approach for multi-class classification. The optimization problem is formulated as minimization of a penalty function built with quadratic separating functions. It is reduced to linear programming. We enhance the optimization problem with various constraints to adjust model flexibility and to avoid data overfitting. We apply this approach to evaluate risks in several financial applications, and compare our methodology with conventional techniques.

**3 - Entropy Approach for Calibrating Probabilistic Distributions**

Konstantin Kalinchenko, University of Florida, Gainesville, FL 32611, kalinchenko@ufl.edu, Stan Uryasev

We are using entropy approach for calibrating probabilistic distributions. The first problem is related to estimating return distributions of a portfolio based on information from analysts. The second problem is from medical area where we are estimating the risk (probability) of cesarean section.

**Thursday, 1:15pm - 2:45pm****ThB01**

Marriott - Chicago A

**Allocations and Scheduling**

Cluster: Approximation Algorithms

Invited Session

Chair: Cliff Stein, Columbia University, 326 S W Mudd Building, 500 W. 120th Street, New York, NY, 10027, cliff@ieor.columbia.edu

**1 - Allocating Goods to Maximize Fairness**

Julia Chuzhoy, TTI, 6045 S. Kenwood Ave., Chicago, United States of America, cjulia@tti-c.org, Deeparnab Chakrabarty, Sanjeev Khanna

In the Max-Min Allocation problem, the input consists of a set of agents, a set of items and utilities  $u(A,i)$  of agent  $A$  for item  $i$ . The goal is to allocate items to the agents, maximizing the minimum utility of any agent. The utility of an agent is the sum of its utilities for items it receives. We show new approximation algorithms for the problem, and in particular provide poly-logarithmic approximation in quasi-polynomial time.

**2 - Primal-dual Algorithm for Maximum Budgeted Allocation**

Deeparnab Chakrabarty, Post-doctoral Fellow, University of Waterloo, 200 University Ave W, Waterloo, ON, N2L2C9, Canada, deeparnab@gmail.com

In the maximum budgeted allocation (MBA) problem, we are given a set of indivisible items and agents bidding on them. Each agent has a budget over which she will not pay. The goal is to allocate the items to maximize revenue. We state a natural linear programming relaxation for the problem and then show a primal-dual algorithm achieving a  $3/4$ -factor matching the integrality gap of the relaxation. This is the best known approximation for the problem to date.

**3 - Scheduling to Minimize Average Response Time**

Cliff Stein, Columbia University, 326 S W Mudd Building, 500 W. 120th Street, New York, NY, 10027, cliff@ieor.columbia.edu

Consider the non-preemptive scheduling problem on one machine and a set of jobs that arrive at different times and have different processing times. The objective is to minimize the average response time. We give new approximation algorithms for this, and related scheduling problems, using resource augmentation. The main technical contribution is a new integer programming formulation and leads to the first constant factor approximations using constant factor faster machines.

**ThB02**

Marriott - Chicago B

**Equilibrium and Variational Inequality Problems**

Cluster: Complementarity Problems and Variational Inequalities

Invited Session

Chair: Michael Hintermueller, Professor, Humboldt-Universitaet zu Berlin, Department of Mathematics, Unter den Linden 6, Berlin, 10099, Germany, hint@math.hu-berlin.de

**1 - A Regularization/semi-smooth-Newton Method for Solving a Cahn-Hilliard Type Problem**

Moulay Hicham Tber, Doctor, University of Graz, Department of Mathematics, Paulustorgasse 15, Graz, 8010, Austria, moulay.tber@uni-graz.at, Michael Hinze, Michael Hintermueller

A Cahn-Hilliard model is considered. The governing system is discretised in time using a semi-implicit scheme. The resulting time-discrete system is formulated as an optimal control problem with constraints on the control. To solve the optimal control problem, we propose a function space algorithm which combines a regularization method to deal with the constraints on the control and a semi-smooth Newton method to solve the optimality systems for the regularized sub-problems.

**2 - An Analysis of M-stationary Points to an Electricity Spot Market EPEC**

Thomas Surowiec, PhD Student, Humboldt-University of Berlin, Department of Mathematics, Unter den Linden 6, Berlin, 10099, Germany, surowiec@math.hu-berlin.de, Rene Henrion, Jiri Outrata

We present a type of solution analysis for equilibrium problems with equilibrium constraints (EPEC). The analysis centers on the disambiguation of M-stationarity conditions, leaving them void of multivalued objects. Conducting this analysis requires a verification of the stability properties of certain multifunctions and constraint qualifications. Depending on the model parameters, this is done in a variety ways, e.g., via a new calmness result for a class of a non-polyhedral multifunctions.



**3 - Nonsmooth Newton Multigrid Methods for Constrained and Nonlinear Minimization Problems**

Carsten Gräser, PhD Student, Freie Universität Berlin, Fachbereich Mathematik und Informatik, Arnimallee 6, Berlin, 14195, Germany, [graeser@math.fu-berlin.de](mailto:graeser@math.fu-berlin.de)

Nonsmooth Newton methods turned out to be an efficient approach to deal with inequality constrained minimization problems. Unfortunately they often lack an inexact global convergence theory. We present a class of nonsmooth Newton methods that can be globalized using the problem inherent energy - even in the case of very inexact solution of the linear subproblems. Using linear multigrid methods for these subproblems a globally convergent overall nonlinear multigrid method is obtained that performs comparable to multigrid methods for linear problems. Since the presented approach incorporates inequality constraints in terms of nonsmooth nonlinear functionals it directly extends to various other nonsmooth minimization problems.

**ThB03**

Marriott - Chicago C

**Decomposition Methods for Models of Energy Markets**

Cluster: Optimization in Energy Systems

Invited Session

Chair: David Fuller, University of Waterloo, 200 University Avenue West, Waterloo, ON, N2L 3G1, Canada, [dfuller@engmail.uwaterloo.ca](mailto:dfuller@engmail.uwaterloo.ca)

**1 - Subproblem Approximation in Dantzig-Wolfe Decomposition of Variational Inequality Problems**

David Fuller, University of Waterloo, 200 University Avenue West, Waterloo, ON, N2L 3G1, Canada, [dfuller@engmail.uwaterloo.ca](mailto:dfuller@engmail.uwaterloo.ca), William Chung

The talk outlines the extension of Dantzig-Wolfe decomposition from pure optimization problems to variational inequality (VI) problems. Several ways to approximate the subproblem can produce better proposals, while retaining the theoretical convergence properties. Illustrations are given for a model of Canadian energy markets.

**2 - Decomposition and Approximation Algorithms for an Equilibrium Model in Electricity Markets**

Emre Celebi, PhD Candidate, University of Waterloo, 200 University Ave. West, Waterloo, ON, N2L 3G1, Canada, [ecelebi@engmail.uwaterloo.ca](mailto:ecelebi@engmail.uwaterloo.ca), David Fuller

An equilibrium model in time-of-use electricity markets with linearized DC network constraints is examined. We sought computationally efficient decomposition algorithms for this model and used approximations to reduce the computational effort. These algorithms and approximations are applied to large-scale realistic test models.

**3 - Solving Stochastic Complementarity Problems with Benders Method**

Steve Gabriel, Associate Professor, University of Maryland, Dept Civil Environ Eng, 1143 Glenn L Martin Hall, College Park, MD, 20742, United States of America, [sgabriel@umd.edu](mailto:sgabriel@umd.edu), David Fuller

In this talk we present a new version of Benders method customized to solve stochastic complementarity problems but based on an earlier decomposition strategy of Fuller and Chung. We provide both the theory as well as numerical experiments that justify the approach.

**ThB04**

Marriott - Denver

**Combinatorial Optimization H**

Contributed Session

Chair: Yuichiro Miyamoto, Sophia University, Kioicho 7-1, Chiyodaku, Tokyo, Japan, [miyamoto@sophia.ac.jp](mailto:miyamoto@sophia.ac.jp)

**1 - An Improved Algorithm for Finding Minimum Cycle Bases in Undirected Graphs**

Edoardo Amaldi, DEI, Politecnico di Milano, Piazza L. da Vinci 32, Milano, 20133, Italy, [amaldi@elet.polimi.it](mailto:amaldi@elet.polimi.it), Claudio Iuliano, Romeo Rizzi

Given an undirected graph  $G$  with a nonnegative weight on each edge, we wish to find a basis  $B$  of the cycle space of  $G$  of minimum total weight, where the weight of  $B$  is the sum of the weights of all the cycles in  $B$ . We present an efficient  $O(m^3)$  hybrid algorithm in which only a substantially reduced set of candidate cycles, the so-called isometric cycles, is considered, and report some computational results.

**2 - Integer Programming Formulations for Graph Partitioning**

Matthias Peinhardt, Otto-von-Guericke University Magdeburg, Universitätsplatz 2, Faculty of Mathematics (FMA/IMO), Magdeburg, D-39106, Germany, [matthias.peinhardt@ovgu.de](mailto:matthias.peinhardt@ovgu.de)

Graph Partitioning is an important optimization problem incorporating many diverse applications. In the past several Integer Programming formulations have been proposed. We compare these formulations experimentally with an emphasis on a formulation that has been dismissed in the past because of its inherent symmetry, albeit its advantage to directly deal with sparse graphs. To circumvent the problems arising from model symmetry we propose several approaches, and evaluate them.

**3 - Levelwise Mesh Sparsification for Point-to-Point Shortest Path Queries**

Yuichiro Miyamoto, Sophia University, Kioicho 7-1, Chiyodaku, Tokyo, Japan, [miyamoto@sophia.ac.jp](mailto:miyamoto@sophia.ac.jp), Takeaki Uno, Mikio Kubo

We propose the levelwise mesh sparsification method that allows fast point-to-point queries in networks using preprocessed data. In our method, several sparse networks are obtained by preprocessing the original network, and the shortest path problem is solved by finding the shortest path in these sparse networks. Computational experiments on real world data show the efficiency in terms of computational time and memory efficiency. The advantage is that it uses only a small amount of memory.

**ThB05**

Marriott - Houston

**Combinatorial Optimization L**

Contributed Session

Chair: Ilya Safro, Postdoc, Argonne National Laboratory, Mathematics and CS Division, 9700 S Cass, Lemont, IL, 60439, United States of America, [safro@mcs.anl.gov](mailto:safro@mcs.anl.gov)

**1 - A Satisfiability Approach to Combinatorial Optimization Problems**

Andrei Horbach, University of Kiel, Olshausenstr.,40, Kiel, 24098, Germany, [horbach@bwl.uni-kiel.de](mailto:horbach@bwl.uni-kiel.de)

We solve combinatorial optimization problems by applying extended SAT techniques. Our approach allows us to efficiently solve several problems of combinatorial optimization, e.g. the Resource Constrained Project Scheduling Problem and real-world scheduling problems of sports leagues. We discuss the bottlenecks of this approach and possibilities to improve it.

**2 - Combinatorial Optimization for Flat Panel Displays**

Andreas Karrenbauer, EPFL, Institute of Mathematics, Station 8, Lausanne, 1015, Switzerland, [andreas.karrenbauer@epfl.ch](mailto:andreas.karrenbauer@epfl.ch)

We use methods from Combinatorial Optimization, i.e. flows and matchings, to improve modern flat panel displays. That is, we reduce the addressing time and thereby also power consumption and degradation effects. To this end, we model the addressing of the pixels as combinatorial matrix decomposition problems. We show NP-hardness and conditions under which polynomial algorithms exist. We derive fully combinatorial approximation algorithms, which are currently implemented by a chip manufacturer.

**3 - Multilevel Algorithms for Combinatorial Optimization Problems**

Ilya Safro, Postdoc, Argonne National Laboratory, Mathematics and CS division, 9700 S Cass, Lemont, IL, 60439, United States of America, [safro@mcs.anl.gov](mailto:safro@mcs.anl.gov)

Linear ordering and partitioning problems appear in many practical applications. We present a general framework of linear multilevel heuristic algorithms and demonstrate (including numerical results) how its parts can be used for minimizing: linear arrangement, bandwidth, partitioning, etc. We introduce a notion of algebraic distance of an edge and show how to use endpoints neighborhood connectivity in Algebraic Multigrid schemes for graphs. Joint work with: A. Brandt, C. Chevalier and D. Ron.

**ThB06**

Marriott - Kansas City

**Applications of Conic Programming in Random Linear and Integer Programs**

Cluster: Conic Programming

Invited Session

Chair: Karthik Natarajan, City University of Hong Kong, Department of Management Science, Hong Kong, Hong Kong - PRC, [knataraj@cityu.edu.hk](mailto:knataraj@cityu.edu.hk)

**1 - Product Line Design with Interdependent Products**

Vinit Kumar, National University of Singapore, 1 Business Link, BIZ 1 Building, Kent Ridge, 117592, Singapore, [vinitkmishra@gmail.com](mailto:vinitkmishra@gmail.com), Chung-Piaw Teo, Hua Tao, Karthik Natarajan

We develop a discrete choice model termed as the Cross Moment Model (CMM) based on Semidefinite programming. This choice model is parsimonious in that it uses only the mean and covariance information of the utility functions. We use this model to solve a "flexible packaging design problem" confronting a local service parts supplier and compare the results with the results obtained by MNL.

## 2 - Mixed Zero-one Linear Programs Under Uncertainty: A Completely Positive Representation

Karthik Natarajan, City University of Hong Kong, Department of Management Science, Hong Kong, Hong Kong - PRC, knataraj@cityu.edu.hk, Chung-Piaw Teo, Zheng Zhichao

We develop a cross moment model based on completely positive programs for mixed 0-1 linear programs under uncertainty. The model captures mean-covariance information and works for mixed 0-1 linear programs. This extends Burer's model from a deterministic to a stochastic setting. The practicality of the model is explored in an order statistics and project management setting. The generality of the model opens up an interesting dimension for research in stochastic discrete optimization models.

## 3 - Basis Partition of the Space of Linear Programs Through a Differential Equation

Zhao Gongyun, National Univ. of Singapore, Department of Mathematics, Singapore, Singapore, matzgy@nus.edu.sg

A linear program (LP) is associated with an optimal basis. The space of linear programs (SLP) can be partitioned into a finite number of sets, each consisting of all LPs with a common basis. If the partition of SLP can be characterized, we can solve infinitely many LPs in closed form. A tool for characterizing the partition of SLP is an ode  $M' = h(M)$ , where  $M$  is a projection matrix. Any LP defines a projection matrix, starting from which the solution of  $M' = h(M)$  converges to a limit projection matrix which can determine the basis of the LP. With the help of  $M' = h(M)$ , it is promising to discover full characterization of the partition of SLP. We will present some properties found so far. Full structure of SLP is still awaiting an exploration.

