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ISMP2003:  Program and Abstracts
(on-line version of printed book)
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The Logo and the Petersen Graph

The ISMP2003 logo, which is used as cover for this book and additionally used as symbol in our posters and on the homepage etc., is composed of two main components: the bridge connecting Denmark and Sweden, and the Petersen graph. The bridge symbolizes international collaboration as well as engineering and mathematical programming skills. The Petersen graph is due to the Danish mathematician Julius Petersen; the following is a short biography written by Bjarne Toft, University of Southern Denmark.

Julius Petersen (1839–1910) was born in the Danish town of Sorø on Zealand. His father was a dyer. In 1854 his parents were no longer able to pay for his schooling, so he became an apprentice in an uncle's grocery store in Jutland. The uncle died however when Petersen had been with him for a year, leaving Petersen enough money to return to school. In 1857 he began to study engineering at the Polytechnic School in Copenhagen (now the Technical University of Denmark), later deciding to concentrate on mathematics. When his inheritance ran out he had to teach to make a living, and he started a lifelong occupation writing textbooks, the first in 1859 on logarithms. One of his books, 'Methods and Theories for the Solution of Geometrical Problems', were translated into eight languages, with the English version last reprinted in the 1960'ies by Chelsea (in the collection 'String Figures and other Monographs') and the French version as recently as 1990, more than a century after the first publication date 1866. Petersen's books are short, succinct and elegant, still a pleasure to read.

From 1859 to 1871 Petersen taught at a prestigious private high school in Copenhagen. (The headmaster Bohr had a gifted son Christian, who became professor of physiology at the University of Copenhagen. He in turn had two gifted sons, Niels Bohr — Nobel prize winner in physics — and Harald Bohr — professor in mathematics at the University of Copenhagen.)

While teaching at Bohr's school, Petersen married, and he and his wife Laura had three children. He obtained a mathematics degree from the University of Copenhagen in 1866 and a doctorate in 1871. In 1871 the Technical University expanded and changed from a two year to a one year schedule, and Petersen was appointed as its professor of mathematics, a position he held for 16 years. In 1887 he changed to a professorship at the University of Copenhagen.

Petersen worked in a wide range of areas, including algebra, analysis, cryptography, geometry, mechanics, mathematical economics and number theory. In many of these fields he made pioneering contributions. His contributions to graph theory, inspired by Sylvester, on the factorization of regular graphs, are his best known work. He was known for his clarity of exposition, problem-solving skills, originality, vigour and sense of humour. He was bubbling and witty in debate, always ready to brake a lance with anybody, in unfailing trust of the soundness of his own arguments. He made a point out of not reading the writings of other mathematicians, not to have his own way of thinking misled or destroyed, sometimes with embarrassing consequences. He is quoted to have said: 'I started to read the proof, but it was eight pages long, so I preferred to do it myself'.

Petersen's mind for numbers can be illustrated by the following account, told by one of his high school students. To entertain the class, Petersen let each pupil write two three digit numbers on the blackboard. He then for a minute or two looked at the list of more than 30 numbers. With his back to the blackboard, he could now repeat the whole list of numbers, forward and backward, and he was able immediately to tell each number's place in the list.

In 1908 Petersen suffered a stroke. When his friends pitied his deteriorating condition he answered them: 'When throughout life you have obtained honour and money for enjoying yourself — what more can you ask for ?'. Petersen's death in 1910 was front page news. A newspaper of the time described him as a Hans Christian Andersen of science — a child of the people who made good in the academic world.

Welcome to ISMP2003

On behalf of the Technical University of Denmark, the University of Copenhagen, and the Mathematical Programming Society we welcome you to ISMP2003, the 18th International Symposium on Mathematical Programming. The symposium is arranged jointly by the two universities and is held at the campus of the Technical University in Lyngby just North of Copenhagen.

The conference program includes 17 invited lectures and 750 contributed talks of which approximately half are included in sessions organized by the participants themselves. The topics span the complete universe of mathematical programming from theory over models, modeling tools and solution methods to applications.

We are indebted to a number of persons, companies and institutions for their support of the symposium. We gratefully acknowledge the contributions from our sponsors, which made it possible to waive the conference fee for more than 100 participants and to provide partial support for accommodation expenses for a number of the participating graduate students.

We are sure that the symposium will initiate and enhance collaboration between mathematical programmers from all over the world. Also, the city of Copenhagen welcomes ISMP2003, and we encourage all of you to explore the many attractions of the city.

We wish you all an enjoyable ISMP2003 in Copenhagen.

Jens Clausen, Technical University of Denmark

Jørgen Tind, University of Copenhagen

Committees

Program Committee

Jørgen Tind (chair), University of Copenhagen; Jens Clausen (cochair), Technical University of Denmark; Rainer Burkard, Technische Universität, Graz; Martin Grötschel, ZIB, Berlin; Michael J. Todd, Cornell University; Stephen J. Wright, University of Wisconsin.

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Sponsors and Support

We gratefully acknowledge the generous support by our sponsors and supporters.

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Overview of Events

Registration and Get-Together

Sunday, August 17, 17:00 – 20:00, Sportshal, Building 101. Registration is also open on Monday, August 18, 8:00 – 9:00, Sportshal, Building 101.

Opening Session

Monday, August 18, 9:00 – 10:45, Sportshal, Building 101. Welcome addresses, awarding of prizes and music by "The Nordic Five". See full program on page 9.

Plenary Sessions

See program on page 10.

Parallel Sessions

See program on page 19.

Conference Dinner

Tuesday, August 19, Base Camp Restaurant, Halvtolv Bygning 148, Holmen. Boat departure from Nyhavn at 18:00, dinner at 19:00.

Reception

Wednesday, August 20, 19:00 – 21:00. Two parallel receptions have been arranged: One at the *City Hall*, Rådhuspladsen, and the other at the *University Celebration Hall*, Frue Plads. Your reception ticket indicates in which reception you have been invited to participate.

Social Program and Activities

A number of different trips are planned by VanHauen Conferences & Incentives. Also, some social activities — such as sport activities — have been arranged. For more information, please contact VanHauen at the registration desk.

Overview of Program

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
9:00 – 10:30	**Opening Session**	Parallel Sessions *TU1*	Parallel Sessions *WE1*	Parallel Sessions *TH1*	Parallel Sessions *FR1*
10:30 – 10:45					
10:45 – 11:00		*Coffee Break*			
11:00 – 11:15		Plenary Session	Plenary Session	Plenary Session	Plenary Session
11:15 – 12:00	Plenary Session				
12:00 – 12:15					
12:15 – 13:15	*Lunch*				
13:15 – 14:45	Parallel Sessions *MO2*	Parallel Sessions *TU2*	Parallel Sessions *WE2*	Parallel Sessions *TH2*	
14:45 – 15:15	*Coffee Break*				
15:15 – 16:15	Semi-Plenary Sessions	Semi-Plenary Sessions	Semi-Plenary Sessions	Semi-Plenary Sessions	
16:15 – 16:30	*Break*			*Break*	
16:30 – 18:00	Parallel Sessions *MO3*			Parallel Sessions *TH3*	
		Dinner *Boat departure at 18:00*	**Reception** *19:00–21:00*		

Opening Session

Monday, August 18, 9:00 – 10:45, Sportshal, Building 101.
Chair: Jens Clausen, Local Organizing Committee Chair.

Call to Order
Jørgen Tind, Program Committee Chair.

Welcome Address
Lars Pallesen, Rector, DTU.

Chairman's Message
Robert Bixby, Chairman of the Mathematical Programming Society.

Prizes

- Dantzig Prize — for original research having a major impact on mathematical programming.
- Lagrange Prize — for outstanding works in the area of continuous optimization.
- Fulkerson Prize — for outstanding papers in discrete mathematics.
- Beale-Orchard-Hays Prize — for excellence in computational mathematical programming.
- Tucker Prize — for an outstanding paper by a student.

Music
The Nordic Five: A modern musical performance of legends and tunes from Scandinavia.

Plenary and Semi-Plenary Sessions

Monday, 11:15 – 12:15, Sportshal, Building 101 (Plenary)

In pursuit of the traveling salesman

WILLIAM J. COOK
Georgia Institute of Technology
Coauthors: David Applegate, Robert Bixby and Vašek Chvátal

Chair: George L. Nemhauser

Dantzig, Fulkerson, and Johnson (1954) introduced the cutting-plane method as a means of attacking the traveling salesman problem; this method has been applied to broad classes of problems in combinatorial optimization and integer programming. In this paper we discuss an implementation of Dantzig et al.'s method that is suitable for TSP instances having 1,000,000 or more cities. Our aim is to use the study of the TSP as a step towards understanding the applicability and limits of the general cutting-plane method in large-scale applications.

Monday, 15:15 – 16:15, Sportshal, Building 101 (Semi-Plenary)

The smoothed analysis of algorithms

DANIEL A. SPIELMAN
Massachusetts Institute of Technology
Coauthor: Shang-Hua Teng

Chair: Stephen J. Wright

We perform a smoothed analysis of a termination phase for linear programming algorithms. By combining this analysis with the smoothed analysis of Renegar's condition number by Dunagan, Spielman and Teng we show that the smoothed complexity of interior-point algorithms for linear programming is $O(m^3 \log(m/\sigma))$. In contrast, the best known bound on the worst-case complexity of linear programming is $O(m^3 L)$, where L could be as large as m. We include an introduction to smoothed analysis and a tutorial on proof techniques that have been useful in smoothed analyses.

Monday, 15:15 – 16:15, Aud 81, Building 116 (Semi-Plenary)

Applications of convex optimization in signal processing and digital communication

ZHI-QUAN LUO
University of Minnesota

Chair: Hans Bruun Nielsen

In the last two decades, the mathematical programming community has witnessed some spectacular advances in interior point methods and robust optimization. These advances have recently started to significantly impact various fields of applied sciences and engineering where computational efficiency is essential. This paper focuses on two such fields: digital signal processing and communication.

In the past, the widely used optimization methods in both fields had been the gradient descent or least squares methods, both of which are known to suffer from the usual headaches of stepsize selection, algorithm initialization and local minima. With the recent advances in conic and robust optimization, the opportunity is ripe to use the newly developed interior point optimization techniques and highly efficient software tools to help advance the fields of signal processing and digital communication. This paper surveys recent successes of applying interior point and robust optimization to solve some core problems in these two fields.

The successful applications considered in this paper include adaptive filtering, robust beamforming, design and analysis of multi-user communication system, channel equalization, decoding and detection. Throughout, our emphasis is on how to exploit the hidden convexity, convex reformulation of semi-infinite constraints, analysis of convergence, complexity and performance, as well as efficient practical implementation.

Monday, 15:15 – 16:15, Aud 42, Building 302 (Semi-Plenary)

Online algorithms: a survey

SUSANNE ALBERS
Institut für Informatik, Albert-Ludwigs-Universität Freiburg

Chair: Martin Zachariasen

During the last 15 years online algorithms have received considerable research interest. In this survey we give an introduction to the competitive analysis of online algorithms and present important results. We study interesting application areas and identify open problems.

Tuesday, 11:00 – 12:00, Sportshal, Building 101 (Plenary)

Recent advances in the solution of quadratic assignment problems

KURT M. ANSTREICHER
Department of Management Sciences, University of Iowa

Chair: Jens Clausen

The quadratic assignment problem (QAP) is notoriously difficult for exact solution methods. In the past few years a number of long-open QAPs, including those posed by Steinberg (1961), Nugent et al. (1968) and Krarup (1972) were solved to optimality for the first time. The solution of these problems has utilized both new algorithms and novel computing structures. We describe these developments, as well as recent work which is likely to result in the solution of even more difficult instances.

Tuesday, 15:15 – 16:15, Sportshal, Building 101 (Semi-Plenary)

Approximation schemes for NP-hard geometric optimization problems: a survey

SANJEEV ARORA
Computer Science Department, Princeton University

Chair: David Pisinger

Traveling Salesman, Steiner Tree, and many other famous geometric optimization problems are NP-hard. Since we do not expect to design efficient algorithms that solve these problems optimally, researchers have tried to design approximation algorithms, which can compute a provably near-optimal solution in polynomial time.

We survey such algorithms, in particular a new technique developed over the past few years that allows us to design approximation schemes for many of these problems. For any fixed constant $c > 0$, the algorithm can compute a solution whose cost is at most $(1+c)$ times the optimum. (The running time is polynomial for every fixed $c > 0$, and in many cases is even nearly linear.) We describe how these schemes are designed, and survey the status of a large number of problems.

Tuesday, 15:15 – 16:15, Aud 81, Building 116 (Semi-Plenary)

How to compute the volume in high dimension?

MIKLÓS SIMONOVITS
Alfréd Rényi Mathematical Institute, Budapest

Chair: Kim A. Andersen

In some areas of theoretical computer science we *feel* that randomized algorithms are better and in some others *we can prove* that they are more efficient than the deterministic ones.

Approximating the volume of a convex n-dimensional body, given by an oracle is one of the areas where this difference can be proved. In general, if we use a deterministic algorithm to approximate the volume, it requires *exponentially many oracle questions* in terms of n as $n \to \infty$. Dyer, Frieze and Kannan gave a randomized *polynomial* approximation algorithm for the volume of a convex body $K \subseteq \mathbb{R}^n$, given by a membership oracle.

The DKF algorithm was improved in a sequence of papers. The area is full of deep and interesting problems and results. This paper is an introduction to this field and also a survey.

Tuesday, 15:15 – 16:15, Aud 42, Building 302 (Semi-Plenary)

Variational conditions with smooth constraints: structure and analysis

STEPHEN M. ROBINSON
University of Wisconsin-Madison

Chair: Kaj Madsen

This is an expository paper about the analysis of variational conditions over sets defined in finite-dimensional spaces by fairly smooth functions satisfying a constraint qualification. The primary focus is on results that can provide quantitative and computable sensitivity information for particular instances of the problems under study, and our objective is to give a personal view of the state of current knowledge in this area and of gaps in that knowledge that require future work. The writing style is informal, in keeping with the objective of focusing the reader's attention on the basic concepts and the relationships between them, rather than on details of the particular results themselves.

Wednesday, 11:00 – 12:00, Sportshal, Building 101 (Plenary)

Necessary conditions and feedback design in optimal and stabilizing control

FRANCIS CLARKE
University of Lyon 1

Chair: Anders Forsgren

We present necessary conditions of optimality for a general control problem formulated in terms of a differential inclusion. These conditions unify and substantially extend previous results in the literature, and also incorporate a 'stratified' feature of a novel nature. When specialized to the calculus of variations, the results yield necessary conditions and regularity theorems that go significantly beyond the previous standard. They also give rise to new and stronger maximum principles of Pontryagin type. The principal focus here is the development of structural criteria on the problem which guarantee *a priori* that the necessary conditions apply to any local minimizer.

Wednesday, 15:15 – 16:15, Sportshal, Building 101 (Semi-Plenary)

Progress on perfect graphs

ROBIN THOMAS
Georgia Institute of Technology
Coauthors: Maria Chudnovsky, Neil Robertson and P. D. Seymour

Chair: Rainer Burkard

A graph is *perfect* if for every induced subgraph, the chromatic number is equal to the maximum size of a complete subgraph. The class of perfect graphs is important for several reasons. For instance, many problems of interest in practice but intractable in general can be solved efficiently when restricted to the class of perfect graphs. Also, the question of when a certain class of linear programs always have an integer solution can be answered in terms of perfection of an associated graph.

In the first part of the paper we survey the main aspects of perfect graphs and their relevance. In the second part we outline our recent proof of the Strong Perfect Graph Conjecture of Berge from 1961, the following: a graph is perfect if and only if it has no induced subgraph isomorphic to an odd cycle of length at least five, or the complement of such an odd cycle.

Wednesday, 15:15 – 16:15, Aud 81, Building 116 (Semi-Plenary)

First- and second-order methods for semidefinite programming

RENATO D. C. MONTEIRO
Georgia Institute of Technology

Chair: Michael J. Todd

In this paper, we survey the most recent methods that have been developed for the solution of semidefinite programs. We first concentrate on the methods that have been primarily motivated by the interior point (IP) algorithms for linear programming, putting special emphasis in the class of primal-dual path-following algorithms. We also survey methods that have been developed for solving large-scale SDP problems. These include first-order nonlinear programming (NLP) methods and more specialized path-following IP methods which use the (preconditioned) conjugate gradient or residual scheme to compute the Newton direction and the notion of matrix completion to exploit data sparsity.

Wednesday, 15:15 – 16:15, Aud 42, Building 302 (Semi-Plenary)

Stochastic programming with integer variables

RÜDIGER SCHULTZ
University Duisburg-Essen

Chair: Stein W. Wallace

Including integer variables into traditional stochastic linear programs has considerable implications for structural analysis and algorithm design. Starting from mean-risk approaches with different risk measures we identify corresponding two- and multi-stage stochastic integer programs that are large-scale block-structured mixed-integer linear programs if the underlying probability distributions are discrete. We highlight the role of mixed-integer value functions for structure and stability of stochastic integer programs. When applied to the block structures in stochastic integer programming, well known algorithmic principles such as branch-and-bound, Lagrangian relaxation, or cutting plane methods open up new directions of research. We review existing results in the field and indicate departure points for their extension.

Thursday, 11:00 – 12:00, Sportshal, Building 101 (Plenary)

Strong formulations for mixed integer programs: valid inequalities and extended formulations

LAURENCE A. WOLSEY
Université Catholique de Louvain, Belgium

Chair: Jørgen Tind

We examine progress over the last fifteen years in finding strong valid inequalities and tight extended formulations for simple mixed integer sets lying both on the “easy" and “hard" sides of the complexity frontier. Most progress has been made in studying sets arising from knapsack and single node flow sets, and a variety of sets motivated by different lot-sizing models. We conclude by citing briefly some of the more intriguing new avenues of research.

Thursday, 15:15 – 16:15, Sportshal, Building 101 (Semi-Plenary)

Capacities of quantum channels and how to find them

PETER W. SHOR
AT&T Labs – Research

Chair: Kaj Holmberg

We survey what is known about the information transmitting capacities of quantum channels, and give a proposal for how to calculate some of these capacities using linear programming.

Thursday, 15:15 – 16:15, Aud 81, Building 116 (Semi-Plenary)

The mathematics of eigenvalue optimization

ADRIAN S. LEWIS
Simon Fraser University

Chair: Trond Steihaug

Optimization problems involving the eigenvalues of symmetric and nonsymmetric matrices present a fascinating mathematical challenge. Such problems arise often in theory and practice, particularly in engineering design, and are amenable to a rich blend of classical mathematical techniques and contemporary optimization theory. This essay presents a personal choice of some central mathematical ideas, outlined for the broad optimization community. I discuss the convex analysis of spectral functions and invariant matrix norms, touching briefly on semidefinite representability, and then outlining two broader algebraic viewpoints based on hyperbolic polynomials and Lie algebra. Analogous nonconvex notions lead into eigenvalue perturbation theory. The last third of the article concerns stability, for polynomials, matrices, and associated dynamical systems, ending with a section on robustness. The powerful and elegant language of nonsmooth analysis appears throughout, as a unifying narrative thread.

Thursday, 15:15 – 16:15, Aud 42, Building 302 (Semi-Plenary)

Toward fully automated fragments of graph theory

SIEMION FAJTLOWICZ
University of Houston

Chair: Martin Grötschel

A recent review of all claims concerning automated conjectures refers to six programs. Since then, two more such claims were made. One of them concerns AGX and the other - Graffiti.PC. Graffiti is the first computer program whose conjectures inspired mathematicians to write papers about them. The program made a number of appealing conjectures that inspired about eighty papers, but even more significant is that for the first time, mathematicians worked on ideas invented by a computer program.

A paper of the author, published at about the same time, addressed aspects of conjecture-making programs in the context of the Turing test and Penrose's claim that digital computers cannot have human mathematical intuitions; it is self-evident that attributing to a program conjecture-making abilities automatically precludes the possibility of confusing such a program with a program written for the purpose of verification, confirmation or testing of human-invented conjectures. Still, for the author, the main goal of automation of the conjecture-making processes is to understand what makes a good conjecture; everything else is a secondary consideration. This goal is germane to Putnam's idea of quasi-empirical mathematics, in which proofs deliberately play a secondary role to observations.

The same experiment was performed with a chemistry version of the program. Minuteman is an offshoot of Graffiti for making conjectures about fullerenes and recently about benzenoids. As a consequence of two conjectures of Minuteman, the author suggested that the stable fullerenes tend to be good expanders and later that they tend to minimize their independence numbers. We know now, thanks to extensive computation of Larson using Fullgen, that for classical fullerenes the independence number is a better statistical predictor of stability than any of the previously proposed criteria.

Friday, 11:00 – 12:00, Sportshal, Building 101 (Plenary)

Optimization in forestry

MIKAEL RÖNNQVIST
Linköping University and the Forestry Research Institute of Sweden

Chair: P. O. Lindberg

Optimization models and methods have been used extensively in the forest industry. In this paper we describe the general wood-flow in forestry and a variety of planning problems. These cover planning periods from a fraction of a second to more than one hundred years. The problems are modelled using linear, integer and nonlinear models. Solution methods used depend on the required solution time and include for example dynamic programming, LP methods, branch & bound methods, heuristics and column generation. The importance of modelling and qualitative information is also discussed.

Parallel Sessions: Overview

A parallel session consists of three presentations, and has a duration of 90 minutes. In total 10 time blocks have been scheduled for parallel sessions from Monday to Friday. There are at most three blocks of parallel sessions each day. They take place at the following times:

1: 9:00 – 10:30

2: 13:15 – 14:45

3: 16:30 – 18:00

On each day from Monday to Wednesday there are two blocks of parallel sessions, on Thursday three blocks and on Friday one block of parallel sessions. Please consult page 7 for details; the blocks are coded according to their weekday and time: MO2, MO3, TU1, TU2 etc.

Up to 26 parallel sessions are taking place simultaneously in each time block. The distribution of clusters (or topics) for all parallel sessions is indicated on the next page.

The rooms are all located in buildings of the 3rd quadrant of DTU. These buildings are numbered 3xx. The location of these buildings is given on the map on the inside of the back cover of this book. Within each building, the room names are indicated, e.g., as 302/41 and 308/T1.

Parallel Sessions: Rooms and Clusters

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<tr><td>302/42</td></tr>
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<tr><td>302/45</td><td colspan="4">INTEGER AND MIXED INTEGER PROGRAMMING</td></tr>
<tr><td>302/49</td><td colspan="10">INTEGER AND MIXED INTEGER PROGRAMMING</td></tr>
<tr><td>306/31</td><td colspan="8">INTEGER AND MIXED INTEGER PROGRAMMING</td><td colspan="2">CLP</td></tr>
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<tr><td>308/T3</td><td colspan="4">MODELING LANG. AND SYSTEMS</td><td colspan="2">ON-LINE OPT.</td><td colspan="4">TELECOMMUNICATION NETWORK DESIGN</td></tr>
<tr><td>341/21</td><td colspan="10">INTERIOR POINT ALGORITHMS</td></tr>
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</table>

BIO: BIOINFORMATICS AND OPTIMIZATION

CLP: CONSTRAINT LOGIC PROGRAMMING

PAR: PARALLEL COMPUTING

SEMI: SEMI-INFINITE AND INFINITE DIMENSIONAL PROGRAMMING

Parallel Sessions: Monday 13:15 – 14:45 (MO2)

Room / Page	Session	Area	Talk 1	Talk 2	Talk 3
302/41 p.31	**Submodular functions and discrete convexity I**, *organizers*: Satoru Fujishige and Kazuo Murota, *chair*: Satoru Fujishige	COMBINATORIAL OPTIMIZATION	KAZUO MUROTA, Conjugacy relationship between M-convex and L-convex functions in continuous variables	AKIYOSHI SHIOURA, Minimization algorithms for M-convex functions	HARIHAR NARAYANAN, Polyhedrally tight functions and convexity
302/42 p.31	**Discrete and continuous optimization in VLSI design**, *organizers*: Bernhard Korte and Jens Vygen, *chair*: Jens Vygen	COMBINATORIAL OPTIMIZATION	STEPHAN HELD, Slack balance algorithms	MARKUS STRUZYNA, Matrix decompositions and iterative solutions of very large quadratic programs	CHRISTIAN SZEGEDY, Gate and wire sizing using Lagrangian relaxation
302/44 p.32	**Combinatorial optimization I**, *chair*: Bill Cunningham	COMBINATORIAL OPTIMIZATION	ADRIAN ZYMOLKA, Polyhedral investigations of stable multi-sets	GIANPAOLO ORIOLO, Solving stable set problems on superclasses of interval graphs	BILL CUNNINGHAM, The polytope of even permutations
302/45 p.32	**Branch-and-cut approaches**, *chair*: Serigne Gueye	COMBINATORIAL OPTIMIZATION	TAMAS KIS, Polyhedral results and a branch-and-cut algorithm for project scheduling with variable intensity activities	GEORG KLIEWER, A branch-and-cut system for capacitated network design	SERIGNE GUEYE, A branch-and-cut algorithm for the graph bipartitioning problem
302/49 p.33	**Integer programming column generation I**, *organizer/chair*: Marco Lübbecke	INTEGER AND MIXED INTEGER PROGRAMMING	MIKKEL MÜHLDORFF SIGURD, Stabilized column generation for set partitioning	EDUARDO UCHOA, Integer program reformulation for robust branch-and-cut-and-price	FRANCOIS VANDERBECK, Automated Dantzig-Wolfe reformulation or how to exploit simultaneaously original formulation and column generation re-formulation
306/31 p.34	**Integer programming**, *organizer/chair*: Gabor Pataki	INTEGER AND MIXED INTEGER PROGRAMMING	JANNY LEUNG, Min-up/min-down polytopes	DANIEL BIENSTOCK, Subset-algebra lift operators for 0/1 integer programming	BALA KRISHNAMOORTHY, The complexity of branch-and-bound
306/32 p.34	**Nonlinear programming**, *chair*: Stanislav Zakovic	NONLINEAR PROGRAMMING	MARK ABRAMSON, Applying a mixed variable filter pattern search algorithm to thermal insulation system design	SUNYOUNG KIM, Numerical stability of path tracing in polyhedral homotopy continuation methods	STANISLAV ZAKOVIC, An interior point algorithm for worst-case optimisation
306/33 p.34	**Nonlinear systems**, *chair*: Per Åke Wedin	NONLINEAR PROGRAMMING	MICHEL BIERLAIRE, A new class of robust methods to solve noisy systems of nonlinear equations	HIDEFUMI KAWASAKI, Conjugate sets for a nonlinear programming problem	PER ÅKE WEDIN, Primal and dual optimization problems in tikhonov regularization
306/34 p.35	**New trust region algorithms**, *organizer/chair*: Jorge Nocedal	NONLINEAR PROGRAMMING	RICHARD WALTZ, An active-set trust-region algorithm for nonlinear optimization	MICHAEL POWELL, A new algorithm for unconstrained minimization without derivatives	STEPHEN WRIGHT, A feasible trust-region algorithm for nonlinear optimization
306/35 p.35	**Recent developments in filter methods I**, *organizers*: Michael Ulbrich, Stefan Ulbrich and Luís N. Vicente, *chair*: Michael Ulbrich	NONLINEAR PROGRAMMING	CHARLES AUDET, A filter pattern search method for nonsmooth constrained optimization	DAVID SHANNO, Filter methods and NLP's with unbounded multipliers	RENATA SILVA, On a primal-dual interior-point filter method for nonlinear programming
306/36 p.36	**Recent advances in nonsmooth optimization I**, *organizers*: Jean-Louis Goffin and Jean-Philippe Vial, *chair*: Jean-Philippe Vial	NONSMOOTH OPTIMIZATION	JEAN-PHILIPPE VIAL, Proximal ACCPM, a cutting plane method for column generation and Lagrangian relaxation: application to the p-median problem	YURII NESTEROV, Smooth minimization of non-smooth functions	CORALIE TRIADOU, A bundle method for convex optimization: implementation and illustrations
306/37 p.36	**Convex optimization methods**, *chair*: Jean-Baptiste Hiriart-Urruty	CONVEX PROGRAMMING	MATIAS COURDURIER, Coupling general penalty schemes for convex programming with the steepest descent and the proximal point algorithm	WIESLAWA OBUCHOWSKA, Conditions for boundedness and the existence results for quasi-convex programmes	JEAN-BAPTISTE HIRIART-URRUTY, Solving some matrix nearness problems via convex optimization
306/38 p.37	**Distributed solution of LP and MIP problems**, *chair*: Richard Van Slyke	PARALLEL COMPUTING	LUCIA DRUMMOND, Towards a grid enabled branch-and-bound algorithm	YUJI SHINANO, Parallelization of a MIP solver in the PUBB2 framework	RICHARD VAN SLYKE, Distributed computing and the simplex method
308/11 p.38	**Airline scheduling I**, *organizer/chair*: Stefan Karisch	AIRLINE OPTIMIZATION APPLICATIONS	SERGEI CHEBALOV, Robust airline crew pairing optimization	CURT HJORRING, Solving crew augmented pairing problems using column generation	LENNART BENGTSSON, Challenges in railway crew pairing
308/12 p.38	**Applications of stochastic programming**, *organizer*: COSP (Chefi Triki), *chair*: Chefi Triki	STOCHASTIC PROGRAMMING	LAUREANO F. ESCUDERO, FRC-S3, a fix-and-relax coordination scheme for stochastic sequencing and scheduling	MARTE FODSTAD, Weekly supply chain coordination with stochastic demand	CHEFI TRIKI, Optimal capacity allocation in multi-auction electricity markets under uncertainty
308/13 p.39	**Stability in stochastic programming**, *chair*: Rene Henrion	STOCHASTIC PROGRAMMING	M. EBRU ANGUN, Response surface methodology with stochastic constraints for expensive simulation	IOANA POPESCU, Robust mean-covariance solutions for stochastic optimization	RENE HENRION, Hoelder and Lipschitz stability of solution sets in programs with probabilistic constraints
308/T1 p.39	**Model building**, *chair*: H.Paul Williams	FINANCE AND ECONOMICS	LUDMILA KOSHLAI, An econometric model of state budget	MIKHALEVICH MIKHAIL, Optimization model of planned technological-structural changes	H.PAUL WILLIAMS, The allocation of shared fixed costs: fairness versus efficiency
308/T2 p.40	**Semidefinite linear complementarity problem**, *organizers*: T. Parthasarathy and Srinivasa R. Mohan, *chair*: Srinivasa R. Mohan	COMPLEMENTARITY AND VARIATIONAL INEQUALITIES	MADHUR MALIK, Geometrical notions of p and related properties in semidefinite linear complementarity problems	MUDDAPPA GOWDA, P-properties of linear transformations on Euclidean Jordan algebras	SRINIVASA R. MOHAN, Semidefinite complementary cones and faces in SDLCP
308/T3 p.40	**Modeling languages and systems I**, *organizer/chair*: Robert Fourer	MODELING LANGUAGES AND SYSTEMS	ALKIS VAZACOPOULOS, Solving large scale supply chain optimization problems	JEAN-PIERRE GOUX, Modeling, optimization and simulation of stochastic dynamic systems	LEONARDO LOPES, A modeling language for stochastic programming
341/21 p.41	**Computational conic programming**, *organizers*: Mituhiro Fukuda and Masakazu Kojima, *chair*: Mituhiro Fukuda	INTERIOR POINT ALGORITHMS	YIN ZHANG, A non-polyhedral primal active-set approach to SDP	MASAKAZU MURAMATSU, A pivoting structure in second-order cone programming	MICHAL KOCVARA, Solving nonconvex SDP problems of structural optimization by PENNON
341/22 p.42	**Facility location**, *chair*: Francisco Saldanha-da-Gama	LOGISTICS AND TRANSPORTATION	HIROAKI MOHRI, Lagrangian approach for hybrid problem of facility location and network design	CARMEN PLESCHIUTSCHNIG, Inverse 1-median problems in the plane	FRANCISCO SALDANHA-DA-GAMA, Location models: a reformulation by discretization
341/23 p.42	**Transportation**, *chair*: Uwe Zimmermann	LOGISTICS AND TRANSPORTATION	FRANK CRITTIN, A new approach to solve large-scale systems of nonlinear equations	MARTIN JOBORN, Solving large scale integer multicommodity network flow problems in one second	UWE ZIMMERMANN, Optimal shunting
321/053 p.43	**Planning in medical applications**, *chair*: Rembert Reemtsen	PRODUCTION AND SCHEDULING	KONRAD ENGEL, Fast simultaneous angle, wedge, and beam intensity optimization in inverse radiotherapy planning	ATSUKO IKEGAMI, An algorithm for scheduling doctors for night duty	REMBERT REEMTSEN, The solution of nonlinear problems of intensity modulated radiation therapy planning by a Lagrangian barrier-penalty algorithm
321/033 p.43	**Integer programming for design problems**, *chair*: Corinne Feremans	NETWORKS	ADELAIDE CERVEIRA, Truss topology design with binary variables	BERNARD FORTZ, The 2-edge connected subgraph problem with bounded rings	CORINNE FEREMANS, The generalized subgraph problem: complexity, approximability and polyhedra
321/133 p.44	**Graphs and matroids**, *chair*: Geir Dahl	GRAPHS AND MATROIDS	DOMINGOS MOREIRA CARDOSO, Graphs with convex-QP stability number	ANNEGRET KATRIN WAGLER, Perfectness is an elusive graph property	GEIR DAHL, Matrices of zeros and ones with given line sums and a zero block

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302/41	**Submodular functions and discrete convexity II**, *organizers*: Satoru Fujishige and Kazuo Murota, *chair*: Kazuo Murota		COMBINATORIAL OPTIMIZATION
p.45	Satoru Iwata, A fully combinatorial algorithm for submodular function minimization	Bianca Spille, A Gallai-Edmonds-type structure theorem for path-matchings	Satoko Moriguchi, Capacity scaling algorithm for scalable M-convex submodular flow problems
302/42	**Network flows in VLSI layout**, *organizers*: Bernhard Korte and Jens Vygen, *chair*: Bernhard Korte		COMBINATORIAL OPTIMIZATION
p.45	Ulrich Brenner, Network flow algorithms in VLSI placement	Dirk Mueller, Fast flow augmentation in bit-pattern-represented grid graphs	Jens Vygen, Multicommodity flow with congestion costs
302/44	**Combinatorial optimization II**, *chair*: Pasquale Avella		COMBINATORIAL OPTIMIZATION
p.45	Andrei Horbach, On the facets and the diameter of the k-cycle polytope	Javier Leonardo Marenco, Chromatic scheduling polytopes coming from the bandwidth allocation problem in point-to-multipoint radio access systems	Pasquale Avella, Computational study of large-scale p-median problems
302/45	**Set partitioning applications**, *chair*: David M. Ryan		COMBINATORIAL OPTIMIZATION
p.46	Jun Imaizumi, A column generation approach for discrete lotsizing and scheduling problem on identical parallel machines	Keisuke Hotta, Political redistricting: a case study in japan	David M. Ryan, Improved solution techniques for multi-period area-based forest harvest scheduling problems
302/49	**Integer programming column generation II**, *organizer*: Marco Lübbecke, *chair*: Ralf Borndörfer		INTEGER AND MIXED INTEGER PROGRAMMING
p.46	Ricardo Fukasawa, Robust branch-and-cut-and-price for the capacitated minimum spanning tree problem	Luis Miguel Torres, Online vehicle dispatching for service units	Ivana Ljubic, Combining column generation with memetic algorithms
306/31	**Integer and mixed integer programming I**, *chair*: Pedro Martins		INTEGER AND MIXED INTEGER PROGRAMMING
p.47	Robert Weismantel, Reformulation techniques based on group relaxations	Hiroo Saito, A polyhedral approach to hub location problems	Pedro Martins, Capacitated minimum spanning tree problem: revisiting hop-indexed models
306/32	**Selection and design**, *chair*: Jens Starke		NONLINEAR PROGRAMMING
p.48	Dag Haugland, Local search methods for the subset selection problem with minimum unit norm	Laura Nicoleta Heinrich-Litan, Computing the center of area of a convex polygon	Jens Starke, Surface design for heterogeneous catalytic reactions
306/33	**Noisy problems**, *chair*: Antanas Zilinskas		NONLINEAR PROGRAMMING
p.48	Michael Kokkolaras, Analytical target cascading in design optimization of hierarchical multilevel systems under uncertainty	Waltraud Huyer, Stable noisy optimization by branch and fit	Antanas Zilinskas, One dimensional global optimization in the presence of noise
306/34	**Optimization applications in biology and chemistry**, *organizer/chair*: Todd Munson		NONLINEAR PROGRAMMING
p.49	Todd Munson, Computing transition states	Michael Wagner, Design of protein folding potentials using mathematical programming	Bastiaan J. Braams, Semidefinite programming for electronic structure calculations
306/35	**Recent developments in filter methods II**, *organizers*: Michael Ulbrich, Stefan Ulbrich and Luís N. Vicente, *chair*: Luís N. Vicente		NONLINEAR PROGRAMMING
p.49	Stefan Ulbrich, On the superlinear local convergence of a filter-SQP method	Andreas Waechter, An interior-point filter line-search method for large-scale nonlinear programming	Elizabeth Karas, On the convergence of a filter algorithm with independent feasibility and optimality phases
306/36	**Recent advances in non-smooth optimization II**, *organizers*: Jean-Philippe Vial and Jean-Louis Goffin, *chair*: Jean-Philippe Vial		NONSMOOTH OPTIMIZATION
p.50	Clovis C. Gonzaga, Using the central path for computing the analytic center of apolytope	Frédéric Babonneau, Nonlinear multicommodity flow and traffic equilibrium	Samir Elhedhli, ACCPM-based branch-and-bound methods for integer programming
306/37	**Semidefinite and conic optimization**, *chair*: Karthik Natarajan		CONVEX PROGRAMMING
p.50	Laura Wynter, Nested optimization for experimental inference problems	Yuriy Zinchenko, The dual cone for the derivative of the non-negative orthant	Karthik Natarajan, Optimal mean-variance upper bounds on the expectation of highest order statistics
306/38	**Parallel methods for combinatorial and global optimization**, *organizer/chair*: Jonathan Eckstein		PARALLEL COMPUTING
p.50	Diego Klabjan, Parallel constrained shortest path	Jeff Linderoth, Computational grid implementations of branch-and-bound methods for nonconvex quadratic programming	Ted Ralphs, A framework for scalable parallel tree search
308/11	**Airline scheduling II**, *organizer/chair*: Stefan Karisch		AIRLINE OPTIMIZATION APPLICATIONS
p.51	Marek Ozana, Large scale airline crew rostering problems in practice	Olivier du Merle, A proximal analytic center cutting plane method to solve the Lagrangian relaxation of the aircraft rotation problem	Claude Ph. Medard, Airline crew scheduling: from planning to operations
308/12	**Real-life applications in stochastic programming**, *chair*: Sin C. Ho		STOCHASTIC PROGRAMMING
p.51	Nina Linn Ulstein, A stochastic programming model for strategic capacity planning in the metal-working industry	Jörgen Blomvall, Optimization based derivative pricing in incomplete and imperfect markets	Sin C. Ho, Designing routing zones for VRP with stochastic demands
308/13	**Stochastic integer programs and network interdiction**, *organizer*: COSP (Maarten H. van der Vlerk), *chair*: Stein W. Wallace		STOCHASTIC PROGRAMMING
p.52	Maarten H. van der Vlerk, On six-pack recourse: convex approximations for a simple mixed-integer recourse model	Joyce Yen, A stochastic programming approach to the generalized assignment problem	Kevin Wood, A stochastic network-interdiction problem: maximizing the probability of sufficient delay
308/T1	**Finance and economics**, *chair*: Alan King		FINANCE AND ECONOMICS
p.52	S. Raghavan, CAMBO: combinatorial auction using matrix bids with order	Vladimir Krivonozhko, Parametric optimization methods for visualization of frontier in DEA and productivity analysis of Russian banks	Alan King, Calibration of options prices to market data using stochastic programming
308/T2	**Complementarity and variational inequalities**, *chair*: Dolf Talman		COMPLEMENTARITY AND VARIATIONAL INEQUALITIES
p.53	Olga Pinyagina, Application of the d-gap function approach to geheral equlibrium problems in Banach spaces	Dolf Talman, Perfection and stability of stationary points with applications to noncooperative games	
308/T3	**Modeling languages and systems II**, *organizer/chair*: Robert Fourer		MODELING LANGUAGES AND SYSTEMS
p.53	Kenneth Holmström, Large-scale optimization with TOMLAB / MATLAB	Johannes Bisschop, The open outer approximation MINLP solver in AIMMS	David Gay, Update on the AMPL/solver interface library
341/21	**Primal-dual algorithms**, *chair*: Mohamed El ghami		INTERIOR POINT ALGORITHMS
p.54	Ana Paula Aires Borges Teixeira, An extension of a predictor-corrector method variant from linear programming to semidefinite programming	Andre Tits, Primal-dual interior-point algorithms for indefinite quadratic programming	Mohamed El ghami, Primal-dual interior-point methods based on a new class of barrier functions
341/22	**Facility location problems**, *chair*: Jakob Krarup		LOGISTICS AND TRANSPORTATION
p.54	Asgeir Tomasgard, Facility location under economics of scale	Helene Gunnarsson, Terminal location integrated with ship routing	Jakob Krarup, The p/q-active facility location problem
341/23	**Vehicle routing**, *chair*: Jens Lysgaard		LOGISTICS AND TRANSPORTATION
p.55	Paula Lorena Zabala, A two-commodity flow approach to vehicle routing problem	Vicky Mak, New valid inequalities and an exact algorithm for the ATSP-TW	Jens Lysgaard, Exact solution of the CVRP for a given set of seed customers: a branch-and-bound approach
321/053	**Sequencing and scheduling**, *chair*: Jacques Desrosiers		PRODUCTION AND SCHEDULING
p.55	Thomas Epping, Theoretical and practical aspects of color sequencing	Günter Rote, Pursuit-evasion with imprecise target location	Jacques Desrosiers, A proximal trust-region algorithm for stabilized column generation
321/033	**Constrained paths**, *chair*: Scott Provan		NETWORKS
p.55	Njål Foldnes, On hop-constrained walk polytopes	Nicolas Stier, Selfish routing in capacitated networks	Scott Provan, A primal-dual algorithm for finding maximum capacity paths with recourse
321/133	**Matroids and antimatroids**, *chair*: Abdón Sanchez-Arroyo		GRAPHS AND MATROIDS
p.56	Masahiro Hachimori, Rooted circuits of convex geometries from affine point configurations	Masataka Nakamura, The max-flow min-cut theorem for stems of rooted circuits of affine convex geometries	Abdón Sanchez-Arroyo, On independence systems and Rado-Hall theorems

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302/41	p.57	**Submodular functions and discrete convexity III**, *organizers*: Satoru Fujishige and Kazuo Murota, *chair*: Satoru Fujishige	Akihisa Tamura, A general two-sided matching market with discrete concave utility functions	Fabio Tardella, Substitutes and complements in linear and nonlinear programming	Yoshio Okamoto, Matroid representation of clique complexes	COMBINATORIAL OPTIMIZATION
302/42	p.57	**Steiner trees**, *organizer/chair*: Gunnar W. Klau	Siavash Vahdati Daneshmand, Practical algorithms for the Steiner problem	Boting Yang, A lower bound and test problem generator for the group Steiner minimal tree problem	João Telhada, On the multi-weighted Steiner tree problem: a reformulation by intersection	COMBINATORIAL OPTIMIZATION
302/44	p.58	**Combinatorial optimization III**, *chair*: Klaus Michael Wenger	Adam Letchford, Fast algorithms for planar graphs, Part I: cycles and cuts	Dirk Theis, Fast computation of a minimum t-cut in an undirected graph	Klaus Michael Wenger, Maximally violated mod-*k* cuts and the capacitated vehicle routing problem	COMBINATORIAL OPTIMIZATION
302/45	p.58	**Machine scheduling**, *chair*: Jose Rafael Correa	Marcus Oswald, A branch-and-cut approach for coupled task problems	Genrikh Levin, Mathematical models and methods for balancing production lines with parallel blocks of operations at workstations	Jose Rafael Correa, Single machine scheduling with precedence constraints	COMBINATORIAL OPTIMIZATION
302/49	p.59	**Integer programming column generation III**, *organizer*: Marco Lübbecke, *chair*: David M. Ryan	Michele Monaci, Models and algorithms for staff scheduling problems	Ralf Borndörfer, Solving duty scheduling problems in public transit	Marcus Poggi de Aragao, Robust branch-and-cut-and-price for the capacitated vehicle routing problem	INTEGER AND MIXED INTEGER PROGRAMMING
306/31	p.59	**Integer and mixed integer programming II**, *chair*: Robert Nauss	Eugene Zak, Simplifying branch-and-price algorithms through lexicographic ordering	Pablo A. Rey, Eliminating redundant solutions of combinatorial integer programs	Robert Nauss, A computational study of elastic and classical generalized assignment problems	INTEGER AND MIXED INTEGER PROGRAMMING
306/32	p.60	**Optimization of engineering systems governed by simulations/PDE, part 1**, *organizer/chair*: Natalia Alexandrov	Martin Bendsoe, Optimization with multiple scales using wavelet based reduced order models	Ivan Oliveira, Reduced-basis techniques for rapid reliable optimization of systems described by parametric partial differential equations	Ekaterina Kostina, Robust optimal design of experiments for DAE and PDE	NONLINEAR PROGRAMMING
306/33	p.61	**Augmented Lagrangian methods I**, *chair*: Otero Rolando Gárciga	Frederic Delbos, Application of an SQP augmented Lagrangian method to a large-scale problem in 3d reflection tomography	Jean Charles Gilbert, Finite time identification of active constraints with an augmented Lagrangian algorithm	Otero Rolando Gárciga, A strongly convergent augmented Lagrangian method	NONLINEAR PROGRAMMING
306/34	p.61	**Advances in algorithms and software for nonlinear programming**, *organizer/chair*: Stephen Wright	Hande Benson, LOQO: an interior-point method for nonconvex nonlinear programming	Jorge Nocedal, Improving to nonlinear interior methods	Michael Paul Friedlander, An LCL algorithm for constrained optimization	NONLINEAR PROGRAMMING
306/35	p.62	**Software session, Dash**, *chair*: James Tebboth				OTHER
306/36	p.62	**Implementation**, *chair*: Andreas Grothey	Kazuhiro Kobayashi, Parallel implementation of metaheuristics for combinatorial optimization problems on global computing systems	Zorana Luzanin, Newton-like method for special class of nonlinear systems	Andreas Grothey, Object-oriented parallel interior point solver for structured nonlinear programs	PARALLEL COMPUTING
306/37	p.62	**Decomposition in convex programming**, *chair*: Kaj Holmberg	Yuri Levin, A decomposition approach to the minimization of a separable convex function on a convex polyhedron generated by a parallel-consecutive structure	Ángel Marín, Solving system design using a type of convex submodels: computational experience	Kaj Holmberg, Mean value cross decomposition for nonlinear convex problems	CONVEX PROGRAMMING
306/38	p.63	**Global optimization I**, *chair*: Nikolaos Sahinidis	Mirjam Duer, Solving fractional programs with stochastic algorithms	Jun-ya Gotoh, Minimal ellipsoid circumscribing a polytope defined by a system of linear inequalities	Nikolaos Sahinidis, Global optimization in informatics problems in biology, chemistry, and physics	GLOBAL OPTIMIZATION
308/11	p.63	**Disruption management**, *organizer/chair*: Niklas Kohl	John-Paul Clarke, Degradable airline schedules	Rajan Batta, A branch-and-price approach for operational aircraft maintenance routing	Darren Dejun Hang, Fast aircraft schedule recovery with crew and passenger constraints	AIRLINE OPTIMIZATION APPLICATIONS
308/12	p.64	**Computational stochastic integer programming**, *organizer/chair*: Andrew Schaefer	Takayuki Shiina, Lagrangian relaxation method for price-based unit commitment problem	Andrew Schaefer, SPAR: stochastic programming with adversarial research	Nan Kong, Two-stage integer programming with stochastic integer right-hand sides	STOCHASTIC PROGRAMMING
308/13	p.64	**Sampling and control in stochastic programming**, *chair*: Andreas Eichhorn	Matti Koivu, Integration quadratures in discretization of stochastic programs	Seiichi Iwamoto, Nondeterministic dynamic programming	Andreas Eichhorn, Stochastic integer programming: limit theorems and confidence intervals	STOCHASTIC PROGRAMMING
308/T1	p.65	**Modeling under uncertainty**, *chair*: Ken Kortanek	Vadim Arkin, Stochastic model of optimal investor behavior in real sector	Wlodzimierz Ogryczak, On extending the LP computable risk measures to account downside risk	Ken Kortanek, How serious are Wets' et al "serious zeros curves"?	FINANCE AND ECONOMICS
308/T2	p.66	**Regularization methods**, *organizer/chair*: Rainer Tichatschke	Dan Butnariu, Convergence and stability of a regularization method for maximal monotone inclusions	Alfredo Noel Iusem, A proximal point method for convex vector-valued optimization	Tim Voetmann, Interior point methods for variational inequalities with weak regularisation	COMPLEMENTARITY AND VARIATIONAL INEQUALITIES
308/T3	p.66	**Modeling languages and systems III**, *organizer/chair*: Robert Fourer	Patrick Valente, XML representation of mathematical programming models for distributed optimisation applications	Robert Fourer, Analyzing submissions to the NEOS server for the purpose of recommending solvers	Kaisa Miettinen, Interactive, synchronous nimbus method for multiobjective optimization	MODELING LANGUAGES AND SYSTEMS
341/21	p.67	**Complexity of interior point methods**, *chair*: Robert Freund	Siming Huang, Expected number of iterations of interior point algorithms for linear programming	Petra Huhn, Average complexity of interior point methods: the expected number of steps	Robert Freund, Comparison of complexity of ipms and the ellipsoid method for conic feasibility and optimization	INTERIOR POINT ALGORITHMS
341/22	p.67	**Applications of optimization in pricing**, *organizer/chair*: Georgia Perakis	Dimitris Bertsimas, A robust optimization approach to supply chain management	Kalyan Talluri, New math programming models for revenue management	Georgia Perakis, A variational inequality model for dynamic pricing under competition	LOGISTICS AND TRANSPORTATION
341/23	p.68	**Vehicle routing with time windows**, *chair*: Oli B.G. Madsen	Myrna Palmgren, Solving truck scheduling problems with branch-and-price	Stefan Røpke, A general heuristic for vehicle routing problems	Oli B.G. Madsen, Vehicle routing with time windows	LOGISTICS AND TRANSPORTATION
321/053	p.68	**Lot sizing**, *chair*: Hamish Waterer	Sergei Chubanov, A FPTAS for a generalized single-item lot-sizing problem	Haldun Sural, A Lagrangean relaxation based branch-and-bound heuristic for lot sizing with setup times	Hamish Waterer, Big bucket lot sizing problems with changeover times	PRODUCTION AND SCHEDULING
321/033	p.69	**Network flow problems**, *chair*: Dorit Hochbaum	Katharina Langkau, Flows over time with flow-dependent transit times	Philippe Mahey, Solving multicommodity flow problems with separable piecewise convex costs	Dorit Hochbaum, A faster algorithm for bipartite matching and for the maximum flow problem on closure graphs	NETWORKS
321/133	p.69	**Combinatorial algorithms**, *organizer/chair*: Kathie Cameron	Kathie Cameron, Finding list partitions of graphs	Jean Fonlupt, Chromatic characterization of biclique cover	Jack Edmonds, Revisiting oracle methods for well-described polytopes	GRAPHS AND MATROIDS
305/205	p.70	**Game programming**, *chair*: M. Aránzazu Estévez-Fernández	Niels Olieman, Stability of coalitions in a Nash-cartel game: a probability analysis	Anatoly Antipin, Extra-proximal method for computing Nash equilibria for two-person nonzero-sum game	M. Aránzazu Estévez-Fernández, On properties of several refinements of optimal solutions in linear programming	GAME THEORY

Parallel Sessions: Tuesday 13:15 – 14:45 (TU2)

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302/42 p.71	**Prize-collecting Steiner trees**, *organizer/chair*: Gunnar W. Klau	COMBINATORIAL OPTIMIZATION	Alexandre Cunha, A relax and cut algorithm for the prize collecting Steiner problem in graphs	Cristina Fernandes, Primal-dual algorithms for prize-collecting Steiner tree	Gunnar W. Klau, The fractional prize-collecting Steiner tree problem on trees
302/44 p.72	**Combinatorial optimization IV**, *chair*: Francesco Maffioli	COMBINATORIAL OPTIMIZATION	Uriel G. Rothblum, Vertices, edge-directions and combinatorial optimization	Gautier Stauffer, On the non-rank facets of the stable set polytope of claw-free and circulant graphs	Francesco Maffioli, On the problem of finding minimum fundamental cycle bases
302/45 p.72	**Traveling salesman I**, *chair*: Genevieve Benoit	COMBINATORIAL OPTIMIZATION	Kevin Cheung, On the subtour-elimination polytope	Sylvia Boyd, Finding the exact integrality gap for small travelling salesman problems	Genevieve Benoit, Finding violated cut constraints for the STSP using a decomposition approach
302/49 p.73	**Integer programming column generation IV**, *organizer*: Marco Lübbecke, *chair*: Jacques Desrosiers	INTEGER AND MIXED INTEGER PROGRAMMING	Nima Golbaharan, Routing of snowploughs- a column generation approach	David Schindl, Graph-coloring and linear programming	Aristide Mingozzi, An exact algorithm for period and multi-depot VRP
306/31 p.73	**Integer and mixed integer programming III**, *chair*: Katalin Meszaros	INTEGER AND MIXED INTEGER PROGRAMMING	Andrew Mason, Branch-and-cut for cyclic staff scheduling	Igor Vasil'ev, Computational experience with a cutting plane algorithm for the university timetabling problem	Katalin Meszaros, A fuzzy logic application as a contribution to solving the bus crew scheduling problem
306/32 p.74	**Optimization of engineering systems governed by simulations/PDE, part 2**, *organizer/chair*: Natalia Alexandrov	NONLINEAR PROGRAMMING	Joerg Gablonsky, Effective parallel optimization of expensive functions	Anthony Giunta, Surrogate-based optimization under uncertainty: formulations and applications	Eric Nielsen, Aerodynamic design optimization using the Navier-Stokes equations
306/33 p.74	**Augmented Lagrangian methods II**, *chair*: Giampaolo Liuzzi	NONLINEAR PROGRAMMING	Elijah Polak, An algorithm for generalized semi-infinite optimization problems based on augmented Lagrangians	Eva Komaromi, Entropy-like Lagrangian method as a unifying approach for solving convex programs	Giampaolo Liuzzi, Use of a truncated Newton direction in an augmented Lagrangian framework
306/34 p.75	**Stability of stationary points**, *organizer/chair*: Bernd Kummer	NONLINEAR PROGRAMMING	Bernd Kummer, Strong Lipschitz stability of stationary solutions in variational analysis under MFCQ: Part I the general condition	Diethard Klatte, Strong Lipschitz stability of stationary solutions in variational analysis under MFCQ, Part II: application to nonlinear optimization	Mikhail Solodov, Newton methods for optimization problems without constraint qualifications
306/35 p.75	**Software session, ILOG**, *organizer/chair*: Irvin Lustig	OTHER			
306/36 p.76	**Recent advances in nonsmooth optimization III**, *organizers*: John Mitchell, Jean-Louis Goffin and Jean-Philippe Vial, *chair*: John Mitchell	NONSMOOTH OPTIMIZATION	Cesar Beltran, The face simplex method in the cutting plane framework	John Mitchell, Properties of a cutting plane method for semidefinite programming	Fatma Gzara, Cut and column generation based on analytic centers for large scale integer programming
306/37 p.76	**Second-order cone programming**, *chair*: Michael Todd	CONVEX PROGRAMMING	Yu Xia, An algorithm for perturbed second-order cone programs with application to the Steiner minimal tree problem	Paul Tseng, Approximation algorithms for conic program with extreme ray constraints	Michael Todd, Distance weighted discrimination: applying SOCP to pattern recognition
306/38 p.77	**Global optimization problems with special structure**, *organizer/chair*: Marco Locatelli	GLOBAL OPTIMIZATION	Yoshitsugu Yamamoto, Global optimization method for solving the minimum maximal flow problem	Marco Locatelli, Undominated D.C. decompositions of quadratic functions and applications to branch-and-bound approaches	Bernardetta Addis, Smoothing local searches: a new approach to global optimization
308/11 p.77	**Generalized convexity I**, *organizer/chair*: Laura Martein	GENERALIZED CONVEXITY/MONOTONICITY	Laura Martein, Pseudomonotonicity and pseudoconvexity under the Charnes-Cooper transformation	Immanuel M. Bomze, From Kato's theorem to a new class of generalized convex functions?	Diehard Ernst Pallaschke, Pairs of compact convex sets
308/12 p.78	**Asset-liability management**, *chair*: Fredrik Altenstedt	STOCHASTIC PROGRAMMING	Ronald Hochreiter, Application of dependent discrete 2-coupling with reduction to financial management	Petri Hilli, A stochastic programming model for asset and liability management of a finnish pension company	Fredrik Altenstedt, A comparison between stochastic programming and parametrized policies for asset liability management
308/13 p.78	**Tucker prize**, *chair*: Rainer Burkard	OTHER			
308/T1 p.78	**Equilibrium models**, *chair*: Jorge Rivera	FINANCE AND ECONOMICS	Pedro Daniel Jara Moroni, A sequential land use equilibrium model with endogenous incomes	Monique Florenzano, General equilibrium analysis in ordered topological vector spaces	Jorge Rivera, The second welfare theorem with public goods in general economies
308/T2 p.79	**Developments in proximal algorithms**, *organizer/chair*: Jonathan Eckstein	COMPLEMENTARITY AND VARIATIONAL INEQUALITIES	Rainer Tichatschke, Interior proximal methods for non-paramonotone variational inequalities	Paulo Jose da Silva e Silva, Double regularization proximal methods for complementarity	Benar Svaiter, Separation-based proximal splitting methods
308/T3 p.79	**Modeling languages and systems IV**, *chair*: Bob Daniel	MODELING LANGUAGES AND SYSTEMS	Arnold Neumaier, Testing global optimization software	Bob Daniel, Xpress-mosel: a modular environment for modelling and solving optimization problems	
341/21 p.79	**Second order cone programming**, *chair*: Farid Alizadeh	INTERIOR POINT ALGORITHMS	Chek Beng Chua, The primal-dual second-order cone approximations algorithm	Gongyun Zhao, On treating second order cone problem as a special case of semidefinite problem	Farid Alizadeh, The q method for optimization over symmetric cones
341/22 p.80	**Design in communication and allocation**, *chair*: Chung-Piaw Teo	LOGISTICS AND TRANSPORTATION	Peter Brostrom, Internet protocol network design and routing	Mustafa C. Pinar, Design of virtual private networks under aggregate traffic uncertainty	Chung-Piaw Teo, Berth allocation planning optmization in container terminal
341/23 p.81	**Optimization in medicine I**, *organizer/chair*: Panos M. Pardalos	BIOINFORMATICS AND OPTIMIZATION	Olvi Mangasarian, Survival-time classification of breast cancer patients and chemotherapy	Ariela Sofer, Optimal treatment planning for radiofrequency ablation of liver tumors	Eva Lee, Beam geometry and intensity map optimization in IMRT via mixed integer programming
321/053 p.81	**Parallel computation in optimization: semidefinite programming and related issues**, *organizers*: Mituhiro Fukuda and Masakazu Kojima, *chair*: Mituhiro Fukuda	PARALLEL COMPUTING	Katsuki Fujisawa, High performance grid computing for mathematical programming	Makoto Yamashita, Parallel computation for semidefinite programming	Kazuhide Nakata, Parallel semidefinite programming algorithm using matrix completion
321/033 p.82	**Shortest path problems**, *chair*: Stefan Krause	NETWORKS	Irina Dumitrescu, A Lagrangean relaxation approach to solving the resource constrained shortest path problem	Andreas Bley, The minimum congestion shortest path routing problem	Stefan Krause, Increasing distances in graphs by deleting minimum edge sets
321/133 p.82	**Graphs and discovery**, *organizer/chair*: Pierre Hansen	GRAPHS AND MATROIDS	Dragan Stevanovic, Computer-assisted research in graph theory	Gilles Caporossi, What forms do interesting conjectures have in graph theory?	Pierre Hansen, How far should, is and could conjecture-making be automated in graph theory?
305/205 p.83	**Cooperative games**, *chair*: Sjur Didrik Flåm	GAME THEORY	Elena Sáiz Pérez, Determination of stable structures in a multiple coalition game	Herbert Hamers, Characterizing convexity of games using marginal vectors	Sjur Didrik Flåm, Extremal convolution and games