## ThB07

Marriott - Chicago D

### Integer and Mixed Integer Programming H

Contributed Session

Chair: Adewale Faparusi, Texas A&M University, 5005 Coachmans Carriage Terrace, Glen Allen, VA, 23059, United States of America, afaparusi@tamu.edu

#### 1 - Chebyshev Center Based Column Generation

Jinil Han, Ph.D. Student, KAIST, 335 Gwahangno, Yuseong-gu, Department of Industrial and Systems Eng, Daejeon, 305-701, Korea, Republic of, hji@kaist.ac.kr, Sungsoo Park, Chungmok Lee

Classical column generation often shows desperately slow convergence. Recently, many acceleration techniques are proposed. We propose Chebyshev center based column generation. In this method, the Chebyshev center is used for centering dual solutions within dual polyhedron. The Chebyshev center can be obtained by solving a linear program, so that our method can be applied with small modification of the classical column generation scheme. Numerical experiments show the effectiveness of our method.

#### 2 - Handling Manufacturing Restrictions in Sheet Metal Design by Mixed Integer Programming

Ute Guenther, TU Darmstadt, Schlossgartenstrasse 7, Darmstadt, 64289, Germany, ugenther@mathematik.tu-darmstadt.de, Alexander Martin

We investigate a network design problem where the task is to find a directed Steiner tree with additional constraints, e.g. on the diameter. We study the underlying polyhedron and present facet-defining inequalities representing connectivity constraints. The study is motivated by an application from engineering, namely how to find design plans for branched sheet metal structures. To include all manufacturing restrictions while maintaining reasonable running time we use branch-and-cut approaches.

#### 3 - Heuristic Solutions for the Fixed Charge Network Flow Problem

Adewale Faparusi, Texas A&M University, 5005 Coachmans Carriage Terrace, Glen Allen, VA, 23059, United States of America, afaparusi@tamu.edu

The Fixed Charge Network Flow Problem (FCNFP) is known to be NP-hard. It has many practical applications and includes the Steiner tree problem, uncapacitated lot-sizing problems, and the fixed charge transportation problem as special cases. Although many exact methods have been developed to solve the FCNFP, in generality their computational requirements are exponentially related to the size of the problem. Modifications to improve existing heuristic algorithms are proposed.

## ThB08

Marriott - Chicago E

### Branch-and-Price II

Cluster: Integer and Mixed Integer Programming  
Invited Session

Chair: Marco Luebbecke, TU Berlin, Institute of Mathematics, Strasse des 17. Juni 136, Berlin, 10623, Germany, m.luebbecke@math.tu-berlin.de

#### 1 - The Fixed Charge Shortest Path Problem

Martin Savelsbergh, Professor, Georgia Tech School of Industrial and Systems Engineering, 765 Ferst Drive NW, Atlanta, GA, 30332, United States of America, mwps@isye.gatech.edu, George Nemhauser, Faramroze Engineer, Jin-Hwa Song

Consider a network in which each arc has a fixed cost, an interval specifying the flow that can be sent along the arc, and a per-unit cost for sending flow along the arc. For each node, there is a maximum flow that can accumulate along a path before reaching the node. The fixed charge shortest path problem (FCSP) seeks to find a minimum-cost path from a source to a sink. We develop an innovative DP algorithm for FCSP. FCSP arises frequently in branch-and-price algorithms.

#### 2 - Exact Reoptimization Algorithms for the Control of Elevator Groups

Benjamin Hiller, Zuse Institute Berlin, Takustr. 7, Berlin, Germany, hiller@zib.de, Torsten Klug, Andreas Tuchscherer

The task of an elevator control is to schedule the elevators of a group such that small average and maximal waiting and travel times for the passengers are obtained. We present exact reoptimization algorithms for this problem. A reoptimization algorithm computes a new optimal schedule for the elevator group each time a new passenger arrives. Our algorithms use column generation techniques and are, to the best of our knowledge, the first exact reoptimization algorithms for a group of elevators. We use our algorithms to compare the potential performance that can be achieved for conventional (ie up/down buttons) and two variants of destination call systems, where a passenger enters his destination floor when calling an elevator.

#### 3 - A Branch-and-price Algorithm for Clusterwise Linear Regression

Yan Jiang, PhD Candidate, Northwestern University, 2145 Sheridan Road, Room C210, Evanston, IL, 60208, United States of America, jiangyan1984@gmail.com, Diego Klafjan

We present a branch-and-price algorithm for performing clusterwise linear regression. The clusterwise linear regression problem is to find clusters such that the overall sum of squared errors in regression within the clusters is minimal. The proposed algorithm is applied in the retail promotion planning to group products according to their seasonal effects. The pricing problem is a specialized MIP, which is shown to be NP-complete.

## ThB09

Marriott - Chicago F

### General-purpose Techniques for Solving MIPS

Cluster: Integer and Mixed Integer Programming  
Invited Session

Chair: Santanu Dey, Université Catholique de Louvain, 1348 Louvain-la-Neuve, Belgium, Santanu.Dey@uclouvain.be

#### 1 - A Counterexample to a Conjecture of Gomory and Johnson

Amitabh Basu, Carnegie Mellon University, 5000 Forbes Avenue, A19B, Posner Hall, Pittsburgh, PA, 15213, United States of America, abasu1@andrew.cmu.edu, Michele Conforti, Gerard Cornuejols, Giacomo Zambelli

In Mathematical Programming 2003, Gomory and Johnson conjecture that the facets of the infinite group problem are always generated by piecewise linear functions. In this paper we give an example showing that the Gomory-Johnson conjecture is false.

#### 2 - Basis Reduction and the Complexity of Branch-and-bound

Gabor Pataki, University of North Carolina-Chapel Hill, Department of Statistics and Operations, Chapel Hill, United States of America, gabor@unc.edu, Mustafa Tural

Branch-and-bound is a classical method to solve integer programming feasibility problems. On the theoretical side, it is considered inefficient: it can take an exponential number of nodes to prove the infeasibility of a simple integer program. Here we show that branch-and-bound is theoretically efficient, if we apply a basis reduction based transformation to the constraint matrix. We prove that if the coefficients of the problem are drawn from  $\{1, \dots, M\}$  for a sufficiently large  $M$ , then for almost all such instances the reformulated problem solves at the rootnode. Besides giving an analysis of branch-and-bound, our main result generalizes a result of Furst and Kannan on the solvability of subset sum problems.

**3 - Hybrid Branching**

Timo Berthold, ZIB / Matheon, Takustr. 7, Berlin, 14195, Germany, berthold@zib.de, Tobias Achterberg

The question how to split a problem into subproblems (branching) is in the core of any branch-and-bound algorithm. Branching on individual variables is very common in CP, MIP, and SAT. The rules, however, which variable to choose for branching, differ significantly. In this talk, we present hybrid branching, which combines selection rules from these three fields. Hybrid branching outperforms state-of-the-art MIP branching rules on general MIP benchmark sets.

**ThB10**

Marriott - Chicago G

**Algorithms and Applications of Global Optimization for Nonlinear Programming Problems**

Cluster: Global Optimization

Invited Session

Chair: Ernesto G. Birgin, University of São Paulo, Institute of Mathematics and Statistics, Rua do Matão, 1010, São Paulo, SP, 05508-090, Brazil, egbirgin@ime.usp.br

**1 - Solving Convex Multiplicative Programs in the Outcome Space**

Paulo A. V. Ferreira, Associate Professor, University of Campinas, Electrical and Computer Engineering, Av. Albert Einstein, 400, Campinas, SP, 13083852, Brazil, valente@dt.fee.unicamp.br, Rúbia M. Oliveira

A convex analysis approach for the global optimization of convex multiplicative problems in the outcome space is proposed. Algorithms for two important classes of convex multiplicative programs - the minimization of a product of convex functions and the minimization of a finite sum of products of two convex functions over a convex set - are detailed and numerically investigated. Global minima for these two classes of nonconvex programs are obtained by solving, respectively, a sequence of quasi-concave problems by vertex enumeration, and a sequence of indefinite quadratic problems by constraint enumeration. Extensions for other classes of convex multiplicative programs are also reported.

**2 - A Branch-and-bound Algorithm for a Location Problem under Distance and Size-sensitive Demands**

Luis Merca Fernandes, Professor, Polytechnic Institute of Tomar and Institute of Telecommunications, Quinta do Contador - Estrada da Serra, Tomar, 2300-313, Portugal, luism@ipt.pt, Joaquim Judice, Antonio Pais Antunes, Hanif D. Sherali

We discuss a discrete location model for finding the number, location, and size of facilities to maximize a demand function that is related to the size of the facilities and the distance between them. The model also assumes that the facilities must satisfy a threshold level of demand. We present a mixed-integer nonlinear programming (MINLP) formulation, and design a novel branch-bound algorithm that is proven to converge to a global optimum. Some numerical results are reported based on a GAMS/MINOS implementation to illustrate the efficacy of the proposed algorithm.

**3 - Augmented Lagrangians for Global Minimization of NLP Problems**

Ernesto G. Birgin, University of São Paulo, Institute of Mathematics and Statistics, Rua do Matão, 1010, São Paulo, SP, 05508-090, Brazil, egbirgin@ime.usp.br, Christodoulos Floudas, Jose Mario Martinez

A novel global optimization method based on an Augmented Lagrangian framework is introduced for continuous constrained nonlinear optimization problems. At each outer iteration the method requires the epsilon-global minimization of the Augmented Lagrangian with simple constraints. Global convergence to an epsilon-global minimizer of the original problem is proved. The subproblems are solved using the alphaBB method. Numerical experiments are presented.

**ThB11**

Marriott - Chicago H

**Robust Optimization, Sparse Solutions and Signal Reconstruction**

Cluster: Robust Optimization

Invited Session

Chair: Constatine Caramanis, University of Texas, Mail Code, C0806, Austin, TX, 78712, cmcaram@ece.utexas.edu

**1 - Thresholded Basis Pursuit: Support Recovery for Sparse and Approximately Sparse Signals**

Venkatesh Saligrama, Professor, Boston University, Boston, MA, United States of America, srv@bu.edu, Manqi Zhao

We present a linear programming solution for support recovery of sparse signals from randomly projected noisy measurements. Our proof technique is based on perturbation of the noiseless  $\ell_1$  problem. Consequently, the maximum achievable sparsity level in the noisy problem is comparable to that of the noiseless problem. Our result offers a sharp characterization in that neither the SNR nor the sparsity ratio can be significantly improved.

**2 - Robust Regression and Lasso**

Huan Xu, University of Texas, Mail Code, C0806, Austin, TX, 78712, xuhuan@cim.mcgill.ca, Constatine Caramanis, Shie Mannor

We first show that the well-known Lasso is a special case of robust regression, thus providing an interpretation of Lasso from a robust optimization perspective. By showing some generalizations, we provide a new methodology for designing regression algorithms. In addition to obtaining new formulations, we directly to show sparsity properties of Lasso, and prove a general consistency result for robust regression problems, including Lasso, from a unified robustness perspective.

**3 - Compressed Sensing of Positive Signals with Minimal Expansion**

Alex Dimakis, Assistant Professor, University of Southern California, Los Angeles, CA, United States of America, adim@eecs.berkeley.edu, Weiyu Xu, Amin Khajehnejad, Babak Hassibi

We investigate the sparse recovery problem of reconstructing a high-dimensional non-negative sparse vector from lower dimensional linear measurements. While initial work focused on dense measurement matrices, such as those arising from Gaussian ensembles, sparse measurement schemes have been constructed recently, using the adjacency matrices of expander graphs. These constructions are crucial in applications, such as DNA microarrays and sensor networks, where dense measurements are not practically feasible. Furthermore, they often lead to recovery algorithms much more efficient than  $\ell_1$  minimization. However, to date, constructions based on expanders have required very high expansion coefficients which can potentially make the construction of such graphs difficult and the size of the recoverable sets small. We construct sparse measurement matrices for the recovery of non-negative vectors, using perturbations of adjacency matrices of expander graphs with much smaller expansion coefficients. We present a necessary and sufficient condition for  $\ell_1$  optimization to successfully recover the unknown vector and obtain expressions for the recovery threshold. We further show that the minimal expansion we use is necessary for any graph for which sparse recovery is possible and that therefore our construction is tight. We finally present a novel recovery algorithm that exploits expansion and is much faster than  $\ell_1$  optimization. We determine theoretical guarantees about the sparsity level of the recoverable vectors for this algorithm and compare it to existing schemes in the literature.

**ThB12**

Marriott - Los Angeles

**PDE-Related Optimization in Image Processing**

Cluster: PDE-constrained Optimization

Invited Session

Chair: Wotao Yin, Assistant Professor, Rice University, Department of Computational and Applied, 3086 Duncan Hall, Houston, TX, 77251, United States of America, wotao.yin@rice.edu

**1 - A Hybrid Method of Bregman Iterations and PDEs for Sparse Deconvolution**

Bin Dong, UCLA, UCLA Mathematics Department, Box 951555, Los Angeles, 90095, United States of America, bdong@math.ucla.edu, Yu Mao, Stanley Osher

We consider a combination of Bregman distance based methods with some specially designed PDEs for sparse deconvolution problems, e.g. deblurring of sparse spikes. The underlying optimization model is the standard  $\ell_1$  minimization with linear equality constraint, where the linear system corresponds to some convolution operator. The PDE is designed as a natural plug-in to the linearized Bregman iterations [Darbon and Osher 2007; Yin et. al. 2008; Osher et. al. 2008] and Bregman iterations [Yin et. al. 2008], and greatly improves the convergence speed for sparse deconvolution problems. Some applications of sparse deconvolutions are also considered.

**2 - Simple Compressive Algorithms for Parallel Many-core Architectures**

Jerome Darbon, UCLA, Mathematics Department, Los Angeles, United States of America, jerome@math.ucla.edu

We consider the recovery of signal via compressive sensing where the signal itself or its gradient are assumed to be sparse. This amounts to solve a  $\ell_1$  or a Total Variation minimization problem. We propose minimization algorithms specifically designed to take advantage of shared memory, vectorized, parallel and many-core microprocessors such as the Cell processor, new generation Graphics Processing Units (GPUs) and standard vectorized multi-core processors (e.g. standard CPUs).