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302/41	p.84	**Domination analysis of combinatorial optimization algorithms**, *organizer/chair*: Gregory Gutin	COMBINATORIAL OPTIMIZATION	Gregory Gutin, Introduction to domination analysis	Joergen Bang-Jensen, When the greedy algorithm fails	Andreas S. Schulz, Approximate local search
302/42	p.84	**Combinatorial optimization V**, *chair*: Marek Libura	COMBINATORIAL OPTIMIZATION	Santosh Kabadi, A strongly polynomial algorithm for integer version of the multipath flow network synthesis problem	Lucas Létocart, Minimal multicut and maximal integer multiflow in rings	Marek Libura, Adjustment problem for binary constrained linear programming problems
302/44	p.85	**Knapsack problems**, *organizer/chair*: David Pisinger	COMBINATORIAL OPTIMIZATION	David Pisinger, A survey of upper bounds and exact algorithms for the quadratic knapsack problem	Ulrich Pferschy, A survey of stochastic aspects of knapsack problems	Hans Kellerer, A survey of approximation algorithms for knapsack-type problems
302/45	p.85	**Traveling salesman II**, *chair*: Nicholas Pearson	COMBINATORIAL OPTIMIZATION	Michal Stern, On the optimal clustering TSP path and stars problems	John Raffensperger, Solving the TSP with decomposition-based pricing	Nicholas Pearson, Fast algorithms for planar graphs, Part II: the traveling salesman problem
302/49	p.86	**Integer programming**, *organizer/chair*: Daniel Bienstock	INTEGER AND MIXED INTEGER PROGRAMMING	Michael Perregaard, A practical implementation of lift-and-project cuts	George Nemhauser, A branch-and-cut algorithm for nonconvex quadratic programming	Sanjeeb Dash, On the use of Gomory's cyclic group polyhedra in cutting-plane generation
306/31	p.86	**Integer and mixed integer programming IV**, *chair*: Agostinho Agra	INTEGER AND MIXED INTEGER PROGRAMMING	Duan Li, Exact solution to separable integer programming	Dorin Preda, Discrete time LQR optimal control problem with logical constraints	Agostinho Agra, MIP cuts based on knapsacks with 2 integer variables
306/32	p.87	**Optimization of engineering systems governed by simulations/PDE, part 3**, *organizer/chair*: Natalia Alexandrov	NONLINEAR PROGRAMMING	Emilio F. Campana, High-fidelity solvers in the design optimization of ships	Martin Berggren, Boundary shape optimization for fluids and waves	Natalia Alexandrov, Problem formulation and modeling in simulation-based design
306/33	p.87	**Least square problems**, *chair*: Jerry Eriksson	NONLINEAR PROGRAMMING	Thomas Viklands, On global minimization of procrustes-penrose regression problems	Irinel Dragan, The least square values and the Shapley value	Jerry Eriksson, The superiority of using regularization over trust-region for ill-conditioned nonlinear least squares
306/34	p.88	**Large scale nonlinear programming I**, *organizers*: Sven Leyffer and Richard Waltz, *chair*: Richard Waltz	NONLINEAR PROGRAMMING	Dominique Orban, An interior-point L1-penalty method for nonlinear optimization	Richard Byrd, Convergence and constraint activity in a successive LP algorithm	Roger Fletcher, An $f-$nonmonotonic filter algorithm for NLP
306/35	p.88	**Software session, COIN-OR**, *organizer/chair*: Ted Ralphs	OTHER			
306/36	p.88	**Cutting plane methods for conic optimization problems**, *organizers*: John Mitchell, Jean-Louis Goffin and Jean-Philippe Vial, *chair*: John Mitchell	NONSMOOTH OPTIMIZATION	Kartik Krishnan, Cutting plane methods for semidefinite programming	Vasile Basescu, Analytic center cutting plane method in conic programming	Mohammad R. Oskoorouchi, Second-order cone cuts vs. semidefinite cuts in the analytic center cutting plane method
306/37	p.89	**Complexity in convex programming**, *chair*: Stefan M Stefanov	CONVEX PROGRAMMING	Fernando Ordonez, Condition number complexity for non-conic convex optimization	Stefan M Stefanov, Convex separable optimization problems with bounded variables	
306/38	p.89	**Bilevel programming**, *chair*: Anton Evgrafov	GLOBAL OPTIMIZATION	Marcia Fampa, A bilevel model and solution algorithm for the stochastic taxation problem	Sophie Dewez, Heuristics for toll setting problem	Anton Evgrafov, Smoothing by relaxing the equilibrium conditions in topology optimization problems for Truss structures in contact
308/11	p.90	**Generalized convexity II**, *organizer*: Laura Martein, *chair*: Riccardo Cambini	GENERALIZED CONVEXITY/MONOTONICITY	Evgeny Belousov, Discontinuity properties of convex polynomial mappings	Riccardo Cambini, Mixed type duality for multiobjective optimization problems with set constraints	
308/12	p.90	**Modeling and computation issues in stochastic programming**, *organizer/chair*: Gus Gassmann	STOCHASTIC PROGRAMMING	Gus Gassmann, SMPS and SMPSReader: an input format and user routines for stochastic programs	Chandra Poojari, Scalability and implementation issues in stochastic programming algorithms	Shane Dye, Subtree decomposition for multistage stochastic programs
308/13	p.91	**Stochastic programming applications in the power and gas industries**, *organizer*: COSP (Markus Westphalen), *chair*: Markus Westphalen	STOCHASTIC PROGRAMMING	Frode Rømo, Value chain management in the liberalized natural gas market	Markus Westphalen, A two-stage stochastic MILP for natural gas transmission optimization with transient flow	
308/T1	p.91	**Portfolio planning**, *chair*: Gautam Mitra	FINANCE AND ECONOMICS	Diana Roman, A review of risk measures with application in financial portfolio analysis	Eranda Cela, Fin4cast: from data mining to optimal portfolio selection	Gautam Mitra, Algorithms for the solution of large-scale quadratic programming (QP) and quadratic mixed integer programming (qmip) models
308/T2	p.92	**Complementarity principle in games**, *organizer/chair*: Samir Kumar Neogy	COMPLEMENTARITY AND VARIATIONAL INEQUALITIES	Samir Kumar Neogy, Complementarity principle and some structured stochastic games	Arup Kumar Das, Some classes of matrices in linear complementarity problem and matrix games	Uwe Schaefer, The linear complementarity problem with interval data
308/T3	p.92	**Deterministic on-line optimization**, *chair*: Joan Boyar	ON-LINE OPTIMIZATION	Winfried Hochstättler, On-line matching on a line	Patrik Flisberg, On-line bleaching control at pulp mills	Joan Boyar, New paging results using the relative worst order ratio
341/21	p.93	**Methods in semidefinite programming**, *chair*: Henry Wolkowicz	INTERIOR POINT ALGORITHMS	Mituhiro Fukuda, Preprocessing sparse semidefinite programs by the conversion method	Paulo Roberto Oliveira, New scaling algorithms and a hybrid bundle method for SDP programming	Henry Wolkowicz, Robust search directions for large sparse semidefinite programming (SDP)
341/22	p.93	**Practical routing problems**, *chair*: K. Ganesh	LOGISTICS AND TRANSPORTATION	Tobias Andersson, Decision support for real-time ambulance planning and control	Armin Fuegenschuh, Simultaneous optimization of school starting times and public bus services	K. Ganesh, Optimization of vehicle routing using evolutionary algorithms for contraceptive logistics in a supply chain
341/23	p.94	**Optimization in medicine II**, *organizer/chair*: Panos M. Pardalos	BIOINFORMATICS AND OPTIMIZATION	Michael Ferris, Fractionation in radiation treatment planning	Wanpracha Chaovalitwongse, Optimization techniques in seizure prediction	Edwin Romeijn, A column generation approach to aperture modulation in radiation therapy treatment planning
321/053	p.95	**Real-life scheduling**, *chair*: Matthew Berge	PRODUCTION AND SCHEDULING	Ryuhei Miyashiro, Characterizing feasible pattern sets with a minimum number of breaks	Yoshiko Ikebe, Feasibility problems in sports scheduling	Matthew Berge, Airline schedule recovery - models and algorithms for air traffic management concept analysis
321/033	p.95	**Efficiency analysis in multicriteria optimization III**, *chair*: Henri Bonnel	MULTICRITERIA OPTIMIZATION	Emilio Carrizosa, Inferring efficient weights from pairwise comparison matrices	Stefan Tigan, Efficiency and generalized concavity in stochastic multiobjective programming	Henri Bonnel, Semivectorial bilevel optimization problem
321/133	p.96	**Linear programming and Markov decision**, *organizer/chair*: Yinyu Ye	LINEAR PROGRAMMING	Yinyu Ye, A new complexity result on solving the Markov decision problem	Michael O'Sullivan, Polynomial-time computation of optimal policies in Markov decision chains	Takashi Tsuchiya, A new iteration-complexity bound for the MTY predictor-corrector algorithm
305/205	p.96	**Optimization in electricity markets**, *organizer/chair*: Andy Philpott	GAME THEORY	Golbon Zakeri, Estimation of market distribution functions in electricity pool markets	Andy Philpott, Optimization models for hydro-reservoir operations in electricity pools	Edward Anderson, Learning collusive strategies in electricity markets

Parallel Sessions: Wednesday 13:15 – 14:45 (WE2)

Room Page	Session	Talk 1	Talk 2	Talk 3
302/41 p.98	**Computational methods for graph-coloring I**, *organizer/chair*: Michael Trick — COMBINATORIAL OPTIMIZATION	KAZUNORI MIZUNO, A systematic approach to generate very hard 3COL instances	SHAHADAT HOSSAIN, Graph-coloring in the estimation of mathematical derivatives	MICHAEL TRICK, Column generation approaches for graph-coloring generalizations
302/42 p.98	**Combinatorial optimization VI**, *chair*: Tomomi Matsyu — COMBINATORIAL OPTIMIZATION	TAMON STEPHEN, The distribution of values in the quadratic assignment problem	FILIPA DUARTE DE CARVALHO, Exact disclosure prevention in general and nonnegative statistical tables	TOMOMI MATSYU, Perfect sampling algorithm for two-rowed contingency tables
302/44 p.98	**Networks and communication**, *chair*: Fulvio Piccinonno — COMBINATORIAL OPTIMIZATION	MARC C. STEINBACH, Nonlinear optimization in gas network operation	NELSON MACULAN, New integer linear programming formulations for the SRAP	FULVIO PICCINONNO, A new map-like algorithm with low memory requirements for decoding error correcting codes
302/45 p.99	**Postman optimization problems**, *chair*: Julián Arturo Aráoz — COMBINATORIAL OPTIMIZATION	FRANCISCO JAVIER ZARAGOZA MARTINEZ, Restricted postman problems on mixed graphs	DINO AHR, A branch-and-cut approach for the min-max *k*-Chinese postman problem	JULIÁN ARTURO ARÁOZ, Privatized rural postman problems
302/49 p.100	**Decomposition algorithms and dynamic cut generation**, *organizer/chair*: Ted Ralphs — INTEGER AND MIXED INTEGER PROGRAMMING	MATTHEW GALATI, Decomposition and dynamic cut generation in integer programming	ABILIO LUCENA, Optimal rectangular partitions	LASZLO LADANYI, Solving lexicographic multiobjective MIPs with branch-cut-price
306/31 p.100	**Computational methods for solving IPs I**, *organizer/chair*: Eva Lee — INTEGER AND MIXED INTEGER PROGRAMMING	LISA EVANS, Generating cutting planes using master cyclic group polyehdra	ANDREA LODI, Lagrangean approaches for optimizing over the semimetric polytope	MATHIEU VAN VYVE, Mixing two sets of mixed integer inequalities
306/32 p.101	**Algorithms for degenerate nonlinear optimization**, *organizer/chair*: Olga Brezhneva — NONLINEAR PROGRAMMING	CATARINA AVELINO, Behavior of NLP codes on a degenerate optimal control problem	CHRISTIAN NAGEL, Quadratic convergence of a nonsmooth Newton-type method for semidefinite programs	OLGA BREZHNEVA, Methods for nonlinear programming without strict complementarity assumption
306/33 p.101	**Approximation of gradients**, *chair*: Benoit Hamelin — NONLINEAR PROGRAMMING	SERGE SHISHKIN, Computationally efficient approximation of derivatives for robust optimization	RENTSEN ENKHBAT, Analysis of response surface problems using quadratic programming	BENOIT HAMELIN, Automatic finite differences, an alternative to automatic derivatives
306/34 p.102	**Large scale nonlinear programming II**, *organizers*: Sven Leyffer and Richard Waltz, *chair*: Richard Waltz — NONLINEAR PROGRAMMING	JIE SUN, A robust primal-dual interior point algorithm for nonlinear programs	ANDERS FORSGREN, On the solution of linear equations arising in interior methods for nonconvex optimization	ANNICK SARTENAER, On interior-point methods using a suitable decomposition for multistage nonlinear stochastic programming
306/35 p.102	**NLP software - state of the art I**, *organizer/chair*: Arne Stolbjerg Drud — NONLINEAR PROGRAMMING	ARNE STOLBJERG DRUD, Detecting unboundedness in practical nonlinear models	STEVEN DIRKSE, Mathematical programs with equilibrium constraints: automatic reformulation and solution via constrained optimization	MICHAEL BUSSIECK, Global optimization with GAMS - applications and performance
306/36 p.103	**Non-convex problems**, *chair*: Michael Overton — NONSMOOTH OPTIMIZATION	WARREN HARE, Partial smoothness and prox-regularity in optimization	ALEXEI DEMYANOV, Nonlocal methods for solving some classes of nonsmooth and nonconvex optimization problems	MICHAEL OVERTON, A robust gradient sampling algorithm for nonsmooth, nonconvex optimization
306/37 p.103	**Duality and optimality**, *chair*: Michael L. Flegel — CONVEX PROGRAMMING	ASUMAN OZDAGLAR, Enhanced optimality conditions and informative multipliers for convex programming	ROMAN POLYAK, Lagrangean transformation in convex optimization	MICHAEL L. FLEGEL, On the Guignard constraint qualification for mathematical programs with equilibrium constraints
306/38 p.104	**Global optimization II**, *chair*: Eligius Maria Theodorus Hendrix — GLOBAL OPTIMIZATION	CHRISTODOULOS FLOUDAS, Deterministic global optimization: a new class of improved convex underestimators for constrained NLPs	HERMANN SCHICHL, Global optimization in the coconut project	ELIGIUS MARIA THEODORUS HENDRIX, Investigating population algorithms; a spatial GA
308/11 p.105	**Generalized convexity III**, *organizer*: Laura Martein, *chair*: Rita Pini — GENERALIZED CONVEXITY/MONOTONICITY	RITA PINI, Coercivity conditions and equilibrium problems	DANIELA MARIAN, Generalized convexity on allures in the sense of elena popoviciu	ANNA MARCHI, On the connectedness of mix semi-efficient frontier
308/12 p.105	**Option prices and optimization**, *chair*: Teemu Pennanen — STOCHASTIC PROGRAMMING	ANA MARGARIDA MONTEIRO, Recovering risk-neutral probabilities from option prices-a convex quadratic programming approach	MARKKU KALLIO, Real option valuation via stochastic optimization	TEEMU PENNANEN, Arbitrage pricing of American contingent claims in incomplete markets
308/13 p.106	**Stochastic programming with risk measures**, *organizer/chair*: Andrzej Ruszczynski — STOCHASTIC PROGRAMMING	ANDRZEJ RUSZCZYNSKI, Risk aversion via stochastic dominance constraints (Part I)	DARINKA DENTCHEVA, Risk aversion via stochastic dominance constraints (Part II)	WERNER ROEMISCH, Risk functionals in stochastic programming: stability and algorithmic issues
308/T1 p.106	**Combinatorial auctions I**, *organizer/chair*: Susan Powell — FINANCE AND ECONOMICS	RICHARD STEINBERG, Pause: a general combinatorial auction procedure	ARNE ANDERSSON, Combinatorial auctions in practice	RAKESH VOHRA, On ascending vickrey auctions for heterogeneous objects
308/T2 p.106	**Complementarity methods for simulating nonsmooth mechanical systems**, *organizer/chair*: Mihai Anitescu — COMPLEMENTARITY AND VARIATIONAL INEQUALITIES	MIHAI ANITESCU, Optimization problems with complementarity constraints in mechanics	JONG-SHI PANG, Differential variational inequalities	XINWEI LIU, A robust sequential quadratic programming method for mathematical programs with linear complementarity constraints
308/T3 p.107	**On-line optimization algorithms**, *chair*: Tjark Vredeveld — ON-LINE OPTIMIZATION	DIANA POENSGEN, Minimizing the maximum flow time in the online dial-a-ride problem	RENE SITTERS, The generalized 2-server problem	TJARK VREDEVELD, Smoothening helps: a probabilistic analysis of the multi-level feedback algorithm
341/21 p.107	**Interior point methods in linear programming**, *chair*: Miguel Argaez — INTERIOR POINT ALGORITHMS	HUA WEI, An iterative method for solving the search direction of linear programming	CORALIA CARTIS, On the convergence of interior point methods for linear programming	MIGUEL ARGAEZ, The role of the notion of quasicentral path for linear programming
341/22 p.108	**Applications of optimization in transportation**, *organizer/chair*: Georgia Perakis — LOGISTICS AND TRANSPORTATION	THANASIS ZILIASKOPOULOS, An inner approximation algorithm for the dynamic user equilibrium problem	SOULAYMANE KACHANI, A fluid dynamics model in distribution systems and transportation	SIRIPHONG LAWPHONGPANICH, On second-best toll pricing problems
341/23 p.108	**Approximation algorithms for metric facility location and spanning tree**, *organizer/chair*: Yinyu Ye — APPROXIMATION ALGORITHMS	BO CHEN, On universal facility location problem	ASAF LEVIN, An efficient polynomial time approximation scheme for the constrained minimum spanning tree using matroid intersection	MATTHIAS MUELLER-HANNEMANN, Approximation of rectilinear Steiner trees with length restrictions on obstacles
321/053 p.109	**Flow shop scheduling**, *chair*: Débora Pretti Ronconi — PRODUCTION AND SCHEDULING	OULAMARA AMMAR, Scheduling with simultaneous task processing for two-machine no-wait flowshop problem	BERTRAND LIN, A branch-and-bound algorithm for the minimization of weighted tardiness in a two-machine flowshop	DÉBORA PRETTI RONCONI, A branch-and-bound algorithm to minimize the makespan in a flowshop with blocking
321/033 p.109	**Efficiency analysis in multicriteria optimization I**, *chair*: Fernanda Maria Pereira Raupp — MULTICRITERIA OPTIMIZATION	DOLORES ROMERO MORALES, A biobjective method for sample allocation in stratified sampling	FRANK HEYDE, Duality in risk minimization and vector optimization	FERNANDA MARIA PEREIRA RAUPP, On minimization over weakly efficient sets
321/133 p.110	**Computational and algorithmic progress in cone programming**, *organizer/chair*: Jos F. Sturm — LINEAR PROGRAMMING	JOS F. STURM, A new variant of the interior point method with rank-1 updates	SAM BURER, Semidefinite programming in the space of partial positive semidefinite matrices	REHA TUTUNCU, New developments in SDPT3
305/205 p.110	**Game theory applications I**, *organizer/chair*: Daniel Granot — GAME THEORY	WALTER KERN, On the complexity of the kernel	MARILDA SOTOMAYOR, Buying and selling strategies in the assignment game	DANIEL GRANOT, Chinese postman games on a class of Eulerian graphs

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302/41	**Computational methods for graph-coloring II**, *organizer/chair*: Michael Trick (COMBINATORIAL OPTIMIZATION)		
p.112	IGOR DJUKANOVIC, Graph-coloring heuristics based on lovasz theta number	RICARDO CORRÊA, Cliques, holes and lower bounds for the vertex coloring problem	ISABEL MENDEZ-DIAZ, Application of mathematical programming to graph-coloring
302/42	**Combinatorial optimization VII**, *chair*: Marco Lübbecke (COMBINATORIAL OPTIMIZATION)		
p.112	BETTINA KLINZ, A fast parametric assignment algorithm with applications in max-algebra	ALANTHA NEWMAN, On semidefinite relaxations for the linear ordering problem	MARCO LÜBBECKE, On the stabbing number of matchings, trees, and triangulations
302/44	**Counting problems**, *chair*: Takeaki Uno (COMBINATORIAL OPTIMIZATION)		
p.113	YASUKO MATSUI, An algorithm for enumerating all substitutions a rooted ordered tree into a term tree	SAMMANI DANWAWU ABDULLAHI, Counting the vertices of certain classes of polyhedra	TAKEAKI UNO, Fast algorithms for enumerating maximal cliques
302/45	**Integer and mixed integer programming V**, *chair*: Atsushi Kawamoto (INTEGER AND MIXED INTEGER PROGRAMMING)		
p.113	CARLO VERCELLIS, On classes of mixed integer programming problems arising in discriminant analysis	DAVID WARME, So it's facet-defining... big, fat, hairy deal!	ATSUSHI KAWAMOTO, Articulated mechanism designs: topology and geometry variations
302/49	**Alternative methods**, *chair*: Chuangyin Dang (INTEGER AND MIXED INTEGER PROGRAMMING)		
p.114	UTZ-UWE HAUS, An augmentation framework for integer programming	MATTHIAS KOEPPE, The integral basis method and extensions	CHUANGYIN DANG, A simplicial approach to integer programming
306/31	**Computational methods for solving IPs II**, *organizers*: Eva Lee and Andrew Miller, *chair*: Eva Lee (INTEGER AND MIXED INTEGER PROGRAMMING)		
p.114	KEREM AKARTUNALI, Strong formulations and separation for multi-level lot-sizing problems	QUENTIN LOUVEAUX, Lifting, superadditivity and single node flow sets revisited	DENISS KUMLANDER, Problems of optimization: an exact algorithm for finding a maximum clique optimized for the dense graphs
306/32	**Applications**, *chair*: Katia Demaseure (NONLINEAR PROGRAMMING)		
p.115	FRANK STRAUSS, Shape optimization in rotordynamics with eigenvalue and eigenvector constraints	OLEG MAKARENKOV, A food problem for a predator-prey interaction model	KATIA DEMASEURE, The progressive addition lens problem : an hybrid approach combining optimization and perturbation techniques
306/33	**PDE-constrained optimization (1)**, *organizers*: Michael Ulbrich and Stefan Ulbrich, *chair*: Stefan Ulbrich (NONLINEAR PROGRAMMING)		
p.115	MATTHIAS HEINKENSCHLOSS, Optimization of time-dependent partial differential equations	CARL KELLEY, Optimal design of groundwater remediation systems	MICHAEL ULBRICH, Multilevel and preconditioning approaches for inequality constrained optimization problems governed by PDEs
306/34	**Large scale problems I**, *chair*: Trond Steihaug (NONLINEAR PROGRAMMING)		
p.116	CRISTINA VILLALOBOS, On the development of a trust-region interior-point method for large-scale nonlinear programs	JR. HERNANDEZ JAIME, An inexact Newton trust region interior-point algorithm for nonlinear programming problems	TROND STEIHAUG, When sparsity counts: optimal direct Jacobian computation
306/35	**NLP software - the state of the art II**, *organizer/chair*: Hans D. Mittelmann (NONLINEAR PROGRAMMING)		
p.116	HANS D. MITTELMANN, The state of the art in software for SDP&SOCP problems	ERLING ANDERSEN, Functional versus conic optimization: what is the better	ARMIN PRUESSNER, Automated performance analysis in the evaluation of nonlinear programming solvers
306/36	**Bundle-based methods**, *chair*: Marko M. Makela (NONSMOOTH OPTIMIZATION)		
p.117	CLAUDIA ALEJANDRA SAGASTIZÁBAL, An infeasible bundle method for nonsmooth convex constrained optimization without a penalty function or a filter	MARJO HAARALA, Large-scale nonsmooth optimization: new limited memory bundle method	MARKO M. MAKELA, A hybrid of simulated annealing and proximal bundle method for continuous global optimization
306/37	**Robust optimization**, *organizer/chair*: Garud Lyengar (CONVEX PROGRAMMING)		
p.117	GARUD LYENGAR, Robust quadratically constrained quadratic programming	AHARON BEN-TAL, Robust optimization approach to multi-stage uncertain decision problems	MELVYN SIM, Robust discrete optimization and network flows
306/38	**Global optimization III**, *chair*: Ivo Nowak (GLOBAL OPTIMIZATION)		
p.118	VINCENZO SCALZO, Relaxation of the semicontinuity for marginal functions	MOHIT TAWARMALANI, Convex extensions and polyhedral basis	IVO NOWAK, Rounding and partitioning heuristics for solving nonconvex minlps
308/11	**Generalized convexity IV**, *organizer*: Laura Martein, *chair*: Nicolas Hadjisavvas (GENERALIZED CONVEXITY/MONOTONICITY)		
p.118	NICOLAS HADJISAVVAS, Quasimonotone variational inequalities	SANGHO KUM, Generalized vector variational and quasi-variational inequalities with operator solutions	ANGELO GUERRAGGIO, Well-posed vector variational inequalities
308/12	**Dynamic stochastic programming: theory and applications**, *organizer/chair*: Lisa Korf (STOCHASTIC PROGRAMMING)		
p.119	LISA KORF, Dynamic stochastic programming: models, information structures, and duality	LEONARD MACLEAN, Risk control of dynamic investment models	ALEXEI GAIVORONSKI, Planning of supply chains under uncertainty: interworking of stochastic programming and simulation
308/13	**Stochastic programming: a panel discussion**, *organizer/chair*: Gautam Mitra (STOCHASTIC PROGRAMMING)		
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308/T1	**Combinatorial auctions II**, *organizer/chair*: Susan Powell (FINANCE AND ECONOMICS)		
p.119	MAKOTO YOKOO, Secure multi-agent dynamic programming and its application to combinatorial auction	THOMAS ELENDNER, Winner determination in combinatorial auctions: Lagrangean heuristic for a generalization of the WJISP	SVEN DE VRIES, Branch-and-price and new testproblems for spectrum auctions
308/T2	**Topics in mathematical programs with equilibrium constraints**, *organizers*: Angel-Victor DeMiguel and Michael Paul Friedlander, *chair*: Michael Paul Friedlander (COMPLEMENTARITY AND VARIATIONAL INEQUALITIES)		
p.120	ANGEL-VICTOR DEMIGUEL, A superlinearly convergent interior-point method for MPECs	CHE-LIN SU, Algorithms for solving EPECs	DANIEL RALPH, Local properties of MPCC methods
308/T3	**Integer programming for the design of ring networks**, *chair*: Rosemary T. Berger (TELECOMMUNICATION NETWORK DESIGN)		
p.120	IRENE LOISEAU, A column generation approach for a network design problem	HERNAN ABELEDO, An exact algorithm for optimal routing and wavelength assignment in ring networks	ROSEMARY T. BERGER, Designing stacks of interconnected bidirectional sonet rings
341/21	**Large scale problems**, *chair*: Michael Alan Saunders (INTERIOR POINT ALGORITHMS)		
p.121	SHANGHUA TENG, Smoothed analysis of condition numbers of linear programs	LETICIA VELAZQUEZ, A trust region inexact Newton interior-point method for solving large scale unconstrained minimization problems	MICHAEL ALAN SAUNDERS, Interior-point solution of large-scale entropy maximization problems
341/22	**Railways / public transportation**, *organizer/chair*: Leo Kroon (LOGISTICS AND TRANSPORTATION)		
p.121	LEO KROON, Rolling stock circulations for passenger trains	DENNIS HUISMAN, Multiple-depot integrated vehicle and crew scheduling	RAMON LENTINK, Shunting passenger train units
341/23	**Algorithms for routing and partitioning**, *chair*: Kimmo Tapio Nieminen (APPROXIMATION ALGORITHMS)		
p.122	YOSHIKO WAKABAYASHI, Approximation algorithms for partitioning a graph into connected subgraphs	PIERRE FOUILHOUX, The multi-layer constrained via minimization problem: formulation andpolyhedral issues	KIMMO TAPIO NIEMINEN, A genetic algorithm for the vehicle routing problem
321/053	**Scheduling with complex constraints**, *chair*: Chris Potts (PRODUCTION AND SCHEDULING)		
p.122	YUE WU, A time staged linear programming model for multi-site aggregate production planning problems	CLIFFORD STEIN, Scheduling to simultaneously optimize two objectives	CHRIS POTTS, Rescheduling for new orders
321/033	**Planning by multicriteria optimization**, *chair*: Alexander Scherrer (MULTICRITERIA OPTIMIZATION)		
p.123	KATHRIN KLAMROTH, An MCDM approach to portfolio optimization	GANNA SHYSHKANOVA, Optimization of debt management in uncertainty by algorithms on graph	ALEXANDER SCHERRER, Intensity modulated radiation therapy - a multicriteria optimization problem
321/133	**Aspects of linear programming**, *chair*: Vincent Guigues (LINEAR PROGRAMMING)		
p.124	F.JAVIER TOLEDO-MELERO, Distance to ill-posedness for linear optimization problems: distance to insolvability	ETIENNE LOUTE, Gaussian elimination as a computational paradigm	VINCENT GUIGUES, Application of robust counterpart technique to production management

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p.125	ARIE M.C.A. KOSTER, Lightpath coloring in all-optical networks	STEVEN PRESTWICH, Hybrid local search on two multi-colouring models	
302/42	**Combinatorial optimization VIII**, *chair*: Sonoko Moriyama		COMBINATORIAL OPTIMIZATION
p.125	TRULS FLATBERG, Reconstructing (0,1)-matrices using Lagrangean decomposition	BALAZS KOTNYEK, A new class of matrices for half-integrality	SONOKO MORIYAMA, Shellability of simplicial complexes and optimization in acyclic orientations
302/44	**Paths in graphs**, *chair*: L. Sunil Chandran		COMBINATORIAL OPTIMIZATION
p.125	EUGENE BARSKY, NP-hardness of some maximum edge-disjoint paths problem	DAVID HUYGENS, Two edge-disjoint hop-constrained paths and polyhedra	L. SUNIL CHANDRAN, Isoperimetric inequalities and the width parameters of graphs
302/45	**Generalized assignment**, *chair*: Alberto Ceselli		INTEGER AND MIXED INTEGER PROGRAMMING
p.126	JOHN WILSON, An LP-based heuristic procedure for the generalized assignment problem with special ordered sets	ANDREAS DREXL, Cut-and-branch for the generalized assignment problem	ALBERTO CESELLI, A branch-and-price algorithm for the multilevel generalized assignment problem
302/49	**Routing in networks**, *chair*: Bruce Shepherd		INTEGER AND MIXED INTEGER PROGRAMMING
p.126	PER OLOV LINDBERG, A prize collecting connected subgraph problem	TOMMY THOMADSEN, The quadratic selective travelling salesman problem	BRUCE SHEPHERD, Maximum multicommodity demand flows
306/31	**Open-source software for mathematical programming**, *organizer/chair*: Robin Lougee-Heimer		INTEGER AND MIXED INTEGER PROGRAMMING
p.127	MATTHEW SALTZMAN, The COIN-OR open solver interface: a progress report	ROBIN LOUGEE-HEIMER, The COIN-OR initative: open-source tools for mathematical programmers	CLAUDE MARTIN TADONKI, Prox-Accpm: a cutting plane solver for convex optimization
306/32	**Surrogate modelling for engineering optimization I**, *organizer/chair*: Kaj Madsen		NONLINEAR PROGRAMMING
p.127	ANDREW CONN, On multivariate polynomial interpolation and its use in derivative-free optimization (parts I and II)	LUÍS N. VICENTE, On multivariate polynomial interpolation and its use in derivative-free optimization (parts I and II)	JAN-ERIK KÄCK, Constrained global optimization with radial basis functions
306/33	**PDE-constrained optimization (2)**, *organizers*: Michael Ulbrich and Stefan Ulbrich, *chair*: Michael Ulbrich		NONLINEAR PROGRAMMING
p.128	FREDI TROELTZSCH, Optimal control of PDEs with mixed control-state constraints	MICHAEL HINTERMÜLLER, Space mapping for optimal control of partial differential equations	PAUL T. BOGGS, Software for rapid source location in chemical/biological defense
306/34	**Large scale problems II**, *chair*: Jacek Gondzio		NONLINEAR PROGRAMMING
p.129	MEHDI LACHIHEB, Approximation of optimum sets of extreme points in a SQP integrated simple decomposition	MASSIMO ROMA, Dynamic scaling based preconditioning for truncated Newton methods in large scale unconstrained optization	JACEK GONDZIO, Parallel solution techniques in financial planning problems
306/35	**Newton-like algorithms I**, *chair*: Oleg Burdakov		NONLINEAR PROGRAMMING
p.129	JELENA NEDIC, Newton-like search directions	JIAN-ZHONG ZHANG, Value function and error bounds of a basic trust region model	OLEG BURDAKOV, On limited memory methods with shape changing trust region
306/36	**Covering problems**, *chair*: Frits Spieksma		NONSMOOTH OPTIMIZATION
p.130	MICHAEL PATRIKSSON, Global optimality conditions for discrete and nonconvex optimiation, with applications to Lagrangian heuristics and column generation	ADILSON ELIAS XAVIER, Optimum order p covering of plane domains by circles via hyperbolic smoothing method	FRITS SPIEKSMA, An approximation algorithm for an interval stabbing problem
306/37	**Conic programming and positive polynomials**, *organizer/chair*: Javier Pena		CONVEX PROGRAMMING
p.130	LUIS ZULUAGA, A conic programming approach to generalized Tchebycheff inequalities	ETIENNE DE KLERK, Global optimization of rational functions: a semidefinite programming approach	JUAN VERA, Using algebraic geometry in 0-1 programming
306/38	**Global optimization IV**, *chair*: Tibor Csendes		GLOBAL OPTIMIZATION
p.131	JÁNOS FÜLÖP, Global optimization methods for approximation by consistent matrices	YOUKANG FANG, Box region in which the local minimizer is global	TIBOR CSENDES, A new interval selection technique for global optimization
308/11	**Generalized convexity V**, *organizer*: Laura Martein, *chair*: Piera Mazzoleni		GENERALIZED CONVEXITY/MONOTONICITY
p.131	PIERA MAZZOLENI, Generalized convexity and dependence structures in equilibrium problems	GABOR KASSAY, On generalized equilibrium points	DAVIDE LA TORRE, On generalized convexity for set valued maps
308/12	**Risk issues in stochastic programming**, *organizer*: COSP (Stephan Tiedemann), *chair*: Stephan Tiedemann		STOCHASTIC PROGRAMMING
p.132	SHABBIR AHMED, Risk modeling in stochastic programming	ANDREAS MAERKERT, Risk aversion in stochastic programs with mixed-integer recourse, Part I	STEPHAN TIEDEMANN, Risk aversion in stochastic programs with mixed-integer recourse, Part II
308/T1	**Dynamic programming and optimal control**, *chair*: Julien Laurent-Varin		DYNAMIC PROGRAMMING AND OPTIMAL CONTROL
p.132	MORITZ DIEHL, Robust dynamic programming for polytopic systems with piecewise linear cost	ANDREI DMITRUK, A relaxation theorem for nonlinear control systems with sliding modes	JULIEN LAURENT-VARIN, An interior points algorithm for optimal control problems
308/T2	**Mathematical programs with equilibrium constraints**, *organizers*: Sven Leyffer and Richard Waltz, *chair*: Sven Leyffer		COMPLEMENTARITY AND VARIATIONAL INEQUALITIES
p.133	LORENZ BIEGLER, Solution and application of MPECs in process engineering	GABRIEL LOPEZ-CALVA, Interior point methods for MPECs	SVEN LEYFFER, Solving complementarity constraints via nonlinear optimization
308/T3	**Scheduling and routing in networks**, *chair*: Hans-Florian Geerdes		TELECOMMUNICATION NETWORK DESIGN
p.133	SYLVIE BORNE, Design of survivable IP-over-optical networks	HANS-FLORIAN GEERDES, The potential of relaying cellular wireless computer networks	
341/21	**Recent development in interior-point methods**, *organizer/chair*: Jiming Peng		INTERIOR POINT ALGORITHMS
p.134	KEES ROOS, What is special with the logarithmic barrier function in optimization?	AKIKO YOSHISE, A homogeneous model for p_0 and p_* nonlinear complementarity problems	TAMAS TERLAKY, Self-regular proximity based dynamic large-update primal-dual ipms for linear optimization
341/22	**Routing by mixed integer programming**, *chair*: Jean-Francois Cordeau		LOGISTICS AND TRANSPORTATION
p.134	JENNY KARLSSON, Modelling of road investments	HENRIK ANDERSSON, A ship routing problem in the pulp industry	JEAN-FRANCOIS CORDEAU, A branch-and-cut approach for the dial-a-ride problem
341/23	**Approximation and trees**, *chair*: Abdel Lisser		APPROXIMATION ALGORITHMS
p.135	VLADIMIR DEINEKO, The double-tree approximation for metric TSP: is the best good enough?	MICHEL GOEMANS, Covering minimum spanning trees of induced subgraphs	ABDEL LISSER, Robust minimum spanning tree
321/053	**Scheduling AND/OR constraints**, *chair*: Valery Gordon		PRODUCTION AND SCHEDULING
p.136	BERIT JOHANNES, Scheduling with or-precedence constraints	VANESSA KAEAEB, Scheduling with AND/OR-networks	VALERY GORDON, Assignment of due dates in scheduling partially ordered jobs
321/033	**Convexity and generalized convexity in multicriteria optimization**, *chair*: Andreas Loehne		MULTICRITERIA OPTIMIZATION
p.136	KHADIJA KHAZAFI, Efficiency conditions and duality for multiobjective fractional variational programming problems	LUIS MAURICIO GRAÑA DRUMMOND, A projected gradient method for vector optimization	ANDREAS LOEHNE, On convex functions with values in semi-linear spaces
321/133	**Numerical approaches I**, *chair*: Neelam Gupta		LINEAR PROGRAMMING
p.136	GAUTAM APPA, Solving DEA models by the Fourier Motzkin elimination method	GIDEON WEISS, A simplex algorithm for separated continuous linear programs	NEELAM GUPTA, Una: a simple numerical algorithm to solve linear constraints in real variables

Parallel Sessions: Thursday 16:30 – 18:00 (TH3)

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302/41 p.138	**Semidefinite liftings in combinatorial optimization**, *organizer/chair*: Miguel Anjos — COMBINATORIAL OPTIMIZATION	MIGUEL ANJOS, Solving the satisfiability problem using semidefinite programming	ANGELIKA WIEGELE, Semidefinite relaxations for sparse max-cut problems	MONIQUE LAURENT, Semidefinite representations for finite varieties
302/42 p.138	**Combinatorial optimization IX**, *chair*: Safia Kedad-Sidhoum — COMBINATORIAL OPTIMIZATION	JUAN JOSÉ SALAZAR GONZÁLEZ, Controlled rounding and other new statistical disclosure limitation methods for tabular data	YOUNG-SOO MYUNG, The graph disconnectivity problem: an improved algorithm and new models	SAFIA KEDAD-SIDHOUM, A new lower bound for the one machine problem with earliness andtardiness penalties
302/44 p.139	**Minimum trees**, *chair*: Francisco Barahona — COMBINATORIAL OPTIMIZATION	CRISTINA REQUEJO, A 2-paths approach for odd-diameter-constrained minimum spanning and Steiner trees	MARCUS BRAZIL, Flexibility of Steiner minimum trees in uniform orientation metrics	FRANCISCO BARAHONA, Network reinforcement
302/45 p.139	**Industrial applications**, *chair*: Ken McKinnon — INTEGER AND MIXED INTEGER PROGRAMMING	JOHN KARLOF, An integer programming solution to optimally locating radioactive waste facilities	BJØRN NYGREEN, Optimal routing of oil and gas from wells to separators	KEN MCKINNON, Branch-and-price to solve a MILP feed mill problem
302/49 p.140	**Theory of 0/1 and integer programming**, *organizer/chair*: Friedrich Eisenbrand — INTEGER AND MIXED INTEGER PROGRAMMING	FRIEDRICH EISENBRAND, Fast integer programming in fixed dimension	VOLKER KAIBEL, The graph-density of random 0/1-polytopes	ERNST ALTHAUS, Point containment in the integer hull of a polygon
306/31 p.140	**Constraint programming**, *chair*: Irvin Lustig — CONSTRAINT LOGIC PROGRAMMING	ERIC BOURREAU, Optimizing TV-break packages offered by satellite channels	MIGUEL CONSTANTINO, A combined mixed integer programming and constraint programming approach to planning and scheduling in a paint company	IRVIN LUSTIG, Scheduling the national football league with constraint programming
306/32 p.140	**Surrogate modelling for engineering optimization II**, *organizer/chair*: Kaj Madsen — NONLINEAR PROGRAMMING	HANS BRUUN NIELSEN, Surrogate modelling by Kriging	RODRIGUE OEUVRAY, A derivative-free algorithm based on radial basis functions (RBF)	DICK DEN HERTOG, Gradient estimation using Lagrange interpolation polynomials
306/33 p.141	**PDE-constrained optimization (3)**, *organizers*: Michael Ulbrich and Stefan Ulbrich, *chair*: Stefan Ulbrich — NONLINEAR PROGRAMMING	MICHAEL HINZE, A generalized discretization concept for control constrained optimal control problems and its numerical realization	ROLAND BECKER, Adaptive finite elements for control of convection-diffusion equation	CHRISTIAN ZILLOBER, Very large scale nonlinear programming by scp methods
306/34 p.142	**Large scale problems III**, *chair*: Ernesto G. Birgin — NONLINEAR PROGRAMMING	GIOVANNI FASANO, Issues on conjugate gradient-type algorithms within truncated Newton methods, in large scale unconstrained optimization	MARIA HELENA CAUTIERO HORTA JARDIM, An $o(n^2 \log n)$ algorithm for projecting a vector on the intersection of two hyperplanes and a box in r^n	ERNESTO G. BIRGIN, Inexact spectral projected gradient methods on convex sets
306/35 p.142	**Newton-like algorithms II**, *chair*: Mehiddin Al-Baali — NONLINEAR PROGRAMMING	HONGCHAO ZHANG, A nonmonotone line search technique and its application to unconstrained optimization	JEAN-PIERRE DUSSAULT, High order Newton-penalty algorithms	MEHIDDIN AL-BAALI, Quasi-Wolfe conditions for Newton-like methods
306/36 p.143	**Nonsmooth optimization**, *chair*: Robert Mifflin — NONSMOOTH OPTIMIZATION	ADIL BAGIROV, Max-min separability and its applications	MATTHIAS KNOBLOCH, Large-scale Lagrangian decomposition problems solved by cutting plane methods	ROBERT MIFFLIN, Properties of functions with primal-dual gradient structure
306/37 p.143	**Geometry and duality in convex optimization**, *organizer/chair*: Gabor Pataki — CONVEX PROGRAMMING	SHUZHONG ZHANG, The D-induced duality and its applications	JAVIER PENA, On the block-structured distance to infeasibility	GABOR PATAKI, Bad semidefinite systems: they look all the same
306/38 p.144	**Global optimization techniques via reformulations, smoothing approaches and DC programming**, *organizer/chair*: Tao Pham Dinh — GLOBAL OPTIMIZATION	HOAI AN LE THI, A difference of convex functions programming approach to image restoration via Markov model	TAO PHAM DINH, DC programming and DCA approaches to variational inequality problems	JIANMING SHI, D.C. and smooth optimization methods for solving minimum maximal network flow problem
308/11 p.144	**Generalized convexity VI**, *organizer*: Laura Martein, *chair*: Matteo Rocca — GENERALIZED CONVEXITY/MONOTONICITY	MARIELLA ROMANIELLO, On a dual method for quasi-variational inequalities	MATTEO ROCCA, Minty variational inequalities and vector optimization	GIOVANNI PAOLO CRESPI, Minty variational inequalities and well-posedness in scalar optimization
308/12 p.145	**Scenario tree generation**, *organizer*: COSP (David Morton), *chair*: David Morton — STOCHASTIC PROGRAMMING	DAVID MORTON, Monte Carlo scenario tree generation for stochastic programming	STEIN W. WALLACE, Scenario generation in stochastic programming - what can we reasonably ask for?	MATTHIAS PETER NOWAK, Generating scenario trees for multidimensional stochastic processes
308/13 p.145	**Complexity in semi-infinite programming**, *chair*: Klaus Meer — SEMI-INFINITE AND INFINITE DIMENSIONAL PROGRAMMING	MARCO A. LÓPEZ-CERDÁ, Distance to ill-posedness for linear semi-infinite inequality systems: applications to lipschitzian analysis	OLIVER STEIN, An outer approximation method for general semi-infinite programming without discretization	KLAUS MEER, On the complexity of some problems in interval arithmetic
308/T1 p.146	**Linear programming approaches to dynamic and stochastic optimization**, *organizer/chair*: Jose Nino-Mora — DYNAMIC PROGRAMMING AND OPTIMAL CONTROL	LODEWIJK KALLENBERG, (Parametric) linear programming for Markovian control problems	MARC UETZ, Scheduling jobs with uncertain processing times on parallel machines	JOSE NINO-MORA, Dynamic allocation indices for restless projects and queueing admission control: a polyhedral approach
308/T2 p.147	**Linear complementarity problems**, *chair*: Vitalij Zhadan — COMPLEMENTARITY AND VARIATIONAL INEQUALITIES	SIMON SCHURR, On polyhedral games, linear complementarity problems, and interior point methods	DEFENG SUN, Nonsmooth matrix valued functions defined by singular values	VITALIJ ZHADAN, Finite Newton's methods for LP and LCP
308/T3 p.147	**Optimization problems in wireless telecommunications**, *organizer/chair*: Federico Malucelli — TELECOMMUNICATION NETWORK DESIGN	PETER VÄRBRAND, Optimization of pilot power in 3G mobile networks	DI YUAN, Scheduling of spatial time division multiple access in multi-hop radio networks	FEDERICO MALUCELLI, Planning of a wireless LAN
341/21 p.148	**Advances in interior point methods**, *organizer/chair*: Tamas Terlaky — INTERIOR POINT ALGORITHMS	MASAKAZU KOJIMA, Exploiting sparsity in sum of squares of polynomials	JIMING PENG, Hybrid primal-dual interior-point methods based on self-regular functions	GORAN LESAJA, Introducing interior-point methods into the first operations research course
341/22 p.148	**Supply chain optimization**, *chair*: Huifu Xu — LOGISTICS AND TRANSPORTATION	DAVID BREDSTRÖM, Ship routing and scheduling in the pulp mill industry	CHIA-SHIN CHUNG, Inventory placement problem for a serial supply chain with the satisficing objective	HUIFU XU, Optimal supply functions in electricity markets with piecewise continuously differentiable profit functions
341/23 p.149	**Approximation algorithms for scheduling problems**, *chair*: David Shmoys — APPROXIMATION ALGORITHMS	VITALY STRUSEVICH, Approximation schemes for the open shop scheduling problem with non-availability constraints	FLAVIO KEIDI MIYAZAWA, Computational experience on approximation algorithms for scheduling unrelated machines	DAVID SHMOYS, Approximation algorithms for the joint replenishment problem
321/053 p.149	**Industrial scheduling problems**, *chair*: Johannes Hatzl — PRODUCTION AND SCHEDULING	JENS BUCHHOLZ, Optimal machine scheduling in a shipyard	JESPER HANSEN, Industrialising the application of mathematical models and methods	JOHANNES HATZL, Makespan minimization for chemical batch processes
321/033 p.150	**Scalarized functions and functionals in multicriteria optimization**, *chair*: Christiane Tammer — MULTICRITERIA OPTIMIZATION	PETRA WEIDNER, A method for calculating tradeoffs in multicriteria optimization	MATTHIAS EHRGOTT, Scalarizations in multiobjective combinatorial optimization	CHRISTIANE TAMMER, A new density result in multicriteria optimization
321/133 p.150	**Numerical approaches II**, *chair*: Karl Heinz Borgwardt — LINEAR PROGRAMMING	WILLIAM HAGER, A sparse implementation of the LP dual active set algorithm	ISTVAN MAROS, An enhanced piecewise linear dual phase-1 algorithm for the simplex method	KARL HEINZ BORGWARDT, Average-case-behaviour of three convex-hull-algorithms under rotation-symmetry

Parallel Sessions: Friday 9:00 – 10:30 (FR1)

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302/41 p.152	**Packing, partitioning and trees**, *chair*: Michal Penn	COMBINATORIAL OPTIMIZATION	GUNTRAM SCHEITHAUER, Phi-functions for complex 2d-objects	MIHALY CSABA MARKOT, The densest packings of 28, 29 and 30 congruent circles in the unit square - a reliable optimality proof	MICHAL PENN, An approximation algorithm for the group Steiner network problem
302/42 p.152	**Combinatorial optimization X**, *chair*: Bjarne Toft	COMBINATORIAL OPTIMIZATION	ALEXANDRE LAUGIER, K-edge-connected graphs and positive semidefiniteness	LEONIDAS PITSOULIS, Bounds for greedy type algorithms for the k-dimensional assignment problem	BJARNE TOFT, Scheduling without waiting periods
302/44 p.152	**Maximum feasible subsystem problem**, *organizer/chair*: Edoardo Amaldi	COMBINATORIAL OPTIMIZATION	MARC PFETSCH, The maximum feasible subsystem problem and related polyhedra	RAPHAEL HAUSER, Generalized boundedness of the relaxation method with an explicit bound in terms of a condition number	EDOARDO AMALDI, Randomized relaxation methods for the maximum feasible subsystem problem
302/45 p.153	**Improved algorithms for mixed-integer programming**, *organizer/chair*: John W. Chinneck	INTEGER AND MIXED INTEGER PROGRAMMING	JONATHAN ECKSTEIN, Pivot, cut, and dive: a class of heuristics for general MIP	EMILIE DANNA, Exploring relaxation induced neighborhoods to improve MIP solutions	JOHN W. CHINNECK, Faster MIP solutions through better variable ordering
302/49 p.154	**Integer programming**, *organizer/chair*: Ismael de Farias	INTEGER AND MIXED INTEGER PROGRAMMING	ISMAEL DE FARIAS, Semi-continuous cuts for mixed-integer programming	ALPER ATAMTURK, A polyhedral approach to robust integer programming	KENT HØJ ANDERSEN, Improving the performance of mixed integer Gomory cuts
306/31 p.154	**Hybrid methods**, *organizer/chair*: John Hooker	CONSTRAINT LOGIC PROGRAMMING	DIMITRIS MAGOS, Constraint and integer programming for the orthogonal latin squares problem	JOHN HOOKER, A relaxation of the cumulative constraint for resource-constrained scheduling	
306/32 p.154	**Surrogate modelling for engineering optimization III**, *organizer/chair*: Kaj Madsen	NONLINEAR PROGRAMMING	KAJ MADSEN, Motivations and applications of the space mapping technique	JOHN BANDLER, Space mapping: engineering modeling and optimization exploiting surrogates	FRANK PEDERSEN, Space mapping optimization using interpolating surrogates
306/33 p.155	**Semidefinite problems**, *chair*: Joachim Dahl	NONLINEAR PROGRAMMING	HECTOR RAMIREZ CABRERA, A global algorithm for nonlinear semidefinite programming	MALICK JEROME, Covariance matrices calibration via semidefinite least-squares	JOACHIM DAHL, Gabor frames with optimal time and frequency localization
306/34 p.155	**Large scale problems IV**, *chair*: Gerardo Toraldo	NONLINEAR PROGRAMMING	MICHAEL STINGL, PENNON - a code for large-scale nonconvex npl and SDP: algorithm, theory, numerial results	JOAO-LAURO FACO´, A parallel NPL code for optimal control problems with bounded states	GERARDO TORALDO, An hybrid algorithm for large-scale quadratic programs
306/35 p.156	**Semidefinite programming and nonnegative polynomials**, *organizer/chair*: Etienne de Klerk	NONLINEAR PROGRAMMING	DMITRII V. PASECHNIK, Optimization subject to a fixed number of quadratic constraints in polytime	YVAN HACHEZ, On the rank-reducibility of barrier functions	PABLO PARRILO, Sum of squares decompositions for structured polynomials
306/36 p.157	**Nonsmooth optimization II**, *chair*: José Herskovits	NONSMOOTH OPTIMIZATION	HRISTO SENDOV, Twice differentiable spectral functions	DOMINIQUE AZÉ, Characterization of error bounds for lower semicontinuous functions	JOSÉ HERSKOVITS, A new feasible directions algorithm for nonsmooth convex optimization
306/37 p.157	**Large-scale semidefinite programming**, *organizer/chair*: Madhu Nayakkankuppam	CONVEX PROGRAMMING	KIM-CHUAN TOH, Solving large scale semidefinite programming via Krylov subspace methods	CHRISTOPH HELMBERG, A conic bundle approach to linear programming over symmetric cones	MADHU NAYAKKANKUPPAM, Solving large-scale SDP's in parallel
306/38 p.158	**Quadratic optimization**, *chair*: Andreas Brieden	GLOBAL OPTIMIZATION	JOHANNES J. DE NIJS, Solving nonconvex quadratic programming problems with simple bound constraints	CLAUDIO SODINI, A solution algorithm for a class of box constrained quadratic programming problem	ANDREAS BRIEDEN, Clustering in agriculture by means of quadratic optimization
308/11 p.158	**Generalized convexity/monotonicity**, *chair*: Evgeny G. Gol'shtein	GENERALIZED CONVEXITY/MONOTONICITY	ORIZON FERREIRA, Convex- and monotone-transformable mathematical programming problems and a proximal-like point method	SUSANA SCHEIMBERG, A projection-type method with variational metric for solving a general variational inequality problem	EVGENY G. GOL'SHTEIN, A method for solving monotone variational inequalities
308/12 p.159	**Sensitivity and stability**, *chair*: Alexey Izmailov	STOCHASTIC PROGRAMMING	VLADIMIR NORKIN, Nonparametric kernel estimation via nonstationary stochastic optimization	ARAM ARUTYUNOV, Stability theory for systems of ineaqualities at abnormal points	ALEXEY IZMAILOV, Sensitivity analysis for abnormal optimization problems
308/13 p.159	**Semi-infinite and infinite dimensional programming**, *chair*: Tatyana Stepanchuk	SEMI-INFINITE AND INFINITE DIMENSIONAL PROGRAMMING	RADHIA BESSI, The obstacle problem for water tanks	TATYANA STEPANCHUK, Solution of the optimal set partitioning problem as problem of minimization the sets function	
308/T1 p.159	**Large-scale dynamic programming - algorithms and approximation**, *organizer/chair*: Marina Epelman	DYNAMIC PROGRAMMING AND OPTIMAL CONTROL	IRWIN SCHOCHETMAN, Efficient average-cost optima for infinite horizon optimization	MATTHEW BAILEY, Solution acceleration through nested aggregation	MARINA EPELMAN, Aggregation in stochastic dynamic programming
308/T2 p.160	**Nonlinear complementarity problems**, *chair*: Natasa Krejic	COMPLEMENTARITY AND VARIATIONAL INEQUALITIES	JOAO PATRICIO, An investigation of a nonlinear obstacle plate optimization problem	SANDRA AUGUSTA SANTOS, Mixed nonlinear complementarity problems via nonlinear optimization: numerical results on multi-rigid-body contact problems with Coulomb friction	NATASA KREJIC, On a quasi-Newton method for complementarity problems
308/T3 p.160	**Models and simulations for planning and control of UMTS (momentum)**, *organizer/chair*: Arie M.C.A. Koster	TELECOMMUNICATION NETWORK DESIGN	ANDREAS EISENBLÄTTER, Challenges in UMTS radio network planning	ROLAND WESSÄLY, Models for UMTS radio network planning	ALEXANDER MARTIN, Optimisation methods for UMTS radio network planning
341/21 p.161	**Second-order cone optimization and extensions**, *organizer/chair*: Erling Andersen	INTERIOR POINT ALGORITHMS	DON GOLDFARB, The simplex method for semidefinite and second-order cone programming	FRANÇOIS GLINEUR, Second-order cone optimization with a single second-order cone	JEROME O'NEAL, Uniform boundedness of a preconditioned normal matrix used in interior point methods
341/22 p.161	**Logistics and transportation**, *chair*: Maria Daneva	LOGISTICS AND TRANSPORTATION	KIN KEUNG LAI, A robust optimization model for empty container allocations	MARIA DANEVA, Conjugate direction Frank-Wolfe methods with applications to the traffic assignment problem	
341/23 p.162	**Priority algorithms: models and approximation bounds for greedy-like algorithms**, *organizer/chair*: Joan Boyar	APPROXIMATION ALGORITHMS	ALLAN BORODIN, What is a greedy (approximation) algorithm	RUSSELL IMPAGLIAZZO, Models of greedy algorithms for graph problems	KIM S. LARSEN, Restricted models for priority algorithms on graphs
321/053 p.163	**Scheduling with variable parameters**, *chair*: Mohamed Haouari	PRODUCTION AND SCHEDULING	NATALIA SHAKHLEVICH, Scheduling problems with controllable processing times and preemption	MING LIANG, Optimizing job sequening and tool replacement decisions	MOHAMED HAOUARI, Optimal parallel machines scheduling with availability constraints
321/033 p.163	**Efficiency analysis in multicriteria optimization II**, *chair*: Irina Pospelova	MULTICRITERIA OPTIMIZATION	CÉSAR GUTIÉRREZ, On a new concept of proper approximate Pareto efficiency	GIANCARLO BIGI, Second order optimality criteria in nonsmooth vector optimization	IRINA POSPELOVA, Existence conditions of game solution in multicriteria case
321/133 p.164	**Mathematical programming techniques in data envelopment analysis**, *organizer/chair*: Niels Christian Petersen	LINEAR PROGRAMMING	NIELS CHRISTIAN PETERSEN, A new algorithm for DEA	OLE BENT OLESEN, Identification and use of efficient faces and facets in DEA	TOR BELTOV, How to bootstrap DEA efficiency scores by using the slice model approach

Parallel Sessions: Abstracts

MO2-302/41 COMBINATORIAL OPTIMIZATION
Submodular functions and discrete convexity I
organizers: Satoru Fujishige and Kazuo Murota
chair: Satoru Fujishige

Conjugacy relationship between M-convex and L-convex functions in continuous variables

KAZUO MUROTA
University of Tokyo
coauthor: Akiyoshi Shioura
keywords: combinatorial optimization, convex function, matroid, submodular function

The main theme of Discrete Convex Analysis is to extract key combinatorial structures in well-solved nonlinear combinatorial optimization problems, and M-convex and L-convex functions play the primary roles. The concepts of M-convexity and L-convexity were originally introduced by Murota (1996,1998) for functions on the integer lattice. These concepts were extended recently to polyhedral convex functions and quadratic functions in continuous variables by Murota–Shioura (2000, 2001). To fully cover the well-solved nonlinear combinatorial optimization problems, it is desirable to further extend these concepts to more general convex functions. In this talk, we consider a further extension of M- and L-convexity to general convex functions, and show that the conjugacy relationship, under the Fenchel-Legendre transformation, between such M-convex and L-convex functions.

Minimization algorithms for M-convex functions

AKIYOSHI SHIOURA
Tohoku University
coauthor: Kazuo Murota
keywords: combinatorial optimization, convexity, minimization, matroid

In this talk, we consider the minimization of an M-convex function. It is a fundamental problem concerning M-convex functions, and various algorithms have been proposed so far. The local minimality implies the global minimality for M-convex functions. Therefore, a minimizer of an M-convex function can be found by a greedy algorithm, which may require exponential time. The first polynomial-time algorithm is proposed by Shioura (1998), where it is shown that a given vector can be efficiently separated from a minimizer of an M-convex function. Later, Moriguchi–Murota–Shioura (2002) showed a proximity theorem and proposed a scaling approach for M-convex function minimization, although the algorithm runs in polynomial time only for a restricted class of M-convex functions. The scaling approach of Moriguchi et al. was polished to a polynomial-time algorithm applicable to general M-convex functions by Tamura (2002). Recently, Shioura (2003) proposed two scaling-based simple and fast algorithms for the minimization of an M-convex function, both of which are fastest so far for M-convex function minimization. We survey this progress on the development of polynomial-time algorithms for M-convex function minimization.

Polyhedrally tight functions and convexity

HARIHAR NARAYANAN
EE Dept., IIT Bombay
keywords: submodular function, convexity, polyhedrally tight functions, separation theorem

A set function $f : 2^S \longrightarrow \Re$, is said to be **polyhedrally tight** (**dually polyhedrally tight**) iff in the set polyhedron (dual set polyhedron) denoted by P_f (P^f) defined by

$$x(X) \leq f(X) \forall X \subseteq S,$$

$$(x(X) \geq f(X) \forall X \subseteq S),$$

every inequality can be satisfied as an equality. The collection of all dual cones associated with the faces of $P_f(P^g)$ is denoted 'the dual cone structure of $f(g)$' and the corresponding sets of generators taken from the rows of the coefficient matrix of the defining inequalities is called 'the dual generator structure of $f(g)$'. We extend $f(g)$ to convex and concave functions on $\Re^S$ by

$$f_{cup}(c) \equiv max_{x \in P_f} c^T x$$

$$(g_{cap}(c) \equiv min_{x \in P^g} c^T x).$$

We then have

Theorem If f is polyhedrally tight, g is dually polyhedrally tight and $f \geq g$ and P_f and P^g have the same dual cone structure then $f_{cup} \geq g_{cap}$ and there exists a modular function h s.t. $f \geq h \geq g$. We give sufficient conditions on the dual generator structures of f, g in order that h is integral when f, g are integral.

Our results can be refined in terms of what may be called 'legal dual cone' and 'legal dual generator' structures.

MO2-302/42 COMBINATORIAL OPTIMIZATION
Discrete and continuous optimization in VLSI design
organizers: Bernhard Korte and Jens Vygen
chair: Jens Vygen

Slack balance algorithms

STEPHAN HELD
University of Bonn
keywords: combinatorial optimization, VLSI design, slack balancing

In the timing analysis of VLSI chips slacks are defined as the differences between required and real arrival times. They act as indicators for the timing-criticality of a chip.

Slack balance problems are a generalization of the minimum ratio cycle problem. We want to show how slack balance algorithms on digraphs can be used in VLSI-design optimization. The slack balance problem is defined as follows:

We are given a directed graph G with arbitrary arc-costs and nonnegative arc-parameters. G must not have negative cost cycles without positive parameters. For any node potential the parameterized slack for an arc with positiv parameter is defined as the ratio between the reduced costs and the arc parameter. We want to find a node potential such that the vector of these slacks is lexicographically maximum after sorting in nondecreasing order.

The special case that all parameters are either 0 or 1 is already known from clock schedule optimization.

In this talk we focus on the general case and its applications. Fast Algorithms for the special case can be applied to the general case losing the strongly polynomial running time. We show how Megiddos concept of optimizing rational objective functions can be applied to achieve strongly polynomial running times.

Matrix decompositions and iterative solutions of very large quadratic programs

MARKUS STRUZYNA
University of Bonn

keywords: quadratic programming, VLSI design, iterative methods

Iterative methods like steepest descent and conjugate gradients have been used for decades for solving large sparse linear equations systems and quadratic programs, often using various preconditioning strategies as incomplete Cholesky decomposition.

We consider geometric quadratic programs arising in VLSI placement, with symmetric and positive definite matrices. For these instances we present an efficient strategy to subdivide extremely large matrices and reduce the number of nonzero entries. This technique allows very fast approximative solutions – for example instances with 2.5 million variables and over 7 million non-zero entries can be solved in less than a minute. This subdivision strategy permits even parallel implementation: the matrix is decomposed into several diagonal blocks which can be computed simultaneously and independently to obtain further speed-up.

Gate and wire sizing using Lagrangian relaxation

CHRISTIAN SZEGEDY
Institue for Discrete Mathematics, University Bonn

keywords: convexity, relaxation, computer aided design

The goal of gate and wire sizing in VLSI design is to determine sizes for the transistors and wires of a chip subject to timing constraints. Convex optimization via the subgradient method and Lagrangian duality turned out to be an extremely efficient method to solve this problem optimally. In this talk, we are going to present an overview of this method with emphasis on practical tricks that allow for finding optimal solutions for large scale instances with millions of variables very quickly.

MO2-302/44 COMBINATORIAL OPTIMIZATION
Combinatorial optimization I
chair: Bill Cunningham

Polyhedral investigations of stable multi-sets

ADRIAN ZYMOLKA
Konrad-Zuse-Zentrum fuer Informationstechnik Berlin (ZIB)
coauthor: Arie M.C.A. Koster

keywords: combinatorics, cutting plane/facet, networks/graphs

Stable multi-sets represent a generalization of the well-known stable sets. A stable multi-set is an assignment of integers to the vertices of a graph such that specified bounds on vertices and edges are not exceeded. Stable sets are the special case in which all these bounds equal one.

For the stable multi-set polytope, several valid and facet-defining inequalities are known. In this talk, we report on further polyhedral investigations. We present a characterization of the extreme points of the linear relaxation polytope. For the so-called odd-valued odd cycle inequalities we specify conditions under which they define facets. Moreover, a polynomial time algorithm for their separation is derived. Finally, we discuss the results of computational experiments.

Solving stable set problems on superclasses of interval graphs

GIANPAOLO ORIOLO
Universita' Tor Vergata
coauthors: Carlo Mannino, Federico Ricci

keywords: interval graphs, independent sets, boxicity of a graph, frequency assignment

We introduce a graph invariant, called thinness, and show that a maximum weighted stable set on a graph $G(V,E)$ with thinness k may be found in $O(\frac{|V|}{k})^k$-time by dynamic programming, when a certain representation is given. A graph has thinness 1 if and only if it is an interval graph.

We investigate some properties of the thinness. We show that a graph with thinness k is the intersection graph of k-dimensional boxes and discuss connections with some superclasses of interval graphs.

We discuss two applications where these results naturally apply: the frequency assignment problem (fap) in GSM networks and the single machine scheduling problem. We show that an efficient search in exponential neighbourhoods for the (fap) may be done in polynomial time by our dynamic programming algorithm. This led us to improving the best known solutions for several benchmark instances of a relevant testbed.

The polytope of even permutations

BILL CUNNINGHAM
University of Waterloo
coauthor: Yaoguang Wang

keywords: polyhedra, facets, graphs, permutations

If we consider a permutation on a set V of n elements, as a subset of $V \times V$, then the convex hull of all permutations is nicely described by the well-known theorem of Birkhoff. Many years ago Alan Hoffman asked what could be said about the convex hull of even permutations. We describe classes of facet inducing inequalities for this polytope, proving a conjecture of Brualdi and Liu that it cannot be described as the solution set of polynomially many linear inequalities. We also consider the difficulty of the membership problem for the polytope, the subject of a second conjecture of Brualdi and Liu.

MO2-302/45 COMBINATORIAL OPTIMIZATION
Branch-and-cut approaches
chair: Serigne Gueye

Polyhedral results and a branch-and-cut algorithm for project scheduling with variable intensity activities

TAMAS KIS
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keywords: project scheduling, resource constraints, integer programming, cutting planes

We consider a project scheduling problem in which the total resource requirements of the activities are known in advance, but the intensity of each activity, and proportionally its current resource usage may be varied over time. Each activity has a time window and may require several resources. Activities are partially ordered by a precedence relation. The resources are renewable, continuously divisible, and have finite capacities. Each resource has a limit above which its utilization incurs a cost. One has to determine the intensity of the activities over time while respecting all constraints and minimizing the total cost.

We have shown that the above problem is NP-hard in the strong sense. Having formalized as a mixed integer-linear program, we solved it by a branch-and-cut algorithm using the polyhedral results obtained. In fact, a relaxation of MIP led to studying the following polytope $P = \operatorname{conv}(\{(x,z) \in \mathbb{R}^n \times \{0,1\}^q \mid \sum_{j=1}^n x_j = 1,\ 0 \leqslant x_j \leqslant a z_j, j = 1,\ldots,q,\ 0 \leqslant x_j \leqslant a, j = q+1,\ldots,n,\ z_j \leqslant z_{j+1}, j = 1,\ldots,q-1\})$. We have obtained a complete description of P in terms of facet defining inequalities by analyzing the cuts of a capacitated network. We have also designed an efficient separation algorithm based on the matroid greedy algorithm. Computational results show that our problem formulation and the generated cuts are really effective in solving even large size instances with hundreds of activities.

A branch-and-cut system for capacitated network design

GEORG KLIEWER
University of Paderborn

coauthor: Larissa Timajev
keywords: network design, variable fixing, branch-and-cut, transportation

We present a Lagrangian relaxation based branch-and-bound system for the capacitated network design problem. We use subgradient optimisation or bundle methods for the computation of lower bounds and compare their performance in the context of branch-and-bound. Several variable fixing strategies (exact and heuristic) are used to reduce the algorithm running time. Furthermore we use problem specific cuts and extend the branch-and-bound algorithm to a branch-and-cut algorithm. The performance of the implemented system components is compared and evaluated on a large set of benchmark instances.

A branch-and-cut algorithm for the graph bipartitioning problem

SERIGNE GUEYE
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coauthor: Philippe Michelon
keywords: branch-and-cut, linearization, quadratic programming, polyhedral techniques

In order to find exact solution of the graph bipartitioning problem, some branch-and-bound schemes, for which the lower bound are derived with a linear programming approach, may be used. Unfortunately, the linear formulation, corresponding to the lower bound, usually involves a huge number of variables and constraints, making the resolution very difficult. To solve the problem, we propose a branch-and-cut, based on an "economical" linear model, involving less variables than a "classical" linearization of the problem. Numerical results are presented.

MO2-302/49 INTEGER AND MIXED INTEGER PROGRAMMING

Integer programming column generation I

organizer/chair: Marco Lübbecke

Stabilized column generation for set partitioning

MIKKEL MÜHLDORFF SIGURD
Dept. of Computer Science, University of Copenhagen

coauthor: David M. Ryan
keywords: column generation, set partitioning

When applying the column generation method, one often experiences a seemingly random behaviour of the dual variables of the master problem. The dual values may assume extremely large (positive or negative) values and may change radically from one iteration to the next. This behaviour is often observed in the beginning of the column generation process and it reflects the poor information content of columns currently in the LP basis. Since new columns are generated based on the value of the dual variables, this behaviour causes further strange columns to be generated.

We present a simple method of stabilizing the column generation method which overcomes the randomness behaviour of the dual variables. Our method is a special case of the stabilization method proposed by du Merle et al. [1]. In considering stabilization in the context of set partitioning or set covering we show that our method reduces the number of simplex iterations and number of columns generated by a factor 10. Furthermore, we show that the stabilization method eliminates the need for hot starting the column generation with a good feasible solution.

[1] Olivier du Merle, Daniel Villeneuve, Jacques Desrosiers, Pierre Hansen: "Stabilized Column Generation", Disc. Math. 194:229-237, 1999.

Integer program reformulation for robust branch-and-cut-and-price

EDUARDO UCHOA
Universidade Federal Fluminense

coauthor: Marcus Poggi de Aragão
keywords: integer programming, column generation, cutting planes

Since cut and column generation were established as two of the most important techniques in integer programming, researchers have looked for ways of combining them into a robust branch-and-cut-and-price algorithm. Here, "robust" means that neither branching nor the addition of cuts should change the structure of the pricing subproblems. In the last few years, several researchers independently noted that cuts expressed in terms of variables from a suitable original formulation could be added to the master problem without disturbing the pricing. This fact is still little known outside the "column generation community" and its consequences on integer programming are just beginning to be explored. This work intends to be a detailed analysis of how to reformulate an integer program in order to build an efficient robust branch-and-cut-and-price. In particular, we propose an alternative master problem that can be quite advantageous in some situations. Another key issue addressed is how to avoid the pitfalls that arise from variable symmetries in the original formulations of many problems. We present extensive computational experiments on the capacitated minimum spanning tree, capacitated vehicle routing, and generalized assignment problems. Remarkable results on benchmark instances from the literature clearly attest the power of combining cut and column generation.

Automated Dantzig-Wolfe reformulation or how to exploit simultaneaously original formulation and column generation re-formulation

FRANCOIS VANDERBECK
MAB, Universite Bordeaux 1

keywords: Lagrangian relaxation, Dantzig-Wolfe decomposition, branch-and-price

A compact model representing a decomposable mixed integer program is introduced. From this representation, a computer code can generate automatically the column generation formulation of the problem as well as the formulation in its original variables (sometimes refered to as the compact formulation). The pricing sub-problem formulations can also be generated if one choose to use a MIP-solver as oracle. The Lagrangian dual formulation is readily available in case one wants to solve the master problem using a dual cutting plane approach such as accpm or the bundle method, or even a sub-gradient algorithm.

Based on this framework, we have developped a generic branch-and-price code, named BaPCod, where the user input is limited to the problem representation in terms of its original variables and constraints, with no need to specify the form of the master columns, their reduced cost and the like. Moreover, the link between the different formulations of the problem (in particular between the formulation in the original variables and its column generation counterpart) is exploited to allow an intelligent initialisation of the master program, to get stronger dual bound through preprocessing and variable fixing, to implement primal heuristics, and to recognise

or enforce integrality through branching.

MO2-306/31 INTEGER AND MIXED INTEGER PROGRAMMING

Integer programming

organizer/chair: Gabor Pataki

Min-up/min-down polytopes

JANNY LEUNG
The Chinese University of Hong Kong

coauthors: Jon Lee, Francois Margot
keywords: mixed integer programming, cutting planes, facets, power generation

In power generation and other production settings, technological constraints force restrictions on the number of time-periods that a machine must stay on once activated, and stay off once deactivated. We characterize the polyhedral structure of a model representing these restrictions. We also describe a cutting-plane method for solving integer programs involving such min-up and min-down times for machines. Finally, we demonstrate how the polytope of our study generalises the well-known cross polytope (.i.e generalised octahedron).

Subset-algebra lift operators for 0/1 integer programming

DANIEL BIENSTOCK
Columbia University

coauthor: Mark Zuckerberg
keywords: integer programming, lift-and-project, Chvatal-Gomory cuts

We present a generalization of the Sherali-Adams, Lovasz-Schrijver, Balas-Ceria-Cornuejols and Lasserre operators, that lifts a 0/1 vector in n dimensions to one whose coordinates are indexed by a polynomial-size set of logical expressions on the initial n variables. The resulting relaxations are provable at least as strong as those cited above, and in several important cases, they are exponentially stronger. One of our results is that for any fixed tolerance ε, and any integer r, there is a polynomial-time relaxation of set-covering whose value is at least $(1-\varepsilon)$ times the value of the rank-r Chvatal-Gomory closure.

The complexity of branch-and-bound

BALA KRISHNAMOORTHY
University of North Carolina

coauthor: Gabor Pataki
keywords: branch-and-bound, basis reduction, correlated knapsack problems

We analyse the number of branch-and-bound nodes that are necessary to solve an IP feasibilty problem in terms of a condition number of the describing linear system. We propose a method to reduce this condition number, and give computational results on several classes of hard IPs. Notably, we solve strongly correlated knapsack problems with large coefficients, that are amenable neither to LP based algorithms without preconditioning, nor to dynamic programming methods.

MO2-306/32 NONLINEAR PROGRAMMING

Nonlinear programming

chair: Stanislav Zakovic

Applying a mixed variable filter pattern search algorithm to thermal insulation system design

MARK ABRAMSON
Air Force Institute of Technology

coauthors: Charles Audet, John Dennis
keywords: nonlinear programming, categorical variables, pattern search, filter ods

This presentation describes the optimization of a load-bearing thermal insulation system. The optimization problem is represented as a mixed variable programming (MVP) problem with nonlinear constraints, in which the objective is to minimize the power required to maintain one surface sufficiently cold. MVP problems are more general than mixed integer nonlinear programming (MINLP) problems in that the discrete variables are categorical; i.e., they must always take on values from a predefined enumerable set or list. Thus, traditional approaches that use branch and bound techniques cannot be applied.

The mixed variable generalized pattern search (GPS)algorithm of Audet and Dennis is extended to handle nonlinear constraints by incorporating a filter. Nonlinear constraints on stress, mass, and thermal contraction are included to generate a more realistic feasible design. Several computational experiments show substantial improvement in power required to maintain the system, as compared to the previous literature. The addition of the new constraints leads to a very different design without significantly changing the power required. The results strate that the new algorithm can be applied to a very broad class of optimization problems, for which no previous algorithm with provable convergence results could be applied.

Numerical stability of path tracing in polyhedral homotopy continuation methods

SUNYOUNG KIM
Ewha W. University

coauthor: Masakazu Kojima
keywords: polynomial system, polyhedral homotopy cont., path tracing

The reliability of polyhedral homotopy continuation methods for solving a polynomial system becomes increasingly important as the dimension of the polynomial system increases. High powers of the homotopy continuation parameter t and ill-conditioned Jacobian matrices encountered in tracing of homotopy paths affect the numerical stability. We present modified homotopy functions with a new homotopy continuation parameter s and various scaling strategies to enhance the numerical stability. Advantages of employing the new homotopy parameter s are discussed. Numerical results are included to illustrate improved performance of the presented techniques.

An interior point algorithm for worst-case optimisation

STANISLAV ZAKOVIC
Imperial College

coauthor: Berc Rustem
keywords: minimax problems, multiple maxima

In this paper an algorithm for the continuous minimax problem with constraints is considered. The algorithm uses quasi–Newton search direction, conditional on approximate maximisers. The initial problem is transformed to an equivalent equality constrained problem, where the logarithmic barrier function is used to ensure feasibility. Satisfaction of the equality constraints is enforced through incorporating an adoptive quadratic penalty function into the objective. Computational results are included which illustrate the efficient performance of the algorithm

MO2-306/33 NONLINEAR PROGRAMMING

Nonlinear systems

chair: Per Åke Wedin

A new class of robust methods to solve noisy systems of nonlinear equations

MICHEL BIERLAIRE
EPFL

coauthor: Frank Crittin
keywords: nonlinear equations, noisy problems, fixed point

Many problems arising in physics, transportations or economics are formulated as the search of a fixed-point, or equivalently as the resolution of a system of nonlinear equations. Unfortunately, in many practical applications, the presence of noise in the evaluation of the function prevents from using standard algorithms. Classical secant Newton methods, as the Broyden method, are disrupted by the noise since they try to interpolate the last two iterates. Classical inexact Newton methods are useless since they rely on finite differences.

In this talk we present a new class of methods building a linear model using a population of previous iterates in order to implicitly smooth the objective function. We propose a least-square approach with an explicit control of the numerical stability.

One instance of this class of methods produces a generalization of the Broyden method. In that case, we proof the local convergence of the corresponding quasi-Newton method. We first validate the method on noise-free problems. It exhibits a robust behavior compared to standard methods. We then present numerical evidence of the efficiency of our new class of methods in presence of noisy nonlinear system of equations.

Conjugate sets for a nonlinear programming problem

HIDEFUMI KAWASAKI
Graduate school of mathematics, Kyushu University

keywords: conjugate sets

The conjugate point is a global concept in the calculus of variations. In variational problems, the variable is not a vector in R^n but a function. So, a simple and natural question arises. Is it possible to establish a conjugate points theory for a nonlinear programming problem: minimize $f(x)$ on $x \in R^n$? Recently, this problem was positively solved. In this talk, we introduce a conjugate set which is a generalization of the conjugate point for a nonlinear programming problem.

Primal and dual optimization problems in tikhonov regularization

PER ÅKE WEDIN
Department of Computing Science
coauthors: Jerry Eriksson, Thomas Viklands

keywords: primal-dual, regularization, ill-conditioning

In order to solve an ill-conditioned problem with numerical optimization there is a need to incorporate a special kind of constraints, here called regularizing constraints. We will consider the regularization of the finite dimensional nonlinear system of equations $f(x) = 0$. To simplify, let us here only consider least squares regularization. We introduce two formulations of the regularization problem. First, one corresponding to a constrained least squares problem

$$\frac{1}{2}\|f(x)\|^2 \quad s.t. \frac{1}{2}\|L(x-x_c\|^2 \qquad (1)$$

and the Tikhonov formulation

$$\frac{1}{2}\|f(x)\|^2 + \lambda\frac{1}{2}\|L(x-x_c\|^2 \qquad (2).$$

Δ and/or λ have to be varied to find a suitable solution of the regularization problem. The points $(\frac{1}{2}\|f(x)\|^2, \frac{1}{2}\|L(x-x_c\|^2)$ corresponding to solutions of (1) lie on the convex decreasing L-curve. Points $(\lambda, \frac{1}{2}\|f(x)\|^2, \frac{1}{2}\|L(x-x_c\|^2)$ corresponding to the dual problem (2) lie on a concave increasing curve. These two curves will be shown to be quite useful in practical computations. This is true even if we do not compute exact solutions of (1) and (2). It is also true if there exist several local minima of (1) and (2).

MO2-306/34 NONLINEAR PROGRAMMING
New trust region algorithms
organizer/chair: Jorge Nocedal

An active-set trust-region algorithm for nonlinear optimization

RICHARD WALTZ
Northwestern University
coauthors: Richard Byrd, Nick Gould, Jorge Nocedal

keywords: trust region, active set, SLP, nonlinear optimization

We will describe an implementation of a SLP-EQP algorithm for nonlinear optimization. This algorithm relies on the solution of linear programming and equality constrained subproblems which we believe makes this approach better able to solve large-scale problems compared with existing active-set methods. We will present numerical results to support this claim and discuss algorithmic advances. Particular focus will be paid to issues of warm-starts and approximate LP solutions for the subproblems.

A new algorithm for unconstrained minimization without derivatives

MICHAEL POWELL
University of Cambridge,

keywords: derivative free optimization

In trust region methods for unconstrained optimization, a typical new vector of variables is generated by minimizing an approximation to the objective function, subject to a bound on the distance from the best trial vector of variables so far. We let the approximation be quadratic as usual, which has (n+1)(n+2)/2 degrees of freedom, where n is the number of variables. For moderate n it is expensive, however, to take up all this freedom by interpolation to function values, which is done by several algorithms when derivatives are not available. Therefore, 16 months ago, the author began to investigate the use of only about 2n+1 interpolation conditions, which provides some information about curvature. The freedom in each new quadratic model is fixed by minimizing the Frobenius norm of the change to the second derivative matrix of the model, this technique being analogous to the symmetric Broyden formula when derivatives are available. Numerical experiments have provided good news and bad news. Recently, however, a matrix factorization has been found that halves the number of digits that are lost through cancellation, and also a positive semi-definiteness property is preserved automatically, but the factorization had not been tried in practice at the time of writing this abstract. An up-to-date account of the research will be presented.

A feasible trust-region algorithm for nonlinear optimization

STEPHEN WRIGHT
University of Wisconsin

keywords: nonlinear programming, trust region method, sequential quadratic progr.

A sequential quadratic programming algorithm for smooth constrained nonlinear optimization problems that maintains feasibility of all iterates with respect to the constraints will be described. Global and local convergence analysis will be discussed. The usefulness of the approach will be demonstrated by outlining an application to nonlinear model predictive control.

MO2-306/35 NONLINEAR PROGRAMMING
Recent developments in filter methods I
organizers: Michael Ulbrich, Stefan Ulbrich and Luís N. Vicente
chair: Michael Ulbrich

A filter pattern search method for non-smooth constrained optimization

CHARLES AUDET
École Polytechnique de Montréal - GERAD
coauthor: John Dennis
keywords: nonlinear programming, filter algorithm, pattern search, nonsmooth optimization

This talk will focus on defining and analyzing a filter pattern search method for general nonlinear programming without derivatives. Since it is a pattern search method, this method is highly dependent on the set of directions it is given to work with. Linear inequalities are treated by an adequate choice of directions, and nonlinear constraints are handled by a filter. We present a hierarchy of optimality results tied to local differentiability of the problem and to the set of directions used by the algorithm. The smoothness assumptions that we analyze vary from lower-semicontinuity, Lipschitz continuity up to strict and continuous differentiability.

Filter methods and NLP's with unbounded multipliers

DAVID SHANNO
Rutgers University
coauthors: Hande Benson, Arun Sen, Igor Griva, Robert J. Vanderbei
keywords: filter methods, unbounded multipliers, interior point method

The talk discusses using a filter method interior point code on problems with unbounded sets of Lagrange multipliers. Theoretical and computational results will be given demonstrating that constraint relaxation can lead to a very efficient algorithm. Implications for convergence theory of filter methods will be discussed.

On a primal-dual interior-point filter method for nonlinear programming

RENATA SILVA
Department of Mathematics - University of Coimbra
coauthors: Michael Ulbrich, Stefan Ulbrich, Luís N. Vicente
keywords: interior point method, primal-dual, filter, global convergence

In this talk, we present the primal-dual interior-point filter method for nonlinear programming developed by Ulbrich, Ulbrich, and Vicente (2000). The method is based on the application of the filter technique of Fletcher and Leyffer (1997) to the globalization of the primal-dual interior-point algorithm, avoiding the use of merit functions and the updating of penalty parameters.

The algorithm decomposes the primal-dual step obtained from the perturbed first-order necessary conditions into a normal and a tangential step, whose sizes are controlled by a trust-region type parameter. Each entry in the filter is a pair of coordinates: one resulting from feasibility and centrality, and associated with the normal step; the other resulting from optimality (complementarity and duality), and related with the tangential step. The method possesses global convergence to first-order critical points.

We present numerical results for large-scale problems and discuss extensions of the original algorithm and of its convergence theory.

MO2-306/36 NONSMOOTH OPTIMIZATION

Recent advances in nonsmooth optimization I

organizers: Jean-Louis Goffin and Jean-Philippe Vial
chair: Jean-Philippe Vial

Proximal ACCPM, a cutting plane method for column generation and Lagrangian relaxation: application to the p-median problem

JEAN-PHILIPPE VIAL
University of Geneva
coauthor: Olivier du Merle
keywords: Lagrangian relaxation, cutting plane methods, analytic center, proximal methods

Proximal ACCPM is a variant of the analytic center cutting plane method, in which a proximal term is added to the barrier function that defines the center. The present paper gives a detailed presentation of the method and of its implementation. Proximal ACCPM is used to solve the Lagrangian relaxation of the p-median problem on two sets of problem instances. Problems of the same collection are tentatively solved with the classical column generation scheme.

Smooth minimization of non-smooth functions

YURII NESTEROV
CORE/UCL
keywords: non smooth optimization, structural optimization, gradient methods, complexity

In this paper we propose a new approach for constructing efficient schemes for non-smooth convex optimization. It is based on a special smoothing technique, which can be applied to the functions with explicit max-structure. Our approach can be considered as an alternative to the black-box minimization. From the viewpoint of efficiency estimates, we manage to improve the traditional bounds on the number of iterations of the gradient schemes from $O\left(\frac{1}{\varepsilon^2}\right)$ to $O\left(\frac{1}{\varepsilon}\right)$, keeping basically the complexity of each iteration unchanged.

A bundle method for convex optimization: implementation and illustrations

CORALIE TRIADOU
CERMSEM (Paris 1) - Artelys
coauthors: Claude Lemaréchal, Jean Maeght, Arnaud Renaud
keywords: bundle methods, Lagrangian relaxation, combinatorial problems

We present the implementation of a bundle method, oriented toward Lagrangian relaxation of combinatorial problems.

Problems to be solved have a non-differentiable objective function, and bound constraints on the variables. The bundle method is a cutting-plane method, in which the deviation of the next iterate from the reference point is penalized by a quadratic term. The next iterate is given by a quadratic programm, ours is a two level one in order to take into account the bounds on the variables. A dynamic and a static management of the penalization's coefficient will be compared.

The presented tests belong to different categories : L1- and L2-norm minimization, Lagrangian relaxations of combinatorial problems, such as traveling salesman (Held & Karp) or p-median. We present results for our bundle method Artelys Dualis on these problems, outlining the peculiarity of each category.

MO2-306/37 CONVEX PROGRAMMING

Convex optimization methods

chair: Jean-Baptiste Hiriart-Urruty

Coupling general penalty schemes for convex programming with the steepest descent and the proximal point algorithm

MATIAS COURDURIER
University of Washington
coauthor: R. Cominetti
keywords: penalty methods

The standard approach in penalty methods is trying to trace the path generated by the solutions of penalized versions of the original problem. If the limit point of these penalized solutions solves the original convex program, then by tracing them we obtain a solution to the problem. This approach is useful because the penalized versions are easier to solve that the original constrained convex program, but we can be expending a lot of computational resources in trying to trace this penalized path. This might be unnecessary when there is a hole family of trajectories converging to the original optimal set. Maybe in that case we can attain convergence to a solution just by following the 'general direction' of this trajectories, by following the direction of the flow. In this paper we study how in the convex program case the dynamics raising from the coupling of the penalty scheme with the steepest descent method gives such a family of trajectories. And how by coupling the penalty schemes with an 'inexact proximal point' we attain convergence by following the general direction of the flow. In the linear program case we also study the convergence of some naturally associated dual variables to an optimal dual solution.

Conditions for boundedness and the existence results for quasi-convex programmes

Wieslawa Obuchowska
Chowan College

keywords: mathematics, convexity

We consider the problem of boundedness and the existence of an optimal solution to the constrained optimization problem. We present necessary and sufficient conditions for boundedness of a convex program where the objective function and the inequality constraints are either faithfully convex functions (satisfying some mild condition) or quasi-convex polynomials. The conditions are provided in the form of an algorithm, terminating after a finite number of iterations, the implementation of which requires the identification of implicit equalities in a homogeneous linear system. We also prove that the optimal solution set of the considered problem is nonempty, which generalizes attainability results proved very recently by other authors for quasi-convex quadratic objective function and convex quadratic constraints and for convex polynomial objective function and constraints. The latter results are on the other hand extensions of the well known Frank-Wolfe theorem for a quadratic objective function and linear constraints. Finally we show that our extension of the Frank-Wolfe theorem immediately implies continuity of the solution set defined by the considered system of (quasi-)convex inequalities.

Solving some matrix nearness problems via convex optimization

Jean-Baptiste Hiriart-Urruty
Paul Sabatier University
coauthors: Marcel Mongeau, Pawoumodom L. Takouda
keywords: convexity, matrices, algorithms

We intend solving the following problem : given a matrix, find its nearest matrix (in the usual Frobenius-Schur norm) in a convex set of matrices structured as the intersection of a closed convex cone with an affine subspace. Instances are: the set of doubly stochastic matrices, the set of correlation matrices, the so-called spectraplex,...Applications arise from: social choice theory (aggregation of preferences), risk management in portfolio optimization, eigenvalue optimization,... Among the algorithmic procedures we might thing of using(alternate projections, based on convex duality, fixed point approach, interior point methods), we focus aur attention on an adaptation of Boyle-Dykstra alternating projection algorithm. We report some numerical experiments (matrices of size up to some hundreds).

MO2-306/38 PARALLEL COMPUTING

Distributed solution of LP and MIP problems

chair: Richard Van Slyke

Towards a grid enabled branch-and-bound algorithm

Lucia Drummond
Fluminense Federal University
coauthors: Jose Viterbo, Clicia Stelling Castro, Eduardo Uchoa
keywords: distributed algorithms, load balance, branch-and-bound, fault tolerance

This work presents a distributed branch-and-bound algorithm to be run on a wide-area-network system provided with an infra-structure that allows to execute applications that require much computational power, the so-called Grid. These systems are usually composed of many heterogeneous computers connected in a hierarquical fashion (clusters of different institutions connected through low-speed links and processors of the same cluster connected via high-speed links). Components of this Grid can fail eventually.

Because of these characteristics we propose a distributed branch-and-bound algorithm that includes procedures of load balance and fault tolerance. Concerning the load balance problem, a distributed dynamic model was employed that favoured the balance among processors concentrated geografically. In order to treat the fault tolerance problem, checkpoint protocols that take advantage of the hierarquical structure of Grids are also been developed.

The procedures proposed are been applied on an already existing sequential branch-and-bound algorithm for the Steiner Problem in graphs. Excellent speed ups are obtained, allowing the resolution of a number of formerly open instances from the SteinLib library in reasonable times. The computational experiments are been run on a Grid with Globus-MPI.

Parallelization of a MIP solver in the PUBB2 framework

Yuji Shinano
Tokyo University of Agriculture and Technology
coauthors: Tetsuya Fujie, Yuusuke Kounoike
keywords: parallel algorithm, mixed integer programming, branch-and-bound, software framework

We introduce a simple method of parallelizing a MIP (Mixed Integer Programming) solver. This method is different from a standard implementation that constructs a parallel branch-and-cut algorithm from scratch (except using an LP solver). The MIP solver we use is ILOG-CPLEX MIP Optimizer (Version 8.0), which is one of the most efficient implementations of branch-and-cut algorithms. The parallelization of the solver is performed by using the software tool PUBB2 developed by the authors. We report a part of our computational experience using up to 24 processors. In addition, we point out some problems that should be resolved for a more efficient parallelization.

Distributed computing and the simplex method

Richard Van Slyke
Polytechnic University
coauthor: Gavriel Yarmish
keywords: simplex method, distributed computing

Several proposals for parallel and distributed implementations of the simplex method have been based on the standard, rather than the revised, simplex method. This is primarily because the standard method is "embarrassingly parallel" in the sense that it can be implemented with minimal communication between processors; this, in turn, allows substantial scalability even when the communication latency between processors is relatively high. On the other hand, it is well known that the revised simplex method is much more efficient least for serial processors solving problems which are sparse, and/or have high aspect ratio (ratio of columns to rows). However, highly scalable revised methods don't exist for using coarse grained, distributed processing.

We exam the tradeoff with the standard method between scalability and the inefficiency of not using the revised method, especially as a function of problem density. To this end we have programmed a new standard method which can easily be executed in a distributed environment. We present and validate performance models for this approach on "real life" and synthetic problems using our implementation.

MO2-308/11 AIRLINE OPTIMIZATION APPLICATIONS

Airline scheduling I

organizer/chair: Stefan Karisch

Robust airline crew pairing optimization

SERGEI CHEBALOV
University of Illinois at Urbana-Champaign
coauthor: Diego Klabjan
keywords: crew scheduling, airline operations research, optimization

Due to the flight disruptions in operations, the crew scheduling cost at the end of a month is substantially higher than the projected cost in planning. We present a model that yields more robust crew schedules in planning. Besides the objective of minimizing the cost, we introduce the objective of maximizing the number of crew that can be swapping in operations. We present a solution methodology for solving the resulting model. The produced crew schedules are evaluated with a simulation. Several possible extensions and directions will be discussed.

Solving crew augmented pairing problems using column generation

CURT HJORRING
Carmen Systems
keywords: personnel scheduling, crew pairing, airline

The basic crew pairing problem is a well known OR problem with direct application to airlines, and many published papers. However, there are a number of important variants to the pairing problem that are less studied. One of these is the pairing problem with crew augmentation, in which the number of crew to operate per flight is a decision variable.

The crew augmentation problem usually arises when planning pairings for long-haul flights. Depending on union and safety rules, an airline may be able to reduce rest times between flights by augmenting the crew, i.e. adding an extra crew member. Even though there are additional costs associated with the extra crew member, it may still be advantageous to operate with additional crew, due to the efficiency improvement from the reduced rest times.

The crew augmentation problem can be approximated using a two step approach that involves solving two basic crew pairing problems. A difficulty with that approach is to estimate the cost of the extra crew when solving the first basic problem. In this talk we introduce a one-shot approach that accurately models the crew augmentation problem, and compare that with the two step approach on real world problems.

Challenges in railway crew pairing

LENNART BENGTSSON
Carmen Systems
keywords: personnel scheduling, crew pairing, railway

Automatic crew planning system are nowadays standard within the airline industry, and they are also finding applications within some of the major European railway companies, such as Deutsche Bahn and Swedish Railways. This talk will focus on the crew pairing part of the crew planning process, in which one or two-day pairings are composed from the individual train legs.

Compared to the airline crew pairing problem, the railway network is very dense, with many short legs within a limited geographic region. In addition, the total number of legs per day often exceeds 10,000, whereas a large airline might operate in the order of 1,000 flights per day. These two factors make the railway crew pairing problem quite challenging to solve.

In the talk, I will present how Carmen Systems has approached some of the difficulties in the railway crew pairing problem. The case in study is Deutsche Bahn, one of the largest transportation companies worldwide.

MO2-308/12 STOCHASTIC PROGRAMMING

Applications of stochastic programming

organizer: COSP (Chefi Triki)
chair: Chefi Triki

FRC-S3, a fix-and-relax coordination scheme for stochastic sequencing and scheduling

LAUREANO F. ESCUDERO
Universidad Miguel Hernández
coauthors: M. F. Clement, Antonio Alonso, M. L. Gil, M. T. Ortuño
keywords: sequencing and scheduling, stochastic integer programming, fix and relax coordination

We present a framework for solving pure 0-1 programs for scheduling and sequencing problems with uncertainty in the objective function coefficients, the constraint matrix and the right-hand-side. Typical elements are: limited availability of the resources, multiperiod operations and precedence relationships. The stochasticity of the problem is due to the operations' execution cost and the resources' consumption by the operations and their availability along the time horizon. A multistage scenario analysis with a mixture of full and simple recourse is used. By considering a splitting variable mathematical representation of the Deterministic Equivalent Model, we present a heuristic approach the so-called Fix-and-Relax Coordination algorithmic framework to exploit the model's structure and, specifically, the non-anticipativity constraints for each scenario group in the stochastic model. We consider a given strategy for partitioning the 0-1 variables in clusters, such that the approach selectively explores the active nodes of the Branch-and-Fix (BF) tree for obtaining (hopefully) good solutions for each scenario related model. The algorithm uses the twin node family concept. It is designed for coordinating and reinforcing the node pruning, variables fixing and branching node and variable selection at each scenario related BF tree.

Weekly supply chain coordination with stochastic demand

MARTE FODSTAD
SINTEF
coauthors: Asgeir Tomasgard, Erik Høeg, Peter Schütz
keywords: supply chain optimization

In this paper we present supply chain optimisation models for the food industry. The focus of the decision support models is to maximize expected profit subject to uncertain demand and shortfall costs. This is done by co-ordination of production at a set of facilities and inventories in different regions and at different levels in the supply chain. The models describe decisions at the operational level at a weekly resolution with a two month horizon. We consider the situation with uncertain demand and present mathematical models based on stochastic linear programming. We describe how to generate scenarios based on quantile regression and present results from a pilot test at the Norwegian meat Co-operative.

Optimal capacity allocation in multi-auction electricity markets under uncertainty

CHEFI TRIKI
University of Lecce

keywords: competitive electricity market, bidding strategies, stochastic model

With deregulation any producer finds himself in front of the problem of choosing how to allocate the available capacity in order to maximize his profit. The multiplicity of auctions in electricity markets and the non trivial constraints imposed by technical and bidding rules make the problem of crucial applicability importance and difficult to model and solve. Further difficulties are represented by the dynamic and stochastic natures that characterize the decision process. Mathematical programming under uncertainty appears to be the most appropriate framework to capture all the aspects of this kind of problems.

The formulation proposed is basically a unit commitment based model that covers a multi-period time horizon. Uncertainty related to the clearing information is incorporated in the model explicitly by means of a set of scenarios incorporated in a multi-stage stochastic program. The recourse stages correspond to the different bidding moments referring to the same time period, and not, as traditionally assumed, the successive time periods referring to the same auction.

Under the assumption that the supplier is price-taking bidder, the resulting model is a multi-stage mixed-integer stochastic optimization. We verified the effectiveness of the generated bidding strategies by using Lingo.

MO2-308/13 STOCHASTIC PROGRAMMING

Stability in stochastic programming

chair: Rene Henrion

Response surface merthodology with stochastic constraints for expensive simulation

M. EBRU ANGUN
Tilburg University
coauthors: Gul Gurkan, Dick den Hertog, Jack P. C. Kleijnen
keywords: simulation based optimization, stochastic constraints, metaheuristics, expensive simulation

In this presentation, we investigate simulation-based optimization problems with a stochastic objective function and stochastic constraints, as well as deterministic box constraints. More specifically, we generalize Response Surface Methodology (RSM) to account for stochastic constraints. This extension is obtained through the generalization of the estimated steepest descent - used in conventional RSM - using ideas from interior point methods, especially affine scaling. The new search direction is scale independent. This is especially important from the practitioners' point of view, since it avoids some numerical complications and problems commonly encountered. Furthermore, we provide a heuristic that uses this search direction iteratively. The heuristic is primarily intended for simulation-based optimization problems in which each simulation run is very expensive and the simulation budget is limited, so that one needs to reach a neighborhood of the true optimum in only a few simulation runs. Numerical illustrations of the heuristic for a Monte Carlo example give encouraging results.

Robust mean-covariance solutions for stochastic optimization

IOANA POPESCU
INSEAD
keywords: robust optimization

We provide a method for deriving robust solutions to stochastic optimization problems with general objective, based only on mean-covariance information about the distribution underlying the random cost vector. For a general class of objective functions, we show that the robust optimization problem is equivalent to solving a certain deterministic parametric quadratic program. Interesting results arise from comparing the robust solutions with those corresponding to entropy maximizing distributions for various criteria, such as target, fractile and option-type. We explore applications in robust portfolio management and multi-product pricing.

Hoelder and Lipschitz stability of solution sets in programs with probabilistic constraints

RENE HENRION
Weierstrass Institute Berlin
coauthor: Werner Roemisch
keywords: probabilistic constraints, Lipschitz stability, stochastic programming

We consider a convex program with probabilistic constraints induced by an r-concave probability distribution. Usually, only limited information about the underlying probability distribution is available, and the problem is solved on the basis of suitable approximations. Therefore, it is reasonable to study quantitative stability of solution sets to such programs under perturbations of the distribution. First we provide conditions implying Hoelder continuity of the solution set w.r.t. the Kolmogorov distance of probability distributions. Here, the perturbed distributions are completely free, which allows to include the important class of empirical approximations. Secondly, applying general stability results by Bonnans/Shapiro, we derive upper Lipschitz continuity for solution sets under more restrictive conditions on the original program and on the perturbed distributions. The stability results are illustrated by numerical tests showing the different asymptotic behaviour of parametric and empirical estimates in a program with a probabilistic constraint under multivariate normal distribution.

MO2-308/T1 FINANCE AND ECONOMICS

Model building

chair: H.Paul Williams

An econometric model of state budget

LUDMILA KOSHLAI
Senior Researcher
coauthor: M. Mikhalevich
keywords: budget modeling, behavioural econometric models, regression function, nondifferentiable optimization

Accounting a rational budget is one of the vital issues of economic growth. Such characteristics of a transition economy as the dominance of formerly state-owned property, strong monopoly influence and prohibitive technology costs result in the complexity of budgetary policy. Dynamic simulation model is considered for solving this problem. Account of budget influences the prices and optimization of taxes are the main its features. Accurate modelling of budget influence needs the development of econometric behavioural models for main economic agents. Another problem of budget modelling is constructing an objective function for its optimization. Methods of ordinary regression can be applied for such problems solution. Parameters of regression function are estimated by this approach as the solution of the system of inequalities. The methods of nondifferentiable optimization can be applied to find a solution (or pseudosolution) to the system and thereby to determine the objective and behavioural functions. The model of state budget is constructed for such known functions as the system of finite-difference equations. The gradient methods for the optimal control problems can be used to find the "best" solution in such model. The mentioned approach is realized in computer decision-support system. The demonstration version of it will be presented.

Optimization model of planned technological-structural changes

MIKHALEVICH MIKHAIL
Academy of Foreign Trade

coauthor: Ludmila Koshlai
keywords: aggregated interindustry model, non linear problems, numerical algorithms, combinatorial optimization

Monetary stabilization and reforms in financial sector for countries in transition must be accompanied by radical adjustment in industrial technological system. Decrease of production costs is a major goal of such technological changes. It can be achieved in a twofold way: first, to reduce inputs of commodities, materials and other manufactured products per unit of output, and second, by gradually reducing the use of energy- and resource-inefficient technologies. Both these approaches reduce the technological coefficients of input-output matrix in aggregated interindustry model. The optimization model for this purpose is considered in our paper. Let A be the matrix of technological coefficient and q is the vector of share of labour cost in the price of each industry product. The problem is to determine what changes in elements of A and q will maximize the consumer income without triggering additional cost-inflationary forces. Dependently from assumptions about possible changes, we obtain the non-linear problems with continuous or (and) discrete variables. Original numerical algorithms based on method of nonsmooth and combinatorial optimization are proposed for the mentioned problem solution. Real-data numerical experiments were done on the basis of 18-industry balances of Ukrainian economy. Several scenarios of possible technological changes were created.

The allocation of shared fixed costs: fairness versus efficiency

H.PAUL WILLIAMS
London School of Economics

keywords: fixed cost allocation, fairness, integer programming duality, game theory

We consider the problem of sharing the fixed costs of facilities among the users. This can be regarded as seeking 'dual values' for an Integer Programme. Alternative solutions are given and considered in relation to criteria of both fairness and efficiency. The obtaining of a 'fair' solution connects to concepts from cooperative Game Theory. The problem is illustrated by that of sharing the costs of central computing provision among the different faculties in a large university.

MO2-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Semidefinite linear complementarity problem

organizers: T. Parthasarathy and Srinivasa R. Mohan
chair: Srinivasa R. Mohan

Geometrical notions of p and related properties in semidefinite linear complementarity problems

MADHUR MALIK
Indian Statistical Institute, Delhi Centre

keywords: semidefinite complementarity, face, complementary cone, subtransformations

In this paper we generalize the notion of complementary cones to the semidefinite setting. The semi-definite linear complementarity problem is a generalization of the well known linear complementarity problem. It is a compelmentarity problem, over the nonpolyhedral self dual closed convex cone of semidefinite matrices and is relevant for a study of the problem of variational inequalities. It arises naturally in the unified formulation of a pair of primal-dual semidefinite programming problems. Certain concepts and results such as those relating to P-matrix available for linear complementarity problems are then generalized to semidefinite linear complementarity problems using the geometry of the semidefinite cone and compared with the algebraic generalizations mabe by Gowda and others.

P-properties of linear transformations on Euclidean Jordan algebras

MUDDAPPA GOWDA
University of Maryland, Baltimore County

keywords: P-property, Euclidean Jordan algebra

An n by n real matrix is said to be a P-matrix if all its principal minors are positive. It is well known that this property can be described in numerous equivalent ways, such as: the non-sign-reversal property based on the componentwise product of vectors, the order P-property based on the minimum and maximum of vectors, the uniqueness property in the standard linear complementarity problem, the (Lipschitzian) homeomorphism property of the (standard) normal map, etc. In this talk, we describe how these concepts can be extended for a linear transformation defined on an Euclidean Jordan Algebra.

Semidefinite complementary cones and faces in SDLCP

SRINIVASA R. MOHAN
Indian Statistical Institute, Delhi Centre

keywords: semidefinite LCP, semidefinite cone, face, cone preserving transformation

Given a real symmetric matrix Q and a linear transformation L from the space of all real symmetric matrices into itself, we consider the semidefinite linear complementarity problem of finding a symmetric positive semidefinite matrix X such that $L(X)+Q$ is positive semidefinite and the trace of $X(L(X)+Q)=0$. There are a number of applications for this problem and a study of such problems is also relevant for problems of variational inequalities over nonpolyhedral closed convex cones. We use the geometry of the semidefinite cone and the structure of its faces to study the properties of transformations that preserve the positive semidefinite cone and transformations that include the Stein transformation, studied earlier by Gowda and others.

MO2-308/T3 MODELING LANGUAGES AND SYSTEMS

Modeling languages and systems I

organizer/chair: Robert Fourer

Solving large scale supply chain optimization problems

ALKIS VAZACOPOULOS
Dash Optimization, Inc.
coauthor: Alan Dormer
keywords: constrained programming, integer programming, supply chain planning, modeling system

The paper will examine the results of a three year EU funded R&D project in large-scale integrated supply chain optimization. The objective of the project was to use mixed-integer programming (MIP) and constraint programming (CP) to address the combined planning and scheduling problem that arises in supply chain planning and optimization. The normal approach is to have two models - a planning model and a scheduling model - with the former solved with MIP and the latter solved with CP. The need to use two models and two separate systems increases the complexity, reliability and lifecycle cost of the system. It also requires some manual intervention to iterate between the two systems which is expensive and unreliable. The project has two main results that will be discussed: firstly a unified achitecture (one system/one model) has been found that works well for the planning and scheduling problem and secondly this architectire has been applied to several real-world problems. Further developments are in progress to refine the technology and make it applicable to the more general planning and scheduling problems that arise in transportation and human resources, for example.

Modeling, optimization and simulation of stochastic dynamic systems

JEAN-PIERRE GOUX
Artelys
coauthors: Nicolas Bonnard, Olivier Teytaud, Arnaud Renaud
keywords: stochastic optimization, dynamic programming, linear programming, risk management

The management of hydro reservoirs, natural gas storages, financial assets portfolios or cement reserves requires to make a sequence of decisions balancing present gains and expected future gains. Complex dynamic management strategies that satisfy demand while maximimizing expected profit and minimizing risk are necessary.

Artelys DynOpt is a C++ model building and solving environment that facilitates the description and the analysis of such systems. Artelys DynOpt implements powerful stochastic dynamic programming algorithms to compute robust management strategies and Monte-Carlo simulations for risk analysis. Design and algorithmic principles will be addressed. Applications in the area of energy stock management, financial contract pricing and supply chain management will be presented.

A modeling language for stochastic programming

LEONARDO LOPES
Northwestern University
coauthor: Robert Fourer
keywords: stochastic programming, modeling languages

StAMPL a modeling tool specifically designed for stochastic programming problems with recourse. It exploits these problems' special structure, using a syntax that stresses aspects important from a modeling focus. As a result, StAMPL models emphasize the dynamic aspect of the decision model, with a notation that focuses on stochastic programming-specific concepts while taking advantage of features in the AMPL modeling language to handle the algebraic components of the model. With this approach, StAMPL can represent models in a clean and scalable format, uncomplicated by indexing over either periods or scenarios.

MO2-341/21 INTERIOR POINT ALGORITHMS

Computational conic programming

organizers: Mituhiro Fukuda and Masakazu Kojima
chair: Mituhiro Fukuda

A non-polyhedral primal active-set approach to SDP

YIN ZHANG
Rice University
coauthors: Kartik Krishnan, Gabor Pataki
keywords: active-set approach, semidefinite programming

We present a non-polyhedral primal active-set approach to semidefinite programming which exploits the low rank of optimal primal extreme point solutions. The goal is to find a proper superset of the range space of an optimal primal extreme-point solution. The algorithm generates a sequence of primal feasible iterares with non-increasing objective values. Under a nondegeneracy assumption, the objective values are strictly decreasing. We will also discuss convergence issues for this approach.

A pivoting structure in second-order cone programming

MASAKAZU MURAMATSU
The University of Electro-Communications
keywords: second order cone programming, pivoting algorithm

We give a framework for a pivotting algorithm for second-order cone programming. First, we discuss how to define basic and nonbasic variables, and a dictionary using them, for second-order cone programming. Then a pivotting procedure is proposed to exchange basic and nonbasic variables. To pick up a variable entering to the basis, we need to solve low-dimensional subproblems. When all the subproblems have zero optimal solution, we terminate the algorithm. This is a try to extend the simplex method for linear and quadratic programming to second-order cone programming.

Solving nonconvex SDP problems of structural optimization by PENNON

MICHAL KOCVARA
Inst. of Applied Mathematics, University of Erlangen
coauthor: Michael Stingl
keywords: semidefinite programming, structural optimization, nonlinear programming

Semidefinite programming offers an elegant way how to formulate optimization problems with constraints on eigenvalues. We introduce new formulations of Truss Topology and Free Material Optimization problems with constraints on self-vibration and global stability of the optimal structure. The resulting semidefinite programming problems will be solved by optimization code PENNON.

The problems with constraints on self-vibration lead to large-scale linear SDP, while the problems with global stability control (that are of more practical importance) result in large-scale nonconvex SDP.

The SDP problems, both the linear and the nonlinear one, are large-scale and extremely difficult to solve. The algorithm used in PENNON is a generalized version of the Augmented Lagrangian method, originally introduced for convex nonlinear programming problems. The efficiency of this approach is based on a special choice of the penalty function for matrix inequalities. This special choice affects the complexity of the algorithm, in particular the complexity of Hessian assembling, which is the bottleneck of all SDP codes working with second-order information. Unlike codes based on interior-point techniques, PENNON can be directly generalized for nonlinear nonconvex SDP.

Number of practical examples will illustrate the importance of the eigenvalue constraints and the efficiency of PENNON.

MO2-341/22 LOGISTICS AND TRANSPORTATION
Facility location
chair: Francisco Saldanha-da-Gama

Lagrangian approach for hybrid problem of facility location and network design

HIROAKI MOHRI
Waseda University

coauthors: Naoto Katayama, Ming Zhe Chen
keywords: network application, network design, facility location, Lagrangian relaxation

We introduce a hybrid problem of facility location and network design. Our problem is a kind of network design problem combined with a facility location problem. This problem includes the network design problem considering fixed arc cost and routing cost as a special case. Also, the problem has many applications especially in planning telecommunication and computer networks. In such cases, cables are arcs and facilities, which are automatic switching machines as such, are special nodes on a connected graph. This problem is proved to be a NP hard problem in terms of Computing Complexity Theory. That is why it is difficult to solve the large size problem. We show that a solution is reached by using a mixed integer programming formulation and efficient algorithms with a focus on the Lagrangian relaxation approach. If time permits, we will show some numerical examples.

Inverse 1-median problems in the plane

CARMEN PLESCHIUTSCHNIG
Graz University of Technology / Department of Mathematics B

coauthors: Rainer Burkard, Jian-Zhong Zhang
keywords: inverse optimization, 1-median, location problem

The inverse 1-median problem consists in changing weights of existing facilities at minimum cost such that a pre-specified location becomes the 1-median under the new weights. The cost is assumed to be proportional to the increase or decrease of the corresponding weight. All new weights have to meet upper and lower bounds. We show that in space the inverse 1-median problem can be solved in O(n log n) time, provided that the distances are measured in rectangular or maximum norm.

Location models: a reformulation by discretization

FRANCISCO SALDANHA-DA-GAMA
University of Lisbon / Operational Research Centre

coauthor: Luis Gouveia
keywords: discrete location, extended formulations

The usual location models contain a set of binary variables Yi indicating whether or not, a facility is built at location i. In this talk we discuss models using binary variables Ziq indicating whether a facility is built at location i AND is serving q clients. We relate formulations involving the new set of variables with previous known formulations. We also present and discuss a set of inequalities using the new set of variables and generated by the Chvatal-Gomory rounding method. We also discuss variations of the problem with nonlinear costs at the facilities (as these are easily modelled by the new variables). Computational results taken from instances with up to 100 client nodes and 20 facility nodes are presented for several variations of the location problem.

MO2-341/23 LOGISTICS AND TRANSPORTATION
Transportation
chair: Uwe Zimmermann

A new approach to solve large-scale systems of nonlinear equations

FRANK CRITTIN
IMA-EPFL

coauthor: Michel Bierlaire
keywords: nonlinear equations, large scale problems, transportation

One of the most basic numerical problems encountered in computational science is to find the solution of a system of nonlinear equations, or equivalently to find a fixed point of a given mapping. Due to the advances in computer sciences these problems involve an increasingly large number of variables, as for example in transportation or economics. Moreover it is not uncommon that the Jacobian matrix of the system is unavailable or, despite progresses in automatic differentiation, costly to compute motivating the use of quasi-Newton or inexact Newton methods to solve these kinds of problems.

In this talk we present a matrix-free iterative algorithm designed to solve large scale problems without resorting to finite differences, which could be a decisive property in the presence of noise, and without imposing particular structures on the problems or the Jacobian.

Practically this method allows us to solve problems, coming from the transportation field, with more than 120'000 variables. Computational experiments on standard problems show that this algorithm outperforms classical large-scale quasi-Newton methods in terms of efficiency and robustness. Moreover, its numerical performances are equivalent to the performances of the Newton-Krylov methods currently considered as one of the best methods to solve high-dimension nonlinear systems of equations.

Solving large scale integer multicommodity network flow problems in one second

MARTIN JOBORN
Carmen Consulting

keywords: railway transportation, empty distribution, multicommodity network flow, decomposition

In an application of real time fleet allocation, an integer multicommodity network flow problem has to be solved repeatedly and a solution is needed very quickly. The problem is decomposed geographically by studying the structure of the transportation network. In an on-line setting, a fast heuristic checks the feasibility of demands. In the heuristic, the problem is decomposed by commodity, by regarding the flow of all commodities but one as fixed. A continuous algorithm provides near optimal solutions. The system and algorithms are designed for the real time setting, and has very fast response time and handles a continuous flow in updated input data. The application is implemented at the rail freight carrier Green Cargo, Sweden.

Optimal shunting

UWE ZIMMERMANN
Dept. Mathematical Optimization. TU Braunschweig

keywords: combinatorial optimization, mixed integer programming, logistics and transportation

Cost for shunting are rather expensive. How to reduce these efforts to the absolute necessary amount? Nice mathematical models lead to various easy and hard combinatorial optimization problems. In view of its applications, shunting occurs as one part of complex railway problems in public and industrial transportation. We report about models, solved and open mathematical problems as well as experience in related practical projects.

MO2-321/053 PRODUCTION AND SCHEDULING
Planning in medical applications
chair: Rembert Reemtsen

Fast simultaneous angle, wedge, and beam intensity optimization in inverse radiotherapy planning

KONRAD ENGEL
Universität Rostock/Fachbereich Mathematik
coauthor: Eckhard Tabbert
keywords: treatment planning, radiation therapy optimization, beam orientation, IMRT

We present a new very fast radiotherapy planning algorithm which determines approximatively optimal gantry and table angles, kinds of wedges, leaf positions and intensities simultaneously in a global way. Other parameters are optimized locally, i.e. independently of each other. The algorithm uses an elaborated field management and field reduction. Beam intensities are determined via a variant of a projected Newton method of Bertsekas. The objective function is a standard piecewise quadratic penalty function, but it is built with efficient upper bounds which are calculated during the optimization process. Instead of pencil beams basic leaf positions are included. The algorithm is implemented in the new beam modelling and dose optimization modul HoMo OptiS.

An algorithm for scheduling doctors for night duty

ATSUKO IKEGAMI
Seikei University
keywords: staff scheduling, nurse scheduling, night duty, subproblem centric approach

Every month, doctors usually work several night duties in addition to their usual day duties. Here we deal with the problem of scheduling doctors to night duties at hospitals in Japan. The appropriate number of doctors and skill level must be assigned to every night duty. Also, to balance the workload among the doctors, the number of night duties that a doctor works on Saturday, Sunday, and week nights must also be considered, as well as the number in total. Certain work patterns that may adversely affect doctors' health, such as consecutive night duties, are also not permitted. The constraints of this problem are of block-angular structure. This structure consists of diagonal blocks of constraints for a specific doctor that can be dealt with independently without a set of linking constraints. We deal with this problem as a variant of the nurse scheduling problem and we solve it by an algorithm based on the 'Subproblem-centric approach' for nurse scheduling. The subproblem-centric approach improves the objective function by repeatedly solving subproblems, where the objective function includes minimizing violations for the linking constraints. This algorithm obtains good schedules efficiently.

The solution of nonlinear problems of intensity modulated radiation therapy planning by a Lagrangian barrier-penalty algorithm

REMBERT REEMTSEN
Brandenburg Technical University Cottbus
coauthor: M. Alber
keywords: radiation therapy planning, large scale optimization, nonlinear optimization, barrier-penalty algorithm

We discuss the solution of large-scale nonlinear optimization problems arising from a biological model for intensity modulated radiation therapy planning in cancer treatment. The model developed elsewhere leads to convex and nonconvex constrained optimization problems with several thousands of variables, for which gradients of the involved functions are available, but computation of Hessians is numerically too costly. It is suggested to solve the optimization problems by a modification of an algorithm by Conn, Gould, and Toint, which for convex problems and special choices of parameters coincides essentially with the nonlinear rescaling method for the modified-logarithmic-quadratic barrier-penalty function by Polyak. In particular, the subproblems in the algorithm are solved by a conjugate gradient method, since the favorable eigenvalue structure of the Hessian of the Lagrangian at a solution of such problems indicates a sufficiently fast (local) rate of convergence. The outcomes of the algorithm are demonstrated by clinical radiation plans.

MO2-321/033 NETWORKS
Integer programming for design problems
chair: Corinne Feremans

Truss topology design with binary variables

ADELAIDE CERVEIRA
UTAD(Trás-os -Montes e Alto Douro University)-Lisbon's University Operational Research centre
coauthor: Fernando Bastos
keywords: semidefinite programming, Truss topology design, duality

In this talk, we consider a truss topology design problem, where all the existent bars have the same cross-sectional area. The goal is to find the stiffest truss subject to the equilibrium equation, a constraint defining the maximum volume (weight) and integrality constraints on the variables. We can formulate the problem as a semidefinite problem with binary variables. We consider and solve, using a freely available SDP software, several semidefinite relaxations of that problem. We use also another approach based on lagrangean decomposition.

The 2-edge connected subgraph problem with bounded rings

BERNARD FORTZ
IAG, Université Catholique de Louvain
coauthors: Pierre Pesneau, Ali Ridha Mahjoub, S. Thomas McCormick
keywords: network design, branch-and-cut

We consider the problem of determining a 2-edge connected subgraph of minimum cost such that each edge belongs to a cycle of using at most K edges. We investigate this problem from a polyhedral point of view. We first give an integer programming formulation for the problem using the natural set of variables, and we discuss several classes of valid inequalities for the associated polytope. We characterize the dimension of that polytope and describe conditions for these inequalities to be facet defining. Moreover, we study separation routines for some of these inequalities. Numerical results obtained with a Branch&Cut algorithm are presented.

The generalized subgraph problem: complexity, approximability and polyhedra

CORINNE FEREMANS
Universiteit Maastricht, Faculty of Economics and Business Administration, Department of Quantitative Economics
coauthors: Martine Labbé, Adam Letchford, Juan José Salazar González
keywords: network design

This paper is concerned with a problem on networks which we call the Generalized Subgraph Problem (GSP). The GSP is defined on an undirected graph where the vertex set is partitioned into clusters. The task is to find a subgraph which touches at most one vertex in each cluster so as to maximize the sum of vertex and edge weights. The GSP is a relaxation of several important problems of a 'generalized' type and, interestingly, has strong connections with various other well-known combinatorial problems, such as the matching, max-flow / min-cut, uncapacitated facility location, stable set, quadratic semi-assignment, vertex cover and max-cut problems.

In this paper, we examine the GSP from a theoretical viewpoint. We show that the GSP is strongly NP-hard, but solvable in polynomial time in several special cases. We also give several approximation results. Finally, we examine two 0-1 integer programming formulations and derive new classes of valid and facet-inducing inequalities that could be useful to develop a cutting plane approach for the exact or heuristic resolution of the problem.

MO2-321/133 GRAPHS AND MATROIDS

Graphs and matroids

chair: Geir Dahl

Graphs with convex-QP stability number

DOMINGOS MOREIRA CARDOSO
Departamento de Matemática, Universidade de Aveiro
keywords: graph theory, stability number, programming involving graphs

Graphs with convex-QP stability number are graphs for which the stability number is equal to the optimal value of a convex quadratic program. It is known that there is an infinite number of graphs with convex-QP stability number. For instance, a connected graph G with at least one edge which is not a star neither a triangle has a perfect matching if and only if its line graph, $L(G)$, has convex-QP stability number. On the other hand, if G is a connected graph with an even number of edges then $L(L(G))$ has convex-QP stability number. In this presentation we introduce several combinatorial and spectral characterizations of graphs for which it is possible to recognize, in polynomial-time, if they have (or not) convex-QP stability number. Furthermore, some hereditary classes of graphs for which such polynomial-time recognition can be done are presented.

Perfectness is an elusive graph property

ANNEGRET KATRIN WAGLER
Konrad-Zuse-Institute for Information Technology
coauthor: Stefan Hougardy
keywords: perfect graphs, elusiveness, graph property testing

A graph property is called elusive (or evasive) if every algorithm for testing this property has to read in the worst case $\binom{n}{2}$ entries of the adjacency matrix of the given graph. Several graph properties have been shown to be elusive, e.g. planarity (Best et al 1974), k-colorability (Bollobas 1978), 2-connectivity (Triesch 1982), or the membership in any minor closed family (Chakrabarti, Khot, Shi 2002). A famous conjecture of Karp (1973) says that every non-trivial monotone graph property is elusive. We prove that a non-monotone but hereditary graph property is elusive: perfectness.

Matrices of zeros and ones with given line sums and a zero block

GEIR DAHL
University of Oslo
coauthor: Richard A. Brualdi
keywords: $(0,1)$-matrices, Gale-Ryser algorithm, structure matrix, majorization

We study the existence of $(0,1)$-matrices with given line sums and a fixed zero block. An algorithm is given to construct such a matrix which is based on three applications of the well-known Gale-Ryser algorithm for constructing $(0,1)$-matrices with given line sums. A characterization in terms of a certain "structure matrix" is proved. Further properties of this structure matrix are also established, and its rank is determined and interpreted combinatorially.

MO3-302/41 COMBINATORIAL OPTIMIZATION

Submodular functions and discrete convexity II

organizers: Satoru Fujishige and Kazuo Murota
chair: Kazuo Murota

A fully combinatorial algorithm for submodular function minimization

SATORU IWATA
University of Tokyo

keywords: submodular function, combinatorial algorithm, strongly polynomial algorithm

Combinatorial strongly polynomial algorithms have been developed for minimizing submodular functions independently by Schrijver and by Iwata, Fleischer, and Fujishige (IFF). These combinatorial algorithms perform multiplications and divisions despite the definition of submodular functions does not involve such numerical operations. In this talk we present a fully combinatorial variant of the IFF algorithm using only additions, subtractions, comparisons, and oracle calls for the function values. The algorithm can be applied to submodular functions over an arbitrary totally ordered additive group.

A Gallai-Edmonds-type structure theorem for path-matchings

BIANCA SPILLE
University of Magdeburg/ FMA-IMO
coauthor: Laszlo Szego
keywords: path-matching, Gallai-Edmonds, structure theorem

As a generalization of matchings, Cunningham and Geelen introduced the notion of path-matchings. We give a structure theorem for path-matchings which generalizes the fundamental Gallai-Edmonds structure theorem for matchings. Our proof is purely combinatorial.

Capacity scaling algorithm for scalable M-convex submodular flow problems

SATOKO MORIGUCHI
Tokyo Institute of Technology
coauthor: Kazuo Murota
keywords: combinatorial optimization, discrete convex function, submodular flow, algorithms

An M-convex function is a nonlinear discrete function defined on integer points, and the M-convex submodular flow problem is one of the most general frameworks of efficiently solvable combinatorial optimization problems. It includes the minimum cost flow and the submodular flow problems as its special cases. In this talk, we first devise a successive shortest path algorithm for the M-convex submodular flow problem. We then propose an efficient algorithm based on a capacity scaling framework for the scalable M-convex submodular flow problem. Here an M-convex function $f(x)$ is said to be scalable if $f(ax+b)$ is also M-convex for any positive integer a and any integer vector b.

MO3-302/42 COMBINATORIAL OPTIMIZATION

Network flows in VLSI layout

organizers: Bernhard Korte and Jens Vygen
chair: Bernhard Korte

Network flow algorithms in VLSI placement

ULRICH BRENNER
Research Institute for Discrete Mathematics, University of Bonn
keywords: flow algorithms, VLSI design

In VLSI placement, millions of components have to be placed disjointly in a given area. In its simplest case, this task can be formulated as an assignment problem and it is natural to apply network flow algorithms to it.

Most placement tools work in two steps: After roughly spreading out the components over the chip ignoring disjointness (global placement), the components are moved to their final position (legalization or detailed placement).

In this talk, we describe how network flow algorithms can be applied both to global and detailed placement. For global placement, our approach leads to minimum cost flow instances on bipartite graphs with several millions of vertices. However, we can give an algorithm that solves these instances efficiently in near-linear time. For detailed placement, a new reduction to a minimum cost flow computation is described that allows legalizing a global placement with very small movement of circuits.

Fast flow augmentation in bit-pattern-represented grid graphs

DIRK MUELLER
Research Institute for Discrete Mathematics, Univ. of Bonn
keywords: multicommodity flow, grid graphs, VLSI design, global routing

We describe a very fast method for finding augmenting paths in grid graphs, a problem motivated by the capacity estimation in the global routing of VLSI chips. Nodes in the given graph, as well as edges with positive residual capacity, are encoded in arrays of bit vectors. Given these bit vectors, we show how to find an augmenting path by performing a series of logical and bit shift operations on them. Using this method as the core of an almost-maximum (multicommodity) flow algorithm, we achieve running times reduced by several orders of magnitude on the real world instances which arise from the capacity estimation problem mentioned above, compared to well-known maximum flow algorithms for general graphs, like the one due to Goldberg and Tarjan.

Multicommodity flow with congestion costs

JENS VYGEN
University of Bonn
keywords: VLSI design, global routing, multicommodity flow

Many optimization problems in practice can be modelled by multicommodity flows. In contrast to the standard model, it is often more expensive to use congested edges. One obvious example is routing traffic flows with congestion-dependent travel times, another one - which we concentrate on - is global routing in VLSI design.

To solve the (integer) multicommodity flow problem with congestion costs, we propose an efficient combinatorial fully polynomial approximation scheme for a fractional relaxation, followed by randomized rounding. The overall deviation from the optimum can be bounded.

This is the first approach to global routing that takes coupling between adjacent wires, bounds on delays along critical paths, and overall capacitance (power consumption) into account.

MO3-302/44 COMBINATORIAL OPTIMIZATION

Combinatorial optimization II

chair: Pasquale Avella

On the facets and the diameter of the k-cycle polytope

ANDREI HORBACH
Christian-Albrechts-Universitaet zu Kiel
coauthors: Eberhard Girlich, Mikhail M. Kovalev
keywords: polyhedral combinatorics, k-cycle polytope, facets, diameter

The k-cycle polytope represents the convex hull of all simple cycles of length exactly k in a complete graph. This polytope generalizes the traveling salesman polytope (TSP). We present a class of facet inequalities for the k-cycle polytope derived from the path inequalities for the TSP, new classes of facet inequalities for the 3-cycle polytope, and bounds on the diameter for the k-cycle polytope.

Chromatic scheduling polytopes coming from the bandwidth allocation problem in point-to-multipoint radio access systems

JAVIER LEONARDO MARENCO
Universidad de Buenos Aires
coauthor: Annegret Katrin Wagler
keywords: bandwidth allocation, polyhedral combinatorics

The bandwidth allocation problem in point-to-multipoint radio access systems is NP-Hard in general and cannot be approximated in polynomial time with a guaranteed quality. One kind of algorithms which turned out to be successful for many other combinatorial optimization problems uses cutting plane methods. For that, knowledge on the associated polytopes is required. The present work contributes to this issue, providing an initial study of chromatic scheduling polytopes. We explore that these polytopes are symmetrical, which is a special property having implications in the search for facets. We also present partial results on the polytopes' dimension, and provide some classes of facet-inducing inequalities.