**3 - Heat Source Identification Based on L1 Optimization**

Yingying Li, Graduate Student, University of California, Los Angeles, 1953 Overland Ave Apt 9, Los Angeles, CA, 90025, United States of America, yingyingli@math.ucla.edu, Stanley Osher, Richard Tsai

We consider inverting the heat equation, which is the problem of recovering the initial condition from given point-value samples at a fixed time or samples at multiple observation times. The initial condition assumed to be sparse. We show that with this assumption, the problem is effectively solved using L1 optimization methods.

**ThB13**

Marriott - Miami

**Optimization Applications in Energy and Environmental Problems**

Cluster: Optimization in Energy Systems  
Invited Session

Chair: Shi-Jie Deng, Associate Professor, Georgia Institute of Technology, 765 Ferst Drive, ISyE, Atlanta, GA, 30332, United States of America, deng@isye.gatech.edu

**1 - Modeling the Impacts of Plug-in Hybrid Electric Vehicles on Electric Power Systems**

Ramtean Sioshansi, Assistant Professor, The Ohio State University, Integrated Systems Engineering, 1971 Neil Avenue, Columbus, OH, 43215, United States of America, sioshansi.1@osu.edu

We discuss the use of detailed unit commitment and vehicle models to simulate the impacts of plug-in hybrid electric vehicles (PHEVs) on electric power systems. Our analysis shows that if the power system has flexibility in when PHEVs can be recharged (e.g. commuters specify only that their vehicles must be recharged the following morning), PHEV charging can be timed to drastically improve generation efficiency. We also discuss some computational issues and extensions of the model.

**2 - Effects of Permits Allocation on Emissions Leakage and Distribution of Future Generating Capacity**

Yihsu Chen, University of California, Merced, 5200 N. Lake Rd, Merced, CA, 95343, United States of America, yihsu.chen@ucmerced.edu, Andrew Liu

We examine the effects of emissions permits allocation schemes on the extent of the emission leakage and distribution of future generating capacity in power sector. We consider three emissions trading programs (e.g., source-, load-based and first-seller) and two allocation approaches. Whereas grandfather separates future permits allocation from today's decisions, the output-based approach links the awarded permits to today's output. The latter effectively subsidizes suppliers, and production costs, encourages more output and elevates permits prices. The results indicate that domestic power price could increase when per unit emissions subsidy is high. Polluting facilities would migrate to locations that are not subject to emissions cap.

**3 - Efficient Frontier of Demand Response and Supply Resources**

Shi-Jie Deng, Associate Professor, Georgia Institute of Technology, 765 Ferst Drive, ISyE, Atlanta, GA, 30332, United States of America, deng@isye.gatech.edu, Li Xu

This paper investigates an efficient frontier framework for an LSE to evaluate the role of DR programs in achieving a desirable tradeoff between profit and risk. We propose a model to obtain an optimal portfolio, consisting of load resources such as DR contracts, spot energy and forward energy contracts, which minimizes the risks or maximizes the utilities of LSEs subject to certain expected profit target.

**ThB14**

Marriott - Scottsdale

**Game Theory B**

Contributed Session

Chair: Bo Chen, Professor, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, United Kingdom, b.chen@warwick.ac.uk

**1 - Minimum Coloring Games and Population Monotonic Allocation Schemes**

Herbert Hamers, Tilburg University, P.O. Box 90153, Tilburg, 5000 LE, Netherlands, h.j.m.hamers@uvt.nl, Silvia Miquel, Henk Norde

A minimum coloring game is defined on a graph in which the value of a coalition equals the chromatic number of the sub-graph spanned by the vertices corresponding to this coalition. Deng, Ibaraki and Nagamochi (2000) showed that minimum coloring games are totally balanced if and only if the underlying graph of the game is perfect. Okamoto (2003) proved that minimum coloring games are submodular if and only if the underlying graph of the game is complete multipartite. This paper shows the existence of a population monotonic allocation scheme (PMAS) of a minimum coloring game if and only if the underlying graphs of the game has neither  $P_4$  nor  $2K_2$  as induced sub-graph.

**2 - The Optimal Timing of Prearranged Paired Kidney Exchanges**

Murat Kurt, PhD Candidate, University of Pittsburgh, 3700 O'Hara Street, 1048 Benedum Hall, Pittsburgh, PA, 15261, United States of America, muk7@pitt.edu, M. Utku Unver, Mark S. Roberts, Andrew J. Schaefer

Paired kidney exchanges (PKE) alleviate the shortage in the supply of kidneys for transplantation. We consider the transplant timing in a PKE and formulate the resulting problem as a non-zero sum stochastic game. We present necessary and sufficient conditions to characterize the stationary equilibria of this game. We bring the equilibrium selection into focus and characterize the welfare maximizing equilibrium as an optimal solution to an MIP. We present numerical results based on clinical data.

**3 - Equilibria in Load Balancing Games**

Bo Chen, Professor, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, United Kingdom, b.chen@warwick.ac.uk

A Nash equilibrium (NE) in a multi-agent game is a strategy profile that is resilient to unilateral deviations. A strong equilibrium (SE) is one that is stable against coordinated deviations of any coalition. We show that, in the load balancing games, NEs approximate SEs in the sense that the benefit of each member of any coalition from coordinated deviations is well limited. Furthermore, we show that an easily recognizable special subset of NEs exhibit even better approximation of SEs.

**ThB15**

Gleacher Center - 100

**PDE Constrained Optimization Under Uncertainty**

Cluster: Stochastic Optimization  
Invited Session

Chair: Ruediger Schultz, University of Duisburg Essen, Department of Mathematics, Lotharstr 65, D-47048 Duisburg, D-47048, Germany, schultz@math.uni-duisburg.de

**1 - Aerodynamic Shape Optimization under Uncertainty**

Claudia Schillings, University of Trier, FB 4 - Department of Mathematics, Trier, 54286, Germany, claudia.schillings@uni-trier.de, Volker Schulz

In this talk, we aim at an improvement of existing simulation and optimization technology, so that uncertainties are identified, quantized and included in the optimization procedure. Beside the scalar valued uncertainties in the flight conditions we consider the shape itself as an uncertainty and apply a Karhunen-Loeve expansion to approximate the probability space. To overcome the curse of dimensionality an adaptively refined sparse grid is used in order to compute statistics of the solution.

**2 - Shape Optimization under Uncertainty via the SIMP-Method**

Claudia Stangl, University of Duisburg-Essen, Department of Mathematics, Lotharstr 65, Duisburg, D-47048, Germany, claudia.stangl@uni-duisburg-essen.de

We consider shape optimization of elastic materials under random loading. A two-stage stochastic programming approach is compared to optimization with respect to the mean load. Via the SIMP-method (solid isotropic material with penalization) a non-linear optimization problem in finite dimension arises. Computational results highlighting the role of nonanticipativity conclude the talk.

**3 - Risk Averse Shape Optimization by Level Set Methods**

Martin Pach, University of Duisburg Essen, Department of Mathematics, Lotharstr 65, Duisburg, D-47048, Germany, pach@math.uni-duisburg.de

For shape optimization of elastic structures under random volume and surface forces we present a framework inspired by two-stage stochastic programming. We extend the risk neutral stochastic optimization perspective by considering risk averse models involving the expected excess and the excess probability. Numerical results for a descent method using level set methods and topological derivatives are presented.

## ■ ThB16

Gleacher Center - 200

### Stochastic Optimization E

Contributed Session

Chair: Sethuraman Sankaran, Postdoctoral Fellow, UCSD, 467 EBU II, UCSD, San Diego, CA, 92122-0411, United States of America, sesankar@ucsd.edu

#### 1 - Convex Polynomial Approximation on Evaluating the First Order Gradient

Lijian Chen, Assistant Professor, University of Louisville, 5241 Craigs Creek Dr, Louisville, KY, 40241, United States of America, lijian.chen@louisville.edu, Tito Homem-de-Mello

We use the remarkable properties of the Bernstein polynomial to evaluate a convex function's gradient by approximating it with convex polynomial. The function is not necessarily to be differentiable. When the function is hard to evaluate, we will estimate the function by the simulated data. The necessary degree is provided for a given accuracy. The application of this method could be large scale stochastic convex programming on logistics, revenue management, and supply chain management.

#### 2 - Convex Approximations of Problems with First-order Stochastic Dominance Constraints

Ebru Angun, Doctor, Galatasaray University, Ciragan Cad. Ortakoy, Istanbul, 34357, Turkey, eangun3@isye.gatech.edu, Alexander Shapiro

We consider optimization problems with first-order stochastic dominance constraints, which can be formulated as continuum of probabilistic constraints. It is well-known that probabilistic constraints may lead to nonconvex feasible regions. After discretization and adding new variables, our aim is to obtain a relaxation through second-order stochastic dominance constraints and a conservative approximation through Bernstein approximations, both of which result in convex optimization problems.

#### 3 - A Stochastic Constrained Optimization Technique using Derivative-free Pattern Search and Collocation

Sethuraman Sankaran, Postdoctoral Fellow, UCSD, 467 EBU II, UCSD, San Diego, CA, 92122-0411, United States of America, sesankar@ucsd.edu, Alison Marsden

We present a mathematical technique for constrained stochastic optimization problems. We employ the sparse-grid stochastic collocation technique for tackling the random dimensions. The Surrogate Management Framework with Mesh Adaptive Direct Search polling strategy and kriging interpolation is employed. Convergence proofs will be discussed in detail. This approach is tested on numerous engineering problems such as thermal and solid mechanics problems with probabilistic reliability constraints.

## ■ ThB17

Gleacher Center - 204

### Logistics and Transportation D

Contributed Session

Chair: Changhyun Kwon, Assistant Professor, University at Buffalo, SUNY, Dept. of Industrial & Systems Engineering, Buffalo, NY, 14260, United States of America, chkwon@buffalo.edu

#### 1 - Applying Nonlinear Programming and Complementarity Models to Crude Oil Scheduling

João Lauro Facó, Professor, Federal University of Rio de Janeiro, Av. Athos da Silveira Ramos, 274, Departamento de Ciência da Computação, Rio de Janeiro, 21941-916, Brazil, jldfacó@gmail.com, Adilson Elias Xavier, Fabio Fagundes

Scheduling problems can be modeled as mixed-integer problems, featuring discrete and continuous constraints. The first group relates to enumerative or logical decisions ("choose A to feed B"), while the second to limitations like "maximum storage of A is 500 m<sup>3</sup>". We model a crude scheduling problem as an NLP with continuous variables only, by substituting discrete constraints by complementarity ones. This strategy is applied to known instances and solved by the GRG method. Results are compared.

#### 2 - Bynary Programming Applied to System of Waste Collection Routes

Javier Arias Osorio, Professor, Universidad Industrial de Santander, Calle 9a. Carrera 27, Bucaramanga, Sa, 57, Colombia, jearias@uis.edu.co, Astrid Johana Reyes Pita

The aim is to optimize the design of waste collection routes the process of waste collection generated by the production and processing of nickel mining at Cerro Matoso S.A through the use of a binary programming model and validate the results. The business waste collection consider the dynamic elements of itself waste generation in a continuous manner and available for collection at any time, this involves the company network that includes 67 points of collection.

#### 3 - Joint Toll Pricing for Hazardous Material Transport and Regular Traffic

Changhyun Kwon, Assistant Professor, University at Buffalo, SUNY, Dept of Industrial & Systems Engineering, Buffalo, NY, 14260, United States of America, chkwon@buffalo.edu, Yingying Kang, Rajan Batta

We consider a joint toll pricing model both for hazardous material transport trucks and regular traffic vehicles. While considering the behavior of networks users induced by tolls, we seek a toll policy that minimizes the total risk. We assume the risk of incidents on an arc is dependent on the number of regular traffic vehicles as well as the number of hazardous material transport trucks. We study mathematical properties of the model and suggest a numerical method.

## ■ ThB18

Gleacher Center - 206

### Reformulation Techniques in Mixed-Integer Nonlinear Programming

Cluster: Nonlinear Mixed Integer Programming  
Invited Session

Chair: Leo Liberti, Doctor, Ecole Polytechnique, LIX, Ecole Polytechnique, Palaiseau, 91128, France, leoliberti@gmail.com

Co-Chair: Giacomo Nannicini, Ecole Polytechnique, LIX, Ecole Polytechnique, Palaiseau, 91128, France, giacomon@lix.polytechnique.fr

#### 1 - Valid Inequalities, Separation, and Convex Hulls for Multilinear Functions

Andrew Miller, Universite de Bordeaux I, INRIA Bordeaux Sud-Ouest, Bordeaux, France, andrew.miller@math.u-bordeaux1.fr, Pietro Belotti, Mahdi Namazifar

We study convex envelopes for a product of variables that have lower and upper bounds, and which is itself bounded. (Since spatial branch-and-bound solvers use polyhedral relaxations of such sets to compute bounds, having tight relaxations can improve performance.) For two variables, the well-known McCormick inequalities define the convex hull for an unbounded product. For a bounded product, we define valid linear inequalities that support as many points of the convex hull as possible. Though uncountably infinite in number, these inequalities can be separated for exactly in polynomial time. We also discuss extensions of such results to products of more than two variables, considering both convex hull descriptions and separation.

#### 2 - Parameter Estimation for Polynomial Discrete Dynamical Systems

Sandro Bosio, Postdoctoral Fellow, Otto-von-Guericke University Magdeburg, Institute for Mathematical Optimization, Universitaetsplatz 2, Magdeburg, 39106, Germany, bosio@mail.math.uni-magdeburg.de, Steffen Borchers, Philipp Rumschinski, Utz-Uwe Haus, Robert Weismantel, Rolf Findeisen

Given a discrete dynamical system and some experimental output measurements (given as sets, accounting for errors and disturbances), the goal of parameter estimation is to outer-approximate the set of system parameters consistent with the measurements (if any). We describe a parameter estimation framework for polynomial systems based on quadratic reformulation and semidefinite relaxation. Based on this, we also discuss a graph approach that allows to model simple experimental design problems.

## ■ ThB19

Gleacher Center - 208

### Nonlinear Mixed Integer Programming E

Contributed Session

Chair: Neng Fan, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32603, United States of America, andynfan@ufl.edu

#### 1 - On Well-posedness of Vector Convex Optimization Problems

Matteo Rocca, Professor, University of Insubria, via Monte Generoso, 71, Department of Economics, Varese, Italy, matteo.rocca@uninsubria.it, Giovanni P. Crespi, Melania Papalia

In this talk we investigate well posedness properties of convex and quasiconvex vector functions. In particular, in a finite dimensional setting, we show that vector optimization problems with quasiconvex objective function are well posed. Then we observe that similarly to the scalar case such a result does not hold in an infinite dimensional setting. Anyway, we show that in this case, well posedness of a convex optimization problem is a generic property, extending a result known for scalar optimization problems.

**2 - A Mixed Integer Convexity Result with an Application to an M/M/s Queueing System**

Emre Tokgoz, University of Oklahoma, 202 W. Boyd, Room 116H, Norman, OK, 73019, United States of America, Hillel Kumin

In this paper, we develop a general convexity result for functions with  $n$  integer and  $m$  real variables by defining a new Hessian matrix for these functions. The result is applied to the optimization of an M/M/s queueing system in which the design parameters are the number of servers and the service rate.

**3 - Integer Programming of Biclustering Based on Graph Models**

Neng Fan, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32603, United States of America, andynfan@ufl.edu

In this paper, biclustering of a data matrix is studied based on graph partitioning models. Several integer programming models are established to realize the clustering under different definitions of cut. The relaxation forms of the IP models include linear programming, semidefinite programming, quadratic programming and spectral methods.

**ThB20**

Gleacher Center - 300

**Numerical Methods for Nonlinear Optimization**

Cluster: Nonlinear Programming

Invited Session

Chair: Ya-xiang Yuan, Professor, Chinese Academy of Sciences (CAS), Institute of Computational Mathematics, Zhong Guan Cun Donglu 55, Beijing, 100190, China, yyx@lsec.cc.ac.cn

**1 - Solving Distance Geometry Problem via Successive Subspace Optimization**

Zhijun Wu, Professor, Iowa State University, 370 Carver Hall, Ames, IA, 50011, United States of America, zhijun@iastate.edu

A distance geometry problem can be formulated as a problem for solving a nonlinear system of equations. The problem is difficult to solve and has great computational challenges. Here we describe a method for the solution of the problem by successively identifying a subsystem of equations that can be solved independently. The whole problem can then be solved by iteratively solving a sequence of subsystems, which can be done relatively efficiently using a nonlinear least squares method.

**2 - An Affine-scaling Algorithm for Nonlinear Optimization with Continuous Knapsack Constraints**

Hongchao Zhang, Professor, Louisiana State University, Department of Mathematics, Baton Rouge, LA, 70803, United States of America, hozhang@math.lsu.edu, William Hager

A gradient based affine-scaling algorithm for continuous knapsack constraints will be presented. This algorithm has the property that each iterate lies in the interior of the feasible set and is more suitable for large dimensional optimization problems where the Hessian of the objective function is a large, dense, and possibly ill-conditioned matrix. Some theoretical properties, especially the local linear convergence of the algorithm will be discussed. Some numerical results will be also reported.

**3 - Using Approximate Secant Equations in Multilevel Unconstrained Optimization**

Vincent Malmedy, Research Fellow F.R.S.-FNRS, University of Namur (FUNDP), Rempart de la Vierge 8, Namur, 5000, Belgium, vincent.malmedy@fundp.ac.be, Philippe Toint, Serge Gratton

The properties of multilevel optimization problems can be used to define approximate secant equations, which describe the second-order behavior of the objective function. We introduce a quasi-Newton method (with a line search) and a nonlinear conjugate gradient method that both take advantage of this new second-order information, and present numerical experiments.

**ThB21**

Gleacher Center - 304

**Algorithms for Network Design**

Cluster: Telecommunications and Networks

Invited Session

Chair: Stavros Kolliopoulos, National & Kapodistrian University of Athens, Department of Informatics, Panepistimiopolis, Ilissia, Athens, 157 84, Greece, sgk@di.uoa.gr

**1 - Energy-efficient Communication in Ad Hoc Wireless Networks**

Ioannis Caragiannis, University of Patras, Dept. of Computer Eng. and Informatics, University of Patras, Rio, 26500, Greece, caragian@ceid.upatras.gr

In ad hoc wireless networks, the establishment of typical communication patterns like broadcasting, multicasting, and group communication is strongly related to energy consumption. Since energy is a scarce resource, corresponding minimum energy communication problems arise. We consider a series of such problems on two suitable combinatorial models for wireless ad hoc networks with omni-directional and directional antennas and present related approximation algorithms and hardness results.

**2 - Network Discovery and Verification**

Alex Hall, Google Switzerland, alex.hall@gmail.com

We consider the problem of discovering the edges and non-edges of a network using a minimum number of queries. This is motivated by the common approach of combining local measurements in order to obtain maps of the Internet or other dynamically growing networks. We give an overview of results obtained in this area in recent years (complexity, inapproximability, lower bounds, and approximation algorithms). We will have a closer look at approximate discovery of random graphs.

**3 - Beating Simplex for Fractional Packing and Covering Linear Programs**

Neal Young, University of California, Riverside, Dept of Computer Science and Engineering, Riverside, CA, 92521, United States of America, neal@cs.ucr.edu, Christos Koufogiannakis

We describe an approximation algorithm for linear programs with non-negative coefficients. Given a constraint matrix with  $n$  non-zeros,  $r$  rows, and  $c$  columns, the algorithm computes primal and dual solutions whose costs are within a factor of  $1 + \epsilon$  of optimal in time  $O((r+c)\log(n)/\epsilon^2 + n)$ . For dense problems (with  $r, c = O(\sqrt{n})$ ) this is linear in the input size, even as  $\epsilon$  tends to zero. Previous Lagrangian-relaxation algorithms take at least  $\Omega(n \log(n)/\epsilon^2)$  time. The Simplex algorithm typically takes at least  $\Omega(n \min(r,c))$  time. (This extends work by Grigoriadis and Khachiyan for approximately solving 2-player zero-sum games in sub-linear time.)

**ThB22**

Gleacher Center - 306

**Implementations, Software B**

Contributed Session

Chair: Marcus Oswald, University of Heidelberg, Im Neuenheimer Feld 368, Heidelberg, 69120, Germany, Marcus.Oswald@informatik.uni-heidelberg.de

**1 - Expression Graphs for Use in Optimization Algorithms**

David M. Gay, Sandia National Labs, P.O. Box 5800, MS 1318, Albuquerque, NM, 87185-1318, United States of America, dmgay@sandia.gov

Expression graphs provide a representation of algebraic functions that is convenient for manipulation. Uses include classification (e.g., linear, quadratic, convex), structure discovery (e.g., sparsity), preparation for evaluation (e.g., simplifications), numerical evaluations, derivative computations, bound computations, and bound propagations (e.g., for "presolve"). I will review some experience with expression graphs made available by AMPL and discuss some recent work on bound computations.

**2 - Supporting Software for Practice of Mathematical Programming**

Hiroshige Dan, Assistant Professor, Kansai University, 3-3-35, Yamate-cho, Suita-shi, Osaka, 564-8680, Japan, dan@kansai-u.ac.jp, Shin-ya Nomura

Application of mathematical programming to real-world problems consists of three steps: (i) formulating a mathematical model, (ii) solving the model to obtain a solution, and (iii) examining the computed solution. We have developed software called DEMP (Development Environment for Mathematical Programming) that supports these steps comprehensively. DEMP has been implemented as a plug-in for Eclipse, which is one of the most popular Integrated Development Environment (IDE).

**3 - Computations of GTSP-Polyhedra**

Marcus Oswald, University of Heidelberg, Im Neuenheimer Feld 368, Heidelberg, 69120, Germany, Marcus.Oswald@informatik.uni-heidelberg.de, David Buettner, Gerhard Reinelt, Dirk Oliver Theis

The Symmetric TSP asks for a minimum length Hamilton cycle in a complete graph. The Graphical Traveling Salesman Problem (GTSP) is defined analogously to the STSP, except that it allows to visit nodes and/or traverse edges more than once. The GTSP-Polyhedron on  $n$  nodes,  $GTSP(n)$ , is equal to the convex hull of all incidence vectors of edge multi-sets of spanning closed walks. We present a parallelized algorithm computing outer descriptions of  $GTSP$ -Polyhedra and show computational results.



## ■ ThB23

Gleacher Center - 308

### Fast Gradient Algorithms for Nuclear Norm and Compressive Sensing Optimization

Cluster: Sparse Optimization  
Invited Session

Chair: Kim-Chuan Toh, National University of Singapore, 2 Science Drive 2, Department of Mathematics, Singapore, SG, 117543, Singapore, mattohkc@nus.edu.sg

#### 1 - Redundancy, Sparsity, and Algorithm

Zuwei Shen, Professor, National University of Singapore, Department of Mathematics, NUS, 2 Science Drive 2, Singapore, 117543, Singapore, matzuows@nus.edu.sg

Efficient algorithms in image restoration and data recovery are derived by exploring sparse approximations of the underlying solutions by redundant systems. Several algorithms and numerical simulation results for image restoration, compressed sensing, and matrix completion will be presented in this talk.

#### 2 - An Accelerated Proximal Gradient Algorithm for Nuclear Norm Regularized Least Squares Problems

Kim-Chuan Toh, National University of Singapore, 2 Science Drive 2, Department of Mathematics, Singapore, SG, 117543, Singapore, mattohkc@nus.edu.sg, Sangwoon Yun

We consider a nuclear norm regularized linear least squares problem. An accelerated proximal gradient algorithm, which terminates in  $\mathcal{O}(1/\sqrt{\epsilon})$  iterations with an  $\epsilon$ -optimal solution, is proposed for the problem considered. We report numerical results for solving large-scale randomly generated matrix completion (MC) problems. The results suggest that our algorithm is efficient and robust. In particular, we are able to solve random MC problems with matrix dimensions up to  $10^5 \times 10^5$  each in less than 10 minutes on a modest PC.

#### 3 - Fast Algorithms for Nonconvex Compressive Sensing

Rick Chartrand, Los Alamos National Laboratory, Theoretical Division, MS B284, Los Alamos, NM, 87545, United States of America, rickc@lanl.gov

Recent work has shown that replacing the  $l^1$  objective function in compressive sensing with the nonconvex  $l^p$  objective with  $p < 1$  provides many benefits. Reconstruction becomes possible with many fewer measurements, while being more robust to noise and signal nonsparsity. Although the resulting nonconvex optimization problem has many local minima, simple algorithms have been very effective at finding the global minimum and recovering sparse signals. In this talk, we show how a recent convex optimization algorithm using operator splitting and Bregman iteration can be extended to the setting of nonconvex compressive sensing. The result is mathematically interesting and computationally very fast for many applications.

## ■ ThB25

Gleacher Center - 404

### Penalty Methods and Critical Points of Lipschitz Functions

Cluster: Variational Analysis  
Invited Session

Chair: Boris Mordukhovich, Wayne State University, Dept. of Mathematics, 1150 Faculty Admin Bldg, Detroit, MI, 48202, aa1086@wayne.edu

#### 1 - Mathematical Programs with Vanishing Constraints

Tim Hoheisel, PhD, University of Wuerzburg, Institute of Mathematics, Am Hubland, 97074 Wuerzburg, Germany, hoheisel@mathematik.uni-wuerzburg.de, Christian Kanzow, Wolfgang Achtziger

We consider a new class of constrained optimization problems called 'mathematical programs with vanishing constraints' (MPVCs), which have important applications, e.g., in the field of topology optimization. One of the major difficulties of these kind of problems arises from the fact that most of the prominent constraint qualifications are likely to be violated and hence, the Karush-Kuhn-Tucker conditions do no longer provide necessary optimality conditions. Thus, the talk will present more problem-tailored constraint qualifications and stationarity concepts and discuss their relationships. Based on these new concepts, numerical algorithms for the solution of MPVCs, using smoothing and regularization ideas, are investigated.

#### 2 - Exact Penalty in Constrained Optimization and Critical Points of Lipschitz Functions

Alexander Zaslavski, Professor, Technion Israel Institute of Technology, Haifa, Israel, ajzasl@techunix.technion.ac.il

We use the penalty approach to study constrained minimization problems in infinite-dimensional Asplund spaces. A penalty function is said to have the exact penalty property if there is a penalty coefficient for which a solution of an unconstrained penalized problem is a solution of the corresponding constrained problem. We establish a simple sufficient condition for exact penalty property using the notion of the Mordukhovich basic subdifferential.

#### 3 - Identifying Global Solutions of Classes of Hard Non-convex Optimization Problems

Vaithilingam Jeyakumar, Professor, University of New South Wales, Department of Applied Mathematics, Sydney, Australia, v.jeyakumar@unsw.edu.au

Due to the absence of convexity, constrained global optimization problems such as quadratically constrained quadratic optimization problems, 0/1 quadratic optimization problems and fractional quadratic optimization problems provide classes of intrinsically hard optimization problems for the development of global optimality conditions and duality theory. Yet, they are important optimization models that often arise in numerous applications. I will provide examples of successful quadratic approximation approaches using under/over-estimators to establishing Lagrangian based global optimality conditions for classes of non-convex optimization problems.

## ■ ThB28

Gleacher Center - 600

### Approximation Methods and Proximal Algorithms

Cluster: Nonsmooth and Convex Optimization  
Invited Session

Chair: Felipe Alvarez, Associate Professor, University of Chile, Santiago, 8370448, Chile, falvarez@dim.uchile.cl

#### 1 - Interior Proximal Algorithm with Variable Metric for SOCP: Application to Structural Optimization

Hector Ramirez C., Universidad de Chile, Chile, hramirez@dim.uchile.cl, Julio Lopez, Felipe Alvarez

In this work, we propose an inexact interior proximal type algorithm for solving convex second-order cone programs. The proposed algorithm uses a distance variable metric, which is induced by a class of positive definite matrices, and an appropriate choice of regularization parameter. This choice ensures the well-definedness of the proximal algorithm and forces the iterates to belong to the interior of the feasible set. Computational results applied to structural optimization are presented.

#### 2 - Primal Convergence of Hybrid Algorithms Coupled with Approximation Methods in Convex Optimization

Miguel Carrasco, Universidad de los Andes, Chile, migucarr@gmail.com

The aim of this talk is to present some theoretical results on the convergence of the Hybrid Algorithms. The motivation for introducing these algorithms is to find the minimum of a function  $f$  approximated by a sequence of functions  $f_k$ . The main assumption will be the existence of an absolute continuous optimal path with finite length. We will prove the convergence of these algorithms to a solution of our minimization problem. To conclude, we shall give some numerical illustrations.

#### 3 - Alternating Proximal Algorithms and Hierarchical Selection of Optima in Games, Control and PDE's

Juan Peypouquet, UTFSM, Av Espa 1680, Valparaiso, Chile, juan.peypouquet@usm.cl, Hady Attouch, Marc-Olivier Czarnecki

We study an alternating diagonal proximal point algorithm: at each iteration a first step uses the resolvent corresponding to a maximal monotone operator and a second step to the subdifferential of a proper closed function weighted by an increasing parameter. The resulting sequence of iterates and - under less restrictive conditions - their averages converge weakly to a point with special properties. The results enable us to solve constrained or bilevel optimization problems. This method is applied to best response dynamics with cost to change, optimal control problems and domain decomposition for partial differential equations.