Computational study of large-scale p-median problems

PASQUALE AVELLA
Università del Sannio
coauthors: Antonio Sassano, Igor Vasil'ev
keywords: p-median, column-and-row generation, cutting planes

Given a directed graph $G(V,A)$, the p-Median problem consists of determining p nodes (median nodes) minimizing the total distance to the other nodes of the graph. The p-Median problem belongs to the class of NP-hard problems.

We present a Branch-and-Cut-and-Price algorithm yielding provably good solutions for instances up to 3795 nodes $(14,402,025$ variables). In our algorithm the LP relaxation is solved by a column-and-row generation: for each variable, which is added to the current master problem, we add the related Variable Upper Bound constraint too. This approach is effective to limit the growth of the master problem.

Several families of cutting planes are used to tighten the formulation. Particularly we introduce a new family of Cycle inequalities, which turned out to be very effective for several classes of instances.

MO3-302/45 COMBINATORIAL OPTIMIZATION
Set partitioning applications
chair: David M. Ryan

A column generation approach for discrete lotsizing and scheduling problem on identical parallel machines

JUN IMAIZUMI
Toyo University
coauthors: Hiroaki Arai, Susumu Morito
keywords: parallel machines, lot sizing, scheduling, column generation

In this paper the Discrete Lotsizing and Scheduling Problem (DLSP) on identical parallel machines with setup times is considered. The problem is a one of determining the sequence and size of production batches for multiple items. The objective is to find a minimal cost production schedule such that deterministic, dynamic demand is fulfilled with backlogging. The problem is formulated as an integer programming problem and reformulated as a Generalized Set Partitioning Problem (GSPP). We present a column generation heuristic to solve GSPP. GSPP is decomposed to subproblems and each subproblem is solvable with dynamic programming. The quality of the solutions can be measured, since the heuristic generates lower and upper bounds. Computational results on a personal computer show that the heuristic is rather effective in terms of quality of the solutions.

Political redistricting: a case study in japan

KEISUKE HOTTA
Bunkyo University
coauthor: Toshio Nemoto
keywords: political redistricting, combinatorial optimization, exact solution

We consider the political redistricting problem for the 300 single-seat constituencies of the House of Representatives in Japan. This problem becomes 47 redistricting subproblems because the 300 single-seats are apportioned to 47 prefectures by law. There are two difficulties to solve them in Japan. One is the size of subproblems. For example, Tokyo consists of 56 cities and 25 districts. The other is the difference in districting rule between Japan and well-studied countries such as the United States. In US, compactness, geographical criteria, is emphasized, but it is of little significance in Japan. It is important not to divide city into smaller parts, and to find the optimal solution to make an index of *gerrymander*. Consequently, it is hard to find the exact solution, not an approximate solution, with a conventional method. However, we formulated subproblems as two combinatorial optimization problems, the set partition type and the graph partition type, solved them with some interesting idea, and then obtained the optimal 300 districts for the first time.

Improved solution techniques for multi-period area-based forest harvest scheduling problems

DAVID M. RYAN
University of Auckland
coauthors: Juan Pablo Vielma, Alan Murray, Andres Weintraub
keywords: forest harvesting, set packing and partitioning, integer programming
Area-based forest harvest scheduling models, where management decisions are made for relatively small forest units subject to a maximum harvest area restriction, are known to be very difficult to solve by exact techniques. Previous research has developed good approaches for solving small and medium sized forestry applications based on projecting the problem onto a cluster graph for which cliques can be applied. The resulting set partitioning and packing models can be solved relatively efficiently. However, as multiple time periods become of interest, current approaches encounter difficulties preventing successful identification of optimal solutions. Timber demand constraints which are intended to smooth production over successive time periods, create very difficult integer programming problems. In this paper we present an approach for elastizacing the timber demand constraints, which significantly improves the integer properties of the LP relaxation and lends itself to an efficient solution technique. It is also possible using this approach to examine trade-offs between objective value performance and maintaining demand constraints.

MO3-302/49 INTEGER AND MIXED INTEGER PROGRAMMING
Integer programming column generation II
organizer: Marco Lübbecke
chair: Ralf Borndörfer

Robust branch-and-cut-and-price for the capacitated minimum spanning tree problem

RICARDO FUKASAWA
GAPSO

coauthors: Marcus Poggi de Aragão, Oscar Porto, Eduardo Uchoa
keywords: integer programming, network planning, column generation

We propose a formulation for the capacitated minimum spanning tree problem that leads to a robust branch-and-cut-and-price algorithm. By "robust", we mean that neither branching nor the addition of cuts change the structure of the pricing subproblem, a very desirable property. The resulting pricing subproblem is a minimum cost subtree problem with a capacity constraint. Since such problem is strongly NP-hard, we generate columns by solving a relaxation, finding a minimum cost connected component (not necessarily a tree) satisfying the capacity. This can be done by a pseudo-polynomial dynamic programming procedure. Our cut generation procedure uses generalized subtour elimination and root cutset cuts, basically the same ones already employed in a branch-and-cut by L. Hall. Computation results on benchmark instances from the OR-Library suggest significant improvement over previously known algorithms. The combination of column and cut generation consistently leads to tighter lower bounds, which allowed us to solve to optimality several open instances in the set.

Online vehicle dispatching for service units

LUIS MIGUEL TORRES
Konrad-Zuse Zentrum Berlin

coauthors: Martin Groetschel, Benjamin Hiller, Sven O. Krumke, Jörg Rambau
keywords: vehicle routing, on-line optimization, column generation

Given a set of guided service vehicles (units), a set of service requests arriving over time, and a set of service contractors (conts), the online vehicle dispatching problem VDP is the task of finding an assignment of requests to units and conts, as well as service tours for all units, such as to minimize a certain objective function. The objective measures the service, overtime and driving costs for the units. Requests assigned to contractors are charged with fixed costs. Moreover, requests specify service deadlines, and late costs are incurred whenever a deadline is missed.

The German automobile association ADAC (Allgemeiner Deutscher Automobil-Club), second in size only to the American Automobile Association (AAA), maintains a heterogeneous fleet of over 1600 units (yellow angels) to help people whose cars break down on their way. As part of their daily work at one of the five ADAC help centers distributed over Germany, human dispatchers constantly face large problem instances of the online VDP that they must sove in real time. We present preliminary results on the development of an online algorithm based on column generation for automating the dispatching task.

Combining column generation with memetic algorithms

IVANA LJUBIC
Vienna University of Technology

coauthors: Petra Mutzel, Guenther Raidl
keywords: column generation, integer programming, branch-and-cut-and-price, applications

We present new results on the combination of branch-and-cut-and-price (B&C&P) algorithms with population based metaheuristics, in particular with memetic or evolutionary algorithms (MAs). We show how exact algorithms might benefit from metaheuristics, which is, to our knowledge, the first survey on this topic.

During the column generation phase, the way how the restricted subproblem is chosen, plays an important role in the design of a B&C&P. We consider the subset selection graph problems which can be rephrased as 0/1 integer programming problems, with one-to-one correspondence between variables and edges of the underlying graph. We usually start from a set of edges/variables representing a sparse graph. We maintain an additional set of promising edges (making a so called reserve graph) first to be checked with respect to their reduced costs.

The standard method of B&C&P to create sparse and reserve graphs is to use k-nearest neighbor graphs. We suggest to run a MA, and to take all edges present in the last population into the sparse graph. Additional edges which are present in earlier stages of the MA form the reserve graph.

Experimental comparisons show that the usage of MAs improves standard branch-and-cut and B&C&P approaches.

MO3-306/31 INTEGER AND MIXED INTEGER PROGRAMMING

Integer and mixed integer programming I

chair: Pedro Martins

Reformulation techniques based on group relaxations

ROBERT WEISMANTEL
University of Magdeburg/ FMA-IMO

coauthors: Matthias Koeppe, Quentin Louveaux
keywords: group relaxations

The paper addresses the question of how and why to use the non-decomposable solutions from knapsack group relaxations for reformulating integer programs in a higher dimensional space. We present theoretical justifications and some numerical evidence that this approach is promising.

A polyhedral approach to hub location problems

HIROO SAITO
The University of Tokyo

coauthors: Tetsuya Fujie, Tomomi Matsui
keywords: hub location problem, mixed integer programming, polytope, cutting planes

Hubs are switching facilities for transportation in an airline network or a postal delivery system, etc. The problem that designs a hub-and-spokes network is known as the Hub Location Problem (HLP). In this talk, we investigate a polytope related to the feasible region of (HLP). We show some polyhedral aspects of a mixed integer programming formulation. Furthermore, we propose a cutting plane method employing new facets. We also show the strength of the cuts through computational experiments.

Capacitated minimum spanning tree problem: revisiting hop-indexed models

PEDRO MARTINS
Coordinate Professor / ISCAC and CIO / Polytechnic Institute of Coimbra

coauthor: Luis Gouveia
keywords: capacitated tree problem, subtour elimination constraint, root-cutset constraints, cutting plane algorithm

We introduce hop-indexed generalizations of the well known subtour elimination constraints as well as the root-cutset constraints and consider them in the context of the hop-indexed Model of Gouveia and Martins. The inclusion of the

two new classes of constraints has permitted us to solve instances not previously solved in the literature.

MO3-306/32 NONLINEAR PROGRAMMING
Selection and design
chair: Jens Starke

Local search methods for the subset selection problem with minimum unit norm

DAG HAUGLAND
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coauthor: Sverre Storøy
keywords: subset selection, local search, pivoting

Given a target vector of length m and a matrix with m rows and n columns, we consider the problem of finding a subset of no more than k columns such that a closest possible approximation to the target can be found in the subspace spanned by the selected columns. The problem is NP-hard when closeness is measured by any p-norm, and in the current work we suggest some local search techniques for the unit norm case. The neighborhood structures on which the search is based, are defined in terms of pivoting operations in a related linear program. Several variants of the local search technique are presented and compared through numerical experiments.

Computing the center of area of a convex polygon

LAURA NICOLETA HEINRICH-LITAN
Braunschweig University of Technology
coauthors: Peter Brass, Pat Morin
keywords: computational geometry

The center of area of a planar convex set C is the point p for which the minimum area cut off from C by any halfplane containing p is maximized. Properties of this point were studied already long ago in classical geometry, but it is quite nontrivial to really determine this point for a given convex set. We describe a simple randomized linear-time algorithm for computing the center of area of a convex n-gon.

Surface design for heterogeneous catalytic reactions

JENS STARKE
University of Heidelberg, Inst. of Applied Math
keywords: reaction diffusion equations, differential equations, structural optimization, material optimization

A catalytic surface reaction is considered whose chemical reactants are given in a well mixed gas phase and can adsorb at a catalytic surface which subsequently enables a reaction step due to lowering the activation energy. Catalysts are usually very expensive so that it is of natural interest to reduce the amount of catalyst, i.e. to distribute a certain amount of a catalyst material on a cheaper carrier material such that the output of the chemical reaction is maximized. For the example of the CO-oxidation on platinum surfaces reaction-diffusion equations are presented which well describe the experimentally observed rich dynamical properties including pattern formation. Bifurcation analysis provides the local dynamical properties in dependence of the parameters representing the respective material of the surface compositon. Based on these results concerning the dynamics of the chemical reaction, the output (CO_2 production) is maximized in dependence of the material compositon (catalyst or carrier) on the surface. The difficulty is that the objective function depends on the solution of a partial differential equation (reaction-diffusion equation) which itself depends on the high-dimensional variable representing the discretized material composition on the surface. Optimization results obtained by first a deterministic and second a stochastic approach are presented.

MO3-306/33 NONLINEAR PROGRAMMING
Noisy problems
chair: Antanas Zilinskas

Analytical target cascading in design optimization of hierarchical multilevel systems under uncertainty

MICHAEL KOKKOLARAS
University of Michigan
coauthor: Panos Y. Papalambros
keywords: design optimization, multilevel systems, target cascading, uncertainty propagation

Analytical Target Cascading (ATC) is a methodology for design optimization of hierarchical multilevel systems. The original deterministic formulation of the associated optimization problems does not take into account uncertainties with respect to design variables and analysis/simulation model parameters. Therefore, the obtained optimal designs, which often lie on the boundaries of the active constraints, are questionable because small variations may generate infeasibility. In this work, we modify the ATC process to include reliability-based design optimization (RBDO) formulations, in which stochastic quantities are treated as random variables and constraints are probabilistic. The design variables in RBDO problems are the means of the random variables, while standard deviations are assumed to be known and constant. The tools available for assessing the reliability of satisfying the probabilistic constraints, namely, quantifying the probability of failure, require knowledge of the statistical properties of the stochastic quantities that are inputs to the simulations. These are assumed to be known only at the bottom of the hierarchy. An iterative linearization algorithm is used to propagate them to higher levels in the hierarchy. In this manner, we can quantify system output variations, which would not be identified accurately when considering an “all-at-once” solution approach in the presence of nonlinearities.

Stable noisy optimization by branch and fit

WALTRAUD HUYER
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coauthor: Arnold Neumaier
keywords: derivative-free optimization, noisy function values

We describe an algorithm for bound constrained optimization, where derivatives are not available and the function values are expensive and subject to noise. It proceeds by successive partition of the box (branching) and building local quadratic models (fit) and combines global and local search. Trust regions are used for local optimization from the best point. In each step, a user-specified number of suggested evaluation points is generated. Moreover, the algorithm allows for hidden constraints and assigns to such points a function value based on the function values of nearby feasible points, and soft constraints are handled with the aid of penalty and barrier functions.

One dimensional global optimization in the presence of noise

ANTANAS ZILINSKAS
Cardiff University UK, IMI Lithuania
coauthor: James Calvin
keywords: global optimization, statistical models, noisy observations, testing

The problem of global optimization of multimodal functions in the presence of noise is one of the most difficult in optimization theory. An approach based on statistical models of an objective function is well-suited for incorporation of noisy

observations. However, implementations of algorithms based on statistical models are complicated.

We consider a problem of one-dimensional global optimization in the presence of noise. A standard Wiener process is accepted for a model of objective functions. Noise is modeled by independent Gaussian random variables with zero mean and known variance. To construct a statistical model based algorithm conditional mean and variance should be calculated repeatedly. A special recurrent algorithm is developed to calculate these characteristics of the statistical model whose computational complexity is of lower degree than that of standard method. In the previous publications on similar subject the convergence was considered assuming the feasible region finite, i.e. the minimization interval has been discretized. Such an assumption greatly simplifies the analysis and implementation. However, the additional error implied by discretization may not always be acceptable. In the present paper we consider a version of a P-algorithm searching over a continuous interval. Implementation issues are considered and testing results are included.

MO3-306/34 NONLINEAR PROGRAMMING

Optimization applications in biology and chemistry

organizer/chair: Todd Munson

Computing transition states

TODD MUNSON
Argonne National Laboratory
coauthor: Jorge More'
keywords: transition states, saddle points, nonlinear optimization

The calculation of transition states is a fundamental problem in computational chemistry where the transition state corresponds to a mountain pass between to minimizers of a potential energy function for a chemical reaction. An algorithm based on nonlinear optimization for finding mountain passes is presented with some convergence results. Numerical results for this algorithm on benchmark problems in computational chemistry are given.

Design of protein folding potentials using mathematical programming

MICHAEL WAGNER
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coauthors: Jarek Meller, Ron Elber
keywords: protein folding, linear programming, MAX FS, support vector machines

We discuss the use of optimization techniques such as linear programming and support vector machines for the design of protein folding potentials. The key computational task lies in solving linear inequality systems with tens of millions of constraints in a few hundred variables. The modeling approach and the resolution of computational challenges as well as results on "real" problems will be presented.

Semidefinite programming for electronic structure calculations

BASTIAAN J. BRAAMS
Courant Institute, New York University
keywords: semidefinite programming, quantum chemistry

The core problem in quantum chemistry is the computation of the ground state energy of a system of electrons in an external potential. Reduced density matrices play an important role in the search for methods of electronic structure calculation that offer a systematic route to better accuracy. In particular, the 2-body reduced density matrix (2-RDM) contains enough information to express exactly (through a known linear functional) the electron Hamiltonian and all other ground-state properties of interest. However, the constructive use of the 2-RDM is hindered by the problem of N-representability that was first clearly described and studied by Coleman and by Garrod and Percus. We describe recent work that uses semidefinite programming to solve the variational problem for the 2-RDM subject to a subset of representability conditions, and we discuss the quality of the resulting approximation. This is joint work with Mituhiro Fukuda, Michael Overton, and Zhengji Zhao. Supported by NSF/DMS-0113852.

MO3-306/35 NONLINEAR PROGRAMMING

Recent developments in filter methods II

organizers: Michael Ulbrich, Stefan Ulbrich and Luís N. Vicente
chair: Luís N. Vicente

On the superlinear local convergence of a filter-SQP method

STEFAN ULBRICH
Zentrum Mathematik, Technische Universitaet Muenchen
keywords: nonlinear programming, filter, SQP, superlinear convergence

In this talk we show transition to superlinear local convergence for a modified version of a trust-region filter-SQP method for nonlinear programming introduced by R. Fletcher, S. Leyffer, and Ph. L. Toint.

Remarkably the algorithm allows transition to superlinear local convergence for the original trust-region SQP-steps without an additional second order correction. The main modification consists in using the Lagrangian function value instead of the objective function value in the filter together with an appropriate infeasibility measure. Moreover, we show that the modified trust-region filter-SQP method has the same global convergence properties as the original algorithm of R. Fletcher, S. Leyffer, and Ph. L. Toint.

An interior-point filter line-search method for large-scale nonlinear programming

ANDREAS WAECHTER
IBM T.J. Watson Research Center
coauthor: Lorenz Biegler
keywords: nonlinear optimization, filter methods, interior point method

Recent improvements of a barrier method for large-scale continuous nonlinear nonconvex optimization will be presented. The algorithm computes search directions from a linearization of the primal-dual equations, and global convergence is guaranteed by a filter line-search procedure. Some details of the implementation, particularly of a new feasibility restoration phase, will be discussed. Numerical results on a large set of test problems, as well as real-life applications (such as tuning of transistors in integrated digital circuits) with problem sizes with up to several hundred thousand variables, will be presented. The code is released as open source under the name IPOPT at www.coin-or.org.

On the convergence of a filter algorithm with independent feasibility and optimality phases

ELIZABETH KARAS
Federal University of Parana
coauthors: Clovis C. Gonzaga, Marcia Vanti
keywords: filter methods, nonlinear programming, global convergence

In this talk we describe a filter algorithm for nonlinear programming based on independent restoration and tangencial steps. Some simple conditions on the efficiency of each of these steps lead

to globally convergent algorithms. We show how to ensure that these conditions are satisfied by available codes for the subproblems, discuss how to deal with Maratos effect and describe a practical application to the Optimal Power Flow problem.

MO3-306/36 NONSMOOTH OPTIMIZATION

Recent advances in non-smooth optimization II

organizers: Jean-Philippe Vial and Jean-Louis Goffin
chair: Jean-Philippe Vial

Using the central path for computing the analytic center of apolytope

CLOVIS C. GONZAGA
Federal University of Santa Catarina
coauthor: Marli Cardia
keywords: cutting plane methods, analytic center, path following algorithms

We describe an algorithm for computing the analytic center of a polytope after the addition of a deep cut. When deep cuts are considered, the greatest difficulty lies in retrieving feasibility to initiate a centering algorithm. Our strategy consists in starting at a nearly centered point for the old polytope, and then following the primal-dual central path for an auxiliary linear programming problem. When this path following algorithm stops, the resulting point is a nearly central point for the new polytope. We show that this method performs well for shallow or deep cuts, and prove that its application to the convex feasibility problem matches the best existing complexity bounds.

Nonlinear multicommodity flow and traffic equilibrium

FRÉDÉRIC BABONNEAU
Université de Genève
coauthor: Jean-Philippe Vial
keywords: Lagrangian relaxation

We formulate the lagrangian relaxation of the nonlinear multicommodity flow problem (nlmcf) as a sum of a smooth convex function and a nondifferentiable one. We extend the proximal analytic center cutting plane method to handle the smooth term directly. We apply method to large scale problem. Since Wardrop traffic equilibria can reduced to the solving of nlmcf, we specialise our nlmcf method to this particular case.

ACCPM-based branch-and-bound methods for integer programming

SAMIR ELHEDHLI
University of Waterloo
keywords: Lagrangean relaxation, ACCPM, branch-and-price

When Lagrangean relaxation is used, obtaining the best Lagrangean bound amounts to solving a non-differentiable optimization (NDO) problem. Within a Lagrangean-based branch-and-bound framework (branch-and-price), the calculation of the Lagrangean bound is done at every node of the branch-and-bound tree. Thus, the success of such algorithms relies heavily on the fast solution of these NDO problems. We show how ACCPM (an interior-point cutting plane method) exploits past information and quickly solves the NDO problems both after adding cuts and after branching, using a primal and a dual interior-point method respectively. Promising numerical results are provided.

MO3-306/37 CONVEX PROGRAMMING

Semidefinite and conic optimization

chair: Karthik Natarajan

Nested optimization for experimental inference problems

LAURA WYNTER
IBM Watson Research Center
coauthors: Zhen Liu, Cathy H. Xia, Fan Zhang
keywords: estimation from experiments, inference, parameter estimation, semidefinite quadratic progr.

We present a parameter estimation, or inference, problem, obtained from an application in queueing networks. The derived model is a semi-definite quadratic program, whose solution gives the parameters of the underlying (queueing) system, for any particular experiment. Each experiment provides the input data of each QP.

Given a set of many such experiments, we would like to best estimate the parameters of the inference model. The non-strict convexity of the quadratic objective poses the problem of nonuniqueness of the solution for any single experiment, and therefore complexifies the task of combining the obtained parameters from all experiments. We propose a series of nested optimization problems, and their properties as well as two variants, for determining the best parameters for the set of experiments.

The dual cone for the derivative of the non-negative orthant

YURIY ZINCHENKO
Cornell University
keywords: hyperbolic polynomials, elementary symmetric functions, dual to the hyperbolicity cone

Elementary symmetric functions (polynomials) are building blocks for hyperbolic polynomials. While one can easily construct a logarithmic self-concordant barrier (SCB) functional for the hyperbolicity cone K_p associated to an arbitrary hyperbolic polynomial p, little is known about the dual cone K_{p*}, even when p is the k-th derivative ($1 \leq k \leq n-2$) in the direction $e = (1,1,\ldots,1)$ of the polynomial $x_1 \cdots x_n$, the standard hyperbolic polynomial for the nonnegative orthant.
For the case $k = 1$ – that is, for the polynomial $p'(x) = \Pi_{n-1}(x) = \sum_{1\leq i\leq n}\prod_{j\neq i} x_j$ – we give an algebraic characterization of the dual cone and show how one can easily construct an SCB functional for it. We also indicate extensions of the result.

Optimal mean-variance upper bounds on the expectation of highest order statistics

KARTHIK NATARAJAN
Singapore-MIT Alliance
coauthors: Dimitris Bertsimas, Chung-Piaw Teo
keywords: mean, variance

In this research, we provide a new approach to solving the classical problem in statistics of computing the tightest possible upper bound on the expectation of the maximum of n real random variables given mean and variance information on the individual random variables. This optimal upper bound is computable in polynomial time by solving a semidefinite program. By further exploiting the structure, we reformulate the problem as an univariate convex minimization problem. An efficient bisection search algorithm is proposed as a solution technique. Using the formulation, we propose two new closed form bounds, that are important due to simplicity and also compare well with previously known bounds based on preliminary empirical testing. An application of the work in an option pricing context will also be discussed.

MO3-306/38 PARALLEL COMPUTING

Parallel methods for combinatorial and global optimization

organizer/chair: Jonathan Eckstein

Parallel constrained shortest path

DIEGO KLABJAN
University of Illinois at Urbana-Champaign

keywords: shortest paths, parallel computing

Parallel algorithms for shortest path have been extensively studied in the past. To the contrary, we are not aware of parallel algorithms to the constrained shortest path problem. We propose several algorithms and variants suitable for acyclic graphs. We present computational experiments showing additional issues that are not present in parallel shortest path implementations.

Computational grid implementations of branch-and-bound methods for nonconvex quadratic programming

JEFF LINDEROTH
Lehigh Univeristy

keywords: global optimization, computational grid, parallel computing, branch-and-bound

We describe branch-and-bound methods for solving nonconvex quadratic programs. The methods make use of novel relaxations of the nonconvexities and are implemented to run on a Computational Grid computing platform. Solution of large-scale instances will be reported.

A framework for scalable parallel tree search

TED RALPHS
Lehigh University

coauthors: Laszlo Ladanyi, Matthew Saltzman, Yan Xu

keywords: parallel algorithm, branch-and-bound, branch-and-cut, software framework

We describe our latest progress developing the Abstract Library for Parallel Search (ALPS), a software framework for implementing parallel tree search algorithms. ALPS is designed specifically to achieve scalability for methods such as branch and cut in which large amounts of "knowledge," such as dynamically generated valid inequalities, are generated and must be shared as the algorithm progresses. Sharing this knowledge effectively is the main challenge of achieving parallel efficiency in such algorithms. In addition to standard facilities for implementing search algorithms, ALPS provides a framework for defining new types of knowledge, along with methods for storing and sharing this knowledge efficiently. Additional layers built on top of ALPS allow the user to implement specific classes of algorithms based on these general principles.

MO3-308/11 AIRLINE OPTIMIZATION APPLICATIONS

Airline scheduling II

organizer/chair: Stefan Karisch

Large scale airline crew rostering problems in practice

MAREK OZANA
Carmen Systems AB

coauthor: Sami Spjuth

keywords: real world application, combinatorial optimization

The Carmen Crew Rostering system could efficiently solve crew assignment problems with up to 3000 crew members. We present heuristic enhancements to the standard generate and optimize approach used in the production system. The improvements are based on a greedy initial algorithm and a stochastic trip locking mechanism. The current system is capable of solving large scale rostering problems of up to 6500 crew to production quality in less than 14 hours.

A proximal analytic center cutting plane method to solve the Lagrangian relaxation of the aircraft rotation problem

OLIVIER DU MERLE
Air France

coauthors: Sébastien Lemaire, Jean-Philippe Vial

keywords: proximal analytic center, column generation, Lagrangian relaxation, aircraft rotation problem

Proximal ACCPM is a variant of the analytic center cutting plane method, in which a proximal term is added to the barrier function that defines the center. In this talk we will give a presentation of the method and of its implementation. We will apply the method to solve the Lagrangian relaxation of a real life problem: the aircraft rotation problem. This problem arises after we have considered the schedule design and the fleet assignment. The aim of this problem is to built successions of flights according to the number of aircrafts and some operational constraints. Numerical results concerning real problems are given comparing proximal ACCPM and column generation approaches.

Airline crew scheduling: from planning to operations

CLAUDE PH. MEDARD
Carmen Systems

coauthor: Nidhi Sawhney

keywords: crew recovery scheduling, pairing/rostering integration, leg base rostering

Crew scheduling problems at the planning level are typically solved in two steps: first, creating working patterns, and then assigning these to individual crew. The first step is solved with a set covering model, and the second with a set partitioning model. At the operational level, the (re) planning period is considerably smaller than during the strategic planning phase. This paper presents an integrated model to solve time critical recovey problems arising on the day of operations. we describe how pairing construction and pairing assignment are done is a single step. We describe solution techniques based on simple tree search and more sophisticated column generation and shortest-path algorithms

MO3-308/12 STOCHASTIC PROGRAMMING

Real-life applications in stochastic programming

chair: Sin C. Ho

A stochastic programming model for strategic capacity planning in the metal-working industry

NINA LINN ULSTEIN
Norwegian University of Science and Technology, NTNU

coauthors: Marielle Christiansen, Bjørn Nygreen, Kari M. Reikvam, Marianne Storhaug Jensen

keywords: stochastic programming, facility location

Dramatic changes in the markets for silicon and ferrosilicon metals in recent years, has resulted in major restructuring processes in the industry. We present a stochastic programming model used by a large metals company with a number of production facilities in Europe and North America. The model support strategic capacity planning in the company. It models decisions for acquisitions and closures of plants, investments in new equipments and production processes and investments in and operation of furnaces. The model is implemented as a large MIP and solved by B&B. The robust solutions produced by the model are more at terms with the philosophy of the company than deterministic solutions for individual scenarios.

Optimization based derivative pricing in incomplete and imperfect markets

JÖRGEN BLOMVALL
Linköpings universitet

keywords: stochastic programming, derivative pricing

With an optimization based framework, derivatives can be priced in a general setting by using utility functions. Within this framework pricing algorithms can be developed. We will present some preliminary results from pricing in both incomplete and imperfect markets.

Designing routing zones for VRP with stochastic demands

SIN C. HO
Department of Informatics, University of Bergen
coauthors: Dag Haugland, Gilbert Laporte
keywords: vehicle routing, stochastic programming, districting, heuristics

We consider the problem of partitioning a set of customers into districts such that all customers within a district are serviced by exactly one vehicle. The allocation of customers to districts is constant over time, even if an occurring demand pattern indicates that a regrouping of the customers is cost effective. When the districts, or routing zones, are defined, the actual demand is observed, and a travel plan must be produced within each district.

In this work, we propose a heuristic solution method for solving the outlined problem. The procedure first finds an initial feasible solution, and next it improves the solution by a sequence of moves to neighboring solutions of smaller costs. We also give an analysis of experimental results on problems with 100 customers.

MO3-308/13 STOCHASTIC PROGRAMMING

Stochastic integer programs and network interdiction

organizer: COSP (Maarten H. van der Vlerk)
chair: Stein W. Wallace

On six-pack recourse: convex approximations for a simple mixed-integer recourse model

MAARTEN H. VAN DER VLERK
University of Groningen

keywords: stochastic programming, mixed integer recourse

We consider a mixed-integer recourse model with simple recourse structure and continuously distributed right-hand side parameters. Due to the integer variables, the expected value function (EVF) of this problem is non-convex in general.

We identify a class of probability density functions (pdf) which yield convexity of the EVF. Moreover, by choosing a suitable pdf from this class to approximate any given pdf, we obtain convex approximations of the corresponding EVF. In doing so, we use the same approach that was successful for pure integer recourse models, also with more general recourse structures.

A stochastic programming approach to the generalized assignment problem

JOYCE YEN
University of Washington
coauthors: Berkin Toktas, Zelda B. Zabinsky
keywords: stochastic programming, integer programming

The Generalized Assignment Problem (GAP) addresses the assignment of a given set of tasks to a set of agents, which use a single resource that is individually capacitated for each agent. In this study, we introduce the Collectively Capacity Multi-Resource Generalized Assignment Problem (CCP) as an extension to the GAP, in which the objective is to find a minimum-cost assignment of tasks to agents that collectively use multiple capacitated resources. We address the CCP with uncertain resource capacities, where the resource capacities have an unknown distribution that can be sampled. We propose four stochastic programming formulations of this problem, which differ mainly in their recourse models. We identify subgradient search techniques that are based on the Lagrangian relaxation of the capacity constraints to solve each formulation, and provide numerical results on a number of test cases.

A stochastic network-interdiction problem: maximizing the probability of sufficient delay

KEVIN WOOD
Naval Postgraduate School
coauthors: Harald Held, David Woodruff
keywords: stochastic programming, network interdiction, shortest paths

We describe a new model formulation for the following stochastic network-interdiction problem: Using limited resources, interdict network nodes or arcs in order to maximize the probability that the shortest-path length is greater than a specified threshold. Uncertainty arises because the interdictor has incomplete knowledge of the topological or numerical data for the network, or because interdiction attempts may fail. We devise and implement a row generation algorithm for the basic formulation and use it to solve several problem variants. We present computational results, and discuss extensions of the modeling paradigm to other interdiction problems.

MO3-308/T1 FINANCE AND ECONOMICS

Finance and economics

chair: Alan King

CAMBO: combinatorial auction using matrix bids with order

S. RAGHAVAN
University of Maryland
coauthor: Robert W. Day
keywords: auctions

Since combinational auctions allow bidders to bid on any combinations of goods, the bid data can be of exponential size. To combat this problem, restrictions have been proposed limiting the number of bundles a bidder is allowed to bid on (as in FCC Auction #31). We describe a new combinatorial auction format, CAMBO, for conducting combinatorial auctions that restricts bidders to submit a fixed number of "matrix bids with order". The advantage of this (restricted preference) approach is that it provides bidders a mechanism to compactly express bids on every possible bundle. We describe many different types of preferences that can be modeled using matrix bids and show that matrix bids are quite flexible, supporting additive, subadditive, and superadditive preferences simultaneously. Further, auctions that restrict the number of bundles can be considered a special case of CAMBO. We model the NP-hard winner determination problem for CAMBO as a polynomially-sized integer program consisting of assignment constraints and side constraints that enforce ordering. We describe a computationally effective technique for solving this problem consisting of the addition of cover inequalities, an objective perturbation heuristic, and a specialized branching scheme. Computational experiments will be discussed.

Parametric optimization methods for visualization of frontier in DEA and productivity analysis of Russian banks

VLADIMIR KRIVONOZHKO

Institute for Systems Analysis of Russian Academy of Sciences

coauthors: Oleg B. Utkin, Andrei Volodin
keywords: DEA

The proposed family of parametric optimization methods constructs cross-sections of the frontier by the two-dimensions plane or by three-dimensional hyperplane. This approach visualizes the frontier in multidimensional space of inputs and outputs and reduces the analysis of complex systems to the investigation of the well-known functions in economics such as production function, isoquant, isocost and so on. Moreover, we can calculate various economic factors in DEA applications, for example, marginal rate of substitution, marginal product, elasticity and so on. We apply our approach to efficiency analysis of Russian banks.

Calibration of options prices to market data using stochastic programming

ALAN KING
IBM Research

coauthors: Teemu Pennanen, Matti Koivu
keywords: options prices

We develop a model for the calibration of options prices to market data that requires no assumptions about the underlying stochastic price processes other than that they be free of arbitrage. The implemention of this model is a stochastic linear program that can be solved using standard packages.

MO3-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Complementarity and variational inequalities

chair: Dolf Talman

Application of the d-gap function approach to geheral equlibrium problems in Banach spaces

OLGA PINYAGINA
Kazan State University

coauthor: Igor Konnov
keywords: equilibrium problems, nonsmooth functions, Banach spaces

We consider a general equilibrium problem (EP) of the form: Find an element $u^* \in U$ such that

$$h(u^*, v) + f(v) - f(u^*) \geq 0 \quad \forall v \in U, \quad (*)$$

where U is a nonempty closed and convex subset of a real Banach space E, $h : E \times E \to R$ is an differentiable equlibrium bifunction, i.e. $h(u,u) = 0$ for every $u \in U$, $f : E \to R$ is a convex continuous, but not necessarily differentiable function. In addition, we assume that $h(u,\cdot)$ is convex for each $u \in E$. Such EPs have a great number of applications in Economics, Mathematical Physics, Transportation, Operations Research and other fields. Moreover, they are closely related to other general problems of Nonlinear Analyses. In particular, EP(*) generalizes fixed point, saddle point, complementarity and variational inequality problems. We propose to apply the D-gap function approach, which was proposed for mixed variational inequalities in a finite-dimensional space, to the solution of EP(*). We show that, under certain additional assumptions, EP(*) can be converted into a problem of finding a stationary point of a differentiable function, which is nothing but a nonlinear equation. Being based on this property, we describe a descent type algorithm whose iteration sequence converges strongly to a solution to the initial problem.

Perfection and stability of stationary points with applications to noncooperative games

DOLF TALMAN
Dept. of Econometrics & OR, Tilburg University

coauthors: Gerard van der Laan, Zaifu Yang
keywords: stationary point, perfectness, stability

Let be given an upper-semicontinuous mapping from a convex, compact set X in Euclidean space to the collection of nonempty, compact, convex sets in the same space. In this paper we refine the solution concept of stationary point by perturbing simultaneously both the set X and the solution concept. In case a stationary point is the limit of a sequence of perturbed solutions on a sequence of sets converging continuously to X we say that the stationary point is stable with respect to this sequence of sets and the mapping which defines the perturbed solution. It is shown that stable stationary points exist for a large class of perturbations. A specific refinement, called robustness, is obtained if a stationary point is the limit of stationary points on a sequence of sets converging to X. We discuss several applications in noncooperative game theory. We show that both perfect Nash equilibrium and proper Nash equilibrium are special cases of our robustness concept. Applying our results to the field of evolutionary game theory yields a refinement of the stationary points of the replicator dynamics. We show that the refined solution always exists, contrary to many well known refinement concepts in the field.

MO3-308/T3 MODELING LANGUAGES AND SYSTEMS

Modeling languages and systems II

organizer/chair: Robert Fourer

Large-scale optimization with TOMLAB / MATLAB

KENNETH HOLMSTRÖM
Dept. of Mathematics and Physics / Mälardalen University

coauthor: Anders Göran
keywords: optimization software, MATLAB, nonlinear programming, integer programming

The TOMLAB Optimization environment in MATLAB (http://tomlab.biz), first presented at ISMP97, has seen a tremendous growth during the last years. With the help of MEX-file interfaces most state-of-the-art optimization software has been hooked up to TOMLAB, e.g. KNITRO, SNOPT and CONOPT for large-scale nonlinear programming, and CPLEX and Xpress-MP for large-scale mixed-integer programming. The unified input-output format in TOMLAB makes it easy to use and compare the solvers. This development also makes MATLAB a possible tool for large-scale optimization and the talk will discuss some interesting TOMLAB user examples, experience, solver comparisons and results.

The open outer approximation MINLP solver in AIMMS

JOHANNES BISSCHOP
Paragon Decision Technology B.V.

keywords: modeling system, open algorithm

Instead of offering a black-box implementation of the outer approximation algorithm for Mixed-Integer NonLinear Programming (MINLP) models, AIMMS offers an open technology to allow for customized and efficient implementations of the algorithm. A novel feature is that each variant of the algorithm is written in the AIMMS modeling language itself. The presentation will introduce, motivate and demonstrate this new technology.

Update on the AMPL/solver interface library

DAVID GAY
AMPL Optimization LLC

coauthor: Robert Fourer
keywords: nonlinear programming, linear programming, stochastic programming, complementarity

Many solvers, particularly nonlinear ones, have idiosyncratic requirements for how problems are presented to them and how certain of their features are exercised. The AMPL modeling language and environment seeks to provide a simple view of solvers that hides the idiosyncrasies. The AMPL/solver interface library facilitates this by providing interface routines and data structures that simplify the task of providing a solver what it needs while letting AMPL users maintain a simplified view of the solver. This talk reviews some of these facilities, focusing in particular on recent and forthcoming additions, such as suffix notation for auxiliary information and extensions for dealing with constraint programming. Sometimes a solver interface must do a custom "tree walk" of expression graphs. Examples include interfaces to some global optimization and constraint programming solvers.

MO3-341/21 INTERIOR POINT ALGORITHMS

Primal-dual algorithms

chair: Mohamed El ghami

An extension of a predictor-corrector method variant from linear programming to semidefinite programming

ANA PAULA AIRES BORGES TEIXEIRA
UTAD (Trás-os-Montes e Alto Douro University)/Lisbon's University Operational Research Centre
coauthor: Fernando Bastos
keywords: semidefinite programming, interior point method, primal-dual algorithms

We intend to present an extension of a predictor-corrector algorithm from Linear Programming to Semidefinite Programming, where the predictor is calculated as an iteration of a primal-dual interior-point algorithm to Semidefinite Programming and where the corrector is calculated in the classical way. To implement this predictor-corrector variant we modified the source code of the package CSDP, version 3.2, and we used Lanczos' method to find primal and dual steplengths. We will present some computational experience.

Primal-dual interior-point algorithms for indefinite quadratic programming

ANDRE TITS
University of Maryland
coauthor: Pierre-Antoine Absil
keywords: quadratic programming, nonlinear programming

A globally convergent (to KKT points), locally quadratically convergent primal-dual interior-point method for nonlinear programming is refined for the case where the objective function is quadratic and the constraints linear. Close to a strong minimizer, the primal-dual Newton direction for the set of perturbed KKT conditions is well defined and, for small enough values of the perturbation parameter μ, its primal component is a direction of descent for the objective function. Away from such solutions, the same holds provided the Hessian matrix is suitably modified by adding to it a small positive definite matrix. An efficient scheme for determining an appropriate such correction is proposed and analyzed. Special consideration is given to the "affine scaling" case ($\mu = 0$).

Primal-dual interior-point methods based on a new class of barrier functions

MOHAMED EL GHAMI
Tudelft
coauthors: J. B. M. Melissen, Kees Roos
keywords: primal-dual interior point alg, kernel function, proximity function, complexity

In this paper we present a new class of barrier functions for primal-dual interior point methods (IPMs). The proposed functions have a finite value at the boundary of the feasible region. They are not exponentially convex and also not strongly convex. In spite of this, the iteration bound of large-update interior-point methods based on these functions is shown to be $O(\sigma n^{\frac{1}{1+p}} \log \frac{n}{\varepsilon})$, with $p \in [0,1]$ and $\sigma \geq 1$. For small-update interior point methods the iteration bound is $O(\sqrt{n} \log \frac{n}{\varepsilon})$, which is the currently best known bound for primal-dual IPMs. In this talk we restrict to linear optimization, but extension of the methods to other cone optimization problem can be derived in a natural way.

MO3-341/22 LOGISTICS AND TRANSPORTATION

Facility location problems

chair: Jakob Krarup

Facility location under economics of scale

ASGEIR TOMASGARD
NTNU
coauthors: Leen Stougie, John van der Broek
keywords: facility location, economics of scale, integer programming

The facility location problem described in this paper comes from an industrial application with economics of scale. The objective function is first concave but changes to convex when marginal costs start to increase.

We present an approach based on linearization of the facility costs and Lagrangean decomposition. We also develop a greedy heuristic to find upper bounds. We use the method to solve a problem instance for the Norwegian Meat Co-operative and compare our results to previous results achieved using standard branch-and-bound in commercial software.

We examine a location-allocation problem focusing on the location of slaughterhouses, their size and the allocation of animals in the different farming districts to these slaughterhouses. Investigations show that the slaughterhouse industry experiences economics of scale in the production facilities, due to high investment costs. The model is general and also have applications within other industries that experience economics of scale.

Terminal location integrated with ship routing

HELENE GUNNARSSON
Department of Mathematics
coauthors: Mikael Rönnqvist, Dick Carlsson
keywords: integer programming, ship routing, transportation, location problem

Södra Cell AB owns three pulp-mills. Ships, trains and trucks are used for supplying customers. Coupled with each harbour there is a terminal. From each terminal, the products are transported to delivery points by truck, train or both combined. Recently, two new pulp-mills in Norway were acquired, which has led to a surplus of terminals. We have developed a mathematical model that selects which terminals are to be used. A new feature combines a facility location aspect with ship routing. The solution procedure includes route generation. Results based on evaluations and implementation at Södra are presented.

The p/q-active facility location problem

JAKOB KRARUP
DIKU (Dept. of Computer Science, Univ. of Copenhagen)
coauthors: U. Leopold-Wildburger, David Pisinger, J. Wanscher
keywords: locational decisions, integer programming

In almost all literature on locational decisions where a prespecified number p of facilities are to be located, facilities are either closed or open. Depending on the cost structure, however, there may be optimal solutions where some of the open facilities serve no users at all. To this end a refinement of the notion "open" is called for. We say that an open facility is either *active* if at least one user is allocated to it and *passive* otherwise. The p/q-active facility location problem is the problem of locating p active facilities, each serving at least q users at a minimum total cost. For the resulting model we present a mixed 0-1 programming formulation, account for its solution properties and propose an exact branch-and-bound algorithm with bounds generated via a dual ascent heuristic.

MO3-341/23 LOGISTICS AND TRANSPORTATION
Vehicle routing
chair: Jens Lysgaard

A two-commodity flow approach to vehicle routing problem

PAULA LORENA ZABALA
Universidad de Buenos Aires
coauthors: Abilio Lucena, Isabel Mendez-Diaz
keywords: vehicle routing, branch-and-cut, facets

A two-commodity flow formulation for the Vehicle Routing Problem (VRP) is considered and a polyhedral study of the associated polytope is carried out. Based on the results obteined from the polyhedral study a branch and cut algorithm for VRP is implemented and computationaly tested for instances from the literature.

New valid inequalities and an exact algorithm for the ATSP-TW

VICKY MAK
University of Melbourne
coauthor: Andreas Ernst
keywords: cutting plane/facet, integer, branch-and-bound, algorithms

In this talk, we present four new classes of inequalities for the ATSP-TW. These new constraints are based on the D_k^- and D_k^+ inequalities, and are strengthened due to precedence restrictions.

We implement these inequalities on a hybrid constraint programming and branch-and-bound algorithm for solving the problems. At each node of the branch-and-bound tree, we implement an Assignment Problem-based Lagrangean relaxation for obtaining lower bounds. When branching, we implement constraint propagation techniques for fixing variables. We present preliminary results for our exact algorithm.

Exact solution of the CVRP for a given set of seed customers: a branch-and-bound approach

JENS LYSGAARD
Aarhus School of Business
keywords: vehicle routing, branch-and-bound, heuristics

The well-known Capacitated Vehicle Routing Problem (CVRP) is the problem of routing a fleet of vehicles from a depot to a number of customers each requiring delivery of a given quantity of a product. Some of the heuristic approaches to the CVRP are socalled two-phase heuristics, among these are a number of cluster first – route second heuristics. The clustering phase in these heuristics are typically based on an initial identification of seed customers, such that the resulting routes each service exactly one seed customer. The identification of seed customers as well as the subsequent clustering and routing decisions are heuristic in nature in classical cluster first – route second heuristics. As such, there are potentially three sources of inoptimality of the resulting routes, namely i) the choice of seed customers, ii) the clustering decisions given the seed customers, and iii) the routing decisions given the clusters. In this presentation we consider a solution approach to the symmetric CVRP where only the choice of seed customers is heuristic. In particular, we present a branch-and-bound procedure which, using an additive bounding procedure, provides the exact solution to the symmetric CVRP for a given set of seed customers.

MO3-321/053 PRODUCTION AND SCHEDULING
Sequencing and scheduling
chair: Jacques Desrosiers

Theoretical and practical aspects of color sequencing

THOMAS EPPING
BTU Cottbus
coauthor: Winfried Hochstättler
keywords: flexible manufacturing, deterministic sequencing

Driven by an application in the paint shop of an automobile plant, we consider the issue of resorting a sequence of colored letters in order to minimize its number of color changes. We resume theoretical and practical results that arise from two different resorting strategies.

The first strategy allows resorting by color interchanges between identical letters only. This results in a combinatorial problem that is NP-complete even if the size of the underlying alphabet or the number of colors is restricted to two. It can be solved in polynomial time if both parameters are bounded. The second strategy assumes the existence of a set of parallel queues that can be used for resorting.

Pursuit-evasion with imprecise target location

GÜNTER ROTE
Freie Universität Berlin, Institut für Informatik
keywords: search and surveillance, on-line scheduling
We consider a game between two persons where one person tries to chase the other, but the pursuer only knows an approximation of the true position of the fleeing person. The two players have identical constraints on their speed. It turns out that the fugitive can increase his distance from the pursuer beyond any limit. However, when the speed constraints are given by a polyhedral metric, the pursuer can always remain within a constant distance of the other person.

This can be applied to buffer minimization in an on-line scheduling problem with conflicts.

A proximal trust-region algorithm for stabilized column generation

JACQUES DESROSIERS
HEC Montreal and GERAD
coauthor: Hatem ben Hamor
keywords: proximal methods, bundle methods, column generation, linear programming
This paper proposes a proximal point algorithm using both penalty and trust region concepts. We establish finite convergence while assuming the successive trust regions are of full dimension and never degenerate to a single point. The approach is specialized to the column generation context. The resulting algorithm converges to a pair of primal and dual solutions. Computational experiments with large-scale multi-depot vehicle scheduling instances show substantial stabilizing and accelerating effects on the column generation approach.

MO3-321/033 NETWORKS
Constrained paths
chair: Scott Provan

On hop-constrained walk polytopes

NJÅL FOLDNES
University of Oslo
coauthors: Geir Dahl, Luis Gouveia
keywords: hop-constrained walks, complete linear description, projection theorem

We study hop-constrained walks from a polyhedral point of view. A hop-constrained walk between two given nodes 0 and n is a 0-n-walk with at most H arcs. We briefly review the case $H \leq 3$ and consider here the case $H = 4$. An extended formulation for 4-walks is presented. We then use the projection theorem of Balas and Pulleyblank to derive a complete linear description of the 4-walk polytope. The dominant of the 4-walk polytope is also briefly discussed. Our main conclusions are:

- Describing the convex hull of hop-constrained paths, hop-constrained walks and their dominant for $H = 4$ is much more complex than giving similar descriptions for $H \leq 3$.
- As expected, describing the convex hull of 4-walks is a lot easier than describing the convex hull of 4-paths.
- Quite surprisingly, for H = 4 it is easier to describe the convex hull of the 4-walks than their dominant.

Selfish routing in capacitated networks

NICOLAS STIER
MIT
coauthors: Jose Rafael Correa, Andreas S. Schulz
keywords: price of anarchy, traffic assignment, noncooperative game, multicommodity flow

According to Wardrop's first principle, agents in a congested network choose their routes selfishly, a behavior that is captured by the Nash equilibrium of the underlying noncooperative game. Because Nash equilibria do not optimize any global criterion per se, there is no apparent reason why they should be close to a solution of minimal total travel time, i.e. the system optimum. In this talk, we offer extensions of recent positive results on the efficiency of Nash equilibria. In contrast to previous work, we present results for networks with capacities and for latency functions that are non-convex, non-differentiable and even non-continuous.

The inclusion of upper bounds on arc flows has early been recognized as an important means to provide a more accurate description of traffic flows. In this more general model, multiple Nash equilibria may exist and an arbitrary equilibrium does not need to be efficient. Nevertheless, our main result shows that the best equilibrium is as efficient as in the model without capacities. The improvements result from a simplified proof, which also allows us to work with broader classes of latency functions.

A primal-dual algorithm for finding maximum capacity paths with recourse

SCOTT PROVAN
Univ. North Carolina
coauthor: Rob Pratt
keywords: stochastic networks, maximum capacity path, primal-dual algorithms

The Maximum Capacity Path with Recourse Problem involves finding a maximum expected capacity path through a stochastic network, in the case where an arc capacity is known only when the tail node of that arc is reached. We study the problem under the assumption that arc capacities reset randomly after each step. (All known no-reset versions of this problem are NP-hard.) In this case a compactly-described strategy can be given for determining the optimal choice of next path-arc at a node, based on knowing the current arc values at that node together with certain predetermined values computed for the forward nodes of these arcs. Finding these predetermined values involves solving an exponentially large LP. We give a polynomial-time algorithm to do this, based on a primal-dual solution technique, for implicitly solving this LP.

MO3-321/133 GRAPHS AND MATROIDS
Matroids and antimatroids
chair: Abdón Sanchez-Arroyo

Rooted circuits of convex geometries from affine point configurations

MASAHIRO HACHIMORI
Institute of Policy and Planning Sciences, University of Tsukuba
keywords: convex geometry, antimatroid, rooted circuits

A convex geometry, whose complement is known as an antimatroid, is a set system arising from many important objects such as posets graphs, point configurations, oriented matroids, and so on. In this work we focus convex geometries arising from affine point configurations with additional fixed points (kernel) in fixed dimensions. Especially we discuss what kind of rooted circuits can be realized in the affine space. We call a set X a stem if $X \cup r$ is a rooted circuit with a root r, and the stems with a fixed root r a stem clutter. We start from a characterization of stem clutters in 2-dimensional case. We then show several generalizations to higher dimensions. It includes a sufficient condition of the stem clutter to be connected, a bound of the number of connected components of the clutter, and the size of kernels needed in the realizations.

The max-flow min-cut theorem for stems of rooted circuits of affine convex geometries

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University of Tokyo
coauthor: Masahiro Hachimori
keywords: convex geometry (antimatroid), closed-set system, packing, max-flow min-cut property

A convex geometry is an abstraction of convex hulls in affine space. The complement of a convex geometry is known as an antimatroid. We firstly introduce the notion of closed-set systems, which leads to a common generalization of rooted circuits both of matroids and convex geometries. In a matroid, (X,e) is a rooted circuit if X is a set not containing element e and $X \cup \{e\}$ is a circuit. We call X a stem of e. A stem clutter is the collection of stems of a fixed element. Seymour (1977) proved that a stem clutter of a binary matroid has the max-flow min-cut property if and only if it does not contain a minor isomorphic to Q_6. We shall present an analogue of this result in affine convex geometries. Precisely, we shall show that a stem clutter of a convex geometry defined from 2-dimensional point configuration has the max-flow min-cut property if and only if the configuration has no subset forming a 'Pentagon' with center e.

On independence systems and Rado-Hall theorems

ABDÓN SANCHEZ-ARROYO
Banco de Mexico
keywords: matroid, SDRs

Rado-Hall Theorems concern systems of representatives of finite families of subsets of a fixed finite set. Rado's Theorem states conditions under which it is possible to find transversals of families of independent subsets on a matroid. In this talk we present some partial results for non-matroidal independence systems in which Rado's Theorem holds.

TU1-302/41 COMBINATORIAL OPTIMIZATION

Submodular functions and discrete convexity III

organizers: Satoru Fujishige and Kazuo Murota
chair: Satoru Fujishige

A general two-sided matching market with discrete concave utility functions

AKIHISA TAMURA
RIMS, Kyoto University

coauthor: Satoru Fujishige
keywords: discrete convex analysis, stable marriage model, assignment model

In the theory of two-sided matching markets there are two standard models called the stable marriage model, due to Gale and Shapley, and the assignment model, due to Shapley and Shubik. Recently, Eriksson and Karlander have introduced a hybrid model of these two and Sotomayor also considered the hybrid model with full generality. In this talk, we propose a common generalization of these models by utilizing a framework of discrete convex analysis introduced by Morota, and verify the existence of a stable solution in our general model.

Substitutes and complements in linear and nonlinear programming

FABIO TARDELLA
Faculty of Economics - University of Rome

keywords: complement, substitute, submodular, parametric LP

Consider an optimization problem (P) whose value depends on some parameters in the objective function and /or in the constraints (e.g., the values of the right-hand sides in the constraints). Two parameters A and B are called complements if the sum of the improvements in the optimal value of (P) when each parameter is separately increased is not greater than the improvement obtained when they are jointly increased. Conversely, A and B are called substitutes if the reverse inequality holds. The concepts of complementarity and substitutability can be equivalently expressed by saying that the optimal value function of (P) is supermodular or submodular with respect to A and B. Starting with the work of Shapley, several authors have established conditions guaranteeing the complementarity or substitutability of some pairs of parameters, especially in network flow problems. Here we propose an extension of most known results of this type to more general classes of linear and nonlinear problems. Furthermore, we discuss some economic applications of our results.

Matroid representation of clique complexes

YOSHIO OKAMOTO
Institute of Theoretical Computer Science, ETH Zurich

coauthors: Kenji Kashiwabara, Takeaki Uno
keywords: independence systems, matroid intersection

In this paper, we approach the quality of a greedy algorithm for the maximum weighted clique problem from the viewpoint of matroid theory. More precisely, we consider the clique complex of a graph (the collection of all cliques of the graph) and investigate the minimum number k such that the clique complex of a given graph can be represented as the intersection of k matroids. This number k can be regarded as a measure of “how complex a graph is with respect to the maximum weighted clique problem” since a greedy algorithm is a k-approximation algorithm for this problem. We characterize graphs whose clique complexes can be represented as the intersection of k matroids for any $k > 0$. Moreover, we determine the necessary and sufficient number of matroids for the representation of all graphs with n vertices. This number turns out to be $n-1$. Other related investigations are also given.

TU1-302/42 COMBINATORIAL OPTIMIZATION

Steiner trees

organizer/chair: Gunnar W. Klau

Practical algorithms for the Steiner problem

SIAVASH VAHDATI DANESHMAND
University of Mannheim

coauthor: Tobias Polzin
keywords: Steiner problem, relaxation

State-of-the-art exact algorithms for $\mathcal{NP}$-hard problems like the Steiner problem consist of many different components, playing together as an "orchestra". We begin with giving an overview over our past and current work on such components, namely relaxations and lower bounds, reduction methods and upper bounds. Then we look more closely at one part of the work, namely methods for improving the linear programming relaxations. Finally, we show the impact of the presented methods on the solution of very large benchmark instances.

A lower bound and test problem generator for the group Steiner minimal tree problem

BOTING YANG
University of Regina

coauthor: P. Gillard
keywords: group Steiner minimal tree, VLSI design, lower bound, test problem generation

The group Steiner minimal tree problem is an extension of the standard Steiner minimal tree problem in graphs, motivated by the problem of wire routing in the area of physical design of very large scale integration (VLSI). This problem is NP-hard, even if there are no Steiner nodes and the graph is a tree; moreover, there exists no polynomial time approximation algorithm with a constant bound on the relative error under the hypothesis that P is not equal to NP. Hence, fast and good heuristic algorithms are needed in practice. In this talk, we describe an integer programming formulation of the problem. Using Lagrangean relaxation and subgradient optimization, we derive a lower bound. In order to test the lower bound, we present a procedure for generating test problems for the group Steiner minimal tree problem that have known optimal solutions. The computational experiments for the test problems demonstrate that the lower bound is very tight and differs from the optimal solutions by only a few percent on average for sparse graphs.

On the multi-weighted Steiner tree problem: a reformulation by intersection

JOÃO TELHADA
CIO / DEIO - FCUL

coauthor: Luis Gouveia
keywords: networks/graphs, Steiner trees, extended formulations

Previously, Gouveia and Telhada (2003) have presented an augmented arborescence formulation (AArb) for the multi-weighted Steiner tree problem. However, this formulation is not symmetric, in the sense that the linear programming (LP) bound depends on the choice of the root node. In this talk we present a new formulation, which is compact although the (AArb) model is not, with the property that its LP feasible set is obtained by intersecting the LP feasible sets of the (AArb) formulation for all possible root choices. We prove that the LP bound of

the new model is at least as good as the LP bound obtained by the (AArb) formulation with the best root choice (a few experiments, indicate that in many cases, a strict improvement is obtained). Computational results with instances involving up to 100 nodes demonstrate the computational advantage of the new modelling scheme.

TU1-302/44 COMBINATORIAL OPTIMIZATION

Combinatorial optimization III

chair: Klaus Michael Wenger

Fast algorithms for planar graphs, Part I: cycles and cuts

ADAM LETCHFORD
Lancaster University
coauthor: Nicholas Pearson
keywords: analysis of algorithms, combinatorial optimization, planar graphs, traveling salesman problem

We present improved algorithms for the following problems when the underlying graph is planar:

i) Minimum weight cut ii) Minimum weight circuit iii) minimum weight odd cut iv) Minimum weight odd circuit.

For the first and second problems (which are equivalent under planar duality), the current best known algorithm is due to Shih, Wu & Kuo and runs in $O(n^{3/2} \log n)$ time. We present a much simpler algorithm with the same running time, and a more complicated version which runs in $O(n^{3/2})$ time.

For the third and fourth problems (which are again equivalent under planar duality), no specialised algorithm currently exists for the planar case. We present a simple algorithm which runs in $O(n^{3/2} \log n)$ time and a more complicated version which runs in $O(n^{3/2})$ time.

These algorithms will be referred to in a companion talk by Nicholas Pearson, entitled "Fast algorithms for planar graphs, Part II: the traveling salesman problem".

Fast computation of a minimum t-cut in an undirected graph

DIRK THEIS
University of Heidelberg
coauthor: Gerhard Reinelt
keywords: polynomial time algorithms, graph algorithms

Given an undirected graph G, positive edge weights c and a set of "odd" nodes T with $|T|$ even, a T-odd cut is a cut edge set $(U : \bar{U})$ such that $|T \cap U|$ is an odd number. The minimum T-odd cut problem asks for a T-odd cut minimizing the weight $c(U : \bar{U}) := \sum_{e\in(U:\bar{U})} c_e$. The problem occurs, e.g., in separation routines for routing problems.

Two algorithms to compute a minimum T-odd cut are known (Padberg, Rao 1982; Rizzi 2003). Both require the solution of up to $|T|-1$ Max-Flow problems, leading to a worst-case running time of $O(|T|\, nm \log(n^2/m))$, if G has n nodes and m edges. We present an algorithm based on the one by Rizzi and with the same worst-case running time, but enhanced significantly. Following shrinking ideas known for the Min-Cut problem, we found ways to notably reduce the average number of Max-Flow computations which are required. The consequence is a clear decrease of running times. We give computational results indicating that our method is considerably faster than both known algorithms.

Maximally violated mod-k cuts and the capacitated vehicle routing problem

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Institute of Computer Science, University of Heidelberg
coauthor: Gerhard Reinelt
keywords: CVRP, branch-and-cut, cutting planes, mod-k

In the CVRP the demands of a set of customers have to be met at minimum total travel cost using vehicles of identical capacity based at a single depot. We report on the usefulness of maximally violated mod-k cuts in branch-and-cut algorithms for the CVRP. Let $Ax \leq b$ be a system of valid inequalities with integer coefficients. Assume there is an integer vector $\mu \geq 0$ such that the coefficients of $\mu^T A$ are divisible by the integer $k \geq 2$ but $\mu^T b \equiv k-1 \pmod{k}$. Then the inequality $\frac{1}{k}\mu^T Ax \leq \frac{1}{k}(\mu^T b - (k-1))$ is valid. Its maximal violation is $(k-1)/k$ which is achieved if $A_{i\cdot}x^* = b_i$ for $\mu_i > 0$ where x^* is the fractional point to be separated. We take the binding constraints of an LP with solution x^* as input and follow the separation procedure suggested by Caprara, Fischetti and Letchford (2000) with restriction to k prime. What can such general-purpose cuts of Chvátal-Gomory type do for the CVRP? We answer this question by a computational study taking the problem-specific rounded capacity, framed capacity, and multistar cuts as foundation. We use an exact separation procedure for rounded capacity inequalities. The conclusion is that maximally violated mod-k cuts are clearly too useful for the CVRP to be ignored.

TU1-302/45 COMBINATORIAL OPTIMIZATION

Machine scheduling

chair: Jose Rafael Correa

A branch-and-cut approach for coupled task problems

MARCUS OSWALD
Institute of Computer Science / University of Heidelberg
coauthors: Dino Ahr, Jozsef Bekesi
keywords: coupled task problem, scheduling, branch-and-cut

The coupled task problem (CTP) is to schedule jobs on a single machine where each job consists of two subtasks and where the second subtask has to be started after a given time gap with respect to the first subtask. The problem has several applications and is NP-hard. Here we discuss an approach to solve the coupled task problem to optimality. We model the CTP as a linear 0/1-program which is the basis for a branch-and-cut algorithm. We describe the implementation of the algorithm and report about computational results.

Mathematical models and methods for balancing production lines with parallel blocks of operations at workstations

GENRIKH LEVIN
United Institute of Informatics problems of the National Academy of Sciences of Belarus
coauthors: Alexandre Dolgui, Nikolai Guschinsky
keywords: line balancing, machinery

We consider a balancing problem for production lines when all operations of the same workstation are partitioned into several subsets (blocks), and all operations of the same block are executed simultaneously by one spindle head. The operation time of a block is usually more than maximal value among operation times of its operations. All blocks of the same workstation are executed simultaneously as well. The problem is to determine the quantity of the workstations and the blocks at every workstation and to assign the operations to the blocks to minimize the total cost of all workstations and blocks. The following constraints have to be taken into account: (1) a partial order relation on the operation set; (2) the necessity or the impossibility to assign some operations to the same block or workstation; (3) required line cycle time; (4) limits on the quantity of the workstations and the blocks at every workstation. Two approaches for solving the problem are proposed. The

approaches reduce the initial problem (1) to a mixed integer program problem and (2) to a constrained shortest path problem. Both approaches are combined with heuristics techniques for solving large-scale problems. Experimental results are discussed.

Single machine scheduling with precedence constraints

JOSE RAFAEL CORREA
MIT
coauthor: Andreas S. Schulz
keywords: scheduling theory, linear programming relaxations, approximation algorithms

We consider the classic problem of scheduling precedence-constrained jobs on a single machine to minimize the average weighted completion time. This problem has attracted much attention by the mathematical programming community since Sidney's pioneering work in 1975.

In this talk, we discuss connections between various linear programming relaxations and some approximation algorithms. Among other things, we present a generalization of Sidney's Decomposition Theorem and show that all known 2-approximation algorithms comply with this decomposition. Moreover, this theorem also yields a simple proof of the polynomial-time solvability of the problem when the precedence constraints are series-parallel.

In addition, we establish a connection between the single-machine scheduling problem and the vertex cover problem. Indeed, in the special case of series-parallel precedence constraints, we prove that the sequencing problem can be seen as a special case of vertex cover. Moreover, we argue that this result is true for general precedence constraints if one can prove that a certain integer program represents a valid formulation of the sequencing problem.

TU1-302/49 — INTEGER AND MIXED INTEGER PROGRAMMING

Integer programming column generation III

organizer: Marco Lübbecke
chair: David M. Ryan

Models and algorithms for staff scheduling problems

MICHELE MONACI
DEIS, University of Bologna
coauthors: Alberto Caprara, Paolo Toth
keywords: combinatorial optimization, column generation, branch-and-bound

We present mathematical models and solution algorithms for staff scheduling problems arising in real life applications. In these problems, the daily assignments to be performed are given and the durations (in days) of the working and rest periods for each employee in the planning horizon are specified in advance, whereas the sequence in which these working and rest periods occur, as well as the daily assignment for each working period, have to be determined. The objective is to minimize the number of employees needed to perform all required daily assignments.

We decompose the problem into two steps: the definition of the sequence of working and rest periods (called *pattern*) for each employee, and the definition of the daily assignment to be performed in each working period by each employee. For step one, we present ILP models and exact enumerative algorithms; practical experience shows that the best approach is based on models involving a large number of variables, thus requiring the adoption of column generation techniques. Step two is stated as a feasibility problem and is solved heuristically. We also propose an ILP formulation for the entire problem, and present computational results on real life instances from an emergency call center.

Solving duty scheduling problems in public transit

RALF BORNDÖRFER
Zuse Institute Berlin
coauthor: Andreas Löbel
keywords: manpower planning, combinatorics, column generation, public transportation

The duty scheduling problem in public transit is to string a set of duty elements, i.e., units of driving work, into a minimum cost set of shifts of work for bus, tram, or subway drivers. Such problems can be modelled as set partitioning problems and solved by column generation techniques. To tackle large-scale instances with several thousands of duty elements and complex labour regulations, special algorithmic techniques are needed.

The talk discusses LP solution, resource constraint shortest path computation, and primal schedule construction methods that aim at exploiting all degrees of freedom in the problem. The methods have been implemented in the optimization system DS-OPT. Computational results for a number of real-world problems will be reported.

Robust branch-and-cut-and-price for the capacitated vehicle routing problem

MARCUS POGGI DE ARAGAO
Pontificia Universidade Católica do Rio de Janeiro
coauthors: Eduardo Uchoa, Ricardo Fukasawa, Marcelo Ladeira Reis
keywords: column generation, routing, integer programming

We propose a branch-and-cut-and-price algorithm for the capacitated vehicle routing problem. The column generation scheme follows the standard set partitioning formulation(Balinsky and Quandt) where the node set is partitioned over the routes (columns). We keep the edge set associated to each column to recover the original formulation where the variables correspond to edges. Capacity cuts are then separated on the original formulation, translated and added back to the column generation scheme. These cuts are defined on the edge variables, the new dual variables added can be distributed over the edges in the cut. This implies that no change is imposed to the column generation subproblem. The same occurs when branching on edge variables. This leads to a robust branch-and-cut-and-price, where neither branching nor the addition of cuts change the structure of the pricing subproblem. Computational results on benchmark instances from the literature are shown. Significant improvement was obtained on previously known lower bounds for instances with a high number of vehicles. On all open instances tested, this algorithm outperformed recently implemented pure branch-and-cut algorithms, even when these make use of several other families of cuts besides the capacity cuts. We also closed a number of open instances.

TU1-306/31 — INTEGER AND MIXED INTEGER PROGRAMMING

Integer and mixed integer programming II

chair: Robert Nauss

Simplifying branch-and-price algorithms through lexicographic ordering

EUGENE ZAK
TietoEnator Majiq
keywords: cutting stock problem, branch-and-price, column generation, lexicographic ordering

In the last decade, several exact algorithms for solving the one-dimensional cutting stock problem have emerged. Most of these algorithms fall into the promising branch-and-price framework

that uses Gilmore-Gomory column generation throughout a branch-and-bound search tree. A new technique, proposed in this talk, has similarities with branch-and-price. The main difference, though, comes from imposing a cutting pattern order relation based on a lexicographic comparison of vectors. This relation is further drawn into a lexicographic ordering over all feasible solutions of the original problem. Due to this lexicographic ordering, branching rules, that happen to be a tricky part in the existing branch-and-price algorithms, become intuitive here. Evidently, the pricing problem turns into a knapsack problem with an additional constraint that lexicographically restricts the knapsack solutions. A computer implementation of the algorithm has been devised and the computational results prove the competitiveness of the proposed technique.

Eliminating redundant solutions of combinatorial integer programs

PABLO A. REY
Universidad de Chile
coauthor: Oscar Porto
keywords: integer programming, redundant solutions

The presence of equivalent solutions in linear integer programming problems make their solution difficult for enumerative algorithms. This work presents a way to exploit known symmetries of linear integer models to eliminate redundant equivalent solutions. This information is used to generate appropriate inequalities which added to the original formulation enhance their solvability. In the examples considered, this approach leads to an impressive reduction of the search tree of enumerative algorithms.

A computational study of elastic and classical generalized assignment problems

ROBERT NAUSS
University of Missouri-St. Louis
keywords: optimization, integer programming, mixed integer programming, assignment problems

The classical generalized assignment problem (GAP) is NP-complete. While certain random problem generators yield GAP problems that are relatively easy to solve, there are at least two generators that produce problems that are very difficult to solve to optimality. Indeed problems on the order of only 1000 binary variables may not admit a provably optimal solution using general-purpose IP solvers or even special purpose codes. For such problems excellent feasible solutions with small relaxation gaps can generally be found, but the difficulty lies in proving optimality. An elastic version of the GAP where the resource constraints may be violated (at a cost) is examined. We explore this approach since a number of researchers have reported on the success of solving elastic (versus nonelastic) versions of various classes of integer programs. We perform computational tests on corresponding cases of classical and elastic GAP problems to determine if the elastic version is easier to solve.

TU1-306/32 NONLINEAR PROGRAMMING
Optimization of engineering systems governed by simulations/PDE, part 1
organizer/chair: Natalia Alexandrov

Optimization with multiple scales using wavelet based reduced order models

MARTIN BENDSOE
Dept. of Mathematics, Technical University of Denmark
coauthors: A. R. Díaz, S. Chellappa
keywords: multiple scales, MPEC, wavelets

In this work we address the possibility of designing structures with multiple scales using concepts from topology design coupled with multi-scale resolution methods that can account for the presence of finite scales. The approach taken is to use a wavelet-Galerkin technique and an associated multi-resolution numerical homogenization meyhod to replace fine-scale operators with coarse-scale averages, that is, reduced order models of the original system in a coarser scale. In general, these homogenized operators are dense and cannot be used easily in optimization. They are used instead in an inverse procedure that obtains an equivalent coarse-scale elasticity problem. Thus the complete process associates an equivalent coarse-scale material layout with each element in a library of fine-scale operators. The topology optimization problem uses this coarse material layout to parameterize the design space, and the optimization process from there on resembles a standard sizing problem – that is, mathematical programming problems with equilibrium constraints (MPEGs). This is joint work with A. R. Díaz and S. Chellappa, Michigan State University, USA.

Reduced-basis techniques for rapid reliable optimization of systems described by parametric partial differential equations

IVAN OLIVEIRA
Massachusetts Institute of Technology
coauthor: A. T. Patera
keywords: reduced-basis, engineering optimization, a posteriori error estimation, partial differential equations

We present a technique for the rapid and reliable optimization of systems characterized by linear-functional outputs of partial differential equations with affine (input) parameter dependence. The critical ingredients are: (Lagrangian) reduced-basis approximation to effect significant reduction in state-space dimensionality; a posteriori error bounds to provide rigorous error estimation and control; “offline/online” computational decompositions to permit rapid evaluation of output bounds, output bound gradients, and output bound Hessians in the limit of many queries; and reformulation of the approximate optimization statement to ensure (true) feasibility and control of suboptimality. To ensure reliable model behavior, we have developed a directionally-scaled trust region algorithm which we employ to solve the resulting mathematical program. To illustrate the method we consider the design of a three-dimensional thermal fin: Given volume and power objective-function weights, and root temperature “not-to-exceed” limits, the optimal geometry and heat transfer coefficient can be determined — with guaranteed feasibility — in only 2.3 seconds on a 500 MHz Pentium machine. Our method thus permits not only interactive optimal design at conception and manufacturing, but also real-time (reliable) adaptive optimal design in operation.

Robust optimal design of experiments for DAE and PDE

EKATERINA KOSTINA
IWR, University of Heidelberg
keywords: design of experiments, numerical methods

Estimating model parameters from experimental data is crucial to reliably simulate dynamic processes. In practical applications, however, it often appears that the experiments performed to obtain necessary measurements are expensive, but nevertheless do not guarantee sufficient identifiability. The optimization of one or more dynamic experiments in order to maximize the accuracy of the results of a parameter estimation subject to cost

and other technical inequality constraints leads to very complex non-standard optimal control problems.

Newly developed successful methods and software for design of optimal experiments for nonlinear processes are based on the expansion of the problem at the nominal value of parameters which lie in a (possibly large) confidence region. Better experiments should be obtained if we optimize the experiments in minimax fashion (worst-case design) over the whole range (confidence region) of an uncertainty set. Such a minimax problem, as a semi-infinite programming problem, has extremely high degree of computational complexity. We have developed efficient and reliable methods for design of robust optimal experiments that reduce the complexity of the semi-infinite programming problem. The methods are successfully applied to real-life problems from chemistry and chemical engineering (joint work with Georg Bock, Stefan Koerkel and Johannes P. Schloeder).

TU1-306/33 NONLINEAR PROGRAMMING

Augmented Lagrangian methods I

chair: Otero Rolando Gárciga

Application of an SQP augmented Lagrangian method to a large-scale problem in 3d reflection tomography

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Institut Français du petrole

coauthors: Jean Charles Gilbert, Delphine Sinoquet
keywords: SQP, Gauss-Newton algorithm, augmented Lagrangian, seismic tomography

Seismic reflection tomography allows the determination of a subsurface model from the traveltimes of seismic waves reflecting on geological interfaces. From an optimization viewpoint, the problem consists in minimizing a nonlinear least-squares functional measuring the mismatch between observed traveltimes and those calculated by raytracing in this model. We introduce geological a priori information thanks constraints in the optimization problem.

We use a Gauss-Newton SQP method globalized by line search to solve this optimization problem. At each Gauss-Newton step, a solution to a strictly convex quadratic model of the objective function subject to linearized constraints is computed using a dual approach. This one is based on an augmented Lagrangian relaxation that requires solving a sequence of primal quadratic subproblems with bound constraints. These large size (20000 unknowns) ill-conditioned ($> 10^7$) subproblems are solved combining efficiently an active set method with a gradient projection method and a preconditioned conjugate gradient method. We use the standard multiplier approach to maximize the augmented Lagrangian dual function.

The strategic choices of the algorithm will be discussed, theoretically motivated and illustrated by extensive numerical experiments on problems arising in 3D reflection tomography.

Finite time identification of active constraints with an augmented Lagrangian algorithm

JEAN CHARLES GILBERT
INRIA Rocquencourt

coauthor: Frederic Delbos
keywords: augmented Lagrangian, active constraints, proximal algorithm, strongly convex optimization

We consider an augmented Lagrangian algorithm for minimizing a strongly convex function subject to linear inequality constraints. It is shown that the active constraints at the solution are identified after a finite number of iterations. This result is a consequence of the proximal interpretation of the method. Algorithmic implications are discussed, in particular when the augmented Lagrangian method is used to solve the quadractic programs arising in the SQP approach.

A strongly convergent augmented Lagrangian method

OTERO ROLANDO GÁRCIGA
UFRJ/IE

keywords: augmented Lagrangians, cone-constrained optimization, strong convergence, inexact solutions

We consider a general optimization problem of the form: min g(x) subject to $-G(x) \in K$, with $g : B_1 \to \mathbb{R}$, $G : B_1 \to B_2$, where B_1 and B_2 are real reflexive Banach spaces and K is a nonempty closed convex cone in B_2. We present an inexact hybrid augmented Lagrangian method for solving this problem. The method generates a primal-dual sequence which converges strongly to an optimal pair. Moreover, we can establish the relation between the strong limit and the initial iterate. Results are guaranteed under G-differentiability and convexity of the data functions (K-convexity for G) and existence of KKT-pairs provided B_2 uniformly convex and uniformly smooth.

TU1-306/34 NONLINEAR PROGRAMMING

Advances in algorithms and software for nonlinear programming

organizer/chair: Stephen Wright

LOQO: an interior-point method for nonconvex nonlinear programming

HANDE BENSON
United States Naval Academy, Mathematics Dept.

coauthors: David Shanno, Robert J. Vanderbei, Igor Griva, Arun Sen
keywords: optimization, nonlinear optimization, interior point method

In this talk, we will present the latest developments to LOQO, an interior-point method for nonconvex nonlinear programming. Extensive numerical results will be provided.

Improving to nonlinear interior methods

JORGE NOCEDAL
Northwestern University

coauthors: Richard Waltz, Richard Byrd
keywords: large scale optimization

We begin by discussing strategies for adaptively choosing the barrier parameter in nonlinear interior methods. A framework for guaranteeing global convergence is described, and numerical results are presented. We also make some remarks on how to handle cases when the central path does not exist in a neighborhood of an iterate. We end the talk by evaluating the performance of a merit function approach, and in particular, by questioning whether filter mechanisms are, in fact, more effective.

An LCL algorithm for constrained optimization

MICHAEL PAUL FRIEDLANDER
Mathematics and Computer Science Div, Argonne Natl Labs

coauthor: Michael Alan Saunders
keywords: large scale optimization, nonlinear optimization, augmented Lagrangian, elastic variables

For optimization problems with nonlinear constraints, linearly constrained Lagrangian (LCL) methods sequentially minimize an augmented Lagrangian subject to linearized constraints. Convergence is rapid near a solution (as proved by Robinson and often observed with MINOS).

To induce global convergence and to unify the approaches used in LANCELOT and MINOS, we work with an elastic form of the linearized constraints (by adding an L1 penalty term to the augmented Lagrangian). Our stabilized LCL method possesses two important properties: the linearly constrained subproblems are always feasible, and they may be solved inexactly.

The current implementation is efficient on large problems, using MINOS to solve the subproblems. Only first derivatives are required. We present numerical results on the COPS and CUTE test problems.

TU1-306/35 OTHER
Software session, Dash
chair: James Tebboth

TU1-306/36 PARALLEL COMPUTING
Implementation
chair: Andreas Grothey

Parallel implementation of metaheuristics for combinatorial optimization problems on global computing systems

KAZUHIRO KOBAYASHI
Department of Mathematical and Computing Sciences/Tokyo Institute of Technology
coauthor: Katsuki Fujisawa
keywords: parallel computing, metaheuristics

We describe parallel implementation of metaheuristics for combinatorial optimization problems. We use global computing system called Ninf. Ninf system enables us to utilize the computational resources connected via local area network or wide area network. Ninf system provides an easy-to-use programming interface and enables us to build Grid-enabled applications. We present some computational experiments on PC Cluster.

Newton-like method for special class of nonlinear systems

ZORANA LUZANIN
Institute of Mathematics and Informatics, University of Novi Sad, Serbia
coauthor: Natasa Krejic
keywords: Newton-like methods, block diagonal structure, computational efficiency, q-convergence

We present an efficient algorithm for solving system of nonlinear equations with a block diagonal structure. The algorithm is based on general Newton method which uses inner iterative method for calculating approximation of the inverse Jacobian matrix. Local q-superlinear and q-quadratic convergence is proved. Numerical experiments and computational efficiency are also presented.

Object-oriented parallel interior point solver for structured nonlinear programs

ANDREAS GROTHEY
University of Edinburgh
coauthor: Jacek Gondzio
keywords: parallel programming, interior point method, nonlinear programming, large scale

Very large optimization problems with millions of constraints and decision variables display usually some special structure. The key to efficient solution of such problems is the ability to exploit the structure. We have developed a structure-exploiting parallel primal-dual interior-point solver for nonlinear programming problems. The solver allows in particular a nested embedding of structures and by this means very complicated real-life optimization problems can be modeled.

Its design uses object-oriented programming techniques. Different matrix structures are implemented as subclasses of an abstract matrix class. This abstract matrix class contains a set of virtual functions (methods in the object-oriented terminology) that: (i) provide all the necessary linear algebraic operations for an IPM, and (ii) allow self-referencing. The program OOPS (Object-Oriented Parallel Solver:

http://www.maths.ed.ac.uk/
~lkgondzio/parallel/solver.html)

can efficiently handle very large nonlinear problems and achieves scalability on a number of different computing platforms.

The efficiency of the solver is illustrated with problems known from the literature: applications arising from telecommunication and financial engineering. Numerical results are given for the solution of nonlinear financial planning problems with sizes over 50 million decision variables.

TU1-306/37 CONVEX PROGRAMMING
Decomposition in convex programming
chair: Kaj Holmberg

A decomposition approach to the minimization of a separable convex function on a convex polyhedron generated by a parallel-consecutive structure

YURI LEVIN
Queen's University School of Business
coauthors: Adi Ben-Israel, Genrikh Levin, Boris Rozin
keywords: convex programming, decomposition, large scale optimization

We consider a problem of minimization of a separable, strictly convex, monotone and differentiable function on a convex polyhedron generated by a system of m linear inequalities. The variables are divided into n disjoint subsets, and variables from each inequality are elements of a direct product of these subsets.

An approximate solution of this problem can be obtained by solving at most m subproblems; each subproblem has exactly one constraint and at most n variables. The authors' Projected Newton Bracketing (PNB) method for linearly constrained convex minimization is used to solve these subroblems. We review the PNB method during the talk.

For the exact solution of this problem we propose the decomposition scheme based on the constraint relaxation idea. This decomposition scheme calls for solution of a dynamically generated sequence of subproblems with equality constraints. A subroblem in the sequence is obtained from the previous one by adding and/or deleting one of the constraints. A modification of the PNB method efficiently solves these subproblems.

The described problem arises in optimization of parameters of mechanical systems with a parallel-consecutive structure subject to reliability of their components.

Solving system design using a type of convex submodels: computational experience

ÁNGEL MARÍN
Universidad Politécnica de Madrid
coauthor: Javier Salmerón
keywords: system design, location, convex programming, decomposition

In this presentation we present an explicit method for solving a convex model which involves a convex objective function and cumulative bound constraints. These models may arise, for example, when Benders' Decomposition or Lagrangean Relaxation-Decomposition is applied to solve large design problems such as the facility location and capacity expansion problems. To attain the

optimal solution of the model we analyze its Karush-Kuhn-Tucker optimality conditions and develop an explicit formulation for the optimal primal and dual solutions. This approach yields higher performance when compared to other convex optimization techniques, MINOS and parametric optimization.

Mean value cross decomposition for nonlinear convex problems

KAJ HOLMBERG
Linkoping University, Department of Mathematics
coauthor: Krzysztof Kiwiel
keywords: nonlinear programming, decomposition methods

Mean value cross decomposition is a symmetric primal-dual decomposition method, suitable for optimization problems with both primal and dual structures. It uses only easily solvable subproblems and no difficult master problems. Originally developed for linear problems, it is in this paper extended to nonlinear convex optimization problems. Convergence is proved for a somewhat generalized version, allowing more general weights. Computational results are presented for a network routing problem with congestion costs, a large-scale nonlinear problem with structures that enable decomposition both with respect to variables and constraints. The main goals of the tests are to illustrate the procedure and to indicate that this decomposition approach is more efficient than direct solution with a well established general code.

TU1-306/38 GLOBAL OPTIMIZATION
Global optimization I
chair: Nikolaos Sahinidis

Solving fractional programs with stochastic algorithms

MIRJAM DUER
Department of Mathematics, Darmstadt University of Technology
coauthor: Zelda B. Zabinsky
keywords: fractional programming, nonlinear programming

Maximization of a sum ratios is an optimization problem which appears in many economic and engineering situations, whenever efficiency of a system is to be optimized. Traditional methods to solve these problems were mainly Branch-and-Bound type algorithms. In this talk, a new approach is discussed: We report on experience treating fractional problems with stochastic algorithms like Improving Hit-and-Run (IHR). It turns out that the performance of IHR is for many problem classes comparable to or better than that of existing algorithms, and that it is more universal in the sense that it can treat many types of objective functions. We discuss benefits and drawbacks of both deterministic and stochastic solution approaches to fractional programs.

Minimal ellipsoid circumscribing a polytope defined by a system of linear inequalities

JUN-YA GOTOH
University of Tsukuba
coauthor: Hiroshi Konno
keywords: minimal ellipsoid, computational geometry, global optimization

Calculation of a minimal sphere circumscribing a polytope has been studied by many authors. In particular, if we know all extreme points of a polytope and if its cardinality is not excessively large, then the problem can be solved efficiently by a number of algorithms. On the other hand, if a polytope is defined by a linear system of inequalities, the problem is NP complete. We are concerned with a problem for calculating a minimal ellipsoid circumscribing a polytope defined by a system of linear inequalities, which is a direct extension of a minimal sphere problem. In this talk we present a global optimization algorithm for the minimal ellipsoid problem where a polytope is of relatively low dimension. We also present some numerical results to show its performance.

Global optimization in informatics problems in biology, chemistry, and physics

NIKOLAOS SAHINIDIS
University of Illinois
keywords: nonconvex optimization, mixed integer nonlinear prog., bioinformatics, chemical informatics

With the recent accumulation of vast amounts of chemical, biological, and clinical data, many scientific fields are becoming increasingly data-driven as opposed to model-driven. This paradigm shift has brought about many challenging computational problems. Even though these problems originate from very disparate fields, they have very similar mathematical structures. In particular, they involve the use of a merit function to evaluate alternatives from very large, often combinatorial, search spaces.

We address the challenging informatics problems of: (a) using group contribution data to design chemicals with desired properties, (b) using X-ray diffraction data to infer three-dimensional structures of crystals, and (c) using DNA sequencing data to predict DNA-protein binding sites. For each problem, we present novel mathematical programming models and algorithms for their solution.

The main conclusion of the paper is that branch-and-reduce algorithms for the global optimization of the underlying nonlinear and mixed-integer nonlinear programming models have now reached the level of maturity required to solve realistic informatics problems.

TU1-308/11 AIRLINE OPTIMIZATION APPLICATIONS
Disruption management
organizer/chair: Niklas Kohl

Degradable airline schedules

JOHN-PAUL CLARKE
MIT
coauthor: Laura Kang
keywords: robust scheduling, airline scheduling, airline operations

We present a methodology for deriving airline schedules that are robust to disruptions caused by bad weather, and that allow airlines to market itineraries and sell tickets based on passenger preference for reliability. In this methodology, an existing schedule is partitioned into independent sub-schedules or layers – prioritized on the basis of revenue – where the highest priority or "protected" layers are designed to both contain the highest revenue itineraries and to be operable in the worse weather. The problem is modeled as an integer program where the candidate aircraft routings are created using a greedy heuristic and a tabu search. Results indicate that no additional aircraft are required to increase the number of itineraries in the protected layers from 891 to 938 and to increase the corresponding revenue in the protected layers from 60% to 76.3%.

A branch-and-price approach for operational aircraft maintenance routing

RAJAN BATTA
University at Buffalo (SUNY)
coauthors: Abdulkadir Sarac, Christopher M. Rump
keywords: airline applications, maintenance routing

We focus on the problem of aircraft routing, which involves generating and selecting a particular route for each aircraft of a sub-fleet that is already assigned to a set of feasible sequences of flight legs. Similar studies typically focus on long-term route planning. However, stochastic events such as severe weather changes, equipment failures, variable maintenance times, or even new regulations mandated by the Federal Aviation Administration (FAA) play havoc on these long-term plans. As a result, these plans are often ignored by personnel in airline operations who are forced on a daily basis to develop quick, ad hoc methods to address these maintenance requirements and other irregular events. To address this problem, we develop an operational aircraft maintenance routing problem formulation that includes maintenance resource availability constraints. We propose a branch-and-price algorithm for solving this problem, which, due to the resource constraints, entails a modification of the branch-on, follow-on branching rule typically used for solving similar problems. Through computational testing, we explore the efficiency of this solution approach under a combination of heuristic choices for column (route) generation and selection.

Fast aircraft schedule recovery with crew and passenger constraints

DARREN DEJUN HANG
Carmen Systems AB

keywords: aircraft schedule recovery, airline operations

The aircraft schedule recovery problem is solved daily by airlines. The objective is to minimize the impact of disruptions on the airline schedule taking into account essential aircraft, crew and passenger data and constraints. Our algorithm generates structurely different solutions within seconds. Experimental results on real life data from major airlines will be presented.

TU1-308/12 STOCHASTIC PROGRAMMING

Computational stochastic integer programming

organizer/chair: Andrew Schaefer

Lagrangian relaxation method for price-based unit commitment problem

TAKAYUKI SHIINA
Central Research Institute of Electric Power Industry

keywords: electric power, unit commitment

The unit commitment problem is an important problem for electric power utilities. The problem is to determine the schedule of power generating units and the generating level of each unit. The decisions are which units to commit at each time period and at what level to generate power meeting the electricity demand. The objective is to minimize the operational cost which is given by the sum of the fuel cost and the start up cost. The electric power industry is undergoing restructuring and deregulation. In this paper we develop a stochastic programming model which incorporates power trading. It is assumed that demand and price uncertainty can be represented by a scenario tree. We propose a stochastic integer programming model in which on/off decisions of generators are made in the first stage. The solution approach is based on Lagrangian relaxation method and dynamic programming.

SPAR: stochastic programming with adversarial research

ANDREW SCHAEFER
University of Pittsburgh
coauthors: Matthew Bailey, Steven Shechter
keywords: stochastic programming, dynamic programming, Markov decision processes, stochastic games

We introduce a general modeling technique for problems involving the design of a system with the knowledge that an adversary may attempt to destroy or significantly decrease the performance of the system after installation. We consider multi-stage problems in which an adversary decides future stages. The decision maker must choose a system configuration so as to minimize the long-run damage inflicted by the adversary. The adversary then solves a multi-stage stochastic optimization problem to maximize the expected damage to the decision maker. We formulate this problem as a two-stage stochastic program with Markov decision process recourse. This method generalizes other approaches, including many stochastic interdiction problems. We discuss health care and military applications, and preliminary computational results.

Two-stage integer programming with stochastic integer right-hand sides

NAN KONG
University of Pittsburgh
coauthor: Andrew Schaefer
keywords: stochastic integer programming, integer duality, global optimization

We consider a two-stage pure integer program with stochastic right-hand sides. We give a dual reformulation with which the value functions of two stages can be evaluated separately. Two cases are addressed with respect to the storage of value functions. When the value function can be explicitly stored, we use a superadditive dual algorithm that is often able to obtain the exact value functions with millions of right-hand sides by only solving very few deterministic integer programs. Once the value functions of both stages are found, the objective function evaluation becomes straightforward. When the value function cannot be explicitly stored, in addition to the superadditive dual approach, we present a global branch-and-bound framework to bound the objective functions on the subproblems. We develop several techniques to speed up the procedure of finding the value functions. A level set approach is also considered to reduce the number of objective function evaluations needed. We provide computational results on instances that are several orders of magnitude larger than problems found in the literature.

TU1-308/13 STOCHASTIC PROGRAMMING

Sampling and control in stochastic programming

chair: Andreas Eichhorn

Integration quadratures in discretization of stochastic programs

MATTI KOIVU
Helsinki School of Economics
coauthor: Teemu Pennanen
keywords: discretization, integration quadratures

Modern integration quadratures are designed to produce finitely supported approximations of a given (probability) measure. This makes them well suited for discretization of stochastic programs. We give conditions that guarantee the epi-convergence of resulting objectives to the original one. Our epi-convergence result is closely related to existing ones but it is easier to apply to discretizations. As examples, we will verify the conditions in three different models of portfolio management and we study the behavior of various discretizations numerically. In our tests, modern quadratures clearly outperform crude Monte Carlo sampling in discretization of stochastic programs.

Nondeterministic dynamic programming

SEIICHI IWAMOTO
Kyushu University

coauthor: Takayuki Ueno
keywords: non deterministic, stochastic, deterministic

We consider dynamic programming from a view point of transition law. A non-deterministic dynamic programming is proposed in a finite (stage, state and decision) framework which includes both deterministic and stochastic dynamic programming. The non-deterministic dynamic programming represents a large class of multi-stage decision problems where today's state may go to more than two tomorrow's states with one-step transition weights. While the stochastic transition probability has both unit-sum property and non-negativity, the non-deterministic one-step transition weight does not have unit-sum property and has non-negativity. An objective function in non-deterministic dynamic programming is a weighted value of additive reward function. It is a generalization of expected value in stochastic dynamic programming. Solving a recursive equation, we can find an optimal policy in non-deterministic dynamic programming.

Stochastic integer programming: limit theorems and confidence intervals

ANDREAS EICHHORN
Humboldt-University Berlin

coauthor: Werner Roemisch
keywords: stochastic programming, mixed integer, empirical process, bootstrap

We consider empirical approximations of two-stage stochastic mixed-integer programs and derive central limit theorems for the objectives and optimal values. The limit theorems are based on empirical process theory and the functional delta method. We also show how such limit theorems for the bootstrapping method can be used to derive confidence intervals for optimal values.

TU1-308/T1 FINANCE AND ECONOMICS
Modeling under uncertainty
chair: Ken Kortanek

Stochastic model of optimal investor behavior in real sector

VADIM ARKIN
Russian Academy of Sciences

coauthor: Alexander Slastnikov
keywords: investment under uncertainty, optimal stopping problem, taxation

We propose a model that can evaluate the influence of tax system and stochastic environment on investor bahavior in real sector of economics. As an object of investment it will be considered a project of a creation of a new enterprise. Investments, necessary for such a project are considered to be instantaneous and irreversible. At any moment the investor can either accept the project and start with the investment, or delay the decision before obtaining new information on the environment. The purpose of the investor is to find a moment for investment, which depends on previous environment observations, so that it maximizes expected net present value. An investor problem is reduced to an optimal stopping problem for two-dimensional geometric Brownian motion and homogeneous terminal functional. We propose the new (variational) approach for solving this problem. It is based on the connection between boundary problem for diffusion processes and Dirichlet problem for PDE of an elliptic type, especially Feynman-Kac formula and variational inequalities.

On extending the LP computable risk measures to account downside risk

WLODZIMIERZ OGRYCZAK
Warsaw University of Technology, Institute of Control & CE

coauthor: Adam Krzemienowski
keywords: portfolio optimization, linear programming, mean-risk, downside risk

A mathematical model of portfolio optimization is usually quantified with mean-risk models offering a lucid form of two criteria with possible trade-off analysis. In the classical Markowitz model the risk is measured by a variance, thus resulting in a quadratic programming model. There were introduced several alternative risk measures which are computationally attractive as (for discrete random variables) they result in solving linear programming (LP) problems. Typical LP computable risk measures, like the mean absolute deviation (MAD) or the Gini's mean absolute difference (GMD) are symmetric with respect to the below-mean and over-mean performances. The paper shows how the measures can be further combined to extend their modeling capabilities with respect to enhancement of the below-mean downside risk aversion. The resulting mean-risk models generate efficient solutions with respect to second degree stochastic dominance, while at the same time preserving simplicity and LP computability of the original models. The models are tested on real-life historical data.

How serious are Wets' et al "serious zeros curves"?

KEN KORTANEK
University of Iowa

keywords: discount function, forward rate function, spot rate function

The recent manuscript by Wets et al, " Serious Zero Curves" [2] of "EpiSolutions Inc" offers an interesting contrast to the Kortanek/Medvedev approach developed in [1]. Both methods rely on continuous compounding relationships between (a) the forward rate FR, (b) the discount DF, and (c) the spot rate SR functions:

$$DF(t) = exp(-\int_0^t FR(s)\,ds),$$

$$SR(t) = -ln(DF(t))/t,$$

and

$$FR(t) = -DF^{'}(t)/DF(t).$$

Both methods incorporate standard nonarbitrage constraints and smoothness proxies.

The former approach is based upon a finite Taylor series approximation to the *DF* function, leading to an *LP* model which seeks an optimal piecewise constant third derivative of *DF*. The latter approach is based upon a dynamic model under uncertainty with perturbations for the FR function leading to a geometric programming model which seeks optimal piecewise constant perturbations.

After the models are compared, preliminary numerical comparisons are given using Wall Street Journal data for about 133 Treasury Bills, Notes, and Bonds.

[1] K. O. Kortanek and V. G. Medvedev. *Building and Using Dynamic Interest Rate Models*. Wiley Finance. John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex PO19 1UD, England, 2001.

[2] R. J. B. Wets, S. W. Bianchi, and L. Yang. Serious zero curves. Technical report, EpiSolutions, Inc, El Cerrito, California, 2002.

TU1-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Regularization methods

organizer/chair: Rainer Tichatschke

Convergence and stability of a regularization method for maximal monotone inclusions

DAN BUTNARIU
University of Haifa, Israel

coauthors: Yakov Alber, Gabor Kassay
keywords: maximal monotone operator, regularization method, convex optimization problem, Mosco convergence of sets

We consider the inclusion $f \in Ax$ where A is a maximal monotone point-to-set operator from the reflexive Banach space with the Kadec-Klee property X to its dual. We assume that the data A and f are given by approximations A^k and f^k converging to the original data in the sense of a Mosco type topology. We prove that the sequence $x^k = \left(A^k + \alpha_k J^\mu\right)^{-1} f^k$ which results from a Tychonov type regularization process converges weakly and, under some conditions, converges strongly to the minimum norm solution of the original inclusion. We show how this results can be applied in order to regularize convex optimization problems with perturbed data, that is problems whose objective functions and/or the constraints are given by approximations.

A proximal point method for convex vector-valued optimization

ALFREDO NOEL IUSEM
Instituto de Matematica Pura e Aplicada

coauthors: Benar Svaiter, Henri Bonnel
keywords: multi objective optimization, vector valued optimization, proximal point methods

We present a proximal point method for finding weakly effficient points of a function defined on a Hiilbert space with values in a Banach space, with an order induced by a closed convex cone. Our method defines a sequence whose functional values decrease in this order, without imposing a predetermined scalarization. We analyze first an exact version, demanding exact solution of the subproblems, and then move over to an inexact one, wihich allows for constant relative errors in the solution of the subproblems, following the criterion introduced by Solodov and Svaiter for scalar-valued optimization. In both cases we establish weak convergenge of the generated sequence to a weakly efficient point, assuming existence of such points.

Interior point methods for variational inequalities with weak regularisation

TIM VOETMANN
University of Trier

coauthor: Rainer Tichatschke
keywords: variational inequalities, interior point method, proximal point methods, Bregman distances

The talk is devoted to the numerical solution of variational inequalities with set-valued monotone operators in a Hilbert space. In contrast to the classical proximal point method that employs the Hilbert space norm as a regularising functional we investigate the use of weaker norms. This leads to a significant acceleration of the convergence process without losing the favorable stability properties of the classical proximal method.

In addition we analyse criteria for the inexact computation of the proximal iterates. These allow us to incorporate approximations, such as enlargements of the monotone operators, and to compute the iterates by a suitable discretisation. For solving the discretised problems we make use of generalised distances, such as Bregman distances, forcing the iterates to stay in the interior of the "feasible" set.

Finally, we address implementation matters and present a scheme coupling a successive discretisation of the variational inequality with regularisation by the generalised proximal point method. Conditions on the choice of the regularising distance functions and monitoring of control parameters ensuring linear convergence are discussed. The practical efficiency of the algorithm is demonstrated by application to contact problems from mathematical mechanics.

TU1-308/T3 MODELING LANGUAGES AND SYSTEMS

Modeling languages and systems III

organizer/chair: Robert Fourer

XML representation of mathematical programming models for distributed optimisation applications

PATRICK VALENTE
CARISMA, Brunel University

coauthor: Gautam Mitra
keywords: modelling, internet, linear programming

DRAFT subject to changes

In recent years, there has been growing interest on the provision of optimisation tools via the internet. This paradigm enables practitioners and developers to remotely access (expensive) software tools such as solvers and modelling systems as well as complete optimisation-based vertical applications. In this paper we tackle the issue of integrating these remote tools into distributed applications. For this purpose we consider a web service model based on XML representation of the model instances and discuss the requirement for a common solver interface based on the SOAP protocol.

Analyzing submissions to the NEOS server for the purpose of recommending solvers

ROBERT FOURER
Northwestern University

coauthor: Dominique Orban
keywords: internet, servers

The NEOS Server has made optimization methods widely available over the Internet, but it continues to rely on individual users to select solvers appropriate to their problems. We describe new utilities that can assist in solver selection, by examining a submitted AMPL problem prior to optimization. Given a problem instance produced by the AMPL translator, an analyzer first checks for properties ranging from size and sparsity to linearity and convexity. A second utility then compares the results to a database of solver characteristics, to produce a list of recommended solvers. Experiments on standard nonlinear problem libraries and on the archive of previous NEOS submissions are reported.

Interactive, synchronous nimbus method for multiobjective optimization

KAISA MIETTINEN
University of Jyvaskyla

coauthor: Marko M. Makela
keywords: multiple criteria programming, interactive methods, nonlinear programming, software

We describe an unconventional philosophy in the methodology development for multiobjective optimization. The presentation is given in the context of the interactive NIMBUS method, where the solution process is based on the classification of objective functions. The idea is to formulate several scalarizing functions, all using the same preference information of the decision maker. Thus, opposed to fixing one scalarizing function (as is done in most methods), we utilize several functions in a synchronous way.

This means that we as method developers do not make the choice but calculate the results of different scalarizing functions and leave the final decision to the expert, the decision maker. Simultaneously, (s)he obtains a better view of the potential compromises corresponding to her/his preferences expressed once during each iteration.

Here we describe a synchronous variant of the classification-based NIMBUS method. In addition, we introduce its implementation WWW-NIMBUS operating on the Internet. WWW-NIMBUS is a software system capable of solving even computationally demanding nonlinear problems. Besides the synchronous philosophy, the new versions of NIMBUS and WWW-NIMBUS also include other desirable features increasing user-friendliness such as a flexible solution database.

TU1-341/21 INTERIOR POINT ALGORITHMS

Complexity of interior point methods

chair: Robert Freund

Expected number of iterations of interior point algorithms for linear programming

SIMING HUANG
Institute of Policy and Management

keywords: interior point algorithms, linear programming, complexity

We show that the expected number of iterations of some interior point algorithms is bounded above by $O(n^{1.5})$. The probabilistic LP model is Borgwordt's model with stable distribution.

Average complexity of interior point methods: the expected number of steps

PETRA HUHN
Augsburg University

keywords: interior point method, linear programming, average complexity

We are interested in the average behaviour of Interior-Point-Methods (IPMs) for Linear Programming problems (LPs). We use the Rotation-Symmetry-Model as probabilistic model for the average case analysis. This model has been used by Borgwardt in his average case analysis of the Simplex-Method. IPMs solve LPs in three phases. First, one has to find an appropriate starting point, then a sequence of interior points is generated, which converges to the optimal face. Finally, the optimum has to be calculated, as it is not an interior point. We present upper bounds on the average number of iterations in the first and the third phase by looking at random figures of the underlying polyhedron. These bounds show, that IPMs solve LPs in strongly polynomial time in the average case, so only the dimension parameters and not the encoding length of the problem determine the average behaviour of IPMs. So far, only high probability results resp. conditional expected values were known under the Rotation-Symmetry-Model. The new results on the average number of steps are total expectations and are valid for all dimensions.

Comparison of complexity of ipms and the ellipsoid method for conic feasibility and optimization

ROBERT FREUND
MIT

keywords: convex optimization, interior point method, computational complexity

We compare different methods for analyzing the complexity of interior-point methods for conic and non-conic optimization and feasibility problems. Moving beyond the bit-model and condition measures for conic problems, we propose to evaluate the complexity of convex optimization using geometric measures of the feasible region or the level sets of the feasible region. Using such measures, we show that the computational complexity of interior-point methods and the ellipsoid method are both bounded by the same geometric measures.

TU1-341/22 LOGISTICS AND TRANSPORTATION

Applications of optimization in pricing

organizer/chair: Georgia Perakis

A robust optimization approach to supply chain management

DIMITRIS BERTSIMAS
MIT

coauthor: Aurelie Thiele
keywords: robust optimization, supply chain management

We propose a general methodology based on robust optimization to address the problem of optimally controlling a supply chain subject to stochastic demand in discrete time. This problem has been studied in the past using dynamic programming, which suffers from dimensionality problems and assumes full knowledge of the demand distribution. The proposed approach takes into account the uncertainty of the demand in the supply chain without assuming a specific distribution, while remaining highly tractable and providing insight into the corresponding optimal policy. It also allows to adjust the level of robustness of the solution, in order to trade off performance and protection against uncertainty. An attractive feature of the proposed approach is that the robust problem is of the same difficulty as the nominal problem, that is, a linear programming problem when there are no fixed costs and a mixed integer programming problem when fixed costs are present. Furthermore, we show that the structure of the optimal robust policy is of the same base-stock character as the optimal stochastic policy for a wide range of inventory problems in single installations, series systems and general supply chains.

New math programming models for revenue management

KALYAN TALLURI
Universitat Pompeu Fabra

keywords: pricing, revenue management, applications of optimization

We present some new stochastic programming based models for O&D revenue management. Comparison with perfect information bounds on a hotel data set will be presented.

A variational inequality model for dynamic pricing under competition

GEORGIA PERAKIS
MIT

coauthor: Anshul Sood
keywords: pricing, optimization, dynamic pricing

In this talk we study a model of dynamic pricing for perishable products in a competitive and dynamically changing market. We take a dynamic optimization approach to build a model that ties the competitive with the dynamic nature of pricing using ideas from variational inequalities. We discuss the model and establish existence results on the equilibrium of the competitive market. We introduce an algorithm for determining optimal pricing policies and establish its convergence. We show some computational results and establish insights. Our results apply in a number of application areas including the airline, service and retail industries.

TU1-341/23 LOGISTICS AND TRANSPORTATION
Vehicle routing with time windows
chair: Oli B.G. Madsen

Solving truck scheduling problems with branch-and-price

MYRNA PALMGREN
Division of optimization, University of Linköping
coauthors: Mikael Rönnqvist, David M. Ryan
keywords: vehicle routing, scheduling, modeling

We consider the log truck scheduling problem (LTSP) which is a variant of the pick up and delivery problem with time windows. Our application arises in forestry and it consists of transporting logs of different assortments from harvesting points to customers such as pulp and sawmills. The set of vehicles that perform this transportation contains trucks of several types and capacities and these are located at different home bases. The LTSP consists in finding a set of minimal cost routes, one for each vehicle in order to satisfy the demands of the customers. Each route should start and end at the driver's home base and it should meet a number of constraints such as the working hours and customers opening hours. We propose a mathematical model where each column represents one feasible route. In order to obtain feasible routes we apply a hybrid column generation method that starts by building clusters of supply and demand points and then enumerate a number of feasible routes within these clusters. All routes generated are kept in a pool. We use branch and price with constraint branching and where the pricing is applied on the pool of columns. Numerical results are presented.

A general heuristic for vehicle routing problems

STEFAN RØPKE
Department of Computer Science at the University of Copenhagen
coauthor: David Pisinger
keywords: vehicle routing, metaheuristics

The *pickup and delivery problem with time windows* is the problem of serving a number of *requests* using a limited amount of vehicles. Each request involves moving goods from a *pickup* site to a *delivery* site. Our task is to construct routes that visit all sites such that corresponding pickups and deliveries are placed on the same route and such that pickups are performed before the corresponding delivery. The routes should satisfy a number of additional constraints such as time window and capacity constraints.

The implemented model is quite rich, this allows us to transform several well-known vehicle routing problems to the model. For example, we can solve *vehicle routing problems with time windows*, *site dependent vehicle routing problems* and *vehicle routing problems with backhauls and time windows* using just one heuristic.

Our heuristic uses large neighborhood search embedded in a simulated annealing framework. A drawback of the heuristic is that it is controlled by a rather large number of parameters. This problem is partially solved by automatically tuning some of the parameters while the heuristic is running.

The heuristic is quite successful as it has found many new best solutions to standard benchmark problem-instances.

Vehicle routing with time windows

OLI B.G. MADSEN
CTT - Centre for Traffic and Transport
coauthor: Brian Kallehauge
keywords: vehicle routing, time windows

This paper reports some recent results of the application of a non-differentiable optimisation method in connection with the vehicle routing problem with time windows (VRPTW). The VRPTW is an extension of the vehicle routing problem. In the VRPTW the service at each customer must start within an associated time window.

The shortest path decomposition of the VRPTW by Lagrangian relaxation requires determining the optimal Lagrangian multipliers. This problem is a concave non-differentiable maximization problem. We propose a cutting-plane algorithm with a trust region stabilizing device for finding the optimal multipliers.

Computational experiences will be reported. We have succeeded in solving some problems with 400 and 1000 customers to optimality.

TU1-321/053 PRODUCTION AND SCHEDULING
Lot sizing
chair: Hamish Waterer

A FPTAS for a generalized single-item lot-sizing problem

SERGEI CHUBANOV
University Siegen
coauthors: Mikhail Y. Kovalyov, Erwin Pesch
keywords: lot sizing, approximation schemes

A generalization of a single-item economic capacitated lot-sizing problem to the case of a non-uniform resource used for production is studied. While the general problem is shown to be non-approximable with any constant relative error in polynomial time, fully polynomial time approximation schemes are presented for important NP-hard special cases, in which no backlogging is allowed or holding costs are all equal to zero.

A Lagrangean relaxation based branch-and-bound heuristic for lot sizing with setup times

HALDUN SURAL
Middle East Technical University
coauthor: Meltem Denizel
keywords: inventory/production, branch-and-bound, heuristics

We consider a lot sizing problem with setup times where the objective is to minimize the total inventory carrying cost. The problem is difficult to solve; besides, the feasibility problem is NP-complete. Using the lagrangean relaxation of the inventory balance constraint, we develop lower bound and upper bound procedures. These are combined in a branch and bound heuristic where we seek improvement on the initial solution. Our enumerative procedure is compared with the Trigeiro-Thomas-McClain heuristic on test problems taken from literature. Computational results are given and the performance of heuristics is discussed.

Big bucket lot sizing problems with changeover times

HAMISH WATERER
CORE/UCL
coauthors: Yves Pochet, Laurence A. Wolsey
keywords: lot sizing, mixed integer rounding, extended formulations

The use of mixed-integer rounding inequalities and a multi-commodity flow extended formulation has been successful in solving practical instances of big bucket lot sizing problems with setup times. We report on the effectiveness of this approach when solving instances of these problems with sequence independent and dependent changeover times. We observe that the cuts generated by a commercial solver can give lower bounds

comparable to those obtained using special purpose cut generation routines. The key is to provide a formulation which allows the solver's cut generator to exploit the appropriate variable upper bounds.

TU1-321/033 NETWORKS
Network flow problems
chair: Dorit Hochbaum

Flows over time with flow-dependent transit times

KATHARINA LANGKAU
TU Berlin
coauthors: Ekkehard Köhler, Martin Skutella, Alex Hall
keywords: networks/graphs:flow algorithm, transportation:vehicle routing, transportation:models:traffic, networks/graphs:multicommodity

Motivated by applications in road traffic control, we consider network flows featuring special characteristics. In contrast to classical static flow theory, time plays a decisive role. Firstly, the flow value on an arc may change over time. In the context of road traffic, this property reflects that the traffic volume on a street changes throughout the day. Secondly, there are transit times on the arcs which may vary with the current amount of flow using this arc. The latter feature is crucial for various real-life applications of flows over time; yet, it dramatically increases the degree of difficulty of the resulting optimization problems.

Most problems dealing with flows over time and constant transit times can be translated to static flow problems in time-expanded networks. We develop an alternative time-expanded network which implicitely models flow-dependent transit times. Again, the whole algorithmic toolbox developed for static flows can be applied. This approach does not entirely capture the behavior of flows over time with flow-dependent transit times. However, we present approximation results for the quickest (multicommodity) flow problem which affirm its surprising quality.

Solving multicommodity flow problems with separable piecewise convex costs

PHILIPPE MAHEY
ISIMA - Universite Blaise Pascal
coauthor: Mauricio C. de Souza
keywords: multicommodity flow, cycle cancelling algorithm, network capacity expansion

We study here a continous model for the routing and capacity expansion problem in the design of telecommunications networks. The originality of the model lies in the combination of investment fixed costs with congestion costs. The combinatorial nature of the problem, related to arc expansion decisions, is embedded in a continuous objective function that encompasses congestion and investment arc costs. The resulting objective function is nonconvex and nondifferentiable though separable with respect to the arcs of the network. In this work, we develop local optimality conditions based on the flow structure.In particular, we show that the negative cycle optimality conditions are necessary and sufficient for the routing and capacity expansion problem. These conditions extend some previous results valid in the convex and smooth case only, and they induce a new cycle-cancelling algorithm. That algorithm is then proved to be convergent with a linear rate. We compare the new algorithm with a classical approach which alternates capacity and flow assignments and present some numerical experiments obtained on real life large size networks. The effectiveness of the proposed algorithm is established and some extensions are discussed..

A faster algorithm for bipartite matching and for the maximum flow problem on closure graphs

DORIT HOCHBAUM
UC berkeley
keywords: maximum flow, parametric analysis, scaling, pseudoflow

We show that the pseudoflow algorithm (Hochbaum 1997) runs on simple bipartite networks in time $O(nn_1 \log n)$ for bipartite networks on n nodes with n_1 nodes on the smaller side of the bipartition. This algorithm uses a word boolean operation to identify a "merger".

For the general maximum flow minimum cut problem on a closure graph with m arcs and maximum source and sink adjacent arcs' capacity U, our algorithm runs in $O(n^2 \log U)$, and with additional $O(mn)$ time to identify mergers without the use of boolean word operations. The algorithm makes use of a novel combination of the pseudoflow scaling algorithm and parametric maximum flow procedure.

TU1-321/133 GRAPHS AND MATROIDS
Combinatorial algorithms
organizer/chair: Kathie Cameron

Finding list partitions of graphs

KATHIE CAMERON
Wilfrid Laurier University
coauthors: Elaine Eschen, Chinh T. Hoang, R. Sritharan
keywords: computational complexity, polytime algorithm, combinatorics, stable set

The k-partition problem is: Given a graph G and a positive integer k, partition the vertices of G into at most k sets, A(1), A(2),...,A(k), where some of the sets may be required to be stable sets and some may be required to induce complete graphs, and some pairs A(i),A(j) may be required to be completely joined and others may be required to not be joined at all, or decide that no such partition exists.

The list k-partition problem generalizes the k-partition problem by specifying for each vertex a list of sets in which it may be placed.

Several well-known problems can be formulated as list k-partition problems: clique cutset, stable cutset and 3-colourability are 3-partition problems; 2-clique cutset and skew partition are 4-partition problems.

We classify the list 4-partition problems as polytime-solvable or NP-complete, with a single exception. In doing so, we give polytime algorithms for many problems whose polytime-solvability was open, including list 2-clique cutset. Previously, Feder, Hell, Klein and Motwani had classified the list 3-partition problems as polytime-solvable or NP-complete, and the list 4-partition problems as "quasipolynomial" or NP-complete. De Figueiredo, Klein, Kohayakawa and Reed had given a polytime algorithm for the skew partition problem.

Chromatic characterization of biclique cover

JEAN FONLUPT
Université Paris 6
coauthor: Denis Cornaz
keywords: networks/graphs, computational complexity, linear programming

A biclique of a simple graph G is the edge-set of a complete bipartite (not necessarily induced) subgraph of G. We will study the two following problems: given a graph G, find the maximum weighted biclique of G and find the minimum number of bicliques which cover the edge-set of G. These two problems are in general NP-Hard; we introduce linear programming relaxations of these two problems . The two linear programs may have an exponential number of constraints with respect to the number of nodes of G;

however we prove that these linear programs can be solved in polynomial time by the use of the ellipsoid method. We prove that the separation problem can be reduced to the following problem: find in a network the shortest weighted odd path between a source an a sink; in our case this last problem may be solved in polynomial time and as a consequence the separation problem for our linear programs can be solved in polynomial time.

Revisiting oracle methods for well-described polytopes

JACK EDMONDS
None

keywords: oracle methods, well-described polytopes, combinatorics, ellipsoid method

It is well known that Khachian's ellipsoid method, and other methods, using a separation oracle for a polytope P, will find either a point in P or else a polynomial size set L of inequalities valid for P such that the volume of the solution-set of L is zero. We describe a simple combinatorial algorithm which uses this to optimize over P or determine that P is empty.

TU1-305/205 GAME THEORY
Game programming
chair: M. Aránzazu Estévez-Fernández

Stability of coalitions in a Nash-cartel game: a probability analysis

NIELS OLIEMAN
Wageningen University
coauthor: Eligius Maria Theodorus Hendrix

keywords: model robustness, stability likelihood, efficient algorithm, Nash equilibrium

In this paper, a methodology is presented for specifying the robustness of model conclusions in relation to uncertain model parameters. This methodology is applied to a mathematical model of world regions forming a coalition, for cooperatively reducing CO_2 emissions. This model first determines the world regions' payoffs for each possible coalition structure. Then the model verifies coalition stability by selecting the Nash-equilibrium coalition structures from the set of all possible coalition structures.

The applied methodology considers all uncertain model parameters as stochastic variables. As a consequence, the stability of a specific coalition structure can be interpreted as a bernoulli variable. For estimating this *stability likelihood*, monte carlo simulation can be applied independent of the probability distribution type of the the stochastic model parameters. An efficient algorithm is discussed for the specific case when model parameters have a symmetric probability distribution, such as the *multivariate normal-* and *multivariate t probability distribution*.

Extra-proximal method for computing Nash equilibria for two-person nonzero-sum game

ANATOLY ANTIPIN
Computing Center of Russian Academy of Sciences

keywords: equilibrium programming, game programming, Nash equilibrium, computing equilibria

We present new results on convergence the extra-proximal method to compute a Nash equilibrium point for two-person nonzero-sum game:find x_1^*, x_2^* such that

$$x_1^* \in \text{Argmin}\{ f_1(x_1, x_2^*) + \varphi_1(x_1) \mid g_1(x_1) \le 0, x_1 \in X_1 \},$$

$$x_2^* \in \text{Argmin}\{ f_2(x_1^*, x_2) + \varphi_2(x_2) \mid g_2(x_2) \le 0, x_2 \in X_2 \}.$$

In this class of games it is very natural to highlight smaller subclass of games with so called convex structure. It can be done by means of special inequality of positive semidefiniteness. This subclass games can be considered as analog of convex programming problems in nonlinear programming. Of course, every game from this subclass is a system of two convex programming problems. To compute Nash equilibrium we scalarize the game and present it as equilibrium problem with functional constraints. The Lagrange function of this equilibrium problem is the function of three variables and generate a double saddle point. To solve the game it needs to compute a double saddle point of Lagrange function for equilibrium problem.

For solving any two-person nonzero-sum game in above subclass we offer new extra-proximal method. The convergence of this method is proved. Derived results spread to a games with coupled constraints, that is, if a functional constraints depend on a parameters.

On properties of several refinements of optimal solutions in linear programming

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coauthor: M.Gloria Fiestras-Janeiro

keywords: linear programming, linear complementary, perfect solution, proper solution

In this paper we investigate the properties of the optimal solutions we obtain when we translate the concepts of perfect, proper and weakly proper solutions from the context of Linear Complementary into the framework of Linear Programming. Other refinements of optimal solutions can be formulated using the relationship between Linear Programming and Game Theory. In this paper is also analysed the relationship between the solutions we obtain when we use the relationship between Linear Complementary and Linear Programming or Game Theory and Linear Programming.

TU2-302/41 COMBINATORIAL OPTIMIZATION

Flows over time and fluid networks

organizer/chair: Martin Skutella

Multicommodity flows over time: efficient algorithms and complexity

MARTIN SKUTELLA
MPI Saarbruecken

coauthors: Alex Hall, Steffen Hippler
keywords: networks/graphs:flow algorithm, network/graphs: multicommodity

Flow variation over time is an important feature in network flow problems arising in various applications such as road or air traffic control, production systems, communication networks (e. g., the Internet), and financial flows. The common characteristic are 'dynamic' networks with capacities and transit times on the arcs which specify the amount of time it takes for flow to travel through a particular arc. Moreover, in contrast to static flow problems, flow values on arcs may change with time in these networks.

While the 'maximum s-t-flow over time' problem can be solved efficiently and 'min-cost flows over time' are known to be NP-hard, the complexity of (fractional) 'multicommodity flows over time' has been open for many years. We prove that this problem is NP-hard, even for series-parallel networks, and present new and efficient algorithms under certain assumptions on the transit times or on the network topology. As a result, we can draw a complete picture of the complexity landscape for flow over time problems.

Quickest flows over time

LISA FLEISCHER
Carnegie Mellon University and IBM

coauthor: Martin Skutella
keywords: multicommodity, flow algorithms, approximation schemes, polynomial time

Flows over time (also called dynamic flows) generalize standard network flows by introducing an element of time. They naturally model problems where travel and transmission are not instantaneous. Traditionally, flows over time are solved in time-expanded networks that contain one copy of the original network for each discrete timestep. While this method makes available the whole algorithmic toolbox developed for static flows, its often fatal drawback is the enormous size of the time-expanded network. We present several approaches for coping with this difficulty.

Firstly, we show that static, length-bounded flows lead to provably good multicommodity flows over time. Secondly, we investigate 'condensed' time-expanded networks using a rougher discretization of time. We prove that a solution of arbitrary precision can be computed in polynomial time through an appropriate discretization leading to a condensed time-expanded network of polynomial size. In particular, our approach yields fully polynomial approximation schemes for the NP-hard quickest min-cost and multicommodity flow problems. For single commodity problems, we show that storage of flow at intermediate nodes is unnecessary; and our algorithms do not use any.

Approximately optimal control of fluid networks

JAY SETHURAMAN
Columbia University

coauthor: Lisa Fleischer
keywords: fluid models, dynamic flows, time expanded networks, continuous linear programming

We consider a broad class of separated continuous linear programs (SCLPs) that arise as fluid relaxations of multiclass queueing networks; such relaxations are typically used to find approximate solutions to complex job shop scheduling problems. The complexity of this problem is not well understood, but there is evidence to suggest that optimal solutions may have exponential size.

For any given $\varepsilon > 0$ and $\delta > 0$, we present an algorithm that finds a solution with value at most $(1+\varepsilon)OPT+\delta$, where OPT is the value of the optimal solution. The complexity of our algorithm and the size of the solution we produce are polynomial in the size of the input network, $1/\varepsilon$, and $\log(1/\delta)$. We introduce a natural discretization of polynomial size and prove that this discretization produces a solution with low cost. This is the first polynomial time algorithm with a provable approximation guarantee for this class of problems.

TU2-302/42 COMBINATORIAL OPTIMIZATION

Prize-collecting Steiner trees

organizer/chair: Gunnar W. Klau

A relax and cut algorithm for the prize collecting Steiner problem in graphs

ALEXANDRE CUNHA
Federal University of Rio de Janeiro

coauthors: Abilio Lucena, Nelson Maculan, Mauricio G.C Resende
keywords: Lagrangean relaxation, cutting planes, prize collecting, network design

In this paper we address the problem of finding a minimal weight tree in an undirected graph with nonnegative edges costs and nonnegative vertex penalties, named the Prize Collecting Steiner Problem in Graphs (PCSPG). In this problem, the weight of the tree is the sum of its edges plus the sum of penalties of those vertices not spanned by the tree. Using an approach proposed by Beasley, we formulate the PCSPG as a restricted minimum forest problem, which is amenable to be solved by a Lagrangean relaxation procedure. In our approach, some inequalities are dualized when they first become violated and are dropped when their corresponding multipliers become zero. As soon as new lower bounds are found, we properly temporarily modify the costs of the edges present in the Lagrangean solution and call an upper bounding procedure based on the Goemans and Williamson approximative algorithm. Computational results are presented.

Primal-dual algorithms for prize-collecting Steiner tree

CRISTINA FERNANDES
University of Sao Paulo

coauthors: Paulo Feofiloff, Carlos E. Ferreira
keywords: approximation algorithms, primal-dual algorithms, prize-collecting Steiner trees

The primal-dual scheme has been used to provide approximation algorithms for many problems. Goemans and Williamson gave a $(2-\frac{1}{n-1})$-approximation for the Prize-Collecting Steiner Tree Problem that runs in $O(n^3 \log n)$ time—it applies the primal-dual scheme once for each of the n vertices of the graph. We present a primal-dual algorithm that runs in $O(n^2 \log n)$, as it applies this scheme only once, and achieves the slightly better ratio of $2-\frac{2}{n}$. We also present a correct ratio and analysis of an algorithm by Johnson, Minkoff and Phillips that uses the primal-dual scheme only once. Tight examples are given for each of the algorithms.

The fractional prize-collecting Steiner tree problem on trees

GUNNAR W. KLAU
Konrad-Zuse-Zentrum fuer Informationstechnik
coauthors: Ivana Ljubic, Petra Mutzel, Ulrich Pferschy, Rene Weiskircher
keywords: networks: tree algorithms, analysis of algorithms, discrete location, engineering

We consider the fractional prize-collecting Steiner tree problem on trees. This problem asks for a subtree T containing the root of a given tree $G = (V,E)$ maximizing the ratio of the vertex profits $\sum_{v \in V(T)} p(v)$ and the edge costs $\sum_{e \in E(T)} c(e)$ plus a fixed cost c_0 and arises in energy supply management. We experimentally compare three algorithms based on parametric search: the binary search method, Newton's method, and a new algorithm based on Megiddo's parametric search method. We show improved bounds on the running time for the latter two algorithms. The best theoretical worst case running time, namely $O(|V| \log |V|)$, is achieved by our new algorithm. A surprising result of our experiments is the fact that the simple Newton method is the clear winner of the tested algorithms.

TU2-302/44 COMBINATORIAL OPTIMIZATION

Combinatorial optimization IV

chair: Francesco Maffioli

Vertices, edge-directions and combinatorial optimization

URIEL G. ROTHBLUM
Technion
coauthors: Shmuel Onn, Yoav Tangir
keywords: combinatorial optimization, vertices, convexity, zonotopes

We consider problems where a function h is to be maximized over a (large) finite set B of vectors. Even when h is restricted to be convex, this framework captures difficult problems like the traveling salesman problem. Still, we develop an approach that facilitates the efficient solution of subclass of these problems. Our approach consists of extending the function h to the convex hull P of B , determining conditions that suffice for h to attain a maximum of h at a vertex (e.g., when the extension of h is (edge-quasi) convex on P), and the development of an efficient method for enumerating the vertices of P . Our vertex-enumeration method relies on a mapping of the normal fan of the zonotope spanned by the edge-directions of P onto the normal fan of P and the availability of an efficient solution of linear programs over P . Applications include partitioning problems, optimization problems over oriented matroids and more.

On the non-rank facets of the stable set polytope of claw-free and circulant graphs

GAUTIER STAUFFER
ROSO-IMA-FSB-EPFL
coauthors: Thomas M. Liebling, Bianca Spille, Gianpaolo Oriolo
keywords: stable set polytope, claw-free graphs, circulant graphs, clique family inequality

We deal with the non-rank facets of the stable set polytope (SSP) of claw-free graphs. We first state some known results and we try to capture the difficulty of characterizing this SSP for the wide class of claw-free graphs. Then we present and discuss a conjecture of Oriolo about the SSP of quasi-line graphs. Finally we extend some results of Giles and Trotter showing that for any non-negative integer a, there exists a circulant graph (a subclass of quasiline-graphs) whose SSP has facet inducing inequality with $(a, a+1)$-valued coefficients, suggesting that this class of graph is of interest in order to understand the conjecture.