Thursday, 3:15pm - 4:45pm

## ■ ThC01

Marriott - Chicago A

### Approximation Algorithms C

Contributed Session

Chair: Leonid Faybusovich, Professor, University of Notre Dame, Department of Mathematics, 255 Hurley Hall, Notre Dame, IN, 46556, United States of America, leonid.faybusovich.1@nd.edu

#### 1 - Fault Tolerant Facility Location: 1.724-approximation Based on Randomized Dependent Rounding

Jaroslav Byrka, EPFL, MA B1 527, Station 8, Lausanne, ch-1015, Switzerland, jaroslav.byrka@epfl.ch, Aravind Srinivasan, Chaitanya Swamy

We give a new LP-rounding 1.724-approximation algorithm for the metric Fault-Tolerant Uncapacitated Facility Location problem. This improves on the previously best known 2.076-approximation algorithm of Shmoys and Swamy. Our work applies a dependent-rounding technique in the domain of facility location. The analysis of our algorithm benefits from, and extends, methods developed for Uncapacitated Facility Location; it also helps uncover new properties of the dependent-rounding approach.

#### 2 - An Algorithm for a Maximum Density Subset Problem Based on Approximate Binary Search

Satoshi Takahashi, Master Course Student, University of Tsukuba, 1-1-1, Tennoudai, Tsukuba, 305-8577, Japan, takahashi2007@e-activity.org, Maiko Shigeno, Mingchao Zhang

In our research, we treat a maximum density subset problem defined on a set-system, and verify appropriateness of our problem in community selection problems. Also, we present an algorithm for solving our problem based on approximate binary search. Furthermore, we discuss that the framework of our algorithm can be applied to max mean cut problems.

#### 3 - Jordan-algebraic Framework for Randomization Technique in Optimization

Leonid Faybusovich, Professor, University of Notre Dame, Department of Mathematics, 255 Hurley Hall, Notre Dame, IN, 46556, United States of America, leonid.faybusovich.1@nd.edu

We describe a very general framework for randomization technique in optimization. The major technique is based on new measure concentration inequalities on products on manifolds of nonnegative elements of fixed rank. Various concrete applications and stochastic modeling technique are discussed.

## ■ ThC02

Marriott - Chicago B

### Algorithms for Variational Inequalities and Related Problems II

Cluster: Complementarity Problems and Variational Inequalities  
Invited Session

Chair: Andreas Fischer, TU Dresden, Institute of Numerical Mathematics, Dresden, 01062, Germany, Andreas.Fischer@tu-dresden.de

#### 1 - Stabilized Newton-type Method for Variational Problems

Damian Fernandez, UNICAMP - IMECC, Rua Sergio Buarque de Holanda, 651, Campinas, SP, 13083-859, Brazil, dfernan@impa.br, Mikhail Solodov

The stabilized sequential quadratic programming algorithm (sSQP) had been developed to guarantee fast convergence for degenerate optimization problems. Superlinear convergence of sSQP had been previously established under the strong second-order sufficient condition for optimality (without any constraint qualification assumptions). We prove the superlinear convergence assuming only the usual second-order sufficient condition. In addition, our analysis is carried out to variational problems.

#### 2 - A New Line Search Inexact Restoration Approach for Nonlinear Programming

Andreas Fischer, TU Dresden, Institute of Numerical Mathematics, Dresden, 01062, Germany, Andreas.Fischer@tu-dresden.de, Ana Friedlander

A new inexact restoration approach is presented. It simplifies the restoration principle by Martinez and Pilotta. After the restoration step the new iterate is obtained by means of a single line search on an approximate tangent direction. All accumulation points generated by the algorithm are proved to satisfy a necessary optimality condition. In addition, the regularity condition that is

usually needed in the restoration step is weakened. To some extent this also enables the application of the new approach to programs with complementarity constraints.

#### 3 - Sequential Optimality Conditions

Gabriel Haeser, PhD Student, State University of Campinas, Department of Applied Mathematics, Campinas, SP, 6065, Brazil, ghaeser@ime.unicamp.br, Jose Mario Martinez, Roberto Andreani

We present new optimality conditions related to the Approximate Gradient Projection condition (AGP). When there is an extra set of linear constraints, we define a linear-AGP condition and prove relations with CPLD and KKT conditions. The CPLD is a new constraint qualification strictly weaker than MFCQ and CRCQ. Similar results are obtained when there is an extra set of convex constraints. We provide some further generalizations and relations to an inexact restoration algorithm.

## ■ ThC03

Marriott - Chicago C

### Supply Function and Bilateral Contract Models of Oligopoly Electricity Markets

Cluster: Optimization in Energy Systems  
Invited Session

Chair: Ross Baldick, The University of Texas at Austin, Department of Electrical and Computer En, Engineering Science Building ENS 502, Austin, TX, 78712, United States of America, Ross.Baldick@enr.utexas.edu

#### 1 - Contract Design and Behavioral Co-ordination in Oligopolies

Fernando Oliveira, ESSEC Business School, Avenue Bernard Hirsch - BP 50105, CEDEX, France, oliveira@essec.fr, Carlos Ruiz, Antonio J. Conejo

In this article, we present a multi-player model of the relationship between forward and spot markets in oligopolies, in the context of bilateral trading. We analyze how different types of contract and market structure interact to influence the behavior of firms and market-efficiency.

#### 2 - A Stability Analysis of the Supply Function Equilibrium in Electricity Markets

Lin Xu, University of Texas at Austin, The University of Texas at Austin, 1 University Station C0803, Austin, TX, 78712, United States of America, linxu@mail.utexas.edu, Ross Baldick

The supply function equilibrium model is a close-to-reality model in electricity markets, but theoretically there exists a continuum of equilibria, which limits its predictive value. We do a stability analysis to refine the equilibria, considering piecewise polynomial function perturbations. As shown in an example, the stable supply function set shrinks as the order of the polynomial function increases, and stable equilibria are likely to exist for practically reasonable perturbation functions.

#### 3 - Mixed-strategy Equilibria in Discriminatory Divisible-good Auctions

Andy Philpott, Professor, University of Auckland, Private Bag 92019, Auckland, AL, 1025, New Zealand, a.philpott@auckland.ac.nz, Par Holmberg, Eddie Anderson

Auctions of divisible-goods occur in a number of settings, the most well-known being electricity pool-markets. There are two common payment mechanisms for these auctions, one where a uniform price is paid to all suppliers, and an alternative that adopts a discriminatory, or pay-as-bid, price. Under the assumptions that demand is uncertain and costs are common knowledge, we study supply-function equilibria in the pay-as-bid auction using the concept of market-distribution functions. We show that pure-strategy Nash equilibria typically do not exist in this setting, and derive mixed-strategy equilibria of various types.

## ■ ThC04

Marriott - Denver

### Submodular Function Maximization II

Cluster: Combinatorial Optimization

Invited Session

Chair: Andreas Schulz, Massachusetts Institute of Technology, E53-357, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States of America, schulz@mit.edu

#### 1 - Maximizing Non-monotone Submodular Functions Over Matroid and Knapsack Constraints

Viswanath Nagarajan, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, United States of America, viswa@cmu.edu, Jon Lee, Maxim Sviridenko, Vahab Mirrokni

Submodular function maximization is a central problem in combinatorial optimization generalizing several problems such as Max-Cut in graphs/hypergraphs, maximum entropy sampling, and maximum facility location. We study the problems of maximizing any non-negative submodular function subject to multiple matroid or knapsack constraints. For any fixed  $k$ , we give a  $[1/(k+2+1/k)]$ -approximation under  $k$  matroid constraints, and a  $1/5$ -approximation under  $k$  knapsack constraints. Our algorithms are based on local search, and assume only a value-oracle access to the submodular function. Previously, results were known only for the special case of monotone submodular functions.

#### 2 - Submodular Maximization Over Multiple Matroids via Generalized Exchange Properties

Maxim Sviridenko, IBM TJ Watson Research Center, P.O. Box 218, Yorktown Heights, NY, United States of America, sviri@us.ibm.com, Jon Lee, Jan Vondrak

Submodular-function maximization is a central problem in combinatorial optimization, generalizing many important NP-hard problems including Max Cut in digraphs, graphs and hypergraphs, certain constraint satisfaction problems, maximum-entropy sampling, and maximum facility-location problems. Our main result is that for any  $k \geq 2$  and any  $\epsilon > 0$ , there is a natural local-search algorithm which has approximation guarantee of  $1/(k+\epsilon)$  for the problem of maximizing a monotone submodular function subject to  $k$  matroid constraints. This improves a  $1/(k+1)$ -approximation of Nemhauser, Wolsey and Fisher [1978] obtained more than 30 years ago. Also, our analysis can be applied to the problem of maximizing a linear objective function and even a general non-monotone submodular function subject to  $k$  matroid constraints. We show that in these cases the approximation guarantees of our algorithms are  $1/(k-1+\epsilon)$  and  $1/(k+1+1/k+\epsilon)$ , respectively.

#### 3 - Submodular Approximation: Sampling-based Algorithms and Lower Bounds

Zoya Svitkina, University of Alberta, Department of Computing Science, Edmonton, AB, Canada, Zoya.Svitkina@UAlberta.ca, Lisa Fleischer

We introduce several generalizations of classical computer science problems obtained by replacing simpler objective functions with general submodular functions. The new problems include submodular load balancing, submodular sparsest cut, and submodular function minimization with cardinality lower bound. We establish tight upper and lower bounds for the approximability of these problems with a polynomial number of queries to a function-value oracle.

## ■ ThC05

Marriott - Houston

### Combinatorial Optimization M

Contributed Session

Chair: Asaf Shupo, AVP; Quant Opera Assoc Cust Strategies Mgr, MBNA Ottawa, Bank of America, 1600 James Naismith Drive, Ottawa, ON, K1B 5N8, Canada, asaf.shupo@mbna.com

#### 1 - Bounded Fractionality of Multiflow Feasibility Problem for $K_3+K_3$ and Other Maximization Problems

Hiroshi Hirai, Assistant Professor, RIMS, Kyoto University, Kyoto 606-850, Kyoto, Japan, hirai@kurims.kyoto-u.ac.jp

We consider the multiflow feasibility problem whose demand graph is the vertex-disjoint union of two triangles. We show that under the Euler condition this problem has a  $1/12$ -integral solution or no solution. This solves a conjecture raised by Karzanov, and completes the classification of the demand graphs having bounded fractionality. We also prove the existence of a  $1/12$ -integral optimal solution for a larger class of multiflow maximization problems.

#### 2 - Madonna Travels: the $k$ -Arc Recovery Robust Shortest Path Problem

Christina Puhl, Technische Universitat Berlin, Strasse des 17. Juni 136, Berlin, 10623, Germany, puhl@math.tu-berlin.de

Recoverable robustness (RR) is a concept to avoid over-conservatism in robust optimization by allowing a limited recovery after the full data is revealed. We consider the setting of a RR shortest path problem, in which the arc costs are subject to uncertainty. As recovery at most  $k$  arcs of a chosen path can be altered. For most scenario sets the problem is strongly NP-complete and inapproximable. A polynomial algorithm is presented for interval scenarios and  $k$  being part of the input.

#### 3 - Using Large-scale Minimum-cost Flow Problem in Optimal Marketing Segmentation

Asaf Shupo, AVP; Quant Opera Assoc Cust Strategies Mgr, MBNA Ottawa, Bank of America, 1600 James Naismith Drive, Ottawa, ON, K1B 5N8, Canada, asaf.shupo@mbna.com

The purpose of this paper is to report a very large minimum-cost flow (MCF) problem arising in the marketing segmentation, and to present an implementation of MCF for its solution. Some of the problems are very large up to 6,447,649 nodes and 57,046,031 arcs. Current work is being performed in optimal marketing segmentation problem arising at Bank of America. The optimal solution ensures that the separation of customers towards all the products available maximizes the marketing return.

## ■ ThC06

Marriott - Kansas City

### SDP and Its Applications

Cluster: Conic Programming

Invited Session

Chair: Masakazu Kojima, Tokyo Institute of Technology, Dept. of Math & Comp Sci, 2-12-1-W8-29 Oh-Okayama Meguro, Tokyo, Japan, kojima@is.titech.ac.jp

Co-Chair: Sunyoung Kim, Professor, Ewha W. University, 11-1 Dahyun dong, Seoul, 120-750, Korea, Republic of, skim@ewha.ac.kr

#### 1 - Nonlinear SDPs by Primal-dual Interior Point Method - Global and Superlinear Convergence

Hiroshi Yamashita, Mathematical Systems Inc., 2-4-3, Shinjuku, Shinjuku-ku, Tokyo, Japan, hy@msi.co.jp, Hiroshi Yabe, Kouhei Harada

We present a class of primal-dual interior point methods for nonlinear semidefinite programming problems. The methods are based on Newton-like method for modified KKT conditions. We apply scaling to the modified complementarity equation, and obtain general expression of search directions which include HRVW/KSH/M and NT in linear SDP. We discuss merit functions that include primal-only function and primal-dual function. We also discuss search algorithms that include line search and trust region. We show that AHO direction has superlinear convergence property under appropriate conditions, and that HRVW/KSH/M and NT directions have two step superlinear convergence under similar conditions. Finally, a few numerical examples will be shown.

#### 2 - Most Tensor Problems are NP Hard

Lek-Heng Lim, Morrey Assistant Professor, University of California, Berkeley, 873 Evans Hall, Berkeley, CA, 94720-3840, United States of America, lekheng@math.berkeley.edu, Christopher Hillar

We show that tensor analogues of many problems that are readily computable in the matrix (i.e. 2-tensor) case are NP hard in both the traditional Cook-Karp-Levin sense and the Blum-Shub-Smale sense, making SDP relaxation an attractive, if not inevitable, alternative. The problems include: computing a best rank-1 approximation, the singular values/vectors, or the spectral norm of a 3-tensor; computing the eigenvalues/vectors of a symmetric 3-tensor; determining the feasibility of a system of bilinear equations or solving such a system in either an exact or least-squares sense. These extend Hastad's result on the NP-hardness of computing tensor rank to other natural tensor problems.