On the problem of finding minimum fundamental cycle bases

FRANCESCO MAFFIOLI
Politecnico di Milano
coauthors: Edoardo Amaldi, Giulia Galbiati, Leo Liberti, Nelson Maculan
keywords: biconnected graphs, fundamental cycle basis, approximability results, heuristics

We consider the problem of finding a cycle basis of minimum total weight in the cycle space associated with an undirected biconnected graph G, where a nonnegative weight is assigned to each edge of G and the total weight of a basis is defined as the sum of the weights of all the cycles in the basis. This problem is polynomially solvable in the general case [Horton 87] but NP-hard if the basis is required to be fundamental, i.e., to consist of the fundamental cycles with respect to the chords of a spanning tree of G [Deo et al. 82]. We prove that this problem is MAXSNP-hard (hence does not admit a polynomial-time approximation scheme unless P=NP) and we derive the first upper bounds on its approximability for several subclasses of graphs. We then propose a tabu search heuristic based on particular edge swaps in the corresponding spanning tree. The impact of these edge swaps is investigated and a structural property leading to major speed-up is proved. Computational results are reported and compared with those obtained with competing heuristics.

TU2-302/45 COMBINATORIAL OPTIMIZATION

Traveling salesman I

chair: Genevieve Benoit

On the subtour-elimination polytope

KEVIN CHEUNG
University of Waterloo
coauthor: Bill Cunningham
keywords: polytope, traveling salesman problem, sphere

The subtour-elimination polytope (SEP) is the feasible region of the linear programming relaxation of an important integer linear programming formulation of the Symmetric Travelling Salesman Problem. In this talk, we look at some properties of the SEP when the graph is not necessarily complete. In particular, we consider the question of the existence of "inner points", which, by a characterization of Rivin, is related to the problem of inscribing a 3-dimensional polytope in a sphere.

Finding the exact integrality gap for small travelling salesman problems

SYLVIA BOYD
SITE, University of Ottawa
coauthor: Genevieve Benoit
keywords: combinatorial optimization, integer programming, linear programming relaxations

The Symmetric Travelling Salesman Problem (STSP) is to find a minimum weight Hamiltonian cycle in a weighted complete graph on n nodes. One direction which seems promising for finding improved solutions for the STSP is the study of a linear relaxation of this problem called the Subtour Elimination Problem (SEP). A well known conjecture in combinatorial optimization says that the integrality gap of the SEP is 4/3 in the metric case. Currently the best upper bound known for this integrality gap is 3/2.

Finding the exact value for the integrality gap for the SEP is difficult even for small values of n due to the exponential size of the data involved. We describe how we were able to overcome such difficulties and obtain the exact integrality gap for all values of n up to 10. Our results give a verification of the 4/3 conjecture for small values of n and also give rise to a new stronger form of the conjecture which is dependent on n.

Finding violated cut constraints for the STSP using a decomposition approach

GENEVIEVE BENOIT
University of Ottawa
coauthor: Sylvia Boyd
keywords: traveling salesman problem, parallel cutting plane, decomposition

The Symmetric Travelling Salesman Problem (STSP) is to find a minimum cost Hamiltonian cycle in the weighted complete graph on n nodes. A well known relaxation of this problem is the Subtour Elimination Problem (SEP) which provides very good lower bounds for the STSP.

We present a new parallel cutting plane approach for solving the SEP. In this approach, many violated cuts are found at each stage by decomposing the current solution into a set of nicely structured points, and then searching for violations in these points in parallel by using an algorithm which exploits this nice structure. We report on our results and discuss how these ideas could be adapted to other separation problems for the STSP as well as other combinatorial optimization problems.

TU2-302/49 INTEGER AND MIXED INTEGER PROGRAMMING

Integer programming column generation IV

organizer: Marco Lübbecke
chair: Jacques Desrosiers

Routing of snowploughs- a column generation approach

NIMA GOLBAHARAN
Mathematics Institution, Devision of Optimization
coauthor: Per Olov Lindberg
keywords: column generation, branch-and-bound, set covering, set partitioning

In the present talk we study optimal routing of snowploughs after and during snowfall. In the first case one has to design a set of routes starting and ending at given depots, such that each road segment gets ploughed within a prescribed time window. In the latter case the time windows of each road segment give a frequence according to which the road segment need to be ploughed. Our solution approach for solving both cases is based on Dantzig-Wolf decomposition combined with column generation. The subproblem of the first case is a Resource Constrained Shortest Path Problem and in the second case a Prize Collecting Connected Subgraph Problem. In the Master problem, which is a set covering problem with additional constraint on the number of utilized snowploughs, generated routes are combined to cover the road segments. In order to obtain an integer solution in the Master problem we have applied two heuristic procedures, one using branch-and-bound on a subset of the columns and the other one a greedy procedure. The solution method is implemented on the operation district of Eskilstuna located in the middle of Sweden. This talk is connected to Lindbergs talk on Prize Collecting Connected Subgraph.

Graph-coloring and linear programming

DAVID SCHINDL
Swiss Federal Institute of Technology
coauthors: Pierre Hansen, Martine Labbé
keywords: graph-coloring, column generation, facets

The graph coloring problem of a graph $G = (V,E)$ can be formulated as a set covering problem, where the ground set is V, the available sets are the maximal (inclusionwise) stable sets of G. Alternatively, it can be expressed as a set packing problem on the same ground set, and where the sets are all stable sets of G. Since the number of variables grows exponentially with the size of G, both linear relaxations require column generation for their optimization. Nevertheless, they give a tight lower bound (called the fractional chromatic number) on the chromatic number of G, hence effective branch and price algorithms can be obtained with it. Both formulations are compared and polyhedral results as well as preprocessing procedures, expressed in simple graphical terms, are presented.

An exact algorithm for period and multi-depot VRP

ARISTIDE MINGOZZI
University of Bologna, Italy
keywords: periodic vehicle routing, multi depot vehicle routing, Lagrangean relaxation, column generation

We present an exact method for solving two generalizations of the Vehicle Routing problem (VRP): the Period VRP (PVRP) and the Multi-Depot VRP (MDVRP). The PVRP consists of designing a set of routes for each day of a given planning period of p days. The PVRP consists of simultaneously selecting a day-combination for each customer and designing the vehicle routes by solving a CVRP for each day of the planning period. The MDVRP is defined on a single day as the VRP but the vehicles operate from different depots and each route must start and end at the same depot. The MDVRP can be viewed as a special case of the PVRP. The exact method proposed involves the computation of a valid lower bound by means of an additive procedure which combines different relaxations to derive an effective feasible solution of the dual of the LP-relaxation of the integer program. The dual solution is used by an iterative exact procedure. The computational results on both PVRP and MDVRP test problems show the effectiveness of the proposed method.

TU2-306/31 INTEGER AND MIXED INTEGER PROGRAMMING

Integer and mixed integer programming III

chair: Katalin Meszaros

Branch-and-cut for cyclic staff scheduling

ANDREW MASON
Dept of Engineering Science
coauthor: David Panton
keywords: staff scheduling, branch-and-bound, cyclic rostering, workforce planning

This paper considers the problem of constructing cyclic staff schedules. In cyclic staff schedules, a single sequence of shifts and days off must be generated that defines a schedule for *n* staff working over *n* weeks. (This is in contrast to dynamic schedules where each staff member works their own individual sequence of shifts and days off.) We present a new solution approach using integer programming with 3-way branching and cuts. This approach includes feature branching in which aggregate features of the solution are branched on to more rapidly focus the search. Computational results are presented using a customised branch and bound implementation with a standard LP solver.

Computational experience with a cutting plane algorithm for the university timetabling problem

IGOR VASIL'EV
Centro di Ricerca in Matematica Pura e Applicata, Universita di Salerno
coauthor: Pasquale Avella
keywords: branch-and-cut, university timetabling

School timetabling problems consist of assigning a set of lectures to rooms and time periods, satisfying some basic and specific constraints, depending on the organization of the educational system.

In this paper we report on a successful experience with a cutting plane algorithm for a real-world university timetabling problem arising at the Facoltá di Ingegneria of the Universitá del Sannio, a small university in the south of Italy. The formulation of the problem is based on an extension of class-teacher model, where the assignment of lectures to rooms is considered and where classes can be joined together for some lectures. Also we consider additional constraints, reflecting particular requirements of the university.

We study the polyhedral structure of the problem and we introduce several families of cutting planes and the related separation algorithms. The cutting planes turned out to be crucial to solve all the test instances to optimality.

A fuzzy logic application as a contribution to solving the bus crew scheduling problem

KATALIN MESZAROS
University of Novi Sad, Faculty of Economics

keywords: public transportation, bus crew scheduling, heuristic algorithm, theory of fuzzy sets

The scheduling of public transport involves difficulties. The problems of crew scheduling take a special place in combinatorial optimization. Each of them is a special type in a manner. It is impossible to exactly define them by models. In the past a heuristic method was developed (by the author of this abstract) for the solving of bus crew scheduling problem, which is working using a special matrix. An improvement of this heuristic method as a step before initialization of old heuristic method is given in this paper. This step could be useful in other heuristics also. Each element of this matrix is an index of preference. Their evaluation is made on the basis of fuzzy logic taking into consideration the quality of buses which are possible to assign to a trip , the significance of trip and the time difference between arrival of i-th trip and departure of j-th trip. The quality of the buses and the significance of trips are described linguistically. This is why they are defined by the theory of fuzzy set. The linguistic information and the fuzzy rules bases are given by the experts of traffic.

TU2-306/32 NONLINEAR PROGRAMMING
Optimization of engineering systems governed by simulations/PDE, part 2
organizer/chair: Natalia Alexandrov

Effective parallel optimization of expensive functions

JOERG GABLONSKY
The Boeing Company
coauthors: Paul Frank, Margaret Curtin

keywords: surrogate model, parallel computing, engineering

This talk presents an approach for optimizing expensive functions that are given by computer simulations. It introduces Design Explorer, a Boeing suite of response modeling tools for performing design studies and optimization on such problems. The use of a newly developed parallel computing framework leads to a significant reduction in the time needed for optimization. We will conclude the talk with examples of this improvement, and of the use of Design Explorer within the Boeing Company.

Surrogate-based optimization under uncertainty: formulations and applications

ANTHONY GIUNTA
Sandia National Laboratories
coauthor: Michael Eldred

keywords: optimization, surrogate model, uncertainty, engineering

Noisy or nonsmooth merit functions are often encountered in computational engineering design studies due to physical phenomena (e.g., shocks in high-speed fluid flow) or artificial phenomena (e.g., adaptive grid refinement, incomplete convergence of an iterative solver). Numerical noise can also arise in optimization under uncertainty problems when the merit function is nondeterministic and is computed using a small number of random samples, i.e., the statistical metrics of the merit function are under-resolved. The numerical noise creates discontinuities in the value and/or gradient of the merit function, and in many cases produces multiple local optima. The usual approach to solving such an optimization problem is to apply a global optimization method. However, in many computational engineering studies global optimization methods are unacceptably expensive. We have developed an optimization algorithm that employs surrogate models of the merit functions, and permits the use of efficient gradient-based local optimization methods. This approach has been shown to be effective in solving optimization problems involving both deterministic and nondeterministic merit functions. We will describe the mathematical formulation of the surrogate-based optimization under uncertainty (SBOUU) algorithm, and we will present several examples that illustrate the utility of applying the SBOUU algorithm to engineering design studies.

Aerodynamic design optimization using the Navier-Stokes equations

ERIC NIELSEN
NASA Langley Research Center

keywords: design, Navier-Stokes equations

Much effort has recently focused on developing a gradient-based design optimization capability based on the Navier-Stokes equations. The presentation will introduce the fundamental components necessary to achieve such a tool and the inherent difficulties that arise with each. The unstructured-grid analysis code that forms the foundation of the current work is described, followed by a discussion on a discrete adjoint-based approach to sensitivity analysis and grid adaptation. Several mesh movement schemes will also be presented.

TU2-306/33 NONLINEAR PROGRAMMING
Augmented Lagrangian methods II
chair: Giampaolo Liuzzi

An algorithm for generalized semi-infinite optimization problems based on augmented Lagrangians

ELIJAH POLAK
University of California, Berkeley
coauthor: Johannes Royset

keywords: generalized min-max, semi infinite optimization, augmented Lagrangian functions

We present an approach for the solution of a class of generalized semi-infinite optimization problems. Our approach uses augmented Lagrangians to transform the generalized semi-infinite optimization problems into ordinary semi-infinite optimization problems, with the same set of local and global solutions as well as the same stationary points. Once the transformation is effected, the generalized semi-infinite optimization problems can be solved using any available semi-infinite optimization algorithm. We illustrate our approach with a numerical example taken structural design subject to reliability constraints.

Entropy-like Lagrangian method as a unifying approach for solving convex programs

EVA KOMAROMI
Budapest University of Economics and Public Administration

keywords: augmented Lagrangian method, penalty/barrier methods, entropy function

Certain penalty/barrier multiplier methods have been shown to belong to the family of augmented Lagrangian methods in which the quadratic term is replaced by a distance-like entropy function. Convergence analysis and computational experiments concerning the solution of linear programs and probabilistic constrained linear programs are presented.

Use of a truncated Newton direction in an augmented Lagrangian framework

GIAMPAOLO LIUZZI
University of Rome

coauthors: Gianni Di Pillo, Stefano Lucidi, Laura Palagi
keywords: nonlinear programming, large scale problems, exact augmented Lagrangians, truncated Newton methods

We consider the problem (P) $\min\{\mathrm{f(x)},\ \mathrm{g(x)} \leq 0\}$, where $f : R^n \to R$ and $g : R^n \to R^m$ are three times continuously differentiable functions. More in particular, we are interested in the "*large-scale*" case, that is, when $n+m$ is large.

In order to solve problem (P) we adopt an efficient and locally convergent algorithm and then globalize it by means of an appropriately chosen merit function.

As concerns the local algorithm, on the basis of an active set strategy, we solve a nonlinear system approximating the KKT conditions of optimality. More precisely, we use a truncated Newton's method, based on a projected conjugate gradient scheme, which, under reasonable assumptions, converges with a superlinear convergence rate, provided that the starting point is sufficiently close to the solution point.

As concerns the globalization technique, we resort to a linesearch approach based on a continuously differentiable exact augmented Lagrangian function.

We show that, under suitable assumptions, the directions produced by the local algorithm are eventually good descent directions for the merit function and that the unit stepsize is always accepted thus retaining the superlinear convergence rate. Preliminary numerical results on the COPS collection of test examples shows the viability of the method.

TU2-306/34 NONLINEAR PROGRAMMING
Stability of stationary points
organizer/chair: Bernd Kummer

Strong Lipschitz stability of stationary solutions in variational analysis under MFCQ: Part I the general condition

BERND KUMMER
Humboldt-University Berlin

coauthor: Diethard Klatte
keywords: stationary point, strong Lipschitz bahavior, NLO, variational inequalities

We completely characterize strong Lipschitz stability of solutions $x(a,b)$ to systems "$a \in h(x) + N_C(x,b)$" where N_C is the B-normal cone at x to $C(b) = \{x \in X : g_i(x) \leq b_i, i = 1,...,m\}, \dim X$ finite, h, g sufficiently smooth. Supposing MFCQ at a solution $z = x(0,0)$ and $g(z) = 0$ (not essential), we show that $x(.,.)$ is locally single-valued and Lipschitz iff both
(i) solutions are persistent near z for small parameters and
(ii) for every Lagrange multiplier y to z and nonzero $u \in X$ such that $y_i Dg_i(z)u = 0 (\forall i)$ the n-vectors $v(x,w) = (Dh(z) + yD^2g(z))u + wDg(x)$ cannot vanish (in the limit) if $w_i Dg_i(z)u \geq 0 (\forall i)$ and x converge to z.

Replacing here x by z and showing that (ii) implies (i) is possible in several (not all !) situations. Other discussions of the conditions will be given in Diethard Klatte's talk. The present one gives an idea of a proof. It applies tools as studied for deriving sharp stability conditions in the authors' book "Nonsmooth Equations in Optimization: ...", Kluwer, 2002. However, for elaborating (ii), new investigations of generalized derivatives at different points are necessary.

Strong Lipschitz stability of stationary solutions in variational analysis under MFCQ, Part II: application to nonlinear optimization

DIETHARD KLATTE
Institut Operations Research, Universität Zürich

coauthor: Bernd Kummer
keywords: strong Lipschitz stability, perturbed nonlinear programs, generalized derivatives, MFCQ

Specifying the results presented in B. Kummer's talk, we characterize strong Lipschitz stability of stationary solutions to nonlinear programs and discuss the relation to other Lipschitz stability concepts. We do not suppose that the constraints satisfy the Linear Independence Constraints Qualification (LICQ). Main tool is again the analysis of suitable generalized derivatives of the stationary solution map defined via the so-called Kojima function. The conditions obtained in this way can be formulated and interpreted in terms of the initial data of the given optimization problem. Our approach and results also apply to variational inequalities, nonlinear complementarity problems and equilibrium models. This continues the studies in the authors' book "Nonsmooth Equations in Optimization: Regularity, Calculus, Methods and Applications", Kluwer, May 2002.

Newton methods for optimization problems without constraint qualifications

MIKHAIL SOLODOV
IMPA

coauthor: Alexey Izmailov
keywords: Newton method, constraints degeneracy, second order sufficiency, MPEC

We consider equality-constrained optimization problems, where a given solution may not satisfy any constraint qualification, but satisfies the standard second-order sufficient condition for optimality. Based on local identification of the rank of the constraints degeneracy via the singular-value decomposition, we derive a modified primal-dual optimality system whose solution is locally unique, nondegenerate, and thus can be found by standard Newton-type techniques. We also discuss applications to mixed equality and inequality-constrained problems, and to mathematical programs with complementarity constraints (MPCC). In particular, for MPCC we obtain a local algorithm with quadratic convergence under the second-order sufficient condition only, without any constraint qualifications, not even the special MPCC constraint qualifications.

TU2-306/35 OTHER
Software session, ILOG
organizer/chair: Irvin Lustig

TU2-306/36 NONSMOOTH OPTIMIZATION

Recent advances in nonsmooth optimization III

organizers: John Mitchell, Jean-Louis Goffin and Jean-Philippe Vial
chair: John Mitchell

The face simplex method in the cutting plane framework

CESAR BELTRAN
Logilab - HEC - University of Geneva

keywords: nonsmooth optimization, Lagrangian relaxation, cutting plane methods, subgradient methods

The maximization of piecewise affine concave functions arise, for example, in the Lagrangian relaxation of linear integer programming problems. In order to maximize a piecewise affine concave function, one can basically use the simplex method or an interior point method. As an alternative, we propose the *face* simplex method. The *vertex to vertex* scheme of the simplex method is replaced by the more general *face to face* scheme in the face simplex method. To improve the current iterate, in the face simplex method, one computes the steepest ascent on the current face of the objective function graph and then an exact line search determines next iterate. This new procedure can be used in the cutting plane framework as a substitute of the simplex method. As a preliminary numerical test, this new version of the cutting plane method is compared with three other methods: subgradient, Kelley cutting plane and ACCPM.

Properties of a cutting plane method for semidefinite programming

JOHN MITCHELL
Rensselaer (RPI)
coauthor: Kartik Krishnan

keywords: semidefinite programming, nonsmooth optimization, column generation, cutting plane methods

A semidefinite programming problem is a nonsmooth optimization problem, so it can be solved using a cutting plane approach. In this talk, we analyze properties of such an algorithm. We discuss characteristics of good polyhedral representations the semidefinite program. We show that the complexity of an interior point cutting plane approach based on a semi-infinite formulation of the semidefinite program has complexity comparable with that of a direct interior point solver. We show that cutting planes can always be found efficiently that support the feasible region. Further, we characterize the cutting planes that give high dimensional tangent planes, and show how such cutting planes can be found efficiently.

Cut and column generation based on analytic centers for large scale integer programming

FATMA GZARA
McGill University, Faculty of Management
coauthor: Jean-Louis Goffin

keywords: cut and column generation, ACCPM, minimum spanning trees

We consider a general class of integer programming with an exponential number of constraints (that can be families of valid inequalities). When relaxing these constraints, the resulting master problem has an exponential number of variables as well as an exponential number of constraints. We propose a cut and column generation algorithm based on analytic centers to solve it. We present numerical results for the capacitated minimum spanning tree problem that outperform the literature

TU2-306/37 CONVEX PROGRAMMING

Second-order cone programming

chair: Michael Todd

An algorithm for perturbed second-order cone programs with application to the Steiner minimal tree problem

YU XIA
Rutgers University
coauthor: Farid Alizadeh

keywords: second order cone programming, semismooth, complementarity, semidefinite programming

The problem of minimizing a convex function subject to second-order cone and linear consraints is reformulated into a system of nonlinear equations. For all the systems of equations, the iterates of semismooth Newton's method converge quadratically, and the solution is stable and accurate. The number of variables and equations of this reformulation is about half of that used by other methods. Furthermore, strict complementarity is not required at optimum and the initial points needn't to be in the cone. Hence it is good for "warm start". Assume the perturbation of the data — including perturbing cost and right hand side parameters, the matrix, and adding and deleting some blocks and equations — is in a certain neighborhood of the original problem. Then starting from the old solution, the semismooth Newton's iterates converge quadratically to the solution for the perturbed problem. Numerical examples are provided to support the theoretical results. The algorithm is further extended to SDP, which also enjoys the above properties.

Approximation algorithms for conic program with extreme ray constraints

PAUL TSENG
Department of Mathematics, University of Washington

keywords: conic program, approximation algorithms, SDP relaxation, SOCP relaxation

Consider a problem of minimizing a linear function subject to linear constraints and a constraint of belonging to an extreme ray of a closed convex cone K. We study approximation algorithms based on relaxing the extreme ray constraint. Examples with K being the semidefinite cone or the second-order cone will be discussed. We also present improved SDP-based approximation of quadratic minimization with ellipsoid constraints.

Distance weighted discrimination: applying SOCP to pattern recognition

MICHAEL TODD
Cornell University
coauthor: J. S. Marron

keywords: pattern recognition, second order cone programming, data classification

We describe a variant of the well-known support vector machine (SVM) method for classifying points into one of two classes based on a training set. Instead of maximizing the minimum (perturbed) residual, or equivalently minimizing the maximum inverse (perturbed) residual, we minimize the sum of the inverse (perturbed) residuals. We call this distance weighted discrimination: it amounts to using an L1 as opposed to L-infinity criterion. The resulting optimization problem can be formulated as a second-order cone programming (SOCP) problem. We also describe and interpret the optimality conditions and the dual problem. Numerical results demonstrate the usefulness of this approach in the high-dimension, low-sample size setting. The L2 version also leads to a SOCP problem.

TU2-306/38 GLOBAL OPTIMIZATION

Global optimization problems with special structure

organizer/chair: Marco Locatelli

Global optimization method for solving the minimum maximal flow problem

YOSHITSUGU YAMAMOTO
Institute of Policy and Planning Sciences, University of Tsukuba
coauthors: Jun-ya Gotoh, Nguyen van Thoai
keywords: minimum maximal flow, optimization on efficient set

The problem of minimizing the flow value attained by maximal flows plays an important and interesting role to investigate how inefficiently a network can be utilized. It is a typical multiextremal optimization problem, which can have local optima different from global optima. We formulate this problem as a global optimization problem with a special structure and propose a method to combine different techniques in local search and global optimization. Within the proposed algorithm, the advantageous structure of network flow is fully exploited so that the algorithm should be suitable for handling the problem of moderate sizes.

Undominated D.C. decompositions of quadratic functions and applications to branch-and-bound approaches

MARCO LOCATELLI
University of Torino
coauthor: Bomze Immanuel
keywords: global optimization, DC programming

We analyze various difference-of-convex (d.c.) decompositions for indefinite quadratic functions. Some decompositions are dominated, in the sense that other decompositions exist with a lower curvature. Obviously, undominated decompositions are of particular interest. We provide three different characterizations of such decompositions, and show that there is an infinity of undominated decompositions for indefinite quadratic functions. Moreover, two different procedures will be suggested to find an undominated decomposition starting from a generic one. Finally, we address applications where undominated d.c.d.s may be helpful: in particular, we show how to improve bounds in branch-and-bound procedures for quadratic optimization problems.

Smoothing local searches: a new approach to global optimization

BERNARDETTA ADDIS
Dip. Sistemi e Informatica
coauthors: Marco Locatelli, Fabio Schoen
keywords: smoothing method, local searches, basin hopping

Most methods for global optimization rely on local optimization: a good global optimization method should be composed of a local search phase (which is best accomplished via non linear optimization) and of a global phase, which usually consists of random sampling. Recently some attempts of using smoothing techniques have been proposed, in the hope that both sampling and local optimization are easier on a smoothed function; however, because of the difficulty of tracking the optimum towards the original one and of the high computational cost, these methods display only limited computational success. In this paper we will present an innovative strategy based on the idea of smoothing the results of local searches. We apply a smoothing method not to the function, but to the results of a local optimization routine. Obviously an analytical smoothing is impossible in this context; thus we use sampling in the neighborhood of the current solution in order to build an approximate smoothing function which is used to guide random explorations towards the global optimum. The details of this method will be presented and comments on numerical results will be provided which show an extremely high efficiency of the proposed method in high-dimensional test functions.

TU2-308/11 GENERALIZED CONVEXITY/MONOTONICITY

Generalized convexity I

organizer/chair: Laura Martein

Pseudomonotonicity and pseudoconvexity under the Charnes-Cooper transformation

LAURA MARTEIN
Dept. of Statistics and Applied Mathematics, University of Pisa
coauthors: Alberto Cambini, Schaible Siegfried
keywords: pseudoconvexity

It is shown that the pseudomonotonicity of the gradient of a differentiable function is preserved under a generalized Charnes-Cooper transformation T. Since a function is pseudoconvex if and only if its gradient map is pseodomonotone, it follows that pseudoconvexity is preserved under T. This last result is used to characterize pseudoconvexity and pseudolinearity of the sums of two linear fractional functions. This last result is used to find necessary and suffficient conditions for the sums of two linear fractional functions to be pseudoconvex or pseudolinear.

From Kato's theorem to a new class of generalized convex functions?

IMMANUEL M. BOMZE
Telekom Austria AG, Vienna, Austria
keywords: generalized convexity, game dynamics, stability, spectral radius
Motivated by research on the balance between mutation and frequency-dependent selection in evolutionary game dynamics, we study the following generalization of Kato's theorem: if a family of bounded linear operators on a vector space depends on the parameter in a log-convex way, then so does their spectral radius. The proof and its generalization leads to the natural (and seemingly open) question how to describe a convex cone of real-valued functions with certain properties. This cone contains all convex functions and and is in turn contained in the (non-convex) cone of all quasiconvex functions. Hence, this function class could turn out to be important for optimization purposes, too.

Pairs of compact convex sets

DIEHARD ERNST PALLASCHKE
University of Karlsruhe, Inst. f. Statistics & Math. Econ
coauthor: Ryszard Urbański
keywords: generalized convexity, quasidifferentiable functions
Pairs of compact convex sets arise in the quasidifferential calculus of V.F. Demyanov and A.M. Rubinov as sub- and superdifferentials of quasidifferentiable functions and in the formulas for the numerical evaluation of the Aumann-Integral.

Of special importance are the inclusion minimal elements in a class of equivalent pairs of compact convex sets. Different types of sufficient criteria for inclusion minimal representations will be presented.

In the plane equivalent inclusion minimal pairs of compact convex sets are uniquely determined up to translations. This is not true for higher dimensional spaces.

Algebraic and geometric characterization of minimality lead to the separation property of convex sets by sets and to the separation law. The equivalence of

the separation law with the order cancellation law will be shown.

Moreover, inclusion minimality under constraints is considered.

Furthermore invariants of a class of equivalent pairs of compact convex sets are considered and it is show that the affine dimension of the minimal representant of an equivalence class is invariant and that each equivalence class has invariant convexificators.

Finally the problem pairs of convex sets is considered in the more general frame of a commutative ordered semigroups with cancellation law, which leads to a fractional arithmetic for convex sets.

TU2-308/12 STOCHASTIC PROGRAMMING
Asset-liability management
chair: Fredrik Altenstedt

Application of dependent discrete 2-coupling with reduction to financial management

RONALD HOCHREITER
Department of Statistics and Decision Support, University of Vienna

coauthors: Georg Pflug, David Giczi
keywords: stochastic programming, scenario generation, probability distributions, asset liability management

In this paper we present a comparison of different algorithms to solve the discrete dependent 2-coupling problem with reduction, i.e. given two discrete marginal probability distributions and their correlation we calculate the joint distribution matrix subject to maximizing the amount of zeros in the joint distribution to achieve a reduction. Implementations of various algorithms - non-linear optimization, branch and bound and stochastic approximation - will be presented and compared. The coupling problem originates from the field of stochastic programming when two or more univariate scenario trees have to be coupled to a multivariate tree during the scenario generation phase. The reduction is necessary to ensure the computational tractability when solving the stochastic model. Two examples from the field of financial engineering, scenario generation for asset liability management based on minimizing of probabilty metrics between the original distribution and its approximation as well as pricing of multivariate options, e.g. basket options, substantiate the applicability of discrete 2-coupling with reduction and conclude the paper. Additionally implementational issues of these algorithms within the AURORA Financial Management System, a Grid-based problem solving environment for modeling and solving large stochastic programs will be discussed.

A stochastic programming model for asset and liability management of a finnish pension company

PETRI HILLI
Helsinki School of Economics

coauthors: Matti Koivu, Teemu Pennanen, Antero Ranne
keywords: asset liability management, stochastic programming, scenario tree generation, out-of-sample tests

This paper describes a stochastic programming model that was developed for asset liability management of a Finnish pension company. In many respects the model resembles those presented in the literature, but it has some unique features stemming from the statutory restrictions for Finnish pension companies. Particular attention is paid to modeling the stochastic factors, implementation and to numerical testing. Out-of-sample tests clearly favor the strategies suggested by our model over fixed-mix strategies.

A comparison between stochastic programming and parametrized policies for asset liability management

FREDRIK ALTENSTEDT
Department of Mathematics

keywords: stochastic programming, parametrized policies, asset liability management

Lately, stochastic programming have been used as an effective tool for asset liability management. SP does however have a number of drawbacks, it is computationally expensive, the solution is rather sensitive to how the randomness is expressed and the resulting solution is not always easy to interpret. As the main purpose of an SP based system is to recommend an action based on a state of the world, a natural alternative is a parametrized policy. Here an explicit policy function maps the state of the world to an action, and a set of parameters of the policy are optimized to find a policy which performs well over a set of test-scenarios. Such an approach suffer from other drawbacks than an SP model, parametrized policy problems are non-convex and a user must still choose the general shape of the policy. Our interest in this line of research is driven by our ALM-model of a swedish life insurance company, but in this presentation we use a simpler model for simplicity. We solve this simple problem using both techniques and use this example to show how policy optimization and stochastic programming may be used in tandem to provide us with the best of two worlds.

TU2-308/13 OTHER
Tucker prize
chair: Rainer Burkard

TU2-308/T1 FINANCE AND ECONOMICS
Equilibrium models
chair: Jorge Rivera

A sequential land use equilibrium model with endogenous incomes

PEDRO DANIEL JARA MORONI
Universidad de Chile

coauthors: Alejandro Jofré, Francisco Martínez
keywords: Walras equilibrium, urban economics, land use

In this talk we introduce a new sequential land use equilibrium model which is based on good and location exchange process including endogenous incomes. We define two possible market equilibrium conditions: bid-rent theory and utility maximization approach. We prove in the first part of this paper that both approaches are equivalent under weak conditions. In the second part we establish an existence result for the utility maximization equilibrium model. In the third part we discuss how a dynamic version of this equilibrium model could work under the rational expectation hypothesis.

General equilibrium analysis in ordered topological vector spaces

MONIQUE FLORENZANO
CNRS

coauthors: C.d. Aliprantis, R. Tourky
keywords: equilibrium, Edgeworth equilibrium, properness, Riesz-Kantorovich formula

The second welfare theorem and the core-equivalence theorem have been proved to be fundamental tools for obtaining equilibrium existence theorems, especially in an infinite dimensional setting. For well-behaved exchange economies that we call proper economies, this paper gives (minimal) conditions for supporting with prices Pareto optimal allocations and decentralizing Edgeworth equilibrium allocations as non-trivial quasi-equilibria. As we assume neither transitivity nor monotonicity on the preferences of consumers, most

of the existing equilibrium existence results are a consequence of our results. A natural application is in Finance, where our conditions lead to new equilibrium existence results, and also explain why some financial economies fail to have equilibria.

The second welfare theorem with public goods in general economies

JORGE RIVERA
DECON, Universidad de Chile
coauthor: Alejandro Jofré
keywords: non convex separation, Pareto optimum, equilibrium

In this paper we prove an extension of the Second Welfare Theorem for a finite non-convex, non-transitive economy, where there exist externalities and public goods. For those purposes we will use the subdifferential to the distance function to both production and preferences sets as the main tool to define the tarification pricing rule. Computation for quasi-equilibrium vector prices and an interpretation of the quasi-equilibrium allocation as a solution of a perturbed optimization problem for each agent is also given in this paper.

TU2-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES
Developments in proximal algorithms
organizer/chair: Jonathan Eckstein

Interior proximal methods for non-paramonotone variational inequalities

RAINER TICHATSCHKE
Dept. of Mathematics, University of Trier
coauthor: A. Kaplan
keywords: regularization, Bregman function, monotone operators

For variational inequalities characterizing saddle points of Lagrangians associated with convex programming problems in Hilbert spaces the convergence of an interior proximal method based on Bregman distance functionals is studied. The convergence results admit a successive approximation of the variational inequality and an inexact treatment of the proximal iterations. An analogous analysis is performed for finite-dimensional complementarity problems with multi-valued monotone operators.

Double regularization proximal methods for complementarity

PAULO JOSE DA SILVA E SILVA
University of Sao Paulo
coauthor: Jonathan Eckstein
keywords: coercive regularizations, monotone operators, multiplier methods

For a given real interval, we consider proximal kernel functions lying between a certain upper and lower envelope, each of which contains a quadratic portion and a coercive portion. We show that all kernels in this range lead to convergent algorithms when applied to monotone complementarity problems that may not have optimization structure. For the interval $[0, +\infty)$, the lower boundary of the envelope is the log-quadratic kernel already shown to have desirable qualities by Auslender and Teboulle. When applied to the dual of a complementarity problem, this kernel yields a multiplier method related to the Chen-Harker-Smale-Kanzow plus function. In the same context, another kernel lying strictly within the envelope gives rise to a a multiplier method related to the "neural network” smooth plus function. Experimenting with complementarity problems from the MCPLIB, we find that the neural network plus method is somewhat faster and more reliable in practice than the loq-quadratic method, although it is still best to use the log-quadratic method to set the multipliers in the very first iteration. These results resemble empirical results obtained by Chen and Mangasarian for smoothing methods not using Lagrange multipliers.

Separation-based proximal splitting methods

BENAR SVAITER
IMPA- Instituto de Matematica Pura e Aplicada
coauthor: Jonathan Eckstein
keywords: splitting methods, proximal point, projection, separator

Given two maximal monotone operators A and B, a *splitting* method for the problem $0 \in A(x) + B(x)$ may evaluate only resolvents of A and B, but not of $A + B$. Methods of this type have previously fallen into three classes: the little-used double-backward class, the forward-backward class generalizing gradient projection, and the Douglas/Peaceman-Rachford class.

We propose a new class of splitting methods based on separators for a certain higher-dimensional set whose projection is the solution set. The separators are computed using (approximate) resolvents of A and B.

These methods retain the attractive theoretical convergence properties of Douglas-Rachford methods, but allow the proximal parameter to be changed an infinite number of times, and in one case to vary even between the operators A and B. Morover, some of the methods permit a relative error criterion for approximating the resolvents of A and B.

A possible additional topic is the use of Solodov-Svaiter strong convergence forcing as an anti-spiraling technique in finite dimension.

TU2-308/T3 MODELING LANGUAGES AND SYSTEMS
Modeling languages and systems IV
chair: Bob Daniel

Testing global optimization software

ARNOLD NEUMAIER
Universitaet Wien
coauthor: Oleg Shcherbina
keywords: testing software

The available test problem collections for constrained global optimization and continuous constraint satisfaction problems are discussed. Test results obtained on these problems for several global optimization codes available are presented.

Xpress-mosel: a modular environment for modelling and solving optimization problems

BOB DANIEL
Dash Optimization
keywords: modeling languages

Mosel is a new environment for modelling and solving problems that is provided in the form of the Xpress-IVE development environment (GUI), libraries for embedding, or a standalone program.

Mosel includes a language that is both a *modelling* and a *programming* language, combining the strengths of these two concepts. Unlike traditional modelling environments like AMPL, for which the problem is described using a modelling language and algorithmic operations are written with a scripting language, Mosel has no separation between model definition statements (e.g., declaring a decision variable or expressing a constraint) and execution statements (e.g. optimizing the problem).

Thanks to this synergy, one can program a complex solution algorithm by interlacing modelling and solving statements.

TU2-341/21 INTERIOR POINT ALGORITHMS
Second order cone programming
chair: Farid Alizadeh

The primal-dual second-order cone approximations algorithm

CHEK BENG CHUA
University of Waterloo

keywords: second order cones, symmetric cone programming, interior point method

We explore the idea of second-order cone approximations for convex conic programming. Given any open convex cone K, a logarithmically homogeneous self-concordant barrier for K and any positive real number $r < 1$, we associate, with each direction $x \in K$, a second-order cone $\hat{K}_r(x)$ containing K. We show that K is the interior of the intersection of the second-order cones $\hat{K}_r(x)$, as x ranges over all directions in K.

Using these second-order cones as approximations to cones of symmetric positive definite matrices, we develop a new polynomial-time primal-dual interior-point algorithm for semi-definite programming. The algorithm is extended to symmetric cone programming via the relation between symmetric cones and Euclidean Jordan algebras.

On treating second order cone problem as a special case of semidefinite problem

GONGYUN ZHAO
National University of Singapore
coauthor: Chee-Khian Sim

keywords: second order cone problem, semidefinite problem

It is well known that a vector is in a second order cone if and only if its "arrow" matrix is positive semidefinite. But much less well-known is about the relation between a second order cone problem (SOCP) and its corresponding semidefinite problem (SDP). The correspondence between the dual problem of SOCP and SDP is quite direct and the correspondence between the primal problems is much more complicated. Given a SDP primal optimal solution which is not necessarily "arrow-shaped", we can construct a SOCP primal optimal solution. The mapping from the primal optimal solution of SDP to the primal optimal solution of SOCP can be shown to be unique. Conversely, given a SOCP primal optimal solution, we can construct a SDP primal optimal solution which is not an "arrow" matrix. Indeed, in general no primal optimal solutions of the SOCP-related SDP can be an "arrow" matrix.

The q method for optimization over symmetric cones

FARID ALIZADEH
Rutgers University
coauthor: Yu Xia

keywords: semidefinite programming, interior point method, second order cone programming, symmetric cones

We present a new algorithm for solving optimization problems over symmetric cones called the Q method. Symmetric cones are the natural generalization of both the cone of positive semidefinite matrices and the second order cone. Our algorithm uses as its main tool box properties of Euclidean Jordan Algebras. The algorithm is a direct generalization the Q method for semidefinite programming. The main idea behind it is using the spectral decomposition of the decision variables and search in the space of eigenvalues and Jordan frames associated with the variables, rather than directly working with the variables themselves. We compare this method with the special case of semidefinite programming and second order cone programming, review its advantages and discuss its local and global convergence.

TU2-341/22 LOGISTICS AND TRANSPORTATION

Design in communication and allocation

chair: Chung-Piaw Teo

Internet protocol network design and routing

PETER BROSTROM
Dept. of Mathematics
coauthor: Kaj Holmberg

keywords: internet protocol, network design, heuristics, routing

In the Internet Protocol Network Design and Routing problem, we design networks for data communication at the same time as deciding a suitable metric for data distribution. Network demands are routed according to the OSPF protocol, i.e. shortest paths with respect to the metric has to be used for each origin/destination pair. Each link is associated with a fixed charge and a stepwise capacity extension cost. The total design cost and the level of reliability compare solutions. A design is considered as reliable when a large amount of the demands can be redistributed even if a single arc is removed, i.e. when a link failure occurs. Demands are rerouted with the same metric during failures as when the network is in normal state. We present a mathematical formulation for the design and routing problem and we suggest a Lagrangean relaxation that provides a lower bound of the total design cost for different security levels. Feasible solutions are obtained by a primal heuristic based on Simulated Annealing. Some preliminary computational results are presented.

Design of virtual private networks under aggregate traffic uncertainty

MUSTAFA C. PINAR
Bilkent University
coauthors: Francesco Maffioli, Edoardo Amaldi, Pietro Belotti, Oya Ekin-Karasan, Francesco Maffioli

keywords: virtual private network design, aggregate traffic uncertainty, multicommodity flow, mixed integer programming

We consider a setting in which a group of nodes, situated in a large, widely accessible network, wishes to reserve bandwidth on this network for secure private communication. A virtual private network (VPN) is a service that supports such requirements by building a virtual subnetwork where bandwidth is reserved for this particular group of nodes. In a recent paper, Gupta et al. (2000) addressed this problem when the traffic generated among the nodes are not known with certainty prior to designing the VPN. They defined different versions of the problem according to desired VPN topology, under the assumption that an aggregate traffic matrix is given, and investigated the complexity and approximability status of the problems. In the present paper, we propose an algebraic representation of the VPN design problem under aggregate traffic demand uncertainty as a mixed-integer programming problem with multicommodity flow structure. We investigate properties of the formulation as well as practical solvability issues and extensions.

Berth allocation planning optimization in container terminal

CHUNG-PIAW TEO
National University of Singapore
coauthors: Jim Dai, Wugin Lin, Rajeeva Moorthy

keywords: berth allocation

In this talk, we present a study on the problem of allocating berth space for in-coming vessels in a container terminal, which is referred to as the berth allocation planning problem. Combining techniques from sequence-pair concept in rectangle packing, and stochastic network stability analysis, we design an effective berth allocation system for

this problem. We address the trade-offs between throughput, berth utilization, choice of planning time window, berth-on-arrival etc. In a moderate load setting, extensive simulation results show that the proposed berthing system is able to allocate space to most of the calling vessels upon arrival, with majority of them allocated to the preferred berthing location. In a heavy load setting, we show that surprisingly, sometime it is beneficial to deliberately delay vessels in order to achieve higher throughput in the berthing system.

TU2-341/23 BIOINFORMATICS AND OPTIMIZATION

Optimization in medicine I

organizer/chair: Panos M. Pardalos

Survival-time classification of breast cancer patients and chemotherapy

OLVI MANGASARIAN
University of Wisconsin
coauthors: Y.- J. Lee, W. H. Wolberg
keywords: breast cancer, chemotherapy, classification, support vector machines

The identification of breast cancer patients for whom chemotherapy could prolong survival time is treated here as a data mining problem. This identification is achieved by clustering 253 breast cancer patients into three prognostic groups: Good, Poor and Intermediate. Each of the three groups has a significantly distinct Kaplan-Meier survival curve. Of particular significance is the Intermediate group, because patients with chemotherapy in this group do better than those without chemotherapy in the same group. This is the reverse case to that of the overall population of 253 patients for which patients undergoing chemotherapy have worse survival than those who do not. We also prescribe a procedure that utilizes three nonlinear smooth support vector machines (SSVMs) for classifying breast cancer patients into the three above prognostic groups. These results suggest that the patients in the Good group should not receive chemotherapy while those in the Intermediate group should receive chemotherapy based on our survival curve analysis. To our knowledge this is the first instance of a classifiable group of breast cancer patients for which chemotherapy can possibly enhance survival.

Optimal treatment planning for radiofrequency ablation of liver tumors

ARIELA SOFER
George Mason University
coauthor: Bradford Wood
keywords: treatment, PDE-constrained optimization

Radiofrequency ablation (RFA) is a minimally invasive technique for killing tumors. A needle diode is placed at the tumor site, and alternating current in the range of radiofrequency is applied. This causes ionic agitation, which in turn creates friction heat. Temperatures in excess of 50 Celsius kill tissue. RFA has recently emerged as a leading method for treatment of hepatic tumors, since most liver cancer patients are not candidates for surgical resection. The ablation treatment plan is to determine the number of needles and their positions, to guarantee that the entire tumor is killed while damage to vital healthy tissue (such as vital blood vessels or the colon) is minimized. Since the spread of heat within the organ is governed by the bio-heat equation, this is a PDE-constrained optimization problem. We discuss the problem and present initial solution approaches.

Beam geometry and intensity map optimization in IMRT via mixed integer programming

EVA LEE
School of Industrial and Systems Engineering, Georgia Institute of Technology
coauthors: Tim Fox, Ian Crocker
keywords: mixed integer programming, cancer treatment, radiation therapy

In Intensity-modulated radiation therapy (IMRT) not only is the shape of the beam controlled, but combinations of open and closed multileaf collimators modulate the intensity as well. In this talk, we offer a mixed integer programming approach which allows optimization over beamlet fluence weights as well as beam and couch angles. Computational strategies, including a constraint and column generator, a specialized set-based branching scheme, a geometric heuristic procedure, and the use of disjunctive cuts, are described. Our algorithmic design thus far has been motivated by clinical cases. Numerical tests on real patient cases reveal that good treatment plans are returned within 30 minutes. The MIP plans consistently provide superior tumor coverage and conformity, as well as dose homogeneity within the tumor region while maintaining a low irradiation to important critical and normal tissues.

TU2-321/053 PARALLEL COMPUTING

Parallel computation in optimization: semidefinite programming and related issues

organizers: Mituhiro Fukuda and Masakazu Kojima
chair: Mituhiro Fukuda

High performance grid computing for mathematical programming

KATSUKI FUJISAWA
National Institute of Advanced Industrial Science and Technology, Grid Technology Research Center
coauthors: Masakazu Kojima, Satoshi Matsuoka
keywords: grid computing, cluster computing, optimization problem

Grid computing has recently received much attention as a powerful and inexpensive methodology for solving large optimization problems that an existing single CPU cannot process. Ninf is a grid computing infrastructure which enables us to easily access computational resources including hardware and software library distributed across a wide area network. The Ninf system employs a client-server model, where the server and client machines are connected via a local area network or the Internet. We have been applying the Ninf system to optimization problems and polynomial systems of equations. Among others, we implemented highly parallel algorithms which utilize several PC clusters connected via the high speed local area network and/or the Internet. In this talk, we discuss grid computing for mathematical programming showing some numerical results.

Parallel computation for semidefinite programming

MAKOTO YAMASHITA
Tokyo Institute of Technology
coauthors: Katsuki Fujisawa, Masakazu Kojima
keywords: nonlinear programming, semidefinite programming, parallel computation, interior point method

One approach to solve large-scale SDPs at high speed is to combine primal-dual interior point methods and parallel computation on PC cluster. We developed a parallel version of the SDPA, the SDPARA (SemiDefinite Programming Algorithm PARAllel version) on PC cluster. The main feature of the SDPARA is to process the linear system with the Schur complement coefficient matrix which is

solved at each iteration to generate a search direction. This part is known to be the most time consuming when solving many large scale SDPs by primal-dual interior point methods. The SDPARA computes the elements of the Schur complement matrix in parallel and applies a parallel Cholesky factorization to the linear system on distributed memory. Through numerical results on 64 PCs, we show that the SDPARA can solve large-scale SDPs at high speed that we could not achieve before. The SDPARA also attains a high scalability on parallel computation.

Parallel semidefinite programming algorithm using matrix completion

KAZUHIDE NAKATA
Tokyo Institute of Technology

coauthors: Katsuki Fujisawa, Masakazu Kojima, Makoto Yamashita
keywords: semidefinite programming, sparsity, matrix completion, parallel computing

When we solve large scale SDPs by primal-dual interior-point methods, the positive semidefinite matrix variable often becomes large and fully dense. To overcome this difficulty, we proposed to use a positive semidefinite matrix completion technique a few years ago. This technique worked very effectively for SDPs with large scale sparse data matrices satisfying special structures. In general sparse cases, however, it requires more cpu time to compute search directions at each iteration than the standard primal-dual interior-point method. An important feature of this technique is considerably less memory spent. To take full advantage of this feature and to reduce much cpu time to compute search directions, we incorporate a parallel matrix completion technique into the SDPARA, a parallel version of the SDPA (Semidefinite Programming Algorithm), which employs a parallel Cholesky factorization of the Schur complement matrix. Our numerical results show that the parallel matrix completion technique works very efficiently for some large scale and sparse SDPs.

TU2-321/033 NETWORKS
Shortest path problems
chair: Stefan Krause

A Lagrangean relaxation approach to solving the resource constrained shortest path problem

IRINA DUMITRESCU
TU Darmstadt

coauthor: Natashia Boland
keywords: networks, Lagrangean relaxation, constrained shortest path

Given a directed graph that has a cost and an amount of consumed resource associated with each arc, the Resource Constraint Shortest Path Problem (RCSPP) consists of finding the least cost path between two specified nodes such that the total amount of resource consumed is less than a specified value. The RCSPP is NP-hard. Preprocessing can be very important when a RCSPP is solved. We will briefly show the effect of preprocessing and propose a new Lagrangean relaxation approach to solving the RCSPP. We will present an improved label setting algorithm that uses preprocessing information as well as all Lagrangean multiplier information collected in a Lagrangean relaxation step. Numerical results obtained for randomly generated and real life test problems will be provided.

The minimum congestion shortest path routing problem

ANDREAS BLEY
Konrad-Zuse-Zentrum Berlin

keywords: network design, shortest path routing, mixed integer programming

Given a capacitated network and some traffic demands between its nodes, the minimum congestion shortest path routing problem is to find non-negative lengths for the network's edges such that for the resulting shortest path routing the maximum flow/capacity ratio of the links is minimized. This problem is of great practical interest, since the most commonly used routing protocol in the Internet, OSPF, is based on shortest path routing. We consider only unsplittable shortest path routing, i.e., for each demand there must be a unique shortest path between its terminals.

We discuss the relation between path systems that arise from shortest path routings and stable sets in some associated hypergraphs, formulate the minimum congestion shortest path routing problem as a mixed-integer linear program, and present a branch-and-cut-and-price algorithm for its solution. Computational results for various real-world problem instances are reported.

We also show that it is NP-hard to approximate the minimum congestion shortest path routing problem within a factor of $O(\langle I\rangle^{1/(2+\varepsilon)})$, $\varepsilon > 0$, where $\langle I\rangle$ is the binary encoding size of the problem.

Increasing distances in graphs by deleting minimum edge sets

STEFAN KRAUSE
TU Braunschweig

keywords: min-cut, shortest paths, set cover

Given a simple and undirected graph G the distance increasing problem (DIP) is to find a minimum edge set such that deleting these edges from G increases the distance of given pairs of vertices by at least a given amount, where vertices of different components have distance ∞. In this talk some special cases of DIP are discussed. We give polynomial time algorithms and proofs of NP-hardness.

TU2-321/133 GRAPHS AND MATROIDS
Graphs and discovery
organizer/chair: Pierre Hansen

Computer-assisted research in graph theory

DRAGAN STEVANOVIC
Faculty of Science and Mathematics

keywords: graph theory, computers in research, graph editing, conjecture testing

One of the first computer programs to assist graph theorists in research, the system GRAPH was developed at the University of Belgrade, Yugoslavia, by Dragos Cvetkovic and his collaborators during 1981–1984. We present the system GRAPH and, based on experience with it, study two important aspects of such programs: graph editing and conjecture testing from the viewpoint of user-friendliness and user-time management. Implementing these observations, we also present a first working prototype of GRAPH 2, which is to be linked to the world-class isomorphism-tester nauty, various graph generators and Mathematica package Combinatorica.

What forms do interesting conjectures have in graph theory?

GILLES CAPOROSSI
HEC Montreal

coauthors: Mustapha Aouchiche, Pierre Hansen, Dragan Stevanovic
keywords: graphs, conjecture

Conjectures in graph theory have multiple forms and involve graph invariants, graph classes, subgraphs, minors and other concepts in premises and/or conclusions. Various abstract criteria have been proposed in order to find interesting ones with computer-aided or automated systems for conjecture-making. Beginning with the observation that famous theorems (and others) have first been conjectures, if only in the minds of those who obtained them, we review forms that they take. We also give examples of conjectures of such forms obtained with the help of, or by, computers when it is the case. It appears that many forms are unexplored and so computer-assisted and automated conjecture-making in graph theory, despite many successes, is pretty much at its beginning.

How far should, is and could conjecture-making be automated in graph theory?

PIERRE HANSEN
GERAD and HEC Montreal

keywords: graphs, conjecture, assisted, automated

Computer-assisted and automated conjecture-making in graph theory is reviewed, focusing on the three operational systems GRAPH,Graffiti and Autographix (AGX). A series of possible enhancements,mostly through hybridisation of these systems, are proposed as well as several research paths for development of the area.

TU2-305/205 GAME THEORY
Cooperative games
chair: Sjur Didrik Flåm

Determination of stable structures in a multiple coalition game

ELENA SÁIZ PÉREZ
Universidad de Sevilla
coauthors: Eligius Maria Theodorus Hendrix, Niels Olieman, Michael Finus

keywords: cooperative, multiple coalitions, Nash equilibrium

Our study is based on work by several researchers on stability of coalition formation in the Kyoto protocol (see papers from Carraro, Finus, Eyckmans, Olieman). We consider multiple coalitions which groups of countries can join. A new notation is presented for specifying the stability and facilitating the implementation into computer coding. The results are shown of an application to study stability conditions to coalitions structures in an Open Membership Game and Exclusive Membership Game with Multiple Coalitions.

Characterizing convexity of games using marginal vectors

HERBERT HAMERS
Tilburg University
coauthors: Bas van Velzen, Henk Norde

keywords: convex cooperative games

This paper studies the relation between convexity of TU games and marginal vectors. Shapley (1971) and Ichiishi (1981) showed that a game is convex if and only if all marginal vectors are core elements. Rafels,Ybern (1995) show that if all even marginal vectors are core elements, then all odd marginal vectors are core elements as well, and vice versa. Hence, if all even or all odd marginal vectors are core elements, then the game is convex. Van Velzen, Hamers, Norde (2002) construct other sets of marginal vectors such that the requirement that these marginal vectors are core elements is a sufficient condition for convexity of a game. This construction is based on a neighbour argument, i.e. it is shown that if two specific neighbours of a marginal vector are core elements, then this marginal vector is a core element as well. In this way they characterize convexity using a fraction of the total number of marginal vectors. In this paper we use combinatorial arguments to obtain sets of marginal vectors that characterize convexity. We characterize these sets of marginal vectors and present the formula for the minimum cardinality of sets of marginal vectors that characterize convexity.

Extremal convolution and games

SJUR DIDRIK FLÅM
Economics Dep. Bergen University

keywords: extremal convolution, production games, core solutions, duality gap

Main objects here are so-called market or production games. These are cooperative, transferable-utility games for which core solutions emerge, in concave instances, via shadow prices on endowments. Such games can model mutual insurance, financial equilibrium and coordinated production. They can also figure as subgames of noncooperative, strategic interaction. We explore all this and elaborate on what happens when payoffs are not concave.

WE1-302/41 COMBINATORIAL OPTIMIZATION

Domination analysis of combinatorial optimization algorithms

organizer/chair: Gregory Gutin

Introduction to domination analysis

GREGORY GUTIN
Dept of Computer Science, Royal Holloway, University of London

keywords: heuristics, approximation algorithms, domination analysis, combinatorial optimization

The study of Domination Analysis (DA) was initiated by F. Glover and A.P. Punnen in 1997. DA provides an alternative and a complement to Aproximation Analysis. In DA, we are normally interested in the minimum possible number (proportion, respectively) of feasible solutions that are worse or equal in quality to the heuristic one. This is called the domination number (domination ratio, respectively) of the heuristic solution.

In many cases, DA is very useful. For example, it is proved in 2002 by A. Yeo and myself, that the greedy algorithm has domination number 1 for many combinatorial optimization problems. In other words, the greedy algorithm, in the worst case, produces the unique worst possible solution (for any size of instances). This is reflected in one of the latest computational experiments with the greedy algorithm, see Chapter 10 (by D.S. Johnson et al.) in the 2002 TSP book, where it was concluded that the greedy algorithm 'might be said to be self-destruct'.

The aim of the talk is to give a short introduction to DA. We'll discuss some results obtained recently by several researchers including N. Alon, J. Bang-Jensen, S. Kabadi, M. Krivelevich, F. Margot, A.P. Punnen, A. Vainshtein, A. Yeo and the speaker. Open problems and applications will also be discussed.

When the greedy algorithm fails

JOERGEN BANG-JENSEN
University of Southern Denmark
coauthors: Gregory Gutin, Anders Yeo

keywords: greedy algorithms, independence systems, combinatorial optimization, traveling salesman problem

We provide a characterization of the cases when the greedy algorithm may produce the unique worst possible solution for the problem of finding a minimum weight base in a uniform independence system when the weights are taken from a finite range. We apply this theorem to TSP and the minimum bisection problem. The practical message of this work is that the greedy algorithm should be used with great care, since for many optimization problems its usage seems impractical even for generating a starting solution (that will be improved by a local search or another heuristic).

Approximate local search

ANDREAS S. SCHULZ
Massachusetts Institute of Technology
coauthors: James B. Orlin, Abraham P. Punnen

keywords: theory of local search, analysis of algorithms, 0/1-integer programming, approximation algorithms

Local search algorithms for combinatorial optimization problems are in general of pseudopolynomial running time and polynomial-time algorithms are often not known for finding locally optimal solutions for NP-hard optimization problems. We introduce the concept of ε-local optimality and show that an ε-local optimum can be identified in time polynomial in the problem size and $1/\varepsilon$ whenever the corresponding neighborhood can be searched fast.

We also discuss various extensions of our main result, we relate it to the complexity class PLS introduced by Johnson, Papadimitriou and Yannakakis, and we point out that it is best possible. In particular, it takes in general exponential time to compute a local optimum for a problem in PLS if it is just described by a neighborhood-search oracle.

WE1-302/42 COMBINATORIAL OPTIMIZATION

Combinatorial optimization V

chair: Marek Libura

A strongly polynomial algorithm for integer version of the multipath flow network synthesis problem

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University of New Brunswick
coauthors: R. Chandrasekaran, K. P. K. Nair, Y. P. Aneja

keywords: network synthesis, graphs, strongly polynomial algorithm, integer rounding property

Given an undirected network G = [N, E], a source-sink pair (s,t) of nodes in N, a non-negative edge capacity u(i,j) for each edge (i,j) in E, and a positive integer q, an elementary q-path flow from s to t is a flow of q units, with one unit of flow along each path in a set of q edge-disjoint paths from s to t. A q-path flow from s to t is a non-negative linear combination of elementary q-path flows from s to t, adhering to edge-capacities. We consider the following network synthesis problem: We are given an nxn, non-negative, symmetric integer-valued matrix R, where each non-diagonal element, R(ij), represents the required value of q-path flow between nodes i and j in an undirected network on the node set N=1,2,...,n. We want to construct a network G =[N, E] with integer-valued edge capacities u(e) :e in E so that each of these requirements can be realized (one at a time) and the sum of all edge-capacities is minimum. We present a strongly polynomial algorithm for the problem and show that, except for a very special case, the problem has integer rounding property.

Minimal multicut and maximal integer multiflow in rings

LUCAS LÉTOCART
CEDRIC CNAM
coauthors: Marie-Christine Costa, Frédéric Roupin

keywords: multicommodity flow, multicut, rings

This presentation deals with the minimization of multicuts and with the maximization of integral multiflows. A ring is a connected graph where all vertices have degree 2. Several simplifications can be made before solving the minimal multicut and the maximal integer multiflow problems in rings. The main one is that a path without terminals, except for its endpoints, may be reduced to a single edge, which is the lowest weighted edge of the path. Moreover problems in bidirectional rings can be transformed in equivalent problems in directed rings by doubling the number of commodities. In fact, without loss of generality, one can assume that there is a source and/or a sink located at each vertex. We propose a polynomial algorithm in $O(min(Kn^2, n^3))$ to solve the minimal multicut problem in ring networks. The algorithm is based on the enumeration of several minimum cuts associated with an arbitrary path, each one containing one different edge of the path; these cuts are obtained by using the algorithm given for rooted trees. We propose also a polynomial algorithm in O(n) to solve the maximal integer multiflow problem in rings with uniform capacities. This algorithm is based on the continuous solution of the problem.

Adjustment problem for binary constrained linear programming problems

MAREK LIBURA
Systems Research Institute, Polish Academy of Sciences
keywords: inverse optimization, linear programming, combinatorial optimization
We consider a pair of optimization problems with the same linear objective function: an initial problem and its restriction. For the initial problem we propose a generalization of standard inverse problem and call it the adjustment problem. The adjustment problem consists in finding such minimum norm perturbations of the objective vector, which guarantee that an optimal solution of the perturbed initial problem is also an optimal solution of the given restriction. We propose a method of solving the adjustment problem when the initial optimization problem is a linear programming problem and all variables in the restriction are binary variables. We illustrate the approach with two examples: For a given graph we calculate such minimum norm perturbations of arc lengths which guarantee that the shortest path connecting two given vertices belongs to some specified subset of paths. Similarly, we calculate such minimum perturbations of objective coefficients in the continuous knapsack problem, which guarantee that an optimal solution of the perturbed problem is integral.

WE1-302/44 COMBINATORIAL OPTIMIZATION
Knapsack problems
organizer/chair: David Pisinger

A survey of upper bounds and exact algorithms for the quadratic knapsack problem

DAVID PISINGER
DIKU, University of Copenhagen
coauthors: Anders Bo Rasmussen, Rune Sandvik
keywords: quadratic knapsack problem, integer programming, upper bounds, knapsack problem
The quadratic knapsack problem (QKP) maximizes a quadratic objective function subject to a linear capacity constraint. Due to its simple structure and challenging difficulty it has been studied intensively during the last two decades. We will give a survey of upper bounds presented in the literature, show the relative tightness of several of the bounds, and experimentally compare their strength and computational effort. Techniques for deriving the bounds include relaxation from upper planes, linearisation, reformulation, Lagrangian relaxation, Lagrangian decomposition, and semidefinite programming. The talk is concluded with the presentation of a new exact algorithm which is capable of solving large-scale QKP problems with up to 1000 variables.

A survey of stochastic aspects of knapsack problems

ULRICH PFERSCHY
University of Graz
keywords: knapsack problem, stochastic analysis, on-line problem
Although the knapsack problem is NP-hard, highly successful optimal algorithms are available for almost all types of instances. Hence, it is of particular interest to study stochastic properties of the knapsack problem to gain more insight into its structure.

In this survey we will review the usually applied probabilistic models and the main structural results describing e.g. the value of the optimal solution, the number of items where integer and continuous optimal solutions differ, and the resulting integrality gap. Furthermore, a number of algorithmic results will be included, concerning both the expected solution quality of simple algorithms, in particular greedy-type methods, and the expected running time of optimal algorithms, which can be bounded by a polynomial.

Related problems such as the subset sum problem and the d-dimensional knapsack problem will also be considered. Special emphasis will be put on the on-line knapsack problem, where an underlying time-line defines the availability of items.

A survey of approximation algorithms for knapsack-type problems

HANS KELLERER
University of Graz
keywords: knapsack, approximation algorithms, dynamic programming
We give a survey on approximation algorithms (heuristics, PTAS, FPTAS) for knapsack-type problems. Especially, we treat the classical knapsack problem, the subset sum problem, the multiple knaspack problem, the multidimensional knapsack problem and other variants.

WE1-302/45 COMBINATORIAL OPTIMIZATION
Traveling salesman II
chair: Nicholas Pearson

On the optimal clustering TSP path and stars problems

MICHAL STERN
Ben Gurion University
coauthor: Ephraim Korach
keywords: clustering spanning trees, clustering TSP path, stars, polynomial graph algorithms
We consider the following problem: Let (V,S) be a given hypergraph where V is a ground set of elements and S is a simple collection of subsets of V. Let G=(V,E) be a complete graph with a cost function. Find in G a minimum cost spanning tree T such that each subset of S induces a subtree in T. In this talk we consider two special cases of this problem: (i) The clustering-TSP-path problem in which the spanning tree is restricted to be a Hamiltonian path, (ii) The optimal-stars-clustering-tree problem in which each subset induces a star. For the first problem finding a feasible solution is equivalent to the Consecutive Ones Property solved by Booth and Lueker. We present a polynomial algorithm for finding an optimal solution for a restricted case. For the latter problem we present a structure theorem and a polynomial algorithm. A motivation is to construct a minimum cost communication network with the above restrictions for a collection of non-disjoint groups of customers such that each group induces a subtree so that the network will provide "group fault tolerance" and "group privacy". For the clustering-TSP-path problem there is another motivation from robotics.

Solving the TSP with decomposition-based pricing

JOHN RAFFENSPERGER
University of Canterbury
keywords: programming, integer, algorithms, relaxation/subgradient
In this paper, we propose to solve the Traveling Salesman Problem using two methods. First, we generate columns using the Held & Karp 1-tree subgradient optimisation procedure, to be used in the standard Dantzig-Fulkerson-Johnson (DFJ) formuation for the TSP. We restrict the DFJ master to arcs found in the subgradient optimisation procedure. Second, we use the same procedure for generating columns, but we use a master formulation for the TSP based on Martin?s LP formulation for the minimum spanning tree. In both cases, we get good bounds on the optimal tour. Use of the DFJ formulation requires standard subtour breaking constraints. The second method does not use the standard subtour breaking constraints, but rather employs auxiliary variables to restrict the assignment to

a 1-tree. The two algorithms resemble Mamer & McBride?s decomposition-based pricing algorithm for linear programming.

Fast algorithms for planar graphs, Part II: the traveling salesman problem

NICHOLAS PEARSON
Lancaster University

coauthor: Adam Letchford
keywords: traveling salesman problem, combinatorial optimization, planar graphs, branch-and-cut

It is well-known that the TSP remains NP-hard even when the underlying graph is planar. However, a polynomial-time approximation scheme is known for the planar TSP, whereas the general TSP is APX-hard.

We present evidence to suggest that the planar TSP may also be easier to solve to optimality than in the general case. In particular, we show that the separation problem for the subtour elimination and 2-matching constraints can be solved in $O(n^{3/2})$ time in the planar case, whereas for general sparse graphs the bound is $O(n^2 \log n)$ for subtour elimination constraints and $O(n^3 \log n)$ for 2-matching constraints. Moreover, for planar graphs there is an $O(n^3)$ separation algorithm for the domino-parity inequalities, which include the comb inequalities as a special case, whereas in the general case no polynomial-time algorithm is known.

We also present a small number of graphs for which the subtour elimination and domino-parity inequalities do not suffice to describe the (graphical) TSP polyhedron, and conjecture that these are the excluded minors for this property.

This talk will draw on results given in a companion talk by Adam Letchford, entitled "Fast algorithms for planar graphs, Part I: cycles and cuts".

WE1-302/49 — INTEGER AND MIXED INTEGER PROGRAMMING

Integer programming

organizer/chair: Daniel Bienstock

A practical implementation of lift-and-project cuts

MICHAEL PERREGAARD
Dash Optimization

keywords: cutting planes, lift-and-project, mixed integer programming

Lift-and-project cuts for mixed integer programs were first introduced in the early 1990s and has its roots in disjunctive programming from the 1970s. Several papers have been published with promising results, but these implementations have all relied on an external linear or mixed integer solver.

We present here the first commercial implementation of lift-and-project cuts where the cut generation is integrated with the solver. It relies on performing regular simplex iterations of the linear programming relaxation instead of the classical approach of solving a separate linear program. We compare the performance on various classes of publicly available problem instances.

A branch-and-cut algorithm for nonconvex quadratic programming

GEORGE NEMHAUSER
ISYE - Georgia Tech

coauthor: Dieter Vandenbussche
keywords: branch-and-cut, nonconvex, quadratic programming, polyhedron

By reformulating quadratic programs using necessary optimality conditions, we present a branch-and-cut approach to solve nonconvex instances. For the bound constrained case, we study a relaxation based on a subset of the optimality conditions. By characterizing its convex hull, we obtain a large class of valid inequalities. These inequalities are tested within a branch-and-cut scheme and the computational results demonstrate the efficiency of the algorithm.

On the use of Gomory's cyclic group polyhedra in cutting-plane generation

SANJEEB DASH
IBM T. J. Watson Research Center

coauthor: Oktay Gunluk
keywords: integer programming, cutting planes, cyclic group

Gomory introduced certain cyclic group polyhedra in 1969 as relaxations of single constraints in integer programs. Gomory showed that facets of these polyhedra yield cutting planes for the associated integer programs; additional properties, and cutting plane ideas, can be found in some recent papers. We continue the study of these polyhedra. In particular, we study a class of facets described in Araoz, Evans, Gomory, and Johnson (the two-slope facets), and present a simple principle - analogous to the basic MIR principle but with three variables and one constraint - and derive the validity of these facets from this principle.

WE1-306/31 — INTEGER AND MIXED INTEGER PROGRAMMING

Integer and mixed integer programming IV

chair: Agostinho Agra

Exact solution to separable integer programming

DUAN LI
Chinese University of Hong Kong

coauthors: Jun Wang, Xiaoling Sun
keywords: integer programming, Lagrangian duality, objective level cut, dynamic programming

A convergent Lagrangian and objective level cut method is proposed for solving separable integer programming problems. The method exposes an optimal solution to the convex hull of a revised perturbation function by successively reshaping the perturbation function. The objective level cut is used to eliminate the duality gap and thus to guarantee the convergence of the Lagrangian method on a revised domain. Computational results are reported for a variety of separable integer programming problems with up to 5000 integer variables.

Discrete time LQR optimal control problem with logical constraints

DORIN PREDA
ENSEEIHT-INP

coauthor: Joseph Noailles
keywords: mixed integer programming, discrete time LQR, logical constraints, GOA GBD

We are interested in a discrete time LQR optimal control problem with logical constraints. These constraints restrain the total time of control on each fixed length time interval. Therefore the problem naturally belongs to the Mixed Integer Programming class; each control variable has its correspondent binary variable expressing his presence or absence in the LQR dynamics.

We first explore the integer feasible space and present mathematical considerations allowing us to reduce the size of this space and to give useful properties of an admissible integer solution. We then present two different formulations of our problem. As usual mixed integer approach involves the generation, at each iteration, of a lower bound and an upper bound of the optimal solution. Our first model, formulated as a Mixed Integer Quadratic Problem, can naturally be solved using classical algorithms: Generalized Benders Decomposition and Generalized Outer Approximation. We show why this is not the best approach and propose, for our second model (a Mixed Integer Nonlinear Problem), an effective way of estimating the successive lower bounds wich ensures a rapid convergence of the algorithm.

For both formulations we present numerical results that seem to be very promising for the approach that we propose.

MIP cuts based on knapsacks with 2 integer variables

AGOSTINHO AGRA
University of Aveiro

coauthor: Miguel Constantino
keywords: knapsack sets, valid inequalities

We consider MIP relaxations leading to integer knapsacks with 2 integer variables and a continuous variable. The convex hull of solutions for these models can be obtained in polynomial time. In order to extend these inequalities to the original model, we consider sequence independent lifting functions. Computational experience is reported.

WE1-306/32 NONLINEAR PROGRAMMING

Optimization of engineering systems governed by simulations/PDE, part 3

organizer/chair: Natalia Alexandrov

High-fidelity solvers in the design optimization of ships

EMILIO F. CAMPANA
INSEAN - The Italian Ship Model Basin

coauthor: D. Peri
keywords: approximation management, nonlinear programming, ship design

The use of high fidelity, CPU time expensive solvers is now quite common in the trial-and-error design process. Their use in a simulation-based design process is however still reduced by the large amount of computational effort needed in a design problem. To reduce the computational cost of running complex engineering simulations, different techniques may be adopted to obtain global approximation of the high-fidelity solvers, as the widely used metamodelling techniques. An alternative approach is the Variable Fidelity Modeling (VFM), which combine less accurate but also incomparably less expensive solvers with high-fidelity models. The use of trust region strategies and of consistency conditions finally ensure the accuracy of the optimal solution. Applications of metamodels and of VFM with trust region strategies are presented for both single and multi-objective complex design problems. Shape optimization of existing surface ships is performed through the solution of CFD solvers, included a high-fidelity finite-volume RANSE code for the prediction of the free surface flow past the ship free to dynamically sink and trim. In the adopted formulation, the accuracy of the metamodels evolve during the optimization cycles. Results show up to a factor of 5 in terms of CPU time.

Boundary shape optimization for fluids and waves

MARTIN BERGGREN
Division of Scientific Computing, Department of Information Technology, Uppsala University

keywords: shape optimization, adjoint equations, Helmholtz equations, Euler equations

We discuss similarities and differences between two shape optimization problems: drag reduction of airfoils or aircraft wings, and transmission optimization of acoustic or microwave transducers. A common problem is how to translate the intension of changing the geometry into a mathematical formulation that make sense in a nonlinear optimization context. We choose to consider normal deflections from a given, fixed reference configuration. The normal deflection, in turn, is the solution of a second-order elliptic boundary-value problem defined on the reference configuration. This formulation has the advantage of being (i) general and parameter free, (ii) producing smooth design updates with specified behavior at edges of the boundary, (iii) being able to handle geometric constraints such as convexity, volume, and local displacement in a uniform way. An issue that differs between the fluid and wave application is how easy it is to accurate compute gradients by the discrete adjoint-equation approach. Fully discrete expressions for Jacobians and gradients are complicated for the fluid equations (compressible Euler). A hybrid approach combining hand-derived expressions with Automatic Differentiation seems to be promising: almost as efficient as fully hand-coded Jacobians, but much less error-prone to implement.

Problem formulation and modeling in simulation-based design

NATALIA ALEXANDROV
NASA Langley Research Center

keywords: simulation based optimization, PDE-constrained optimization, variable fidelity modeling, multidisciplinary optimization

Complex engineering design optimization problems governed by computational simulations rarely lend themselves to straightforward formulation and solution by conventional methods of nonlinear programming. Two of the most difficult aspects are the multidisciplinary nature of the problems and the expense of repeated function evaluation via high-fidelity simulations, such as the Navier-Stokes equations of computational fluid dynamics. Such problems are not only prohibitively expensive, but they can also thwart optimization because function and constraint evaluation is not robust. We address the expense of simulations via a rigorous use of models simplified both in physics and in mesh resolution to obtain solutions to models of higher physical fidelity with significant savings in terms of high-fidelity simulations. We address the multidisciplinary nature of the problem via a modular approach to problem formulation, in which basic computational components can be combined into different optimization formulations and solution algorithms with relative ease.

WE1-306/33 NONLINEAR PROGRAMMING

Least square problems

chair: Jerry Eriksson

On global minimization of procrustes-penrose regression problems

THOMAS VIKLANDS
Department of computing science

coauthor: Per Åke Wedin
keywords: weighted orthogonal, least squares, several minima, iterative algorithms

Consider the set of matrices Q with orthonormal columns defined by $\mathcal{V}_{m,n} = \{Q \in R^{m\times n} : Q^TQ = I_n, 1 \leq n \leq m\}$. The set $\mathcal{V}_{m,n}$ is called the Stiefel manifold. We want to minimize a real valued quadratic or linear function of Q over the Stiefel manifold. One problem of that kind is the Procrustes problem $\min ||AQ - B||_F^2$ s.t. $Q \in \mathcal{V}_{n,n}$. This problem has an unique minimum value. The solution can be computed by using the SVD of A^TB. Most quadratic problems defined on the Stiefel manifold have several minima. We have made a detailed study of algorithms for one problem of some practical interest, the Penrose regression problem $\min ||AQX - B||_F^2$ s.t. $Q \in \mathcal{V}_{m,n}$. For this problem we have constructed an algorithm that computes all the minima with a method of a new kind. Having computed one minimum we use the "normal plane" to the surface defined by AQX, $Q \in \mathcal{V}_{m,n}$ for the minimizer Q_*

to compute a set of orthonormal matrices. Remarkably each of these matrices lies in the vicinity of other minima due to the special geometry of the surface.

The least square values and the Shapley value

IRINEL DRAGAN
University of Texas, Mathematics

keywords: Shapley value, least square values

The Least Square Values of cooperative TU games (briefly LS-values), have been introduced as optimal solutions depending on parameters of a quadratic optimization problem by M. Keane (1969), and axiomatized by L. Ruiz, F. Valenciano and J. Zarzuelo (1998). The Shapley value is a member of the family. In an earlier paper of the author (Dragan,1992), a so-called average per capita formula for the Shapley value was proved and a computational algorithm has been derived. In the present paper, we prove an Average per capita formula for the LS-values. The main result is that any LS-value is the Shapley value of a game easily obtained from the given game. This fact led to the so-called poten- tial basis of the space of games relative to LS-values and to the solution of the inverse problem: for a given n-vector, find out the set of games for which the LS-value is the given vector. The inverse problem for Shapley value was earlier solved (Dragan,1991).

The superiority of using regularization over trust-region for ill-conditioned nonlinear least squares

JERRY ERIKSSON
Umeå University

keywords: regularization, inverse problems, Gauss-Newton, nonlinear least squares

Trust-region methods are very efficient and a natural first choice when solving nonlinear least squares. Their main advantages include strong global convergence properties, simplicity and reliability. However, for problems that are ill-conditioned in the neighbourhood of a solution point (local minimizer) these methods suffer from weak theoretical and practical convergencee rate. As alternativ, for such ill-conditioned problems, we propose methods based on regularization. We use two well-known techniques; Tikhonov (lagrangian) regularization and truncation to augment (or modify) the objective function. This leads to well-defined problems on which first-order methods such as a Gauss-Newton method performs well.

The theory presented also reveals information of the curvature properties in both the parameter space and the function space. This information is potentially very useful already in an early phase when modelling an inverse problem.

We will give practical algorithms and their performance based on Gauss-Newton, Quasi-Newton, and conjugated gradient methods. We also present numerical results when optimizing feed-forward neural networks, which includes convergence rates but also the problems curvature properties.

WE1-306/34 NONLINEAR PROGRAMMING
Large scale nonlinear programming I
organizers: Sven Leyffer and Richard Waltz
chair: Richard Waltz

An interior-point L1-penalty method for nonlinear optimization

DOMINIQUE ORBAN
Northwestern Univeristy

coauthors: Nick Gould, Philippe L. Toint
keywords: primal-dual interior method, L1 penalty, mixed interior/exterior

We discuss the merits of a mixed interior/exterior-point method for nonlinear programming in which all nonlinear constraints are treated by an ℓ_1 penalty function. Inspired by a proposal by Mayne and Polak, a suitable decomposition of the constraints allows us to derive an exact differentiable penalty function involving only inequality constraints, which may then be treated using a logarithmic barrier. Exactness of the exterior penalty function eliminates the need to drive the corresponding penalty parameter to infinity. Global and fast local convergence of the proposed scheme are exposed.

Convergence and constraint activity in a successive LP algorithm

RICHARD BYRD
University of Colorado

coauthors: Nick Gould, Richard Waltz Jorge Nocedal
keywords: nonlinear programming, active set, trust region

Although it is sometimes desirable to solve large-scale constrained nonlinear optimization problems by an active set method, techniques of active-set quadratic programming appear to put limits on the size of problems that approach can efficiently handle. For that reason we have developed SLIQUE, an active set algorithm that uses solution of a linear programming subproblem to determine a working set, on which a quadratic approximation of the Lagrangian is minimized. In this talk we study the behavior of this algorithm, considering its global convergence and the asymptotic choice of the working set. We also analyze experimental results on the stability of the active set, and on the cost of linear program solution.

An f−nonmonotonic filter algorithm for NLP

ROGER FLETCHER
University of Dundee

coauthor: Sven Leyffer
keywords: filter algorithm, nonmonotonicity, SQP, trust region

This paper extends the global convergence proof for an SQP trust region filter algorithm given by Fletcher, Leyffer and Toint, SIAM J. Optim., 13,2002, 44-59. This algorithm exhibits a certain degree of nonmontonicity, but reverts to a monotonic algorithm when applied to an unconstrained problem. For such problems, nonmonotonic line searches, such as that proposed by Grippo, Lampariello and Lucidi, have proved very effective. In this talk it is first shown how the GLL modification can be applied in an unconstrained trust region context. A simple proof is sketched, which illustrates a feature of the GLL algorithm that may not be well understood. It is shown how these ideas can be introduced into the FLT filter algorithm, in such a way that nonmonotonicity in the unconstrained case is allowed. Some familiarity with the FLT proof will be assumed.

WE1-306/35 OTHER
Software session, COIN-OR
organizer/chair: Ted Ralphs

WE1-306/36 NONSMOOTH OPTIMIZATION
Cutting plane methods for conic optimization problems
organizers: John Mitchell, Jean-Louis Goffin and Jean-Philippe Vial
chair: John Mitchell

Cutting plane methods for semidefinite programming

Kartik Krishnan
Rice University

coauthor: John Mitchell
keywords: semidefinite programming, nondifferentiable optimization, cutting plane methods

Interior point methods for semidefinite programming (SDP) are fairly limited in the size of problems they can handle. Cutting plane methods provide a means to solve large scale SDP's cheaply and quickly. We give a survey of various cutting plane approaches for SDP in this paper. These cutting plane approaches arise from two perspectives: the first is based on the polynomial separation oracle for the SDP that is utili zed by polynomial interior point cutting plane methods; the second rewrites an SDP with a bounded feasible set as an eigenvalue optimization problem, which in turn is solved using bundle methods for nondifferentiable opti mization.

We present an accessible and unified introduction to various cutting plane approaches that have appeared in the literature; in particular we show how each approach arises as a natural enhancement of a primordial LP cutting plane scheme based on a semi-infinite formulation of the SDP.

Analytic center cutting plane method in conic programming

Vasile Basescu
Rensselaer Polytechnic Institute

coauthor: John Mitchell
keywords: conic programming, analytic center

We analyze the problem of finding a point strictly interior to a bounded, fully-dimensional set from a finite dimensional Hilbert space. We try to generalize the results obtained for the LP, SDP and SOCP cases. The cuts added by our algorithm are central and linear. In our analysis, we will find an upper bound for the number of Newton steps required to compute an 'approximate' analytic center. Also, we will provide an upper bound for the total number of cuts added to solve the problem. This bound depends on the quality of cuts, the dimensionality of the problem and the 'thickness' of the set we are considering.

Second-order cone cuts vs. semidefinite cuts in the analytic center cutting plane method

Mohammad R. Oskoorouchi
Assistant Professor, Cal State University, San Marcos

coauthor: Jean-Louis Goffin
keywords: second order cone, semidefinite cut, analytic center, cutting planes

Recent applications of nonsmooth optimization deal with nonpolyhedral cutting planes such as semidefinite cuts (max-cut problem). An efficient cutting plane technique in nonsmooth optimization is the analytic center cutting plane method (ACCPM). This method uses subgradient information to generate cutting planes. Incorporating semidefinite cuts into the ACCPM results in a polynomial approximation but yields to computational difficulties in practice. Replacing semidefinite cuts by second-order cone cuts is considered. Theoretical issues as well as pros and cons of this replacement are discussed. We show that an approximate analytic center can be recovered after adding a second-order cone cut, in one Newton step and that the analytic center cutting plane method with second order cone cuts is a fully polynomial approximation scheme.

WE1-306/37 CONVEX PROGRAMMING
Complexity in convex programming
chair: Stefan M Stefanov

Condition number complexity for non-conic convex optimization

Fernando Ordonez
ISE- University of Southern California

coauthor: Robert Freund
keywords: condition number, convex optimization, complexity

The condition number of optimization problems in conic form, as introduced by Renegar, has been shown to bound the sizes of feasible and optimal solutions, the changes to solutions due to changes in the data, and the complexity of algorithms to solve the problem. Although any convex problem can be transformed to conic form, such transformations are neither unique nor natural given the natural description of many problems. Therefore the relevance of condition number bounds of equivalent conic formulations for non-conic problems is questionable.

Recent research has extended the definition of the condition number to non-conic convex optimization problems of the form $\min\{c'x | Ax - b \in C_Y, x \in P\}$. We show that the condition number for non-conic convex optimization problems bounds the sizes of feasible and optimal solutions, the change in solution due to changes in the data, and the complexity of interior point algorithms to solve the problem. These bounds also depend on other natural problem parameters such as the size of the data (A, b, c) and the complexity parameter for the self-concordant barrier of the convex set P.

Convex separable optimization problems with bounded variables

Stefan M Stefanov
Neofit Rilski South-West University

keywords: convex programming, separable programming, algorithms, computational complexity

Consider minimization problems with a convex separable objective function subject to a separable convex inequality constraint of the form "less than or equal to" / linear equality constraint / linear inequality constraint of the form "greater than or equal to", and bounds on the variables. The three problems are denoted by (C), $(C^=)$ and $(C^\geq)$, respectively. Such problems arise, e.g., in scheduling theory, in allocation of resources, in inventory control, in facility location problems, in the theory of search, in subgradient optimization, in implementation of projection methods when the feasible region is of the same form as the feasible sets under consideration, etc. For each of problems (C) and $(C^=)$, a necessary and sufficient condition is proved for a feasible solution to be an optimal solution to the respective problem, and a sufficient condition is proved for a feasible solution to problem $(C^\geq)$ to be an optimal solution. Algorithms of polynomial complexity for solving these problems are suggested and convergence of these algorithms is proved. Some important convex functions for the three problems as well as computational results are presented.

WE1-306/38 GLOBAL OPTIMIZATION
Bilevel programming
chair: Anton Evgrafov

A bilevel model and solution algorithm for the stochastic taxation problem

Marcia Fampa
Universidade Federal do Rio de Janeiro

coauthors: Nelson Maculan Filho, Luidi Simonetti
keywords: global optimization, bilevel programming, taxation problem, stochastic model

Bilevel programming problems are optimization problems where a subset of decision variables is not controlled by the principal optimizer or by the leader, but by a second agent, the follower, who optimizes his own objective function with respect to this subset of variables. We consider the class of bilinear bilevel problems obtained when the leader imposes taxes on a specified set of services, while the follower makes his decision, taking into account the taxation scheme devised by the leader and also by his competitors.

An important obstacle observed in practical implementation of those taxation problems is the uncertainty of the taxes imposed by the leader's competitors. We deal with this obstacle, considering a stochastic taxation model and we present an exact algorithm for this problem. Finally, we show how the stochastic taxation program can be used to model the strategic bidding problem in wholesale energy markets and present some numerical results for this problem.

Heuristics for toll setting problem

SOPHIE DEWEZ
Service d'optimisation / Université Libre de Bruxelles
coauthors: Martine Labbé, Patrice Marcotte, Gilles Savard
keywords: bilevel programming, transportation, networks, pricing

We consider the problem of determining a set of optimal prices on a subset of all arcs of a highway network in order to maximize the revenu of the government or private socities.

We can formulate this problem as bilinear bilevel problem. We developp heuristics to solve the problem and present computational results.

Smoothing by relaxing the equilibrium conditions in topology optimization problems for Truss structures in contact

ANTON EVGRAFOV
Department of Mathematics/Chalmers University of Technology
coauthor: Michael Patriksson
keywords: structural optimization, MPEC, bilevel programming, smoothing

We consider the problem of maximizing the mechanical performance of a truss in unilateral, frictionless contact with rigid obstacles, by the means of redistributing the available material among the structural members. Some parts of the structure can be completely removed by allocating the material of volume zero to them. The resulting problem belongs to the class of bilevel programming problems, or mathematical programs with equilibrium constraints (MPEC). Problems of this type violate the standard nonlinear programming constraint qualifications, are known to be non-smooth and non-convex, and, as a result, are hard to solve.

We propose a smooth approximation of the problem, which allows us to solve a sequence of smooth problems instead. We study the sequences of stationary (respectively, globally optimal) solutions to the approximating problems, and show that their limit points are stationary (respectively, globally optimal) for the original MPEC.

The approach is illustrated with numerical examples.

WE1-308/11 GENERALIZED CONVEXITY/MONOTONICITY

Generalized convexity II

organizer: Laura Martein
chair: Riccardo Cambini

Discontinuity properties of convex polynomial mappings

EVGENY BELOUSOV
Moscow State University, Faculty of Economics
keywords: convex mappings, convex polynomial mappings, Hausdorff (semi)continuity

We consider a convex polynomial mappings (CP-mappings) given with a finite system of convex polynomial inequalities

$$A(\lambda) = \{x \in E_n \mid f_i(x) \le \lambda_i,\ i = 1,\dots,m\}, \qquad (1)$$

The main goal of this work is to describe the possible structure of set B_ω of partial limits for lower excess function $d_\omega(\lambda) = \rho(A(\omega), A(\lambda))$ and set B^ω of partial limits for upper excess function $d^\omega(\lambda) = \rho(A(\lambda), A(\omega))$ as $\lambda \to \omega$. It turns out that for CP-mappings inclusion $0 \in B_\omega \cap B^\omega$ always holds.It was shown that for mapping of form (1) the set B_ω has fairly simple structure: it can be either zero or a closed interval of the form $0 \le b \le b_0$, or ray $b \ge 0$. For the set B^ω we still do not know the full description of its possible structure, but we constructed the examples of CP-mappings with the following structure of set B^ω :1) B^ω is the union of zero and arbitrary finite set of positive numbers, 2) B^ω is the union of zero and either a closed interval, or a closed ray, 3) B^ω consists of two elements - finite (zero) and infinite $(+\infty)$In this talk we suggest the conjecture about possible structure of the set B^ω for CP-mappings.

Mixed type duality for multiobjective optimization problems with set constraints

RICCARDO CAMBINI
Dept. Statistics and Applied Mathematics
coauthor: Laura Carosi
keywords: vector optimization, generalized convexity, duality, set constraints

We propose a pair of vector dual programs where the primal has a feasible region defined by a set constraint, equality and inequality constraints. The suggested dual problem can be classified as a "mixed type" one. The duality results are proved under suitable generalized concavity properties.

As parameters in the "mixed type" dual program take different values, different dual problems can be obtained and different generalized concavity properties can be used in order to get the duality results.

Furthermore, we deep on the role of vector ρ-quasiconcavity and, in the case the feasible region has no set constraints, we state duality results assuming the vector (F,ρ)-quasiconcavity.

WE1-308/12 STOCHASTIC PROGRAMMING

Modeling and computation issues in stochastic programming

organizer/chair: Gus Gassmann

SMPS and SMPSReader: an input format and user routines for stochastic programs

GUS GASSMANN
Dalhousie University
keywords: stochastic programming, input format, computation

The SMPS format is a modification of the MPS format for stochastic linear programs. It was recently extended to include chance-constrained programs, stochastic problem dimensions, quadratic objectives and free-format input.

This talk gives an overview of the format and describes a collection of user routines that convert the format to internal data structures, explicitly or implicitly building the deterministic equivalent linear program. These routines are available without restriction to algorithm developers and other researchers.

Scalability and implementation issues in stochastic programming algorithms

Chandra Poojari
Centre for the analysis of risk and optimisation modelling applications, Brunel university
coauthors: Frank Ellison, Gautam Mitra, Suvrajeet Sen
keywords: decomposition, multi-stage, warm start

We present an overview of the current progress in solving Stochastic programming problems and discuss the outstanding issues the needs to be addressed for the further growth of the field. We emphasis the need for decomposition based structure exploiting algorithms to process practical instances of two stage and multi-stage SP problems. Using industrial models and models from the SP test library, we will compare the performances of two such approaches- Benders' decomposition and Stochastic decomposition. Our industrial models are from the domains of finance, supply chain and telecom. We will discuss the techniques such as parallelisation and warm starts through which such SP algorithms can be scaled up to process large instances of practical problems.

Subtree decomposition for multistage stochastic programs

Shane Dye
University of Canterbury
keywords: stochastic programming, decomposition

An algorithm for solving multistage stochastic recourse problems is described. The scenario tree is decomposed using a cover of subtrees. The progressive hedging algorithm is used to ensure implementability across the entire tree. The approach leads to a class of methods based on the subtree cover chosen (the class includes the original implementation of the progressive hedging algorithm). Computational testing indicates that the method can provide improved performance over the original progressive hedging algorithm.

WE1-308/13 STOCHASTIC PROGRAMMING

Stochastic programming applications in the power and gas industries

organizer: COSP (Markus Westphalen)
chair: Markus Westphalen

Value chain management in the liberalized natural gas market

Frode Rømo
SINTEF Industrial Management
coauthors: Asgeir Tomasgard, Matthias Peter Nowak, Marte Fodstad
keywords: natural gas, decision support systems, dynamic markets, value chain optimization

This presentation gives an overview of a 4-year ongoing project SINTEF and NTNU are doing for Statoil.

The aim is to develop methodology and decision support models that incorporate an overall view of production, transportation and market behavior for the supply of natural gas from the Norwegian continental shelf. A major challenge is to establish decision-making processes that facilitate a dynamic coordination of the activities aimed at the market place. This is especially important considering the gas directive from the European commission. It is expected that the directive and the initiatives to liberalize the European energy markets will lead to a new situation for the gas producers with a particular focus on increased short-term variation in supply and demand.

Statoil is Norway's largest gas producer, producing about 30% of the natural gas on the Norwegian shelf and selling about 70% of the Norwegian gas. Norwegian gas sale is approximately 10% of the west European consumption.

We give an overview of tactical and operational decision support models for coordination of production, transportation and sales of natural gas in Statoil. The models include physical properties of the transportation network, contracts and forward markets. The modeling framework is stochastic mixed integer programming.

A two-stage stochastic MILP for natural gas transmission optimization with transient flow

Markus Westphalen
University Duisburg-Essen
coauthors: Andreas Maerkert, Ruediger Schultz
keywords: stochastic programming, integer programming, natural gas

We model natural gas transmission and distribution in a pipeline system by linear mixed-integer optimization. Physical laws and technological layout determine the transient gas flow in pipelines and the features of other network elements, e. g. compressor stations. In presence of uncertain consumer demand we develop a stochastic integer program for minimizing transportation costs. Our algorithm employs a decomposition method based on Lagrangian relaxation of nonanticipativity and branch-and-bound to solve the stochastic program. We report computational experiences with a transmission network in Germany, which includes more than 2.000 km of pipelines and 10 compressor stations.

WE1-308/T1 FINANCE AND ECONOMICS

Portfolio planning

chair: Gautam Mitra

A review of risk measures with application in financial portfolio analysis

Diana Roman
Brunel University, Department of Mathematical Sciences
coauthors: Ken Darby-Dowman, Gautam Mitra
keywords: risk measure, expected utility, stochastic dominance, coherence

We consider the general problem of comparing random variables assuming an outcome as large as possible is preferred. This problem has widespread application in decision making in general and is of particular relevance in the area of portfolio selection. Mean-risk models and expected utility/ stochastic dominance models are important methods for modelling choice under uncertainty. With mean-risk models, the choice of the risk measure to be used plays an important role in capturing a decision maker's preferences. Commonly used risk measures: variance, mean absolute deviation, lower partial moments, value-at-risk, conditional value-at-risk are reviewed, properties are stated and a short historical perspective is given. The compatibility of mean-risk models with expected utility maximization and stochastic dominance is explored. Lastly, the coherence of risk measures is examined. Risk measures (which evaluate the overall seriousness of possible losses) and deviation measures (which measure the uncertainty in terms of variability around the mean) are often considered to be equivalent terms. However, when addressing the issue of coherence, this distinction may be important. Deviation measures fail to satisfy the risk-free condition. The derivation of risk measures (some of which are coherent) from deviation measures is examined.

Fin4cast: from data mining to optimal portfolio selection

Eranda Cela
Siemens Austria AG
keywords: data mining, input selection, forecast models, optimal portfolio selection

fin4cast is a complex system which can forecast financial instruments and use the produced forecasts to select an optimal portfolio. An optimal portfolio would maximize the difference between protfolio return and portfolio risk, where the portfolio risk is measured in a classical manner. fin4cast is used to (a) do the data mining and the input selection for some prespecified target(s) to be forecast (b) build the forecast model(s) (c) analyze the performance of the later and, (d) select the optimal portfolio over a set of prespecified financial instruments. The selection of inputs is based on statistical methods, sensitivity analysis and search algorithms. The backbone of this process is the fin4cast own database which practically covers the whole universe of financial data. The forecast models range from classical statistical and econometrical models to neural network models. The portfolio selection is based on classical quadratic programming algorithms, as far as quadratic optimization problems are concerned. More complex optimization problems including combinatorial and ranking constraints are solved by heuristic algorithms developed with fin4cast. Other important ingredients of fin4cast are the tool for the selection of the best forecast model and the tool for the optimal tuning of the portfolio selection strategy.

Algorithms for the solution of large-scale quadratic programming (QP) and quadratic mixed integer programming (qmip) models

GAUTAM MITRA
CARISMA, Department of Mathematical Sciences

coauthors: Frank Ellison, Marion Guertler

keywords: portfolio planning, quadratic programming, discrete optimization, large scale optimization

The increasing acceptance of M-V model and its extensions in the finance industry has rekindled interest in the solution of large-scale convex QP models. There is also growing interest in the processing of QMIP models and their use as a practical portfolio planning tool. In this talk we consider the algorithmic issues of the sparse simplex method and interior point method for the solution of large QPs. We also consider how the dual SSX is adopted to solve QMIP models. We provide computational experience of processing index tracking models, with 22 factors and a universe of 4752 stocks leading to models with 19016 rows ,23963 variables and 129099 nonzeroes.

WE1-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Complementarity principle in games

organizer/chair: Samir Kumar Neogy

Complementarity principle and some structured stochastic games

SAMIR KUMAR NEOGY
Indian Statistical Institute

keywords: structured stochastic game, linear complementarity problem, switching control game, ARAT game

Solving a general zero-sum stochastic game problem is a very complex problem. The game may not possess the ordered field property. For undiscounted games, the problem is more complex since in general optimal (or equilibrium) stationary strategies do not exist. For the zero-sum stochastic games with some structural assumptions have led to algorithmic results. Examples of the structured zero sum stochastic games are ARAT(additive reward and additive transition) and Switching control Stochastic game. For structured zero sum stochastic games, the scope of applicability of Lemke's and other pivot algorithms which uses complementarity principle are discussed. We show that Lemke's algorithm solves discounted switching control games and Cottle-Dantzig's algorithm(a generalization of Lemke's algorithm) solves undiscounted ARAT games under some mild assumptions.

Some classes of matrices in linear complementarity problem and matrix games

ARUP KUMAR DAS
Indian Statistical Institute

keywords: matrix game, value of the game, almost $\bar{N}$ matrix, E_0^f matrix

Von Neumann's Minimax Theorem and Kaplansky's result on completely mixed game were used to derive certain results in Linear Complementarity. In this paper some more results are proved which further establishes the connections between LCP and matrix game. We show that an almost matrix with value greater than zero is a Q matrix. Certain new sub-classes of (introduced by Stone) are also studied using the game theoretic approach. The classes of matrices studied here are also important from an algorithmic point of view.

The linear complementarity problem with interval data

UWE SCHAEFER
Universitaet Karlsruhe

keywords: linear complementarity problem, enclosure method, applications, free boundary problem

We consider an LCP where the entries of the matrix M and the entries of the vector q under consideration are not explicitly known but can be enclosed in intervals; i.e., given an interval matrix [M] and an interval vector [q] we are interested in the set S([M],[q]) where S([M],[q]) is the set of all vectors z such that z is a solution of the LCP defined by M and q where M belongs to [M] and q belongs to [q]. Since it is difficult to describe S([M],[q]) we are satisfied to calculate an interval vector [z] which includes S([M],[q]) for the case that S([M],[q]) is bounded. As an application we present an enclosure method for an ordinary free boundary problem which is based on an LCP with interval data by discretizing the differential equation without neglecting the discretization error. We present some numerical examples which illustrate the theoretical results.

WE1-308/T3 ON-LINE OPTIMIZATION

Deterministic on-line optimization

chair: Joan Boyar

On-line matching on a line

WINFRIED HOCHSTÄTTLER
BTU Cottbus

coauthors: Bernhard Fuchs, Walter Kern

keywords: on-line algorithms, matchings, competitive analysis

Given a set $S \subseteq R$ of points on the line, we consider the task of matching a sequence $(r_1, r_2, \ldots)$ of requests in R to points in S. It has been conjectured that there exists a 9-competitive on-line algorithm for this problem, similar to "hide and seek" on a line. We disprove this conjecture and show that no on-line algorithm can achieve a competitive ratio strictly less than 9.001.

On-line bleaching control at pulp mills

PATRIK FLISBERG
Division of Optimization, Linkoping University

coauthor: Mikael Rönnqvist

keywords: nonlinear optimization, process control, industrial application, on-line optimization

We present an on-line control system for the bleaching process of pulp mills. It supplies target values for the chemical charges in order to minimize the cost of used bleaching chemicals. Approximate functions to describe each stage of the process are established dynamically by solving constrained least square problems. Then an overall nonlinear optimization problem is solved to generate the target values. This problem makes use of the approximate functions together with linking constraints between several process stages. The system is implemented at a Swedish pulp mill and shows a 10 percent decrease of the mill's cost of bleaching chemicals.

New paging results using the relative worst order ratio

JOAN BOYAR
University of Southern Denmark
coauthors: Lene Favrholdt, Kim S. Larsen
keywords: on-line algorithms, relative worst order ratio, paging, look-ahead

We consider a measure for the quality of on-line algorithms, the relative worst order ratio, which was recently proposed by Boyar and Favrholdt and shown to provide new and easier separations for on-line algorithms for two variants of bin packing. This new ratio is used to compare on-line algorithms directly by taking the ratio of their performances on their respective worst orderings of a worst-case sequence. Here we consider the paging problem, where a processor has a cache of size k, pages requested must be in the cache to be processed, and there is unit cost for bringing a page into the cache. The goal is to minimize the total cost of a sequence of page requests. Using standard competitive analysis, Least-Recently-Used (LRU) is an optimal deterministic algorithm for the problem, obtaining exactly the same ratio, k, as many other algorithms. We propose a new algorithm which is better than LRU according to the relative worst order ratio. In addition, using standard competitive analysis, look-ahead, allowing the algorithm to see the next s page requests before deciding which page to evict, cannot produce better algorithms. In contrast, we show that with the relative worst order ratio, look-ahead helps significantly.

WE1-341/21 INTERIOR POINT ALGORITHMS

Methods in semidefinite programming

chair: Henry Wolkowicz

Preprocessing sparse semidefinite programs by the conversion method

MITUHIRO FUKUDA
New York University, Courant Institute of Mathematical Sciences
coauthors: Katsuki Fujisawa, Kazuhide Nakata
keywords: semidefinite programming, chordal graph, preprocessing, matrix completion

We present a method to convert certain sparse semidefinite programs (SDPs) into equivalent SDPs with small block matrices which can be solved more efficiently by any primal-dual interior-point method code. The conversion method can be viewed as a preprocessing of the SDP data. The method is based on the matrix completion theory, and it directly manipulates the sparsity structure represented by a graph of a given SDP. The conversion of the problem is performed on this graph exploiting basic properties of chordal graphs and clique trees. A heuristic procedure to estimate the computational cost of the converted problem is employed in this method.

New scaling algorithms and a hybrid bundle method for SDP programming

PAULO ROBERTO OLIVEIRA
COPPE/Federal University of Rio de Janeiro
coauthor: Ronaldo Gregorio
keywords: nonlinear programming, semidefinite programming, proximal methods, non smooth optimization

This talk has two parts, both motivated by some applications of Riemannian geometry tools. In the first, we present a new class of scaling metrics, defined in the Rn hypercube. For that class, we show that the corresponding Riemann manifold is complete, and has null sectional curvature. Those metrics, when applied to continuous optimization, in proper settlings, lead to projective (gradient) or sub-gradient geodesic algorithms, in a metric dependent scheme. As a consequence, we can apply some previous results, where we ensured global convergence in the convex case, for complete Riemannian manifolds, with nonnegative curvature. Besides, in the projective case, we have also the linear rate of convergence for strongly convex functions. As an outcome, we assure the linear rate of convergence for the usual gradient method, with line search. The second part deals with the application of a previous result, where we proved the global convergence of the proximal method for complete Riemannian manifolds, with non positive curvature. An important example of this kind of space is the positive definite matrix set. We apply that method to create a hybrid bundle algorithm in semidefinite programming. Some constructions are made, in order to get a computable algorithm.

Robust search directions for large sparse semidefinite programming (SDP)

HENRY WOLKOWICZ
University of Waterloo
keywords: large sparse systems, optimization, algorithms

Current paradigms for search directions for primal-dual interior-point methods for SDP use: (i) symmetrizethe linearization of the optimality conditions at the current estimate; (ii) form and solve the Schur complement equation for the dual variable dy; (iii) back solve to complete the search direction. These steps result in loss of sparsity and ill-conditioning/instability, in particular when one takes long steps and gets close to the boundary of the positive semidefinite cone. This has resulted in the exclusive use of direct, rather than iterative methods, for the linear system.

We look at alternative paradigms based on least squares, an inexact Gauss-Newton approach, and a matrix-free preconditioned conjugate gradient method. This avoids the ill-conditioning in the nondegenerate case. We emphasize exploiting structure in large sparse problems. In particular, we look at LP and SDP relaxations of the: Max-Cut; Quadratic Assignment; Theta function; and Nearest Correlation Matrix problems.

WE1-341/22 LOGISTICS AND TRANSPORTATION

Practical routing problems

chair: K. Ganesh

Decision support for real-time ambulance planning and control

TOBIAS ANDERSSON
Dep of Science and Technology / University of Linkoping
coauthor: Peter Värbrand
keywords: ambulance service, transportation, decision support systems

SOS Alarm AB is the company controlling all ambulance movements in Sweden. In case of an emergency, an ambulance controller working in an SOS central quickly has to decide which unit (or units) to dispatch. This allocation of an ambulance to the emergency may however affect the ability to handle future emergencies, since some area might be left uncovered as a result. This makes it necessary to relocate other available units for better coverage of the considered area. Ambulances are not only used for emergencies, but also for planned, not urgent, patient transports. In these cases the objective is to execute the assignment as close to the planned time as possible, and not like in the urgent cases where it is crucial to get an ambulance to the patient as quickly as possible. The situation may be further complicated by restrictions on what kind of assignments an ambulance unit can serve, the working schedule of the ambulance crew and so on. Here, a mathematical model and a solution algorithm providing decision support for the ambulance controllers are presented.

Simultaneous optimization of school starting times and public bus services

ARMIN FUEGENSCHUH
Darmstadt University of Technology
coauthor: Alexander Martin
keywords: transportation, vehicle scheduling, time windows

In many rural areas, the public bus service is demand-oriented: By far the biggest group of customers are pupils who are transported to their schools within certain strict time limits. Usually, all schools start around the same time, which causes a morning peak in the number of deployed buses. However, schools are allowed to change their starting times within some intervall. The question is, how to simultanenously rectify the starting times for all schools and bus trips in a certain county so that the number of scheduled buses is minimal. We present a mixed-integer programming formulation for this optimization problem and address its solution for some real-world instances.

Optimization of vehicle routing using evolutionary algorithms for contraceptive logistics in a supply chain

K. GANESH
Indian Institute of Technology Madras
coauthor: T. T. Narendran
keywords: vehicle routing, evolutionary algorithms, contraceptive logistics, supply chain

In today's era of globalization and cut-throat competition, customer satisfaction has become an issue of prime concern and that is where the role of supply chain, which link together the suppliers, manufacturers, distribution channels and customers, as one single organization of pooled resources and skills. Logistics costs constitute a major portion of the total costs in a supply chain. Transportation plays an important role in logistics and another element of logistics system is the allocation and routing of vehicles for the purpose of collection and delivery of goods and services on regular basis. The system may involve a single depot or multiple depots; the objectives may be aimed at cost minimization; time minimization or distance minimization. This problem involves the design of several vehicle tours to meet a given set of requirements for customers with known locations, subjected to several constraints. The main focus of this paper is to optimize the vehicle routing for contraceptive logistics (Family Planning Logistics) and hence solving the problem using evolutionary algorithms like Genetic Algorithms (GA) and Simulated Annealing (SA) and meet the objective of vehicle routing problem.

WE1-341/23 BIOINFORMATICS AND OPTIMIZATION

Optimization in medicine II

organizer/chair: Panos M. Pardalos

Fractionation in radiation treatment planning

MICHAEL FERRIS
University of Wisconsin
coauthor: Meta M. Voelker
keywords: radiation therapy, stochastic programming, treatment planning

In many cases a radiotherapy treatment is delivered as a series of small dosages over a period of time. New generations of machines generate accurate information of the actual dose delivered, allowing a planner to compensate for errors in delivery in an adaptive fashion. We formulate a model of the day-to-day planning problem as a stochastic linear program and exhibit the gains that can be achieved by incorporating uncertainty about errors during treatment into the planning process. Due to size and time restrictions, the model becomes intractable for realistic instances. We show how neuro-dynamic programming can be used to approximate the stochastic solution, and derive results from our models for realistic time periods. These results allow us to generate practical rules of thumb that can be immediately implemented in current planning technologies.

Optimization techniques in seizure prediction

WANPRACHA CHAOVALITWONGSE
Department of Industrial and Systems Engineering
coauthors: Panos M. Pardalos, J. Chris Sackellares, Leonidas D. Iasemidis, D.-S. Shiau, Paul R. Carney
keywords: quadratic programming, EEG time series, seizure prediction, chaos theory

There is growing evidence that temporal lobe seizures are preceded by a preictal transition, characterized by a gradual dynamical change in electroencephalogram (EEG) time series from asymptomatic interictal state to seizure. We present a new methodology of studying the spatiotemporal patterns in EEG by employing chaos theory and optimization techniques, specifically multi-quadratic integer programming. The application of this methodology is to select brain electrode sites that exhibit the dynamical convergence in the measure of chaos, which can be identified by optimization techniques, for the prediction of epileptic seizures. The algorithm was tested in continuous, long-term EEG recordings obtained from 5 patients with temporal lobe epilepsy. The results suggest that it may be possible to develop automated seizure warning devices for diagnostic and therapeutic purposes.

A column generation approach to aperture modulation in radiation therapy treatment planning

EDWIN ROMEIJN
University of Florida, Department of Industrial and Systems Engineering
coauthors: Ravindra K. Ahuja, James F. Dempsey, Arvind Kumar, Jonathan G. Li
keywords: health care - treatment, radiation therapy, column generation

We consider the problem of radiation therapy treatment planning for cancer patients. During radiation therapy, beams of radiation pass through a patient, killing both cancerous and normal cells. Thus, the radiation treatment must be carefully planned so that a clinically prescribed dose is delivered to targets containing cancerous cells, while nearby organs are spared. Using a modern technique called intensity modulated radiation therapy (IMRT), each of the beams

is decomposed into many small beamlets, the intensities of which can be controlled individually. When all beamlet intensities (together called the fluence map) are given, this fluence map is, for delivery purposes, decomposed into (and approximated by) a limited number of apertures for each beam, each with its associated intensity. We propose a new formulation of the fluence map optimization problem that integrates the two phases. To overcome the problem that the number of allowed apertures is enourmous, we propose a column generation approach. We study different pricing problems, each corresponding to a particular choice for the set of feasible apertures, and provide polynomial time algorithms. Experiments show that this approach can reduce the number of apertures required for treatment without a clinically significant reduction in treatment plan quality.

WE1-321/053 PRODUCTION AND SCHEDULING
Real-life scheduling
chair: Matthew Berge

Characterizing feasible pattern sets with a minimum number of breaks

RYUHEI MIYASHIRO
University of Tokyo
coauthor: Tomomi Matsui
keywords: sports scheduling, integer programming

Creating a round-robin schedule with home/away assignment is a significant problem of sports scheduling. When tournament organizers construct such schedules, they often create home/away assignment first, i.e. fix a pattern set, then assign an opponent to the pattern set. However, not all pattern sets can be completed into a schedule; valid pattern sets called feasible pattern sets. Although finding feasible pattern sets is at the heart of many scheduling algorithms, good characterization of feasible pattern sets is not known yet. We consider the feasibility of pattern sets and propose a new necessary condition for feasible pattern sets. For a special class of pattern sets, called pattern sets with a minimum number of breaks, we developed a polynomial-time algorithm to check whether a given pattern set satisfies the necessary condition. Computational experiment shows that, when the number of teams is up to 26, the proposed condition characterizes feasible pattern sets with a minimum number of breaks.

Feasibility problems in sports scheduling

YOSHIKO IKEBE
Dept. of Management Science, Tokyo Univ. of Science
keywords: sports timetableing, round robin tournament, graphs, list coloring

In sports timetabling, a frequently used approach for constructing schedules for round robin tournaments is to (i) fix travel patterns (Home-Away patterns) for all teams, then (ii) enumerate schedules which conform to the fixed pattern set. Thus, the problem of deciding whether a given pattern set is feasible or not is significant, and there have been numerous studies devoted to this problem. Of special interset have been the pattern sets which have a minimum number of breaks. In this talk we discuss this problem, and show some results for the case when the number of teams is a multiple of four. We also explore relations to the list coloring problem for graphs.

Airline schedule recovery - models and algorithms for air traffic management concept analysis

MATTHEW BERGE
Boeing, Phantom Works
keywords: airline scheduling, air traffic management, Lagrangian relaxation, dynamic programming

This paper presents a modeling methodology to assess a range of operational concepts for collaborative air traffic flow management. The focus is on the problem of airline schedule recovery in conditions where both airports and airspace sectors are capacity limited due to conditions such as weather events or system outages. This model is embedded in a dynamic simulation environment representing the US National Airspace System. The airline schedule recovery model is based on an optimization formulation that allows a representation of adaptive airline behavior in current and future operations. The recovery options considered include ground delay, re-routing and flight cancellation. Constraints include airport arrival and departure rates, sector occupancy limits, and aircraft flow. The problem is formulated as a large-scale integer linear program and solved using an efficient Lagrangian Relaxation based approximation method. This relaxation method enables the dual problem to be decomposed into airplane itinerary subproblems which can be solved by dynamic programming. Efficiency is particularly important because this recovery problem must be solved many times in the context of a single simulation experiment. The paper presents a problem definition, description of the solution approach, and some simulation and computational results.

WE1-321/033 MULTICRITERIA OPTIMIZATION
Efficiency analysis in multicriteria optimization III
chair: Henri Bonnel

Inferring efficient weights from pairwise comparison matrices

EMILIO CARRIZOSA
university of seville
coauthors: Rafael Blanquero, Eduardo Conde
keywords: AHP, vector optimization, eigenvector method

Several Multi-Criteria-Decision-Making methodologies assume the existence of weights associated with the different criteria, reflecting their relative importance.

One of the most popular ways to infer such weights is the Analytic Hierarchy Process, which constructs first a matrix of pairwise comparisons, from which weights are derived following one out of many existing procedures, such as the eigenvector method or the least (logarithmic) squares. Since different procedures yield different results (weights) we pose the problem of describing the set of weights obtained by "sensible" methods: those which are efficient for the (vector-) optimization problem of simultaneous minimization of discrepancies.

A characterization of the set of efficient solutions is given, which enables us to assert that the least-logarithmic-squares solution is always efficient, whereas the (widely used) eigenvector solution is not, in some cases, efficient, thus its use in practice may be questionable.

Efficiency and generalized concavity in stochastic multiobjective programming

STEFAN TIGAN
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coauthor: I.m. Stancu-Minasian
keywords: stochastic programming, multiobjective programming, minimum-risk problem, pseudomonotonic programming

The purpose of this paper is to derive relations among several efficiency concepts (local and global weakly efficient, efficient and properly efficient solutions) to some multiobjective minimum-risk problems with given levels of minimum satisfaction and stochastic programming problems of Kataoka type with given

probabilities of satisfaction. For the multiobjective linear-fractional stochastic programming problem with given probabilities of satisfaction, in the case of normal distribution of the random vectors in the objectives, we obtain a local-global property. We also derive a result providing sufficient conditions on the distribution functions of the objectives in order to be equal the sets of the properly efficient solutions for the multiobjective minimum-risk problem with given levels of minimum satisfaction and multiobjective stochastic programming problem with given probabilities of satisfaction. Finaly, via multi-criteria pseudomonotonic programming, we give sufficient conditions of generalized concavity type in order to the minimum-risk linear fractional problem has the property that any its efficient solution is a properly efficient solution too.

Semivectorial bilevel optimization problem

HENRI BONNEL
University of New Caledonia

coauthor: Jacqueline Morgan
keywords: vector optimization, bilevel optimization, multiobjective optimization

We consider a bilevel optimization problem, where the lower level is given by a vector (in particular : multicriteria) optimization problem. The upper level is a real valued function. The bilevel problem contains as a particular case the well known problem of optimizing a scalar function over an efficient (Pareto) set. Of course, our problem generalizes also the usual (salar) bilevel optimization problem. We present some optimality conditions and a penalty approach.

WE1-321/133 LINEAR PROGRAMMING

Linear programming and Markov decision

organizer/chair: Yinyu Ye

A new complexity result on solving the Markov decision problem

YINYU YE
Stanford University

keywords: linear programming, Markov decision problem, computational complexity

We present a new complexity result on solving the Markov decision problem (MDP) with n states and a number of actions for each state, a special class of real-number linear programs with the Leontief matrix structure. We prove that, when the discount factor θ is strictly less than 1, the problem can be solved in at most $O(n^{1.5}(\log\frac{1}{1-\theta}+\log n)$ classical interior-point method iterations and $O(n^4(\log\frac{1}{1-\theta}+\log n))$ arithmetic operations. Our method is a combinatorial interior-point method related to the work of Ye and Vavasis and Ye. To my knowledge, this is the first strongly polynomial-time algorithm for solving the MDP when the discount factor is a constant less than 1.

Polynomial-time computation of optimal policies in Markov decision chains

MICHAEL O'SULLIVAN
University of Auckland

coauthor: Arthur F. Veinott Jr.
keywords: dynamic programming, stochastic, infinite horizon

This paper shows that the problem of finding an n-optimal (resp., n-present-value optimal, n-Cesàro-overtaking-optimal) policy for a finite-state-and-action infinite-horizon stationary Markov decision chain is solvable in polynomial time. (Where n is the number of states, this is equivalent to finding a policy that has maximum present value for all sufficiently small positive interest rates.) This is done by decomposing the problem into a sequence of at most $3n+5$ subproblems. Each subproblem is either a maximum-transient-value or a maximum-reward-rate problem, and can be solved by linear programming or policy improvement. Moreover, for the case of unique transition systems, i.e., each action in a state sends the system to at most one state, the problem is shown to be solvable in strongly polynomial time. The last case includes standard deterministic dynamic programs.

A new iteration-complexity bound for the MTY predictor-corrector algorithm

TAKASHI TSUCHIYA
The Institute of Statistical Mathematics

coauthor: Renato Monteiro
keywords: interior point algorithms, primal-dual algorithms, condition number, crossover events

In this talk, we present a new iteration-complexity bound for the Mizuno-Todd-Ye predictor-corrector (MTY P-C) primal-dual interior-point algorithm for linear programming. Our analysis is based on the important notion of crossover events introduced by Vavasis and Ye. For a standard form linear program $\min\{c^T x : Ax = b, x \geq 0\}$ with decision variable $x \in \Re^n$, we show that the MTY P-C algorithm started from a well-centered interior-feasible solution with duality gap $n\mu_0$ finds an interior-feasible solution with duality gap less than $n\eta$ in $O(n^2\log(\log(\mu_0/\eta)) + n^{3.5}\log(\mathrm{chistarA}+\mathrm{n}))$ iterations, where chistarA is a scaling invariant condition number associated with the matrix A. More specifically, chistarA is the infimum of all the conditions numbers $\bar{\chi}_{AD}$, where D varies over the set of positive diagonal matrices. Under the setting of the Turing machine model, our analysis yields an $O(n^{3.5}L_A + n^2\log L))$ iteration-complexity bound for the MTY P-C algorithm to find a primal-dual optimal solution, where L_A and L are the input sizes of the matrix A and the data (A,b,c), respectively. This contrasts well with the classical iteration-complexity bound for the MTY P-C algorithm which depends linearly on L instead of $\log L$.

WE1-305/205 GAME THEORY

Optimization in electricity markets

organizer/chair: Andy Philpott

Estimation of market distribution functions in electricity pool markets

GOLBON ZAKERI
University of Auckland

coauthors: Geoffrey Pritchard, Andy Philpott
keywords: electricity market, market distribution function, non parametric estimation

The market distribution function is a probabilistic device that can be used to model the randomness in dispatch and clearing price that generators in electricity pool markets must take account of when submitting offers. We discuss techniques for estimating the market distribution function, and ways of measuring the quality of these estimators, using both classical statistical approaches and in the context of optimization.

Optimization models for hydro-reservoir operations in electricity pools

ANDY PHILPOTT
University of Auckland

coauthors: Geoffrey Pritchard, Philip Neame
keywords: electricity market, hydroelectric reservoirs, dynamic programming, equilibria

In electricity pool markets, generators offer supply functions in each trading period to an independent system operator who dispatches these to minimize the cost of meeting an observed load. The optimal supply function for each hydro generator must take account of the opportunity cost of using water for generation now as compared with releasing it later. To compute this opportunity cost we consider a dynamic programming model in which generators optimize with stochastic electricity prices, and compare this with models in which generators offer supply functions as participants in a dynamic game.

Learning collusive strategies in electricity markets

EDWARD ANDERSON
Autralian Graduate School of Management

coauthor: Thai Doan Hoang Cau
keywords: collusion, electricity market, genetic algorithm, co-evolution

Wholesale electricity markets operate as repeated games between relatively small numbers of participants in which we can expect to see implicit collusion emerging. This may in practice amount to no more than market participants being less aggressive in their bidding than would be optimal for a one stage game. In this paper we use a coevolutionary genetic algorithm framework to show how agents with limited memory can learn to play collusive strategies. The collusive strategies which emerge can have a rich structure (for example they are more complex than the forgiving trigger strategies that occur in the literature). Besides exploring the learning behaviour we also use this framework to investigate the market characteristics which make collusion more likely to occur. For example we ask whether collusion is more likely when market participants are similar or when they are different.

WE2-302/41 COMBINATORIAL OPTIMIZATION

Computational methods for graph-coloring I

organizer/chair: Michael Trick

A systematic approach to generate very hard 3COL instances

KAZUNORI MIZUNO
Institute of Information Sciences and Electronics, University of Tsukuba
coauthor: Seiichi Nishihara
keywords: computational complexity, graph-coloring, phase transition, NP-complete

Graph colorability, COL, and propositional satisfiability, SAT, are typical constraint satisfaction problems to which phase transition phenomena, PTs, are important in the computational complexity of combinatorial search algorithms. Secondary PT, rather than primary PT, is significant and subtle because it claims that, in the secondary PT region, extraordinarily hard instances are found that may require exponential-order computational time to solve. To clarify the PT mechanism, many studies have been undertaken to produce very hard instances, many of which were based on generate-and-test approaches. We propose a rather systematic or constructive algorithm that repeats the embedding of 4-critical graphs to arbitrarily generate large extraordinarily hard 3-colorability (3COL) instances. We demonstrate experimentally that the computational cost of our 3COL instances is of an exponential order by using a few actual coloring algorithms.

Graph-coloring in the estimation of mathematical derivatives

SHAHADAT HOSSAIN
University of Lethbridge
coauthor: Trond Steihaug
keywords: sparse jacobians, patterns

We describe graph coloring instances arising in numerical estimation of mathematical derivatives. The coloring instances are obtained from a matrix partitioning problem. The size of the generated graphs is dependent on the number of segmented columns which can be varied between the number of columns and the number of nonzeros in the associated matrix.

Column generation approaches for graph-coloring generalizations

MICHAEL TRICK
Carnegie Mellon
coauthors: Anuj Mehrotra, Hakan Yildiz
keywords: graph-coloring, graph theory, heuristics

Column generation and branch-and-price is an effective approach for exact graph coloring. We extend this work to coloring generalizations such as multicoloring and bandwidth problems.

WE2-302/42 COMBINATORIAL OPTIMIZATION

Combinatorial optimization VI

chair: Tomomi Matsyu

The distribution of values in the quadratic assignment problem

TAMON STEPHEN
Institute for Mathematics and its Applications
coauthor: Alexander Barvinok
keywords: combinatorial optimization, quadratic assignment problem

We survey some results on the distribution of objective values in the objective function of the Quadratic Assignment Problem (QAP). We are interested in how many permutations σ produce a value $f(\sigma)$ within a given range of the optimal value $f(\tau)$ and how far such permutations σ are from τ in the Hamming distance on the symmetric group.

Exact disclosure prevention in general and nonnegative statistical tables

FILIPA DUARTE DE CARVALHO
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coauthor: M. T. Almeida
keywords: combinatorics, integer programming, relaxation/subgradient, applications

Statistical offices release information in two-dimensional tables. To prevent disclosure of confidential data, these offices often use a technique called cell suppression. As the name suggests, this technique consists of suppressing from the tables the confidential values, before the tables are released. Suppressing only confidential data cells from the tables may not prevent their values from being disclosed, due to the linear relationships that can be deduced from table row and column subtotals. Some non-confidential data cells must then be suppressed as well. The selection of a set of non-confidential data cells to be suppressed, in order to prevent exact disclosure of the confidential data at minimum cost, is a NP-hard problem. The exact disclosure problem may be defined in general tables in which cells can take any real value and in nonnegative tables where all cell values are nonnegative. We present compact formulations for the exact disclosure problem in general and nonnegative tables and use a lagrangean approach to obtain near optimal solutions and an upper bound on their deviations from the optimum. Computational results will be presented to show the effectiveness of this new approach.

Perfect sampling algorithm for two-rowed contingency tables

TOMOMI MATSYU
University of Tokyo
coauthor: Shuji Kijima
keywords: sampling, Markov chain, contingency table, counting problem

This paper proposes a polynomial time perfect (exact) sampling algorithm for $2 \times n$ contingency tables. Our algorithm is a Las Vegas type randomized algorithm and the expected running time is bounded by $O(n^3 \ln N)$ where n is the number of columns and N is the total sum of whole entries in a table. The algorithm is based on monotone coupling from the past (monotone CFTP) algorithm and new Markov chain for sampling two-rowed contingency tables uniformly. We employed the path coupling method and showed that the mixing rate of our chain is bounded by $n(n-1)^2(1+\ln(nN))$. Our result shows that uniform generation of two-rowed contingency tables is easier than the corresponding counting problem, since the counting problem is known to be #P–complete.

WE2-302/44 COMBINATORIAL OPTIMIZATION

Networks and communication

chair: Fulvio Piccinonno

Nonlinear optimization in gas network operation

MARC C. STEINBACH
Zuse Institute Berlin
coauthor: Klaus Ehrhardt
keywords: nonlinear programming, network operation, natural gas

A routine task in providing natural gas is the operative planning of the load distribution in the pipeline network to satisfy the current demand. Variable operating costs are dominated by the energy for the gas transport; thus minimizing the cost requires sophisticated control strategies for the technical equipment. Mathematically this leads to highly dimensional

mixed-integer optimization problems involving various physical, technical, and contractual restrictions.

Due to the enormous complexity of the overall problem we pursue a hierarchical solution approach. Binary decisions are determined by mixed integer linear programming using approximations of the nonlinearities; continuous control variables are then optimized using a nonlinear control problem with fixed combinatorial decisions. The lecture concentrates on the modeling and numerical solution of the latter problem, addressing in particular the hyperbolic gas flow equations with underlying network topology and the nonlinear behavior of compressors. Computational optimization results will finally be presented.