#### 3 - Duality in the Positive Semidefinite Matrix Completion and Its Application to SDPs

Masakazu Kojima, Tokyo Institute of Technology, Dept. of Math & Comp Sci, 2-12-1-W8-29 Oh-Okayama Meguro, Tokyo, Japan, kojima@is.titech.ac.jp

We present a necessary and sufficient condition for a sparse and symmetric matrix  $A$  to be positive semidefinite as a dual approach of the positive semidefinite matrix completion method. Here we assume that the sparsity pattern of  $A$  is characterized with a chordal graph  $G(N,E)$ . The  $i$ th row or  $i$ th column of  $A$  corresponds to the node  $i$  in  $N$ , and nonzero  $(i,j)$ th element of  $A$  to the edge  $(i,j)$  in  $E$ . We also discuss how the condition can be utilized for exploiting the sparsity of linear and nonlinear SDPs.



## ■ ThC07

Marriott - Chicago D

### Integer and Mixed Integer Programming I

Contributed Session

Chair: David Warme, Member of Technical Staff, Group W, Inc., 8315 Lee Highway, Suite 303, Fairfax, VA, 22031, United States of America, David@Warme.net

#### 1 - Convex Reformulations for Integer Quadratic Programs

Amelie Lambert, PhD Student, CEDRIC-CNAM, 292 Rue Saint Martin, Paris, 75003, France, amelie.lambert@cnam.fr,  
Alain Billionnet, Sourour Elloumi

Let (QP) be an integer quadratic program that consists in minimizing a quadratic function subject to linear constraints. To solve (QP), we reformulate it into an equivalent program with a convex objective function, and we use a Mixed Integer Quadratic Programming solver. This reformulation, called IQCR, is optimal in a certain sense from the continuous relaxation bound point of view. It is deduced from the solution of a SDP relaxation of (QP). Computational experiments are reported.

#### 2 - Primal Heuristic for Integer Linear Programming with Automated Aggregations

Jakub Marecek, The University of Nottingham, School of Computer Science, Jubilee Campus, Nottingham, NG81BB, United Kingdom, jxm@cs.nott.ac.uk, Edmund K. Burke,  
Andrew J. Parkes

The heuristic has three stages. First, we aggregate: Variables are partitioned into min. number of singletons and support sets of constraints forcing convex combinations of binary variables to less than or equal to one. Second, we solve the aggregated instance. Finally, we extend this solution to the original instance. Notice the first stage can provide a lower bound and a feasible solution can be guaranteed to exist at the third stage, if at all. This works well for instances from scheduling.

#### 3 - Planning and Scheduling of Combat Air Patrol Missions in the STORM Military Campaign Simulation

David Warme, Member of Technical Staff, Group W, Inc., 8315 Lee Highway, Suite 303, Fairfax, VA, 22031, United States of America, David@Warme.net

The objective of Combat Air Patrol (CAP) missions is to occupy and control regions of airspace continuously over a time interval, subject to range, endurance and resource constraints. We present an algorithm to plan and schedule CAP missions using 3 distinct formulations (2 MIPs and 1 LP). Two heuristics and certain cuts obtain solutions that are almost always optimal within 5-10 CPU seconds. The application is STORM, a stochastic discrete-event campaign simulation used by the US military.

## ■ ThC08

Marriott - Chicago E

### Decomposition Methods for Integer Programming

Cluster: Integer and Mixed Integer Programming

Invited Session

Chair: Matthew Galati, Optimization Interface Lead, SAS Institute, Philadelphia Regional Office, Suite 201, 1400 Morris Drive, Chesterbrook, PA, 19087, United States of America, Matthew.Galati@sas.com

#### 1 - Lagrangean Relaxation Decomposes a Stochastic Mining Problem

Monique Guignard-Spielberg, Professor, University of Pennsylvania, OPIM Department, Philadelphia, PA, 19104, United States of America, guignard\_monique@yahoo.fr, Felipe Carvallo, Laureano Escudero, Andres Weintraub

We consider a stochastic integer optimization problem based upon planning ore extraction in a Chilean copper mine, with uncertain future copper prices. One typical instance has 858,750 constraints and 635,750 variables (with 494,350 0-1). We use Lagrangean relaxation to decompose the problem into one subproblem per scenario, and use a "lazy Lagrangean heuristic" to get feasible solutions. The Lagrangean dual is solved with the volume algorithm. We will concentrate on the algorithmic approach.

#### 2 - A Fast Column Generation Algorithm for the Regionalization Problems

John Raffensperger, Senior Lecturer, University of Canterbury, Dept. of Management, Private Bag 4800, Christchurch, 8140, New Zealand, john.raffensperger@canterbury.ac.nz

I give a new algorithm for the regionalization problem —finding boundaries for political or operational reasons, and ecological connectivity. Past work shows this problem is hard. The method decomposes the problem into a subproblem and master. The subproblem is solved with a customised Kruskal's algorithm to find forests of connected regions. After this, the master is solved to optimality.

Solution times appear to be orders of magnitude faster than anything else reported in the literature.

#### 3 - Benders Decomposition Based on an Interior Point Cutting Plane Method and Branch-and-cut

Joe Naoum-Sawaya, University of Waterloo, Department of Management Sciences, 200 University Ave. West, Waterloo, ON, N2L3G1, Canada, jnaoumsa@uwaterloo.ca, Samir Elhedhli

We present the novel integration of the Analytic Center Cutting Plane Method (ACCPM) in Benders decomposition. Unlike the classical Benders decomposition where cuts are generated using extreme points, Benders cuts are generated from a central point of the master problem. A branch-and-cut approach is used to implement the ACCPM based Benders decomposition. Computational results on the capacitated facility location problem show that our algorithm outperforms the classical Benders decomposition.

## ■ ThC09

Marriott - Chicago F

### Models and Cutting Planes for Mixed-integer Programming

Cluster: Integer and Mixed Integer Programming  
Invited Session

Chair: Ismael de Farias, Texas Tech, Department of Industrial Engineering, Lubbock, TX, United States of America, ismael.de-farias@ttu.edu

#### 1 - On an Intersection of Mixing Sets

Simge Kucukyavuz, Ohio State University, 1971 Neil Ave, Columbus, OH, United States of America, kucukyavuz.2@osu.edu

We consider the intersection of multiple mixing sets with common binary variables arising in the deterministic equivalent of mathematical programs with chance constraints. We propose a "blending" procedure that gives strong valid inequalities for the intersection of mixing sets. We also describe a relationship between the blending coefficients and the p-efficient points defined for chance-constrained programs.

#### 2 - Solving Nonlinear Engineering Problem with Piecewise-linear Approximation Techniques

Armin Fuegenschuh, Zuse Institut Berlin (ZIB), Takustrasse 7, Berlin, 14195, Germany, fuegenschuh@zib.de

Several real-world optimization and control problems, in particular in engineering applications, consist of both nonlinear continuous phenomena and discrete decisions. In order to find proven global optimal solutions, one possible way is to model such problems as linear mixed-integer programs, for which effective solvers are available. However, one has to approximate the nonlinearities using only linear constraints and mixed-integer variables. In this talk we outline such approximation techniques. Thereafter we discuss applications to different industrial problems, such as the optimal control of airplanes under free-flight conditions, or the optimal separation of substances in process engineering, and present numerical results.

#### 3 - Valid Inequalities for a Piecewise Linear Objective with Knapsack and Cardinality Constraints

Tallys Yunes, University of Miami, School of Business Administration, Coral Gables, FL, 33124-8237, United States of America, tallys@miami.edu, Ismael de Farias

We study the problem of maximizing a nonlinear function that can be approximated by a sum of separable continuous piecewise linear functions. The variables are constrained by a knapsack constraint and by a cardinality constraint stating that at most K of them can be positive. Cardinality constraints have applications in many fields, including finance and bio-informatics. We propose a family of valid inequalities for this problem and discuss computational experiments.

## ■ ThC10

Marriott - Chicago G

### Exact and Heuristic Techniques for MINLP

Cluster: Global Optimization

Invited Session

Chair: Pietro Belotti, Visiting Professor, Lehigh University, 200 W Packer Ave, Bethlehem, PA, 18015, United States of America, belotti@lehigh.edu

#### 1 - An Algorithmic Framework for Separable Non-convex MINLP

Claudia D'Ambrosio, DEIS, University of Bologna, viale Risorgimento 2, Bologna, 40136, Italy, c.dambrosio@unibo.it, Andreas Waechter, Jon Lee

We propose an algorithm to globally solve separable non-convex MINLPs. We define a convex MINLP relaxation approximating via linear relaxation the concave subintervals of each non-convex univariate function. These and the convex subintervals are glued together using binary variables. Then we get an upper bound fixing the integer variables and locally solving the obtained non-convex NLP. We finally refine our convex MINLP relaxation. Experiments on different classes of instances are presented.

#### 2 - Inequalities from Strong Branching Information for Mixed Integer Nonlinear Programs

Mustafa Kilinc, University of Wisconsin, Mechanical Engineering Bldg, 1513 University Avenue, Madison, WI, 53706, kilinc@wisc.edu, Jeff Linderoth, James Luedtke, Andrew Miller

Strong Branching is an effective branching technique that can significantly reduce the size of branch-and-bound tree for Mixed Integer Nonlinear Programs (MINLPs). We will demonstrate how to effectively use "discarded" information from strong branching to create disjunctive cutting planes in a linearization-based solver for convex MINLPs. Computational results reveal that the tree size can be effectively reduced using these inequalities.

#### 3 - Feasibility Pump Based Heuristics for Mixed Integer Nonlinear Programs

Kumar Abhishek, United Airlines, 1002 N Plum Grove Road, Apt 314, Schaumburg, IL, 60173, United States of America, kua3@lehigh.edu, Sven Leyffer, Jeff Linderoth

We explore three heuristics for finding feasible points for MINLPs based on the feasibility pump. The first approach alternates between rounding and solving an NLP. The second approach extends the feasibility pump of Bonami et al., and solves an MILP iteratively instead of rounding. Finally, our third approach integrates the feasibility pump within an LP/NLP-based branch-and-cut framework. We present detailed numerical results to demonstrate the effectiveness of these heuristics.

## ■ ThC11

Marriott - Chicago H

### Robust Optimization and Applications

Cluster: Robust Optimization

Invited Session

Chair: Georgia Perakis, MIT, 50 Memorial Drive, Cambridge, MA, United States of America, georgiap@mit.edu

#### 1 - Dynamic Pricing Through Scenario Based Optimization

Ruben Lobel, PhD Candidate, MIT, 77 Massachusetts Ave, Bldg. E40-149, Cambridge, MA, 02139, United States of America, rlobel@mit.edu, Georgia Perakis

We consider a robust approach to the dynamic pricing problem, with fixed inventory and uncertain demand. Our goal is to find approximate closed-loop pricing policies for different types of robust objective. We introduce a scenario based optimization approach that can solve the problem to an arbitrary level of robustness, based on the number of scenarios used. We will show how this methodology can be used either with historical data or by randomly sampling data points.

#### 2 - Models for Minimax Stochastic Linear Optimization Problems with Risk Aversion

Xuan Vinh Doan, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States of America, vanxuan@MIT.EDU, Dimitris Bertsimas, Karthik Natarajan, Chung-Piaw Teo

We study the minimax stochastic linear optimization problems with assumption that probability distribution of random parameters belongs to a distribution class specified by first and second moments. We show that the model is tractable for problems with random objective and some special problems with random right-hand side. We provide explicit worst-case distributions in these cases. We compare the performance of minimax solutions with data-driven solutions under contaminated distributions. Applications include a production-transportation problem and a single facility minimax distance problem. Computational results show that minimax solutions hedge against worst-case distributions and provide lower variability in cost than data-driven ones.

#### 3 - Robust Supply Chain Management with Expected Shortfall Constraints

Garud Iyengar, Columbia University, 500W 120th Street, New York, United States of America, garud@ieor.columbia.edu

The robust optimization based approximations available in the literature typically control the probability of constraint violation. They do not control the degree of constraint violation. We propose a new formulation that allows the decision-maker to control both the probability and expected value of constraint violation. We show how to construct tractable approximations for this new formulation. The methodology can be used for both bounded and unbounded uncertain parameters. We apply this methodology to problems in inventory management and contract selection.

## ■ ThC12

Marriott - Los Angeles

### PDE Constrained Optimization Problems in Finance

Cluster: PDE-constrained Optimization

Invited Session

Chair: Ekkehard Sachs, Universitat Trier, Trier, 54286, Germany, sachs@uni-trier.de

#### 1 - A Reduced Basis for Option Pricing

Nicolas Lantos, PhD Student, LJLL (Paris 6) & Natixis CS, 175, rue du Chevaleret, Paris, 75013, France, lantos@ann.jussieu.fr, Rama Cont, Olivier Pironneau

Galerkin methods approximate solution of PIDE on a finite basis of functions. The choice of this basis is driven by: the numerical efficiency of the basis' computation and the suitability of its asymptotic behavior. We introduce a one dimensional reduced basis designed on the Black-Scholes solution. Preliminary results for a call option show that less than twenty basis are needed to obtain a reliable accuracy. This methodology can be applied to any payoff that has a (semi-) closed form.

#### 2 - Valuation of Options and Calibration under Finite Activity Jump-diffusion Models

Jari Toivanen, Stanford University, Stanford, United States of America, toivanen@stanford.edu

We consider finite activity jump-diffusion models like Merton's and Kou's model. Implicit finite difference discretizations lead to sequence of linear (complementarity) problems with full matrices. We describe rapidly converging iterations requiring solutions of problems with tridiagonal matrices. We formulate the calibration of the model parameters as a nonlinear least squares problem. We study the efficient iterative solution of these ill conditioned problems.

#### 3 - Calibration of Local Volatility Models

Andre Lörx, Dipl.-Math. oec., Universität Trier, Trier, 54286, Germany, Ekkehard Sachs

In this talk we review techniques used in practice for the calibration of the local volatility model which is an extension of the Black-Scholes model for option pricing. We compare the advantages of various approaches like quadratic programming, Dupire's equation and the adjoint approach for a least squares formulation.

## ■ ThC13

Marriott - Miami

### Energy Models Using Stochastic MIPs

Cluster: Optimization in Energy Systems

Invited Session

Chair: Javier Salmeron, Naval Postgraduate School, 1411 Cunningham Road, Monterey, United States of America, jsalmero@nps.edu

#### 1 - A Scenario Tree-based Decomposition of Multistage Stochastic Mixed-Integer Problems in Power Supply

Debora Mahlke, TU Darmstadt, Schlossgartenstrasse 7, Darmstadt, 64289, Germany, mahlke@mathematik.tu-darmstadt.de, Andrea Zelmer, Alexander Martin

We consider a multistage stochastic mixed-integer model, where uncertainty is described by a scenario tree. To solve this block-structured problem, we present a decomposition approach based on splitting the scenario tree into subtrees. Solving the decoupled subproblems, a branch-and-bound algorithm is used to ensure feasibility. As an application, we present a power generation problem with fluctuating wind power supply, investigating the use of energy storages to balance supply and demand.

## 2 - Optimizing a Coupled Network Design Problem Involving Multiple Energy Carriers

Andrea Zelmer, TU Darmstadt, Schlossgartenstr. 7, Darmstadt, 64289, Germany, zelmer@mathematik.tu-darmstadt.de,  
Debora Mahlke, Alexander Martin

We present a network design problem where single energy carrier networks are coupled by cogeneration plants. Modeling the physical properties results in a complex mixed-integer nonlinear problem. The nonlinearities are approximated by piecewise linear functions yielding a mixed-integer linear problem. Investigating subpolyhedra regarding semicontinuous variables provides cutting planes which are used in a branch-and-cut approach. This algorithm is enhanced by an approximate-and-fix heuristic.

## 3 - Worst-case Interdiction, and Defense, of Large-scale Electric Power Grids

Javier Salmeron, Naval Postgraduate School, 1411 Cunningham Road, Monterey, United States of America, jsalmero@nps.edu,  
Kevin Wood, Ross Baldick

We generalize Benders decomposition to maximize a non-concave function and solve a bilevel electric power interdiction problem to identify a worst-case attack: a set of components, limited by interdiction resource, whose destruction maximizes disruption. The subproblem solves a set of DC optimal power-flow models for various states of repair and a load-duration curve. We also show how defensive resources can be replaced to minimize disruption. Test problems describe regional U.S. power grids.

## ■ ThC14

Marriott - Scottsdale

### Game Theory C

Contributed Session

Chair: Nayat Horozoglu, Research Student, London School of Economics and Political Science, Houghton Street, WC2A 2AE, London, United Kingdom, n.horozoglu@lse.ac.uk

#### 1 - A Framework to Turn Approximation Algorithms into Truthful Cost Sharing Mechanisms

Janina Brenner, TU Berlin, Institut fuer Mathematik,  
Sekt. MA 5-1, Strasse des 17. Juni 136, Berlin, 10623, Germany,  
brenner@math.tu-berlin.de, Guido Schaefer

We present a general framework for turning any  $c$ -approximation algorithm into a  $c$ -budget balanced weakly group-strategyproof cost sharing mechanism. The mechanisms we derive with this technique beat the best possible budget balance factors of Moulin mechanisms for several scheduling and network design problems, and achieve the first constant budget balance and social cost approximation factors for completion time scheduling. Our framework also works for competitive online algorithms.

#### 2 - How Hard is it to Find Extreme Nash Equilibria in Network Congestion Games?

Johannes Hatzl, Graz University of Technology, Steyrergasse 30,  
Department of Optimization and Discrete, Graz, 8010, Austria,  
hatzl@opt.math.tu-graz.ac.at, Elisabeth Gassner, Gerhard  
Woeginger, Heike Sperber, Sven Krumke

We study the complexity of finding extreme pure Nash equilibria in symmetric (unweighted) network congestion games. In our context best and worst equilibria are those with minimum respectively maximum makespan. On series-parallel graphs a worst Nash equilibrium can be found by a Greedy approach while finding a best equilibrium is NP-hard. For a fixed number of users we give a pseudo-polynomial algorithm to find the best equilibrium in series-parallel networks. For general network topologies also finding a worst equilibrium is NP-hard.

#### 3 - Shortest Path Tree Games In Wireless Multi-hop Networks (WMNs)

Nayat Horozoglu, Research Student, London School of Economics and Political Science, Houghton Street, WC2A 2AE, London, United Kingdom, n.horozoglu@lse.ac.uk, Katerina Papadaki

A WMN is composed of a root node that provides connectivity to the Internet to a number of users, where users can relay information for other users. If all the users cooperate, they can use their shortest path tree to route the information. Given the shortest path cost of all transmissions, the users need to find a mutually satisfactory cost allocation. We formulate the problem as a cooperative game, derive structural properties of the game, and investigate possible cost allocation concepts.

## ■ ThC15

Gleacher Center - 100

### Stochastic Integer Programming

Cluster: Stochastic Optimization

Invited Session

Chair: Maarten van der Vlerk, University of Groningen, P.O. Box 800, Groningen, 9700 AV, Netherlands, m.h.van.der.vlerk@rug.nl

#### 1 - Cutting Plane Methods for Stochastic Programs with Dominance Constraints Induced by Linear Recourse

Dimitri Drapkin, University of Duisburg-Essen, Lotharstr 65,  
Duisburg, D-47048, Germany, dimitri.drapkin@googlemail.com

We consider optimization problems whose constraints involve stochastic order relations between decision-dependent random variables and fixed random benchmarks. The decision-dependent random variables are given by the total costs arising in two-stage stochastic programs with linear recourse. With finite probability spaces, we propose a cutting plane algorithm for this class of problems, enabling decomposition into single-scenario subproblems. We conclude with computational results indicating that our method is favourable over the application of general-purpose mixed-integer linear programming solvers.

#### 2 - Two-stage Problems with Dominance Constraints - Closedness Property and a Decomposition Algorithm

Ralf Gollmer, Assistant, University of Duisburg-Essen, FB  
Mathematik, Forsthausweg 2, Duisburg, D-47057, Germany,  
ralf.gollmer@uni-due.de, Ruediger Schultz, Uwe Gotzes, Frederike  
Neise

For risk modeling in mixed-integer linear two-stage problems via first- and second-order stochastic dominance constraints closedness of the constraint set mapping and thus well-posedness of the problem is established. We propose a decomposition algorithm for the case of finite probability distributions and discuss some computational results for it.

#### 3 - Multi-stage Stochastic Programming with Integer Variables and Endogenous Uncertainty

Natashia Boland, Professor, University of Newcastle, School of  
Mathematical & Physical Scienc, Callaghan, 2308, Australia,  
natashia.boland@newcastle.edu.au

We consider the difficult case of multi-stage integer stochastic programming under endogenous uncertainty. We show that this uncertainty can be modelled naturally using integer variables. The resulting models have a large number of constraints which can be reduced using the scenario structure, even for quite general underlying probability distributions. These concepts are illustrated with an application in open-pit mine production scheduling.

## ■ ThC16

Gleacher Center - 200

### Stochastic Optimization F

Contributed Session

Chair: Paul Boggs, Sandia National Laboratories, East Ave., Livermore, CA, 94551, United States of America, ptboggs@sandia.gov

#### 1 - Optimal Maintenance Scheduling of Multicomponent Systems with Stochastic Life Limits

Adam Wojciechowski, PhD Student, Chalmers University of  
Technology, Department of Mathematical Sciences, Göteborg, 412  
96, Sweden, wojcadam@chalmers.se, Michael Patriksson,  
Ann-Brith Strömberg

For many companies maintenance is viewed as a large source of cost, while it should rather be viewed as an investment in availability. Previously, little optimization has been performed on maintenance planning problems over a finite horizon. We focus on optimization of maintenance activities in multicomponent systems where each maintenance occasion generates a fixed cost. An integer linear programming model for opportunistic maintenance planning taking into account the uncertainty of component lives is presented, along with complexity and polyhedral analyses and preliminary numerical results.

#### 2 - The Joint Hurdle-race Problem

Bernardo Pagnoncelli, Assistant Professor, Universidad Adolfo  
Ibanez, Diagonal Las Torres 2640 oficina 533C, Santiago, Chile,  
bernardokp@gmail.com, Steven Vanduffel

Consider an economic agent who needs to determine the current capital required to meet future obligations. Furthermore, for each period separately he needs to keep his capital above given thresholds, the hurdles, with high probability. We generalize the problem into a joint chance constrained problem assuming the decision maker has to pass the hurdles jointly. Using sample average approximation (SAA) we are able to obtain good candidate solution and bounds for the true optimal value.



### 3 - Optimal Allocation of Resources under Uncertainty Following an Anthrax Attack

Paul Boggs, Sandia National Laboratories, East Ave., Livermore, CA, 94551, United States of America, ptboggs@sandia.gov,  
David M. Gay, Jaideep Ray

The early stages of an anthrax attack will be characterized by much uncertainty. Almost nothing will be known about the extent, timing, size, and dose. Nor will emergency managers know how many cities were attacked and when subsequent targets were hit. In response to this situation, we have developed a way to assess the uncertainty in such a way that allows one to obtain a range of possible scenarios. We show how to use these possible scenarios to compute an optimal response.

## ■ ThC17

Gleacher Center - 204

### Logistics and Transportation E

Contributed Session

Chair: Sergio Garcia Quiles, Universidad Carlos III, Avenida de la Universidad, 30, Leganos, Madrid, 28911, Spain, sergio.garcia@uc3m.es

#### 1 - Distance-to-go Labels for Computing Shortest Paths in Large Road Networks

Hamish Waterer, University of Newcastle, School of Math & Physical Sciences, University of Newcastle, Callaghan NSW, 2308, Australia, hamish.waterer@newcastle.edu.au, Geoff Leyland

Preliminary results are presented of an investigation into computing shortest paths in real time when very limited information computed a priori can be stored. A single additional label on each arc is considered. These labels store the maximum distance from each arc to the end of any shortest path that uses the arc. Computational results show that these simple distance-to-go labels significantly improve the efficiency of Dijkstra's algorithm with the use of minimal additional storage.

#### 2 - Dynamic Construction of Time-discretized Networks for Very Large Scale Operational Railway Planning

Frank Fischer, Chemnitz University of Technology, Fakultät für Mathematik, Chemnitz, 09107, Germany, frank.fischer@mathematik.tu-chemnitz.de, Christoph Helmberg

For the German railway network we search for a conflict free schedule for trains with given stopping intervals that observes sequence dependent headway times and station capacities. Our model uses time-discretized networks and configuration networks for the headway-constraints. The huge number of variables is handled by dynamic network generation within a combined Lagrangian relaxation and cutting plane approach. This is solved by a bundle method using primal aggregates for separation and rounding. Some promising results towards handling ten percent of the entire network are presented.

#### 3 - Resolution of Large P-median Problems with a Column-and-row Generation Algorithm

Sergio Garcia Quiles, Universidad Carlos III, Avenida de la Universidad, 30, Leganos, Madrid, 28911, Spain, sergio.garcia@uc3m.es, Alfredo Mariin, Martine Labbe'

In the p-median location problem, a set of p medians must be located among a set of potential locations so that the total allocation cost of the non-medians to the medians be minimum. This presentation will show how very large problems (the largest of them, with more than ten thousand nodes) can be solved by using a formulation based on a set covering approach combined with a very particular column-and-row generation method.

## ■ ThC18

Gleacher Center - 206

### Nonconvex Programming

Cluster: Nonlinear Mixed Integer Programming

Invited Session

Chair: Jon Lee, IBM TJ Watson Research Center, P.O. Box 218, Yorktown Heights, NY, 10598, United States of America, jonlee@us.ibm.com

#### 1 - Extending a CIP Framework to Solve MINLPs

Stefan Vigerske, Humboldt-University, Department of Mathematics, Rudower Chaussee 25, 12489 Berlin-Adlers, Berlin, 10099, Germany, stefan@math.hu-berlin.de

We present extensions of the constraint integer programming framework SCIP for solving mixed-integer nonlinear programs. Nonlinear constraints (convex or nonconvex) are handled within an LP-based branch-and-cut algorithm by generating suitable linear relaxations and by domain propagation. The implementation is based on several other software packages, e.g., Couenne, CppAD, and Ipopt. Preliminary numerical results are presented.

#### 2 - Projected Formulations for Non-convex Quadratically Constrained Programs

Anureet Saxena, Axioma Inc, 8800 Roswell Rd., Atlanta, GA, 30338, anureet@yahoo.com, Jon Lee, Pierre Bonami

A common way to produce a convex relaxation of a MIQCP is to lift the problem into a higher dimensional space by introducing additional variables to represent bilinear terms, and strengthening the resulting formulation using SDP constraint and disjunctive programming. In this paper, we study projection methods to build low-dimensional relaxations of MIQCP that capture the strength of these extended formulations.

#### 3 - Strong Valid Inequalities for Orthogonal Disjunctions and Polynomial Covering Sets

Jean-Philippe Richard, University of Florida, Department of Industrial and Systems Eng, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32611, richard@ise.ufl.edu, Mohit Tawarmalani, Kwanghun Chung

We propose a convexification tool to construct the convex hull of orthogonal disjunctive sets using convex extensions and disjunctive programming techniques. We describe a toolbox of results to verify the assumptions under which this tool can be employed. We then extend its applicability to nonconvex sets that are not naturally disjunctive. We illustrate the use of our results by developing convex hulls of certain polynomial covering sets and by reporting promising computational results.

## ■ ThC19

Gleacher Center - 208

### Stochastic Optimization A

Contributed Session

Chair: Marc Letournel, PhD Student, LRI Graphcomb Staff, Université d'Orsay, LRI bat 490, Orsay, 91405, France, letournel@lri.fr

#### 1 - A 0-1 Stochastic Model for the Air Traffic Flow Management Problem

Celeste Pizarro, University Rey Juan Carlos, c/ Tulipan s/n, Madrid, Spain, celeste.pizarro@urjc.es, Laureano Escudero, Alba Agustaaan, Antonio Alonso-Ayuso

We present a framework for solving large-scale multistage mixed 0-1 problems for the air traffic flow management problem with rerouting under uncertainty in the airport arrival and departures capacity, the air sector capacities and the flight demand. A scenario tree based scheme is used to represent the Deterministic Equivalent Model of the stochastic mixed 0-1 program with complete recourse. We propose the so-called Fix-and-Relax Coordination algorithm to solved it.

#### 2 - A Branch-and-cut Framework for Stochastic Programming Problems under Endogenous Uncertainty

Christos Maravelias, Assistant Professor, University of Wisconsin - Madison, Chemical and Biological Engineering, 1415 Engineering Dr., Madison, WI, 53706, United States of America, maravelias@wisc.edu, Matthew Colvin

First, we exploit the structure of the problem to derive theoretical properties. We show that a large number of inequality nonanticipativity constraints (NACs) can be removed and others can be replaced by equalities, leading to smaller and tighter MIP models. We also develop a B&C method, where the tree search starts with a reduced MIP formulation where necessary NACs are added as needed, thus requiring all solutions to be examined before updating the bounds.

**3 - Stochastic Knapsack Problem with Continuous Distributions**

Marc Letournel, PhD Student, LRI Graphcomb Staff, Université d'Orsay, LRI bat 490, Orsay, 91405, France, letournel@lri.fr, Stefanie Kosuch, Abdel Lisser

We present and discuss a Stochastic Knapsack Problem with expectation constraint where the weights are assumed to be independently normally distributed. We present two methods to estimate the gradient of the constraint function in expectation: The first one is an approximate method that uses Finite Differences. The second method allows an exact estimation of the gradient via Integration by Parts. Numerical results of both methods are presented, compared and analyzed.

**ThC20**

Gleacher Center - 300

**Trust Region Methods and Subproblems**

Cluster: Nonlinear Programming

Invited Session

Chair: William Hager, University of Florida, P.O. Box 118105, Gainesville, FL, 32611, hager@math.ufl.edu

Co-Chair: Jennifer Erway, Wake Forest University, P.O. Box 7388, Winston Salem, NC, 27109, United States of America, erwayjb@wfu.edu

**1 - Solving Large Nonlinear Least-squares Problems by Subspace Trust-region Methods**

Margherita Porcelli, Università di Firenze, Viale Morgagni 67a, Firenze, 50134, Italy, porcelli@math.unifi.it, Nick Gould, Philippe Toint

Unconstrained nonlinear least-squares problems model many real applications and their solution forms basis of many methods for constrained optimization problems. We consider different subspace approaches for solving the trust-region subproblem arising at each iteration: methods based on nested subspaces associated with the Lanczos process and the low-dimensional subspaces minimization methods. The numerical performance of the two approaches is compared and numerical experiments with large problems from the CUTER set are presented.

**2 - A Stopping Criterion for Solving the SQP System in SSM**

Ning Guo, Student, University of Florida, Department of Mathematics, 358 Little Hall, University of Florida, Gainesville, FL, 32611, United States of America, guoning@ufl.edu, William Hager

SSM(sequential subspace method) is used in solving the trust region subproblem. The method and the algorithm will be briefly discussed. Inside each iteration, we obtain the SQP(sequential quadratic programming) iterate by solving the linear system generated by applying one step of Newton's method to the first-order optimality system. A stopping criterion is provided concerning how accurately the system should be solved to get an at least linear convergence for the non-degenerate case. Some Numerical results will be provided.

**3 - An Exact Algorithm for Solving the Graph Partitioning Problem**

Dzung Phan, University of Florida, 358 Little Hall, P.O. Box 118105, Gainesville, FL, 32611-8105, United States of America, dphan@ufl.edu, William Hager

In this talk, we present an exact algorithm for solving the node and edge weighted graph partitioning problem. The algorithm is based on a continuous quadratic formulation of the problem. Necessary and sufficient optimality conditions for a local minimizer of the quadratic program are introduced. These conditions relate the graph structure and the first-order optimality conditions at the given point. Lower bounds for the rectangular branch and bound algorithm are obtained by writing the objective function as the sum of a convex and a concave function and replacing the concave part by the best affine underestimator. Numerical results show that the proposed algorithm is highly competitive with state-of-the-art graph partitioning methods.

**ThC21**

Gleacher Center - 304

**Network Design Optimization**

Cluster: Telecommunications and Networks

Invited Session

Chair: Petra Mutzel, Professor Doctor, TU Dortmund, Computer Science LS11, Otto-Hahn-Str. 14, Dortmund, 44227, Germany, petra.mutzel@tu-dortmund.de

**1 - A Branch-and-cut-and-price Algorithm for Vertex-biconnectivity Augmentation**

Ivana Ljubic, University of Vienna, Bruennerstr. 72, Vienna, 1210, Austria, ivana.ljubic@univie.ac.at

Given a spanning subgraph of an edge-weighted graph, we search for the cheapest augmentation that makes it vertex-biconnected. We show that orienting the undirected graph does not help in improving the quality of lower bounds obtained by relaxing cut-based ILPs. We then develop a practically feasible branch-and-cut-and-price approach: Complete graphs with 400 nodes are solved to provable optimality, whereas for graphs with more than 2000 nodes, optimality gaps below 2% are reported.

**2 - Dimensioning Multi-level Telecommunication Networks: Integer Programming Approaches**

Maren Martens, Zuse Institute Berlin, Takustr. 7, Berlin, 14195, Germany, martens@zib.de, Andreas Bley

Modern telecommunication networks are structured hierarchically into access and metro areas and a core network: Users are connected to regional metro networks via access links, while the metro networks are connected through a core. Decisions when planning such structures target the choice of good (cost efficient) locations for metro and core nodes and the dimensioning of links such that all traffic demands can be routed. We present approaches that achieve exact solutions for such problems.

**3 - Dual-based Local Search for the Connected Facility Location and Related Problems**

S. (Raghu) Raghavan, University of Maryland, 4345 Van Munching Hall, College Park, MD, 20742, United States of America, raghavan@umd.edu, M. Gisela Bardossy

The connected facility location problem is an NP-complete problem that arises in the design of telecommunication and data networks where open facilities need to communicate with each other. We propose a dual-based local search heuristic that combines dual-ascent and local search that together yield strong lower and upper bounds to the optimal solution. Our procedure applies to a family of closely related problems (namely the Steiner tree-star (STS) problem, the general STS problem, and the rent-or-buy problem) that unite facility location decisions with connectivity requirements. We discuss computational experiments, which indicate that our heuristic is a very effective procedure that finds high quality solutions very rapidly.

**ThC22**

Gleacher Center - 306

**Optimization in the Oil Industry and Mixed Energy Problems**

Contributed Session

Chair: Luis Francisco Ferreira Senne, Petrobras, Av Republica do Chile, 65, sala 1902, Centro, Rio de Janeiro, RJ, 20031912, Brazil, luis\_senne@yahoo.com.br

**1 - A Decentralized Resilient Mixed-energy Infrastructure (L3) Model of America in the Next 40 Years**

Jinxu Ding, Iowa State University, Coover 2215, Ames, IA, 50011-3060, United States of America, jxding@iastate.edu, Arun Somani

The non-renewable energy infrastructure is highly-centralized and mainly depends on the crude-oil, natural gas and coal. This results in pollution and dependence on the foreign countries. And, the fossil energy will be used up in future. Thus, we propose the decentralized resilient mixed-energy infrastructure such that (1) Generate renewable energy locally; (2) Consume renewable energy locally; (3) Local people get benefits from new jobs, and clean energy. This can be summarized as L3 principle.

**2 - Polynomial Penalty Functions Applied to Oil Production Optimization**

Davood Shamsi, PhD Student, Stanford University, Terman Engineering Center, Room 373, 380 Panama Mall, Stanford, CA, 94305, United States of America, davood@stanford.edu, Dongdong Ge, David Echeverria Ciaurri, Yinyu Ye

In oil production optimization, one often needs to maximize the net present value of a reservoir subject to nonlinear constraints (e.g., maximum water injected rate). The introduction of polynomial penalty functions for constraint violation represents a novel strategy for controlling infeasibility. We show, for realistic examples, that the optimization paths associated to the use of penalty functions are smooth, and that the corresponding optimal solutions have acceptable quality in practice.

### 3 - Incorporation of Uncertainties in the Supply Plan of an Oil Company

Luis Francisco Ferreira Senne, Petrobras, Av Republica do Chile, 65, sala 1902, Centro, Rio de Janeiro, RJ, 20031912, Brazil, luis\_senne@yahoo.com.br, Virgilio J. M. Ferreira Filho

To considerate uncertainty in the supply plan of an oil company stochastic programming techniques were employed. Eleven stochastic (two and multi-stage) recourse models were studied. Each of those models was compared with each other and with a deterministic one. To measure the impact of uncertainties in the plan some information were chosen to be watched. Different degrees of impact were associated to different kinds of uncertainty. The VSS as well as the computational effort were also analyzed.

## ■ ThC23

Gleacher Center - 308

### Matrix Min-Rank and Matrix Completion Problems

Cluster: Sparse Optimization  
Invited Session

Chair: Wotao Yin, Assistant Professor, Rice University, Department of Computational and Applied, 3086 Duncan Hall, Houston, TX, 77251, United States of America, wotao.yin@rice.edu

#### 1 - A Singular Value Thresholding Algorithm for Matrix Completion

Jian-Feng Cai, CAM Assistant Adjunct Professor, Department of Mathematics, UCLA, 6363 Math Sciences Bldg, UCLA, Los Angeles, CA, 90095-1555, United States of America, caijf@hotmail.com, Emmanuel Candes, Zuowei Shen

We propose a simple and easy-to-implement algorithm to approximate the matrix with minimum nuclear norm among all matrices obeying a set of convex constraints. The algorithm is extremely efficient at addressing problems in which the optimal solution has low rank. We demonstrate that our approach is amenable to very large scale problems by recovering matrices of rank about 10 with nearly a billion unknowns from just about 0.4% of their sampled entries.

#### 2 - Fixed Point and Bregman Iterative Methods for Matrix Rank Minimization

Shiqian Ma, Columbia University, 500 W. 120TH ST, Mudd, Department of IEOR, New York, NY, 10027, United States of America, sm2756@columbia.edu, Donald Goldfarb, Lifeng Chen

In this talk, we present and analyze fixed point and Bregman iterative algorithms for solving the nuclear norm minimization problem, which is a convex relaxation of matrix rank minimization problem. By using an approximate SVD procedure, we get a very fast, robust and powerful algorithm that can solve very large problems. Our numerical results on matrix completion problems demonstrate that this algorithm is much faster and provides much better recoverability than SDP solvers such as SDPT3.

#### 3 - The Linearized Bregman Method

Wotao Yin, Assistant Professor, Rice University, Department of Computational and Applied, 3086 Duncan Hall, Houston, TX, 77251, United States of America, wotao.yin@rice.edu

The linearized Bregman method has been used in sparse optimization and matrix completion problems. This talk presents the history of the method, its theoretical properties, latest numerical enhancements, as well as its comparisons with other popular methods in sparse optimization. In particular, we show that the linearized Bregman method is equivalent to a gradient descent algorithm applied to a dual penalty formulation, which has an interesting property of exact penalty.

## ■ ThC25

Gleacher Center - 404

### Infinite Dimensional Variational Analysis and Applications

Cluster: Variational Analysis  
Invited Session

Chair: Nguyen Mau Nam, University of Texas-Pan American, 1201 West University Drive, Edinburg, TX, 78539, nguyennm@utpa.edu

#### 1 - The Tangential Distance with its Applications

Bingwu Wang, Associate Professor, Eastern Michigan University, 504D Pray-Harold building, EMU, Ypsilanti, MI, 48187, United States of America, bwang@emunix.emich.edu

The talk involves the tangential distance, which appears recently in variational analysis, and plays an important rule in deriving formulas regarding direct images. Some of these applications will be explored, as well as basic properties of the tangential distance. The talk is based on joint work with Boris Mordukhovich and Nguyen Mau Nam.

#### 2 - Necessary and Sufficient Conditions of One-sided Lipschitz Mappings and Applications

Hoang Nguyen, Graduate Student, Wayne State University, Mathematics Dept. WSU 656 W.Kirby, 1150 F/A B, Detroit, MI, 48202, United States of America, ba2609@wayne.edu

This talk discusses the necessary and sufficient conditions of one-sided Lipschitz mappings defined on Hilbert spaces. The second part of the talk, we will discuss about the necessary optimality conditions of Bolza problem for one-sided Lipschitzian differential inclusions.

#### 3 - Subdifferential of Suprimum and Infimum of Infinite Functions and its to Infinite Optimization

Mehari Gebregziabher, GTA, Department of Mathematics, Wayne State University, 3905 Evaline, Hamtramck, MI, 48212, United States of America, aw9095@wayne.edu

In this paper a representation for the basic subdifferential of suprimum of infinite Lipschitz continuous functions on reflexive space is obtained. A representation for subdifferential of infimum of infinite continuous functions is also given provided that the infimum is attainable in an open neighbourhood. As a result a representation for superdifferentials and Clarke subdifferential is obtained. A necessary optimality condition for infinite optimization is also proved.

## ■ ThC28

Gleacher Center - 600

### Nonsmooth, Linear and Robust Optimization

Cluster: Nonsmooth and Convex Optimization  
Invited Session

Chair: Stephen Wright, Professor, University of Wisconsin-Madison, Computer Sciences, 1210 West Dayton Street, Madison, WI, 53706, United States of America, swright@cs.wisc.edu

#### 1 - Constraint Reduction for Linear Programs in General Form

Meiyun He, University of Maryland, Department ECE and ISR, College Park, MD, 20742, United States of America, myheglqh@gmail.com, Andre Tits

Linear programs (LPs) in general form are readily recast into LPs in standard primal or dual form. The resulting "A" matrix has a sparsity structure that ought to be exploited at solution time. Constraint reduction techniques reduce the work per iteration when interior-point methods are used for solving standard-form LPs for which A has many more columns than rows. Here such techniques are applied to general-form LPs, tailored to exploit the sparsity structure of the transformed problem.

#### 2 - Problem Geometry and Problem Robustness

Jorge Vera, Professor, Pontificia Universidad Catolica de Chile, Campus San Joaquín, Vicuna Mackenna 4860, Santiago, 7820436, Chile, jvera@ing.puc.cl

The geometry of a set has been shown to explain complexity properties of related convex optimization algorithms. It is a relevant question whether these properties influence sensitivity of optimal solutions with respect to changes in the data, in a similar way as with condition numbers. In this work we show some of those connections and address its potential implications for the computation of robust solutions. Robust solutions are protected from data variation, but the change in the robust solution with respect to nominal solutions is related to the robustness and well posedness of the problem itself. We show how feasible set geometry could be used as a way of measuring this robustness.

#### 3 - Composite Optimization: Algorithm and Identification Properties

Stephen Wright, Professor, University of Wisconsin-Madison, Computer Sciences, 1210 West Dayton Street, Madison, WI, 53706, United States of America, swright@cs.wisc.edu, Adrian Lewis

We seek to minimize composite function of the form  $h(c(x))$ , where  $c$  is a smooth vector function and  $h$  is usually nonsmooth, possibly nonconvex, and possibly extended-valued. This paradigm encompasses many problems of current interest, including compressed sensing and matrix completion, as well as more established problems such as  $l_1$  penalty formulations of nonlinear programming. We propose a method that is based on a linearization of  $c$  together with a smooth proximal penalty on the step, and analyze convergence of this method in the case of  $h$  prox-regular. We also discuss issues of identification in this setting, that are extensions of active constraint identification in nonlinear programming.