New integer linear programming formulations for the SRAP

NELSON MACULAN
Politecnico di Milano

coauthors: Elder Macambira, Cid C. de Souza
keywords: integer formulation, telecommunication, node partitioning

In this work, we consider the problem of assigning customer sites with given demands to SONET rings of equal capacity. The so-called SONET Ring Assignment Problem (SRAP) is known to be NP-hard and can be described formally as a node-partitioning problem. Each site is assigned to exactly one ring and a special ring, called federal ring, interconnects the others rings together. The objective is to minimize the number of rings in the network.

We propose two new integer linear programming formulations for the SRAP. Computational results for both formulations are discussed. Comparisons with other formulations presented earlier in the literature are made. Empirical evidence indicates that our formulations perform much better than the existing ones. While previous models cannot be solved to optimality in a reasonable amount of time, our models are computed much faster and optimal solutions are obtained in minutes in a typical desktop machine.

A new map-like algorithm with low memory requirements for decoding error correcting codes

FULVIO PICCINONNO
Università di Venezia

keywords: computational complexity, coding, turbo codes

In this work we propose a new MAP-like algorithm for decoding error correcting codes. Actually convolutional codes and turbo-codes, obtained usually with the concatenation of two or more convolutional codes, are the most used classes of codes when good performances at low signal-to-noise ratios are needed. The turbo-codes decoding process is based on soft-decoding component convolutional codes and needs both a lot of computing time and memory. We will propose a new family of algorithms, derived form MAP algorithm, that with a computational complexity of the same order and much reduced memory requirements will obtain identical results.

WE2-302/45 COMBINATORIAL OPTIMIZATION
Postman optimization problems
chair: Julián Arturo Aráoz

Restricted postman problems on mixed graphs

FRANCISCO JAVIER ZARAGOZA MARTINEZ
Department of Combinatorics and Optimization, University of Waterloo

coauthor: Bill Cunningham
keywords: postman problems, mixed graphs, combinatorial optimization, approximation algorithms

Given a strongly connected mixed graph $M = (V,E,A)$, with nonnegative costs c on its edges E and arcs A, the mixed postman problem is to find a tour T of M, traversing all its vertices, edges and arcs at least once, and with minimum cost $c(T)$. There exists a $\frac{3}{2}$-approximation algorithm for $c(T)$ due to Raghavachari and Veerasamy [IPCO 1998]. We are interested in approximating the measure $r(T) \equiv c(T) - c(E \cup A)$, that is, the cost of the repeated edges and arcs. In this talk, we introduce a generalization of the mixed postman problem where we require that the tours traverse a given subset $R \subseteq E \cup A$ exactly once. In particular, we discuss the special cases of this restricted mixed postman problem when $R = E$ and $R = A$, and relate our results to the approximation of $r(T)$.

A branch-and-cut approach for the min-max k-Chinese postman problem

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coauthor: Gerhard Reinelt
keywords: Chinese postman problem, branch-and-cut

Given an undirected edge-weighted graph and a depot node, the Min-Max k-Chinese Postman Problem (MM k-CPP) consists of finding $k > 1$ tours (starting and ending at the depot node) such that each edge is traversed by at least one tour and the length of the longest tour is minimized.

We will present a Branch-And-Cut approach which is based on a sparse IP-formulation of the MM k-CPP. Besides the usual parity and connectivity constraints we use a new class of constraints which is similar to the capacity constraints used in the context of the Capacitated Arc Routing Problem (CARP) and the Capacitated Vehicle Routing Problem (CVRP), respectively. We will report computational results on an extensive set of instances from literature as well as self generated instances.

Privatized rural postman problems

JULIÁN ARTURO ARÁOZ
Universidad Politecnica de Cataluña

coauthors: Elena Fernández, Cristina Zoltan
keywords: postman problems, graphs, combinatorial optimization, integer programming

In this work we analyze the Privatized Rural Postman Problem which is the edge version of the Traveling Salesman Problems With Profits. Given an undirected graph G(V,E) with a distinguished vertex d, called the Depot, and two non negative real functions from the edge set E, the profit function b and the cost function c, such that every time an edge e is traversed a cost c(e) is incurred, but the profit b(e) is collected only the first time the edge is traversed. The Privatized Rural Postman Problem is to find a cycle C, passing through d and not necessarily simple, which maximizes the value of the sum of the profit of the traversed edges (counting only one time the profit) minus the sum of the cost of the traversed edges, but this time counting every time the edge is traversed. That is, $\max_C\{\sum_{e\in C}(b(e) - t(e)c(e))\}$ where t(e) is the number of times that edge e is traverse in C. We consider the properties of the problem, its relation with known and new problems, special cases with good algorithms, the polyhedral structure and the possibility of the use of Branch and Cut methods and some Heuristics for the problem. We finish with remarks about future research.

WE2-302/49 INTEGER AND MIXED INTEGER PROGRAMMING

Decomposition algorithms and dynamic cut generation

organizer/chair: Ted Ralphs

Decomposition and dynamic cut generation in integer programming

MATTHEW GALATI
Lehigh University
coauthor: Ted Ralphs
keywords: integer programming, Dantzig-Wolfe, cutting planes, relaxation

Decomposition algorithms such as Lagrangian relaxation and Dantzig-Wolfe decomposition are well-known methods that can be used to develop bounds for integer programming problems. We draw connections between these classical approaches and techniques based on generating strong valid inequalities. We also discuss several methods for integrating dynamic cut generation with decomposition and present a decomposition-based separation algorithm called decompose and cut. The algorithm takes advantage of the fact that separation of an integer solution is often much easier than separation of an arbitrary fractional solution.

Optimal rectangular partitions

ABILIO LUCENA
Universidade Federal do Rio de Janeiro
coauthors: Felipe Calheiros, Cid C. de Souza
keywords: rectangular partition, relax and cut, Lagrangian relaxation, cutting planes

Assume that a rectangle R is given on the Euclidean plane together with a finite set P of points that are interior to R. A rectangular partition of R is a partition of the surface of R into smaller rectangles. The length of such a partition equals the sum of the lengths for the line segments that define it. The partition is said to be feasible if no point of P is interior to a partition rectangle. The Rectangular Partitioning Problem (RPP) seeks a feasible rectangular partition of R with the least length. Computational evidence from the literature indicates that RPPs with noncorectilinear points in P, denoted NCRPPs, are the hardest to solve to proven optimality. In this paper, some structural properties of optimal feasible NCRPP partitions are presented. These properties allow substantial reductions in problem input size to be carried out. Additionally, a stronger formulation of the problem is also made possible. Based on these ingredients, a hybrid Relax and Cut - Linear Programming Relaxation exact solution algorithm is proposed. Such an algorithm has proved capable of solving NCRPP instances more than twice as large as those found in the literature.

Solving lexicographic multiobjective MIPs with branch-cut-price

LASZLO LADANYI
IBM Research
coauthors: Marta Eso, David L. Jensen
keywords: mixed integer programming, branch-and-cut-and-price, Dantzig-Wolfe decomposition, lexicographic multiobjective

In this talk we will first describe an application, the FCC Auction 31, and its two formulation: one with a compact representation solvable via branch-and-cut, and one with column generation using branch-and-price. We will show how the second formulation can be interpreted as a Dantzig-Wolfe decomposition and that this interpretation leads to a branch-cut-price algorithm. Then we will demonstrate how to apply the same principle to a general Mixed Integer Programming problem. Finally, we extend the applicability of linear complementarity to integer programming to solve problems with multiple (lexicographic) objective.

WE2-306/31 INTEGER AND MIXED INTEGER PROGRAMMING

Computational methods for solving IPs I

organizer/chair: Eva Lee

Generating cutting planes using master cyclic group polyehdra

LISA EVANS
University of Minnesota
coauthor: Ellis Johnson
keywords: integer programming, cutting planes

We will review the master cyclic group polyhedron, and discuss how its facets can be used to generate cutting p lanes for general integer programming problems. Some practical implementation issues will be discussed, and co mputational results will be given.

Lagrangean approaches for optimizing over the semimetric polytope

ANDREA LODI
DEIS, University of Bologna
coauthors: Fred Glover, Antonio Frangioni, Giovanni Rinaldi
keywords: linear programming, Lagrangean techniques, cutting planes

The semimetric polytope associated to a complete undirected graph G is an important structure in combinatorial optimization, and it is related to several relevant optimization problems such as the max-cut problem. A family of facet-defining inequalities for the semimetric polytope, the so-called triangle inequalities, often provide a quite tight approximation of the polytope, which results in strong bounds on the related optimization problems. Unfortunately, the corresponding linear program, which has a number of variables and constraints that are respectively quadratic and cubic on the number of nodes of G, is usually very degenerate and almost impossible to solve efficiently, for large graphs, even when using state-of-the-art linear programming software and constraint-generation techniques. We show how to interpret the relaxation corresponding to the polytope defined by all the triangle inequalities associated to one fixed node as a classical transshipment problem, and how to efficiently solve this relaxation, called rooted semimetric polytope. Building on this, we construct Lagrangean-based approaches for maximizing a linear function over the semimetric polytope, i.e., by considering all the triagle inequalities. We report extensive computational results on several classes of graphs showing that, in general, the proposed approaches clearly outperform ordinary linear programming techniques.

Mixing two sets of mixed integer inequalities

MATHIEU VAN VYVE
CORE - Universite Catholique de Louvain
coauthors: Andrew Miller, Miguel Constantino
keywords: mixed integer programming, mixed integer rounding, convex hull

We study the polyhedral structure of the following mixed-integer set $X = \{(s,z) \in R_+ \times Z^{|I_1|+|I_2|} | s + z_i \geq b_i, i \in I_1, s + Cz_i \geq b_i, i \in I_2\}$, where C is a positive integer. The set X naturally appears as a submodel of production planning problems involving variable lower bounds on production (i.e. the production must be either zero or higher than some value L) or start-ups.

We characterize the extreme points and extreme rays of $conv(X)$. We provide a description of $conv(X)$ by linear inequalities and show how to separate over $conv(X)$ in $O(n \log n)$ time. We also provide an integral extended formulation of $conv(X)$ of polynomial size. Finally, we give some conditions under which

$conv(X) \cap \{Nz \leq d\}$ is an integral polyhedron. These results generalize earlier results of Gunluk and Pochet for the case $I_2 = \emptyset$.

WE2-306/32 NONLINEAR PROGRAMMING

Algorithms for degenerate nonlinear optimization

organizer/chair: Olga Brezhneva

Behavior of NLP codes on a degenerate optimal control problem

CATARINA AVELINO
University of Coimbra

coauthor: Luís N. Vicente
keywords: nonlinear optimization, degeneracy, optimal control

Our test problem is a discretized optimal control problem governed by a semilinear elliptic equation. When there are only bounds on the control variables this discretized problem can be shown to be always nondegenerate (in the sense that the gradients of the functions defining the active constraints are linearly independent). However, the problem becomes degenerate by including an appropriate number of bounds on the state variables (active at the solution).

We ran the following NLP codes on our problem instances: IPOPT (line search, filter, barrier interior point), KNITRO (trust region, SQP, barrier interior point), and LOQO (line search, primal-dual interior point). We tried a preliminary implementation of an augmented Lagrangian multipliers method using the optimal control structure (AUGCON). In the nondegenerate case we also ran TRICE (trust-region, SQP, affine-scaling interior point, optimal control structure).

In this talk we will report our numerical results for different settings of the problem (including different mesh sizes) and provide explanations for some of numerical behavior that has been observed.

Quadratic convergence of a nonsmooth Newton-type method for semidefinite programs

CHRISTIAN NAGEL
University of Wuerzburg

coauthor: Christian Kanzow
keywords: semidefinite program, quadratic convergence, nondegeneracy, strict complementarity

Semidefinite programs may be viewed as generalizations of linear programs with the variables being symmetric matrices rather than vectors. Under a Slater-type constraint qualification a semidefinite program is equivalent to the associated (primal-dual) optimality conditions.

In this talk we consider a semismooth reformulation of these optimality conditions as a nonsmooth system of equations $\Theta(W) = 0$. This reformulation is done using the matrix valued minimum function. In order to prove local fast convergence of a nonsmooth Newton method applied to this reformulated system, we first investigate the B-subdifferential of Θ at a solution W^*.

The nonsmooth Newton-type method presented here achieves a local quadratic rate of convergence under a linear independency assumption and a (modified) nondegeneracy condition. We try to avoid strict complementarity.

Methods for nonlinear programming without strict complementarity assumption

OLGA BREZHNEVA
IMA, University of Minnesota

keywords: nonlinear programming, superlinear convergence, degeneracy, strict complementarity

For nonlinear constrained optimization problems, we consider the case when the strict complementarity condition does not hold. In this situation, only linear rate of convergence can be guaranteed for most classical algorithms. In this talk, we present new local methods that are slight modifications of the well-known algorithms. Proposed methods attain superlinear convergence even when the strict complementarity condition does not hold and subsume the case when this condition holds.

WE2-306/33 NONLINEAR PROGRAMMING

Approximation of gradients

chair: Benoit Hamelin

Computationally efficient approximation of derivatives for robust optimization

SERGE SHISHKIN
Sawtek, Inc.

keywords: robustness, zero-order optimization, nonlinear programming theory, computational complexity

Consider the optimization problem in which the variables and parameters may fluctuate randomly within given limits, but the optimization is to be performed by a "conventional" optimization package. This can be achieved by replacing all functions by their "robust" modifications: some differentiable functional of absolute values of the function derivatives is to be added to each function.

Suppose, however, that only values but not derivatives of the object and constraint functions are available. In this case the calculation of finite difference approximations of the derivatives of "modified" functions may be computationally expensive since the second derivatives of the "original" function must be estimated. In this paper, an efficient scheme for such approximation is proposed. It normally requires $n+k+3$ calculations of the "original" function, and never needs more than $2n+k+3$ calculations, where n is the number of optimization variables and k is the number of parameters. Thus the proposed scheme allows robust zero-order optimization at almost the same expense as the conventional non-robust approach, while using the same optimization packages.

The method has successfully been applied to the design of high-frequency electrical filters.

Analysis of response surface problems using quadratic programming

RENTSEN ENKHBAT
National University of Mongolia

coauthor: T. Ibaraki
keywords: quadratic programming, optimization method, response surface, design of experiments

The mathematical theory of experimental design is divided into two parts: design of extremal experiments and response surface problems. The main principle of extremal experiment is to obtain the maximum information about investigated process for a given number of experiments and reduce the number of experiments for a given precision for the model expressed by nonlinear regression functions. Meanwhile, the response surface deals with optimization problems defined over a given criteria of experiment and experimental region.

In this paper we consider the response surface problems which are formulated as the general quadratic programming. The general quadratic programming is split into: convex quadratic maximization, convex quadratic minimization and indefinite quadratic programming. Based on optimality conditions, we propose finite algorithms for solving those problems. As application, some real practical problems arisen in the response surface, one of the main part of design of experiment, have been solved numerically by the algorithms.

Automatic finite differences, an alternative to automatic derivatives

BENOIT HAMELIN
Université de Sherbrooke
coauthor: Jean-Pierre Dussault
keywords: unconstrained optimization, automatic differentiation, robust implementation

We previously proposed to adapt the forward automatic differentiation technique to compute finite differences instead of derivatives. We then used the finite differences to reduce the cancellation error when computing the actual descent within a differentiable optimization algorithm, whether of line search or trust region type. In this presentation, we generalize the use of automatic finite differencing to compute accurate finite difference estimates of directional derivatives. We thus propose robust and efficient truncated Newton and quasi-Newton algorithms enhanced by the clever use of automatic finite differences. We analyze the respective benefits of the automatic finite difference and those of the automatic derivative approaches. Numerical comparisons on a set of test functions are reported for many algorithmic variants.

WE2-306/34 NONLINEAR PROGRAMMING
Large scale nonlinear programming II
organizers: Sven Leyffer and Richard Waltz
chair: Richard Waltz

A robust primal-dual interior point algorithm for nonlinear programs

JIE SUN
National University of Singapore
coauthor: Xinwei Liu
keywords: nonlinear optimization, interior point method, global convergence

We present a primal-dual interior point algorithm for solving optimization problems with nonlinear inequality constraints. The algorithm has some of the theoretical robustness of a trust region method, but works entirely by line search. Global convergence properties are derived without assuming regularity conditions. The penalty parameter ρ in the merit function is updated adaptively and plays two roles in the algorithm. First, it guarantees that the search directions are descent directions for the updated merit function. Second, it helps to determine a suitable search direction in a decomposed SQP step. It is shown that if ρ is bounded for each barrier parameter μ, then every limiting point of the sequence generated by the algorithm is a Karush-Kuhn-Tucker point; otherwise the sequence has a limiting point which is either a feasible point with gradients of the active constraints being linearly dependent or an infeasible point which is also a stationary point of minimizing the ℓ_2-norm of the infeasibility. The algorithm produces the correct results for some hard problems, including the examples provided by Wächter and Biegler and Byrd, Marazzi and Nocedal.

On the solution of linear equations arising in interior methods for nonconvex optimization

ANDERS FORSGREN
Royal Institute of Technology (KTH)
keywords: nonlinear programming, interior method

When solving smooth optimization problems by interior methods, an important step at each iteration is the solution of a system of linear equations. The matrix involved is typically symmetric and indefinite, often referred to as the barrier KKT matrix. For large-scale problems, the barrier KKT matrix is often sparse. An important feature for nonconvex problems is that it is of interest to know the inertia of the barrier KKT matrix, in order to determine if the problem may be considered locally convex around the current iterate. We discuss methods for solving the linear equations involving the barrier KKT matrix which reveal the inertia.

On interior-point methods using a suitable decomposition for multistage nonlinear stochastic programming

ANNICK SARTENAER
FUNDP
coauthors: Jie Sun, Fabian Bastin
keywords: stochastic programming, nonlinear programming, interior point method

We consider a multistage stochastic optimization problem, with nonconvex nonlinear objective function, linear equality constraints and nonnegativity constraints. In order to take the uncertainty into account, we make use of a scenario formulation that transforms the original problem into a larger but highly structured linearly constrained problem. We then present a feasible primal-dual barrier approach globalized by a trust-region technique to solve this problem. We first show how the primal-dual Newton equations can be solved efficently, by exploiting the structure and solving three systems, two of which being totally seperable with respect to the scenarios and the third one enjoying a very sparse structure, again exploitable. We then give our general algorithm, whose inner iteration solves a trust-region barrier subproblem by a dogleg method that combines a quasi-Newton step (computed via the above-mentioned decomposition) with a projected Cauchy point. We draw the main theoretical properties of the proposed class of algorithms and present some preliminary numerical experimentations.

WE2-306/35 NONLINEAR PROGRAMMING
NLP software - state of the art I
organizer/chair: Arne Stolbjerg Drud

Detecting unboundedness in practical nonlinear models

ARNE STOLBJERG DRUD
ARKI Consulting & Development A/S
keywords: nonlinear programming, unboundedness

Nonlinear models can be unbounded without having unbounded rays. To prove unboundedness it is therefore often necessary to actually move towards infinity. This can cause numerical problems, e.g. with large derivatives, scaling, etc. and the chance of mislabeling unbounded models is large, in practice often over 50%.

We compare a set of NLP solvers on several simple unbounded models, classify types of unboundedness, and suggest ways to improve the classification of the models.

Mathematical programs with equilibrium constraints: automatic reformulation and solution via constrained optimization

STEVEN DIRKSE
GAMS Development Corp.
coauthors: Michael Ferris, Alex Meeraus
keywords: MPEC, NLP, reformulation, complementarity

Constrained optimization has long been used to solve large scale (non)linear programming problems arising in a variety of disciplines. A separate set of models have been generated more recently, using

complementarity to model various phenomenon, particularly in general equilibria. The unifying framework of mathematical programs with equilibrium constraints (MPEC) has been postulated for problems that combine facets of both optimization and complementarity. In this talk we briefly review some methods available to solve these problems and describe a new suite of tools for working with MPEC models. These tools automatically reformulate the MPEC model as an NLP, solve the NLP, and recover the MPEC solution. We present computational results from a large set of test problems demonstrating the potential of the different nonlinear programming reformulations of MPEC problems. In addition, the advantages of using a domain-specific function library to implement these reformulations are discussed.

Global optimization with GAMS - applications and performance

MICHAEL BUSSIECK
GAMS Development Corp.

coauthors: Leon Lasdon, Janos Pinter, Nikolaos Sahinidis
keywords: global optimization, modeling system

Mixed integer non-linear optimization problems can be formulated and solved with GAMS for more than a decade. Users of non-linear models had to cope with the limits of available local solvers. Lots of effort can go into finding a “good” starting point. Furthermore, the local solver stops at the first local optimum. Recent advances in global optimization (GO) made the introduction of three solid GO solvers into the GAMS system possible: BARON, LGO, and OQNLP. These solvers help to overcome some of the limits of local optimization. In this talk we will discuss different modeling requirements for local and global codes. We will focus on differences between the three solvers, present favored application, and compare performance.

WE2-306/36 NONSMOOTH OPTIMIZATION
Non-convex problems
chair: Michael Overton

Partial smoothness and prox-regularity in optimization

WARREN HARE
Simon Fraser University

coauthor: Adrian S. Lewis
keywords: nonsmooth optimization, prox-regularity, partly smooth, variational analysis

The prox-regularity condition, developed by Poliquin and Rockafellar in 1996, is a useful generalization of convexity. In particular, in 2000, Poliquin, Rockafellar, and Thibault showed that a prox-regular set has a locally single-valued projection mapping.

In 2003, Lewis introduced the class of partly smooth functions. These functions, though nonsmooth, have a smooth substructure. By adding a prox-regularity condition to his definition, we can exploit this substructure to identify active constraints, analyse critical points, and ensure uniqueness of active manifolds.

Nonlocal methods for solving some classes of nonsmooth and nonconvex optimization problems

ALEXEI DEMYANOV
Saint-Petersburg State University

keywords: sum-min function, max-min functions, nonsmooth optimization, exchange algorithms

Let X be a metric space, $\Omega \subset X$. Functions $\varphi_{ik} : X \to R$ and index sets $I = \{1,\ldots,N\}$, $J_i = \{1,\ldots,m_i\}$, $i \in I$ are given. Define the functions

$$F_1(x) = \sum_{i\in I} \min_{k\in J_i} \varphi_{ik}(x),$$

$$F_2(x) = \max_{i\in I} \min_{k\in J_i} \varphi_{ik}(x).$$

The problem is to minimize the functions F_1 and F_2 on the set Ω. In fact we aim at being able to minimize not only these functions, but also more general functionals of the so-called "sum-min" and "max-min" types.

The problem of minimizing functions of sum-min, max-min or similar types represent a very important, though extremely complicated class of optimization problems. When dealing with such functions one has to face the following difficulties: their nonsmoothness, nonconvexity, and a large number of local minimizers they possess.

The following approach is suggested: it is shown that the problem is equivalent to another problem, and this equivalence has remarkable consequences allowing to state conditions for a minimum of nonlocal type. The definition of a stationary point is introduced, that enables one to decrease the number of invloved local minimizers. Using these conditions some methods for finding and “improving” local minimizers are constructed (Exchange and $\varepsilon-$Exchange algorithms).

Some applications to solving problems of classification and cluster analysis are presented. Numerical results are demonstrated.

A robust gradient sampling algorithm for nonsmooth, nonconvex optimization

MICHAEL OVERTON
New York University

coauthors: James Burke, Adrian S. Lewis
keywords: nonconvex, nonsmooth, non Lipschitz

Let $f : R^n \to R$ be nonconvex, continuous, and continuously differentiable on an open dense subset of R^n where its gradient is easily computed. We present a practical, robust algorithm to locally minimize such functions based on gradient sampling.

If, in addition, f is locally Lipschitz and coercive and the sampling diameter ε is fixed, then, with probability one, the algorithm generates a sequence with a cluster point that is Clarke ε-stationary. Furthermore, if f has a unique Clarke stationary point $\bar{x}$, then the set of all cluster points generated by the algorithm converges to $\bar{x}$ as ε is reduced to zero.

We present numerical results that demonstrate the robustness and utility of the algorithm in a variety of contexts, including cases where f is not Lipschitz at minimizers. Approximate local minimizers are reported for functions in the applications literature that have not, to our knowledge, been obtained previously. When the termination criteria of the algorithm are satisfied, a precise statement about nearness to Clarke ε-stationarity is obtained. A MATLAB implementation is freely available.

WE2-306/37 CONVEX PROGRAMMING
Duality and optimality
chair: Michael L. Flegel

Enhanced optimality conditions and informative multipliers for convex programming

ASUMAN OZDAGLAR
MIT

coauthors: Dimitri Bertsekas, Paul Tseng
keywords: optimality condition, Lagrange multiplier, sensitivity

In previous work, we presented a new development of Lagrange multiplier theory for smooth problems, which is motivated by an enhanced set of optimality conditions. These optimality conditions led to the introduction of new conditions, which generalize, unify, and streamline the theory of constraint qualifications.

In this talk, we will focus on convex constrained optimization problems and present enhanced Fritz John type optimality conditions for these problems without assuming the existence of a primal optimal solution. In particular, under general conditions, we show the existence of informative multipliers that carry sensitivity information by indicating the constraints to relax to affect a cost reduction. We also present enhanced optimality conditions for the dual optimization problem and investigate existence of informative dual optimal solutions, which provide sensitivity information even when there is a duality gap, and hence there exist no multipliers.

This work is part of the new book "Convex Analysis and Optimization" by D. Bertsekas, with A. Nedic, and A. Ozdaglar, published in April 2003.

Lagrangean transformation in convex optimization

ROMAN POLYAK
George Mason University

keywords: Lagrangian transformation, prox method, duality

We assume that the optimal set of the convex programming problem

$$X^* = \arg\max\{f(x)/c_i(x) \geq 0, i = 1, \dots, m\} \quad (1)$$

is bounded and Slater conditions holds. Let Ψ be a class of concave funcitons $\psi \in C^2$ with particular properties(see [1]).Along with Lagrangean $L(x,\lambda) = f(x) - \sum \lambda_i c_i(x)$ we consider the Lagrangean Transformation(LT) $Ł : R^n \times R^m_+ \times R^m_{++} \to R$ given by formula

$$Ł(x,\lambda,k) = f(x) - \sum k_i^{-1}\psi(k_i\lambda_i c_i(x))$$

Let $\lambda^o \in R^m_{++}, k^o \in R^m_{++}$ and $\mu > 0$ The LT method generates the primal,dual and the scaling vector sequences by formulas. x^{s+1} :

$$\nabla_x Ł(x^{s+1},\lambda^s,k^s) = \nabla_x L(x^{s+1},\lambda^{s+1}) = 0 \quad (2)$$

$$\lambda_i^{s+1} = \psi'(\mu(\lambda_i^s)^{-1}c_i(x^{s+1}))\lambda_i^s \quad (3)$$

$$k_i^{s+1} = \mu(\lambda_i^{s+1})^{-2} \quad (4)$$

Let $d(\lambda) = \inf_x L(x,\lambda)$ be the dual function $\psi^*(s) = \inf_t\{st - \psi(t)\}$ be the Fenchel conjugate for the transformation $\psi \in \Psi$ and $\varphi = -\psi^*$ be the kernel of the second order Entropy-like distance function $D(u,v) = \sum_{i=1}^n v_i^2 \varphi(u_i.v_i^{-1})$

Theorem 1:The LT method $(2)-(4)$ is well defined and equivalent to the Interior Prox method with Entropy-like distance function $D(u,v)$ (see [1]).

Theorem 2: The primal-dual sequence $\{x^s,\lambda^s\}$ to the primal-dual solution in value, i.e

$$f(x^*) = \lim_{s\to\infty} f(x^s) = \lim_{s\to\infty} d(\lambda^s) = d(\lambda^*)$$

The max constraints violation and the duality gap are bounded by $o((\mu s)^{-0.5})$

Theorem 3: If the complementarity condition satisfies in the strong form: $\max_{1\leq i\leq m}\{\lambda_i^*, c_i(x^*)\} > 0$, then

$$d(\lambda^*) - d(\lambda^s) = o(\mu s)^{-1}$$

Consider an LP:

$$(a,x^*) = \min\{(a,x)/Ax \geq b\}. \quad (5)$$

Theorem 4: If the dual LP to (5) has a unique solution and the kernel φ is well defined(see[1]) then there exists $c > 0$ independent on $\mu > 0$ that

$$(b,\lambda^*) - (b,\lambda^{s+1}) \leq c\mu^{-1}((b,\lambda^*) - (b,\lambda^s))^2$$

Reference 1.*Polyak R.* Nonlinear Rescaling vs. Smoothing technique in convex optimization. Math Programming Ser A92:197-235(2002)

On the Guignard constraint qualification for mathematical programs with equilibrium constraints

MICHAEL L. FLEGEL
University of Würzburg
coauthor: Christian Kanzow

keywords: MPECs, constraint qualifications, Guignard CQ, first order conditions

Mathematical programs with equilibrium constraints (MPECs) are nonlinear constrained optimization problems which, at no feasible point, satisfy any of the standard constraint qualifications known from nonlinear programming. One exception to this is the Guignard constraint qualification. Recent research in the area of constraint qualifications for MPECs has uncovered a string of modifications to standard constraint qualifications which lead to suitable first order optimality conditions, the strongest of which is a KKT-point of the MPEC, known as strong stationarity in the MPEC community. We show where the Guignard constraint qualification stands in relation to the constraint qualifications introduced in the context of MPECs. This yields an elementary approach to strong stationarity.

WE2-306/38 GLOBAL OPTIMIZATION

Global optimization II

chair: Eligius Maria Theodorus Hendrix

Deterministic global optimization: a new class of improved convex underestimators for constrained NLPs

CHRISTODOULOS FLOUDAS
Princeton University
coauthors: Ioannis G. Akrotirianakis, Christodoulos A. Floudas

keywords: convex underestimators, global optimization, constrained NLPs

A novel class of convex underestimators for twice continuously differentiable nonconvex functions is introduced. The convex underestimating functions are based on a relaxation component that involves a sum of univariate parametric exponential terms. An efficient procedure based on interval arithmetic determines the parameter values and the same time it verifies convexity. Computational studies and comparisons with the aBB global optimization approach illustrate the improved convex underestimators.

Global optimization in the coconut project

HERMANN SCHICHL
Universität Wien

keywords: global optimization, verified computing, directed acyclic graphs

In this talk, a solver platform for global optimization will be presented, as it is developed in the COCONUT project. There will be a short description of the basic algorithmic concept and of all relevant components, the strategy engine, inference engines, and the remaining modules. A compact description of the search graph and its nodes and of the internal model representation using directed acyclic graphs (DAGs) and their advantages completes the presentation.

Investigating population algorithms; a spatial GA

ELIGIUS MARIA THEODORUS HENDRIX
Wageningen University

keywords: evolutionary algorithms, spatial optimization

Population (evolutionary) algorthims are applied nowadays for solving for instance optimal control, parameter estimation and spatial optimization problems. As more tradional approaches from nonlinear and global optimization could also be applied, it is useful to follow this development in a critical way: what could be advantages and drawbacks of such approaches. We were involved in several projects where analysis and experiments of population algorithms play a role. A recent application has been in spatial optimization, where the evolutionary algorithms are designed especifically for decision variables that have a spatial structure. We will report about the experience with applying and experimenting with such algorithms.

WE2-308/11 GENERALIZED CONVEXITY/MONOTONICITY
Generalized convexity III
organizer: Laura Martein
chair: Rita Pini

Coercivity conditions and equilibrium problems

RITA PINI
Università di Milano-Bicocca
coauthor: Monica Bianchi
keywords: equilibrium problems, coercivity conditions, generalized monotonicity

We consider an equilibrium problem in a reflexive Banach space in the framework of the formulation proposed by Blum and Oettli, which includes, for instance, variational inequalities and vector optimization problems as particular cases. The study of the existence of solutions of such problems on unbounded domains usually involves the same sufficient assumptions as for bounded domains together with a coercivity condition. We focus on two different conditions. The first one is obtained by assuming the existence of a bounded set such that no elements outside is a candidate for a solution; the other one allows the solution set to be unbounded. Our results exploit the generalized monotonicity properties of the function f defining the equilibrium problem. It turns out that, both in the pseudomonotone and in the quasimonotone setting, an equivalence can be stated between the nonemptyness and the boundedness of the solution set, and these coercivity conditions. In the pseudomonotone case, we compare various coercivity conditions appeared in literature with ours.

Generalized convexity on allures in the sense of elena popoviciu

DANIELA MARIAN
Grup Scolar de Transporturi Cai Ferate Cluj-Napoca
keywords: convex sets

We use the notion of allure, in the sense of Elena Popoviciu, in definition of many roughly convex sets. We define and study φ-convex respectively δ-convex, midpoint δ-convex, lightly δ-convex, midpoint γ-convex, *r*-convexlike sets related to an allure. Some relations between them are also presented.

On the connectedness of mix semi-efficient frontier

ANNA MARCHI
University of Pisa
keywords: connectedness, efficiency

In this paper the concepts of mix semi-efficint point and quasi-concave set are introduced. By means of these concepts we will investigate the connectedness of the mix semi-efficient frontier for vector maximization problems, having an objective function whose components are quasi-concave, strictly and strong quasi-concave functions. We will prove that the mix semi-efficient frontier of a mix quasi concave problem is a closed and connected set.

WE2-308/12 STOCHASTIC PROGRAMMING
Option prices and optimization
chair: Teemu Pennanen

Recovering risk-neutral probabilities from option prices-a convex quadratic programming approach

ANA MARGARIDA MONTEIRO
University of Coimbra
coauthors: Reha Tutuncu, Luís N. Vicente
keywords: risk neutral pdf, estimation, option prices, convex quadratic programming

We present a new approach to compute the risk-neutral probability density function (pdf) of an underlying asset from option prices written on the asset. The estimation is carried out in the space of cubic splines functions, yielding appropriate smoothness. The resulting optimization problem, used to invert the data and determine the corresponding density function, is a convex quadratic programming problem, which can be efficiently solved by nowadays numerical optimization software. The nonegativeness of the risk-neutral pdf is ensured by imposing linear inequality constraints at the nodes. We tested our approach using data generated from Black-Scholes option prices and from the SPX 500 Index. The numerical results presented show the effectiveness of this methodology for estimating the risk-neutral probability density function.

Real option valuation via stochastic optimization

MARKKU KALLIO
Helsinki School of Economics
keywords: real options, stochastic programming, asset pricing, arbitrage theory

A general approach for (real) option valuation is presented in a discrete time, discrete probability space framework. An option is defined by a compact choice set of stochastic cash flow streams resulting from feasible choices within an option. Based on the buying price principle, option value is determined as a competitive price; i.e. the maximum price an agent is willing to pay, given competing investment opportunities, such as publicly traded financial instruments. We show consistency of such valuation with arbitrage pricing theory. For evaluations, an agent's multi-period utility is determined by a yield stream, such as profit, consumption or wealth, and a multi-stage portfolio model is employed to find optimal levels of yield and investment in competing assets. Additive exponential utility functions allow major savings in computational burden of valuation.

Arbitrage pricing of American contingent claims in incomplete markets

TEEMU PENNANEN
Helsinki School of Economics, Department of Management Science
coauthor: Alan King
keywords: stochastic programming, convex duality, American contingent claims, arbitrage

Convex optimization provides a natural framework for studying the pricing of financial derivatives in incomplete market models. Besides its simplicity, one of the main advantages of the optimization approach is that it is computational. Indeed, many algorithms are available for pricing problems as soon as they are set up as optimization problems. Moreover, convex optimization duality theory has been shown to yield well-known expressions for the prices of European contingent claims in terms of martingale measures. This paper extends the analysis to the case of American style contingent claims. The pricing problems of the seller and the buyer of an American contingent claim are shown to be expressible as convex optimization problems. After this, martingale expressions for the buyer's and seller's prices are obtained by inspecting the dual optimization problems.

WE2-308/13 STOCHASTIC PROGRAMMING

Stochastic programming with risk measures

organizer/chair: Andrzej Ruszczynski

Risk aversion via stochastic dominance constraints (Part I)

ANDRZEJ RUSZCZYNSKI
Rutgers University
coauthor: Darinka Dentcheva
keywords: stochastic programming, risk, stochastic dominance, convex analysis

We introduce a new stochastic optimization model involving stochastic dominance constraints and we discuss its relations to existing models. It is a convex infinite dimensional optimization problem with partial order constraints in the space of integrable random variables. We develop necessary and sufficient conditions of optimality for this problem. We show that the Lagrange multipliers corresponding to dominance constraints are concave nondecreasing utility functions.

Risk aversion via stochastic dominance constraints (Part II)

DARINKA DENTCHEVA
Stevens Institute of Technology
coauthor: Andrzej Ruszczynski
keywords: stochastic programming, convex analysis, stochastic dominance, risk

We analyze a new class of stochastic optimization problems involving stochastic dominance constraints. The problem is formulated as an optimization problem with decisions in a separable locally convex Hausdorff vector space and with constraints in the form of a stochastic order between random outcomes. We develop duality theory for these models, involving utility functions as dual variables associated with dominance constraints. We also construct specialized decomposition methods for the case of discrete distributions.

Risk functionals in stochastic programming: stability and algorithmic issues

WERNER ROEMISCH
Humboldt-University Berlin, Institute of Mathematics
coauthor: Andreas Eichhorn
keywords: stochastic programming, risk, stability, decomposition

We study the continuity of risk functionals with respect to suitable probability metrics and their consequences on stability of the underlying stochastic programs. In particular, we present stability results for models containing coherent risk measures. Furthermore, we discuss properties of risk functionals that are favourable for maintaining decomposition structures of (multistage) stochastic programs. The results are motivated by applications to stochastic power management models.

WE2-308/T1 FINANCE AND ECONOMICS

Combinatorial auctions I

organizer/chair: Susan Powell

Pause: a general combinatorial auction procedure

RICHARD STEINBERG
University of Cambridge
coauthors: Ailsa Land, H.Paul Williams
keywords: bidding/auctions

Pause is an auction procedure proposed by Kelly and Steinberg that permits all combinatorial bids while being computationally tractable for the auctioneer and transparent to the bidders. We examinine in detail bidder behaviour and illustrate this with numerical examples.

Combinatorial auctions in practice

ARNE ANDERSSON
Uppsala University, Dept of Information Technology
keywords: auctions, combinatorial auctions, business applications

The presentation will cover some experiences from real-world use of combinatorial auctions, inculding some scientific challenges.

On ascending vickrey auctions for heterogeneous objects

RAKESH VOHRA
Northwestern University
coauthors: Sven de Vries, James Schummer
keywords: auctions, duality

We consider a setting in which bidders have nonadditive valuations for sets of heterogeneous, indivisible objects. We construct an ascending auction by using a primal-dual algorithm associated with a linear programming formulation of the efficient-allocation problem for this setting. The auction assigns nonanonymous prices to sets, and asks bidders which sets they demand in each round. Prices are increased by determining a “minimally undersupplied" set of bidders. We consider this concept to be the natural generalization of an “overdemanded" set of objects, introduced by Demange, Gale and Sotomayor for the one-to-one assignment problem.

Under a substitutes condition, the auction implements the Vickrey-Clarke-Groves outcome. Furthermore, we show that this substitutes condition is a necessary condition to do so.

WE2-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Complementarity methods for simulating nonsmooth mechanical systems

organizer/chair: Mihai Anitescu

Optimization problems with complementarity constraints in mechanics

MIHAI ANITESCU
Argonne National Laboratory
keywords: nonsmooth mechanics, complementarity constraints
We discuss recent algorithmic results for complementarity-based simulation for time-dependent nonsmooth mechanics. We present applications of our results to robotics and granular mechanics.

Differential variational inequalities

JONG-SHI PANG
The Johns Hopkins University
coauthor: David E. Stewart
keywords: variational inequalities, complementarity problem, differential systems
This paper introduces the class of differential variational inequalities (DVIs) in a finite-dimensional Euclidean space. The DVI provides a powerful modeling paradigm for many applied problems in which dynamics, inequalities, and discontinuities are present; examples of such problems include constrained time-dependent physical systems with unilateral constraints, differential Nash games, and hybrid engineering systems with variable structures. The DVI unifies several mathematical problem classes that include ordinary differential equations (ODEs) with smooth and discontinuous right-hand sides, differential algebraic equations (DAEs), and dynamic complementarity systems. We present conditions under which the DVI can be converted, either locally or globally, to an equivalent ODE with a Lipschitz continuous right-hand function. For DVIs that cannot be so converted, we consider their numerical resolution via an Euler time-stepping procedure, which involves the solution of a sequence of

finite-dimensional variational inequalities. Borrowing results from differential inclusions (DIs) with upper semicontinuous, closed and convex valued multifunctions, we establish the convergence of such a procedure. Lastly, we present a class of DVIs for which the theory of DIs is not directly applicable, and yet a similar convergence result can be established.

A robust sequential quadratic programming method for mathematical programs with linear complementarity constraints

XINWEI LIU
Singapore-MIT Alliance, National University of Singapore
coauthor: Jie Sun
keywords: complementarity constraints, inequality relaxation, global convergence, regularity and nondegeneracy

The relationship between the mathematical program with linear complementarity constraints (MPCC) and its inequality relaxation is studied. A new sequential quadratic programming method is presented for solving the MPCC based on this relationship. A function with a penalty term measuring the violation of the complementarity constraint relaxation is used to decide the stepsize in each iteration. Global convergence results are derived without assuming the linear independence constraint qualification for MPCC and nondegeneracy of the complementarity constraints. Preliminary numerical results show the validity of the algorithm for the test problems generated by QPECgen and the test problems with non-quadratic objective functions.

WE2-308/T3 ON-LINE OPTIMIZATION

On-line optimization algorithms

chair: Tjark Vredeveld

Minimizing the maximum flow time in the online dial-a-ride problem

DIANA POENSGEN
Konrad-Zuse-Zentrum fuer Informationstechnik (ZIB)
coauthors: Sven O. Krumke, Alberto Marchetti-Spaccamela Luigi Laura, Maarten Lipmann, Willem E. de Paepe, Leen Stougie
keywords: on-line dial-a-ride problem, maximum flow time, fair adversary

In the Online Dial-a-Ride Problem (OLDARP), a server of unit speed and given capacity C must transport objects between points of a metric space. Each transportation request is defined by its release time, its source, and its destination. An online algorithm learns about the existence of a request at its release time, and it must serve each request by transporting an object from the given source to the destination, never carrying more than C objects at once. The goal is to minimize the maximum flow time, where the flow time of a request is the difference between the time when the object reaches its destination and its release time.

It is easy to see that competitive analysis fails to distinguish online algorithms for this problem unless the adversary is restricted. We extend the fair adversary defined for the real line by Blom et al. to the uniform metric space and show that a simple first-come-first-serve strategy is 2-competitive and best possible, if source and destination of each request coincide. For the case that they differ, we provide a worst-case construction that shows that no deterministic online algorithm can be competitive for the OLDARP, not even against the fair adversary.

The generalized 2-server problem

RENE SITTERS
Technische Universiteit Eindhoven
coauthor: Leen Stougie
keywords: on-line algorithms

We consider the generalized 2-server problem in which at each step both servers receive a request, which is a point in a metric space. One of the two servers has to move to its request. If the sequence is known in advance, then the problem can be solved efficiently by dynamic programming. It has been a well-known open question in online optimization if a constant factor approximation algorithm exists for the generalized 2-server problem. We answer this question in the affirmative sense by providing a constant competitive algorithm based on the so called work function.

Smoothening helps: a probabilistic analysis of the multi-level feedback algorithm

TJARK VREDEVELD
Konrad-Zuse-Zentrum
coauthors: Luca Becchetti, Stefano Leonardi, Alberto Marchetti-Spaccamela, Guido Schaefer
keywords: smoothed competitive analysis, on-line algorithms, multi-level feedback algorithm, probabilistic analysis

Spielman and Teng introduced the concept of smoothed analysis to explain the success of algorithms that are known to work well in practice while presenting poor worst case performance. Spielman and Teng [STOC 01] proved that the simplex algorithm runs in expected polynomial time if the input instance is smoothened with a normal distribution.

We extend this notion to analyze online algorithms. In particular we introduce smoothed competitive analysis to study the Multi-Level Feedback (MLF) algorithm, at the basis of the scheduling policies of Unix and Windows NT, when the processing times of jobs released over time are only known at time of completion.

We show that, if the k least significant of K bits describing the processing time of a job are randomly changed, MLF achieves a tight smoothed competitive ratio of $O(2^{K-k})$ to minimize the average flow time. A direct consequence is a first constant approximation for this problem in the average case under a quite general class of probability distributions.

For various other smoothening models, including the one used by Spielman and Teng, we present a higher lower bound of $\Omega(2^K)$.

WE2-341/21 INTERIOR POINT ALGORITHMS

Interior point methods in linear programming

chair: Miguel Argaez

An iterative method for solving the search direction of linear programming

HUA WEI
University of Waterloo
coauthors: Maria Gonzalez-Lima, Henry Wolkowicz
keywords: linear programming, large sparse problems, linear equations, interior point method

We give a new method to solve the perturbed optimality condition to get the search direction in interior-point method for linear programming. A typical method to solve the perturbed optimality condition is to form the normal equation and then use Choleski factorization to directly solve it. We show that the normal equation approach may not be stable near the boundary of the feasible region due to the back solve. We then show that by using a different block elimination, we can get another linear system that does not become ill-conditioned under nondegeneracy assumptions. This system is a sparse non-symmetric system. It is

equivalent to the so-called Quasi- definite system after a scaling. We then apply direct method as well as iterative method to solve the system to get the search direction. The iterative method uses the fact that the sparse pattern of the system does not change. We construct an approximate inverse of the system at each iteration as a preconditioner. The preconditioner in next iteration can use the sparse pattern information of the preconditioner in the current iteration. Thus we can construct a preconditioner very efficiently after the first iteration. Numerical result is presented.

On the convergence of interior point methods for linear programming

CORALIA CARTIS
University of Cambridge

keywords: linear programming, interior point method

We consider a long-step primal-dual interior point method and a second-order variant of it, applied to linear programming problems. The iterates are feasible with respect to the primal and the dual equality constraints. The behaviour of the two methods is analyzed on an illustrative problem. We address the problem of the convergence of the sequences of iterates generated by the two algorithms to the analytic centre of the optimal primal-dual set, both when the centring parameter is bounded away from zero and when it converges to zero.

The role of the notion of quasi-central path for linear programming

MIGUEL ARGAEZ
University of Texas at El Paso
coauthors: Leticia Velazquez, Osvaldo Mendez

keywords: linear programming, interior point method

The notion of central path plays an important role in the development of most primal-dual interior-point algorithms. In this work we prove that a related notion called quasicentral path, introduced by Argaez and Tapia in nonlinear programming, is an enough region to guide the iterates towards a solution of the problem. We use a new merit function for advancing to the quasicentral path, and weighted neighborhoods as proximity measures of this central region.

WE2-341/22 LOGISTICS AND TRANSPORTATION

Applications of optimization in transportation

organizer/chair: Georgia Perakis

An inner approximation algorithm for the dynamic user equilibrium problem

THANASIS ZILIASKOPOULOS
Northwestern University

keywords: flow algorithms, equilibrium models

Traffic network equilibrium models, commonly used by planning agencies, assume link travel time functions monotonically increasing with flow; this makes these models unsuitable for congested networks for which such a monotonic relationship does not hold. This paper introduces a Variational Inequality (VI) formulation for computing equilibrium flows that circumvents this drawback by relying on traffic flow theoretical models and non-steady state demand inflow. An Inner Approximation (IA) algorithm is proposed that efficiently solves the VI formulation; the formulation and the algorithm can solve large networks for steady state or time varying origin-destination demand. The IA equilibrium algorithm relies on a traffic simulator to evaluate the link travel times; we demonstrate that under some mild assumptions, the algorithm converges to a user equilibrium solution. Computational experiments on large networks, such as the Chicago's six-county network , indicate reasonable convergence in acceptable CPU times.

A fluid dynamics model in distribution systems and transportation

SOULAYMANE KACHANI
Columbia University
coauthor: Georgia Perakis

keywords: fluid models, distribution systems, transportation, supply chain

In this talk, we present a fluid dynamics model as it applies in anticipatory route guidance as well as in supply chain management. This fluid model is motivated from the dynamic network loading model which is used for modeling the dynamic traffic assignment problem. We consider the model's application in a particular type of supply chain, that is, a distribution system with several wholesalers, intermediate distributors, and retailers who are subsidiaries of the same company producing and selling multiple products. Furthermore, we consider the model's application in the anticipatory route guidance problem which aims to provide consistent messages to drivers based on forecasts of traffic conditions in order to assist the drivers in their path selections. We design a framework for the analysis of the fluid model in these two application areas and establish existence of solution.

On second-best toll pricing problems

SIRIPHONG LAWPHONGPANICH
University of Florida
coauthor: Don Hearn

keywords: congestion pricing, traffic equilibrium, MPEC

In this talk, we address the second-best toll pricing problems with fixed and elastic travel demand, and discuss how they can be applied to the current practices such as cordon toll pricing, High-Occupancy Toll (HOT), and Fast and Intertwine Regular (FAIR) lanes. We provide three equivalent MPEC formulations, establish existence conditions for optimal toll vectors, and relate them to marginal social cost pricing tolls. In addition, we develop a cutting constraint algorithm to solve the problems and present a framework for determining a second-best toll vector that both induces a user equilibrium flow and achieves a desired (secondary) goal, such as minimizing the maximum toll, the number of toll facilities, and, for the fixed demand case, total toll revenue.

WE2-341/23 APPROXIMATION ALGORITHMS

Approximation algorithms for metric facility location and spanning tree

organizer/chair: Yinyu Ye

On universal facility location problem

BO CHEN
University of Warwick
coauthors: Yinyu Ye, Jiawei Zhang

keywords: facility location, approximation algorithms

We address the Universal Facility Location (UniFL) problem, in which one is given a set of facility locations and a set of demands with locations. The objective is to assign the demands to facilities in such a way that the sum of service and facility costs is minimized. While the service cost is proportional to the distance between the facility and the demand it services, the facility cost of each facility is a non-decreasing function of the amount of demand it services. A most difficult special case of UniFL problem is when the facilities have arbitrary hard capacities.

Following the recent first constant (8.53 + eps)-approximation algorithm for the problem with arbitrary hard capacities and then the first constant (7.88 + eps)- approximation algorithm for UniFL problem, we present improved approximation results on both upper and lower bounds.

An efficient polynomial time approximation scheme for the constrained minimum spanning tree using matroid intersection

ASAF LEVIN
Tel-Aviv university
coauthor: Refael Hassin
keywords: approximation algorithms, matroid intersection, Lagrangean relaxation

Given an undirected graph G=(V,E) with |V|=n and |E|=m, non-negative integers c_e and d_e for each edge $e \in E$, and a bound D, the constrained minimum spanning tree problem (CST) is to find a spanning tree $T = (V, E_T)$ such that $\sum_{e \in E_T} d_e \leq D$ and $\sum_{e \in E_T} c_e$ is minimized. We present an efficient polynomial time approximation scheme (EPTAS) for this problem. Specifically, for every $\varepsilon > 0$ we present an $(1+\varepsilon)$-approximation algorithm with time complexity $O((\frac{1}{\varepsilon})^{O(\frac{1}{\varepsilon})}(n^4 \log^2 n))$. Our method is based on Lagrangean relaxation and matroid intersection.

Approximation of rectilinear Steiner trees with length restrictions on obstacles

MATTHIAS MUELLER-HANNEMANN
Research Institute for Discrete Mathematics, Bonn
coauthor: Sven Peyer
keywords: rectilinear Steiner trees, obstacles, VLSI design, approximation algorithms

We consider the problem of finding a shortest rectilinear Steiner tree for a given set of points in the plane in the presence of rectilinear obstacles. The Steiner tree is allowed to run over obstacles; however, if we intersect the Steiner tree with some obstacle, then no connected component of the induced subtree must be longer than a given fixed length. This kind of length restriction is motivated by its application in VLSI design where a large Steiner tree requires the insertion of buffers (or inverters) which must not be placed on top of obstacles.

We show that the length-restricted Steiner tree problem can be approximated with a performance guarantee of 2 in $O(n \log n)$ time, where n denotes the size of the associated Hanan grid.

Moreover, we prove that a certain variant of the Hanan grid always contains an optimal solution. Based on this structural result, we can improve the performance guarantee of approximation algorithms for the special case that all obstacles are of rectangular shape or of constant complexity. For such a scenario, we give a $(2k)/(2k-1)\alpha$-approximation for any integral $k \geq 4$, where α denotes the performance guarantee for the ordinary Steiner tree problem in graphs.

WE2-321/053 PRODUCTION AND SCHEDULING
Flow shop scheduling
chair: Débora Pretti Ronconi

Scheduling with simultaneous task processing for two-machine no-wait flowshop problem

OULAMARA AMMAR
LORIA-INRIA
keywords: no-wait flowshop, complexity, batch processing machines, Lagrangian relaxation

In this paper, we consider a no-wait flowshop problem on two *sum-batch machines*. A machine is called a sum-batch processing machine, if it can process several tasks sequenctially. The set of tasks processed together is called a batch. The processing time of a batch is equal to the sum of the processing times of tasks in batch. A batch can only begin to processed when all tasks of this batch are available on the corresponding machine and all tasks assigned to the same batch start and completed at same time. A setup time s (depending only on machine) is required on such a machine before each execution of a batch. It correspondins to tool changes or to machine cleaning and adjustment. On the second machine, we study the case in which the setup time is processed with anticipation (as) and the case in which the setup is processed without anticipation(ns).

A branch-and-bound algorithm for the minimization of weighted tardiness in a two-machine flowshop

BERTRAND LIN
National Chi Nan University
coauthor: Kenny K.Y. Chen
keywords: scheduling, flowshop, weighted tardiness, branch-and-bound

There is a set of jobs to be processed in a two-machine flowshop. In addition to the processing times on two machines, each job is associated with a due date and a weight, whcih will be used to penalize a job when it is not completed by the due date. This problem is already known to be strongly NP-hard. To design branch-and-bound algorithms for deriving exact solutions, we develop several properties to curtail unnecessary exploration. Our properties include two dominance rules and a lower bound. Besides, we propose a branching scheme that not only provides a new tree structure but also facilitate the enhancement of our lower bounds. We performed a set of computational experiments to study the performances of the proposed properties. Computational experiments show that our proposed properties can reduce computational efforts required by tree exploration. Statistics also suggest complimentary results between the conventional depth-first-search and our new scheme. This result can suggest a line of thinking in constructing search tree as well as improving lower bounds for some optimization problems.

A branch-and-bound algorithm to minimize the makespan in a flowshop with blocking

DÉBORA PRETTI RONCONI
UNIVERSIDADE DE SÃO PAULO
keywords: multiple machines, scheduling, branch-and-bound, makespan

This paper analyzes the minimization of the makespan criterion for the flowshop problem with blocking. In this environment there are no buffers between successive machines, and therefore intermediate queues of jobs waiting in the system for their next operations are not allowed. While there is a considerable amount of research that deals with flowshop with no storage constraints, few works have addressed the flowshop with blocking in process. The particular case of three machines, which is NP-hard in the strong sense for such criterion, can indicate the difficulty level of this problem. This paper proposes a lower bound which exploits the occurrence of blocking. A branch-and-bound algorithm that uses this lower bound is described and its efficiency is evaluated on several problems. Numerical experiments indicated that the bounding scheme works better than the lower bound proposed by Ronconi and Armentano (2001).

WE2-321/033 MULTICRITERIA OPTIMIZATION
Efficiency analysis in multicriteria optimization I
chair: Fernanda Maria Pereira Raupp

A biobjective method for sample allocation in stratified sampling

DOLORES ROMERO MORALES
Universiteit Maastricht

coauthor: Emilio Carrizosa
keywords: stratified random sampling, sample allocation, biobjective integer program

The two main and contradicting criteria guiding sampling design are accuracy of estimators and sampling costs. In stratified random sampling, the sample size must be allocated to strata in order to optimize both objectives.

In this presentation we address, following a biobjective methodology, this allocation problem. A two-phase method is proposed to describe the set of Pareto-optimal solutions of this nonlinear integer biobjective problem. In the first phase, all supported Pareto-optimal solutions are described via a closed formula, which enables quick computation. Moreover, for the common case in which sampling costs are independent of the strata, all Pareto-optimal solutions are shown to be supported. For more general cost structures, the non-supported Pareto-optimal solutions are found by solving a parametric knapsack problem.

The methods and results obtained are also extended to more general settings, such as estimation problems with missing values and various types of multi-response sampling.

Duality in risk minimization and vector optimization

FRANK HEYDE
Martin Luther University Halle-Wittenberg

keywords: coherent risk measure, duality, vector optimization

We investigate duality in minimization of coherent risk measures as introduced by Artzner/Delbaen/Eber/Heath and point out connections with proper efficient points of appropriate vector optimization problems.

On minimization over weakly efficient sets

FERNANDA MARIA PEREIRA RAUPP
LNCC

coauthor: Wilfredo Sosa
keywords: weakly efficient points, multicriteria optimization, global optimization

We are interested in minimizing a linear function over the set of weakly efficient solutions for a linear multiobjective problem, which has many practical applications in Economy, specially in Industry . We build a cone such that every belonging vector gives at least one weakly efficient solution. We also show that each weakly efficient solution corresponds to a vector in such cone. We claim that in the case that the original problem has a solution, this solution is obtained solving a linear programming problem, where the objective function is composed by a vector in such cone.

WE2-321/133 LINEAR PROGRAMMING

Computational and algorithmic progress in cone programming

organizer/chair: Jos F. Sturm

A new variant of the interior point method with rank-1 updates

JOS F. STURM
Department of Econometrics, Tilburg University

keywords: interior point method

TBA

Semidefinite programming in the space of partial positive semidefinite matrices

SAM BURER
University of Iowa

keywords: semidefinite programming, interior point algorithms, sparsity

We build upon the work of Fukuda et al. and Nakata et al., in which the theory of partial positive semidefinite matrices has been applied to the semidefinite programming (SDP) problem as a technique for exploiting sparsity in the data. In contrast to their work, which improves an existing algorithm that is based on the HRVW/KSH/M search direction, we present a primal-dual path-following algorithm that is based on a new search direction, which, roughly speaking, is defined completely within the space of partial symmetric matrices. We show that the proposed algorithm computes a primal-dual solution to the SDP problem having duality gap less than a fraction $\varepsilon > 0$ of the initial duality gap in $O(n \log(\varepsilon^{-1}))$ iterations, where n is the size of the matrices involved. Moreover, we present computational results showing that the algorithm possesses several advantages over other existing implementations.

New developments in SDPT3

REHA TUTUNCU
Carnegie Mellon University, Dept of Math. Sciences

keywords: semidefinite programming

We discuss our recent work related to SDPT3, a MATLAB based software for semidefinite-quadratic-linear optimization. This work includes new routines for special handling of fixed or free variables, an interface for control problems, and specialized routines for optimizing linear functions over an intersection, rather than product, of two or more cones.

WE2-305/205 GAME THEORY

Game theory applications I

organizer/chair: Daniel Granot

On the complexity of the kernel

WALTER KERN
University of Twente

coauthors: U. Faigle, J. Kuipers
keywords: cooperative games, kernel, complexity

We study classes of cooperative games with the property that the surplusses s_{ij} (relative to a given game in the class and a given allocation x) are efficiently computable. We show that for such classes of games also the problem of computing an element in the kernel is easy.

Buying and selling strategies in the assignment game

MARILDA SOTOMAYOR
University of São Paulo - Brazil

keywords: optimal matching, core allocation, competitive price, Nash equilibrium

For a version of the "Assignment market" of Shapley and Shubik, the strategic games induced by a class of market clearing price mechanisms are analyzed. In these procedures, buyers and sellers in different stages reveal their demand and supply functions, and a competitive equilibrium rule is used. We obtain a necessary and sufficient condition for the existence of subgame perfect equilibria. Precise answers can be given to the strategic questions raised.

Chinese postman games on a class of Eulerian graphs

DANIEL GRANOT
University of British columbia

coauthors: Herbert Hamers, J. Kuipers, M. Maschler
keywords: Eulerian graphs, cooperative games, core, nucleolus

The Extended Chinese Postman (ECP) enterprize is induced by a connected and undirected graph with a special vertex, called the post office, wherein a server is located. Each edge has a prize, which can be collected only once, and a cost attached to it, and each player resides in an edge. The server has to travel along the edges, starting and returning to the post office, and visiting all edges in which players reside. The issue is to allocate the net cost of travelling among all players. We show that for ECP enterprizes induced by Eulerian graphs having the 4-cut property, the core as well as the nucleolus are the Cartesian products of cores and nucleoli of ECP enterprizes associated with simple cycles derived from the original graph. We further demonstrate that one can check core membership in linear time for an ECP enterprize induced by a simple cycle or a chain, and we develop a quadratic algorithm to calculate the nucleolus of such an enterprize. These results imply that we can check core membership in linear time and we can calculate the nucleolus in quadratic time for ECP enterprizes induced by Eulerian graphs having the 4-cut property.

TH1-302/41 COMBINATORIAL OPTIMIZATION
Computational methods for graph-coloring II
organizer/chair: Michael Trick

Graph-coloring heuristics based on lovasz theta number

IGOR DJUKANOVIC
University of Maribor / School for Economics and Business
coauthor: Franz Rendl
keywords: graphs, heuristics, vertex coloring, SDP

SDP formulation of Lovasz theta number does not provide us only with a lower bound on the chromatic number of a graph, but also with a matrix which approximately describes the optimal coloring. This matrix is used to define several recursive heuristics. Tighter SDP relaxations for the chromatic number then theta number may also be employed.

Cliques, holes and lower bounds for the vertex coloring problem

RICARDO CORRÊA
Federal University of Ceará
coauthors: Manoel Campêlo, Yuri Frota
keywords: graph-coloring, integer programming, facets of polyhedra

Given a graph $G = (V,E)$, where V is its set of vertices and E, its set of edges, and a positive integer k, a k-coloring of G is an assignment of colors from $\{1,\cdots,k\}$ to the vertices of G so that each vertex receives at least one color and the endpoints of any edge are assigned different colors. The vertex coloring problem is defined as the problem of finding the minimum number of colors $\chi(G)$ such that G admits a $\chi(G)$-coloring. Observe that there exists a coloring of G with $\chi(G)$ colors in which each vertex is assigned exactly one color.

In this paper we propose a new 0-1 formulation of the vertex coloring problem. We show that certain particular substructures of G induce classes of facet defining inequalities of the associated polytope, particularly maximal cliques and odd hole and anti-holes. Some computational experiments were carried out in order to evaluate the lower bound provided by this formulation, and their results are presented. A comparison of the results obtained are made with those of the column generation approach from the literature.

Application of mathematical programming to graph-coloring

ISABEL MENDEZ-DIAZ
Universidad de Buenos Aires
coauthor: Paula Lorena Zabala
keywords: graph-coloring, branch-and-cut, facets

We present a Branch-and-Cut algorithm for the graph coloring problem. In a previous work, we studied the facet structure of the 0/1-polytope associated with an integer programming formulation of the graph coloring problem. Based on these theoretical results a Branch-and-Cut algorithm is developed. Our computational experiences compare favorably with the well-known exact graph coloring algorithm DSATUR.

TH1-302/42 COMBINATORIAL OPTIMIZATION
Combinatorial optimization VII
chair: Marco Lübbecke

A fast parametric assignment algorithm with applications in max-algebra

BETTINA KLINZ
TU Graz
coauthor: Elisabeth Gassner
keywords: networks/graphs, matchings, parametric programming, max-algebra

This talk deals with parametric assignment problems and their application to max-algebra where "max´´ plays the role of "+´´ in linear algebra and "+´´ the role of "·´´. The max-characteristic polynomial $\xi_A(\lambda)$ of an $n \times n$ matrix A serves a similar role in max-algebra than the characteristic polynomial in linear algebra. $\xi_A(\lambda)$ can be computed by computing the optimal value function of a nonlinear parametric assignment problem with cost matrix $B(\lambda) = (b_{ij})$ where $b_{ii} = \max\{a_{ii},\lambda\}$ and $b_{ij} = a_{ij}$ for $i \neq j$.

We start with investigating the following linear parametric assignment problem (PAP): We are given a bipartite graph $G = (V_1 \cup V_2, E)$, a subset $P \subseteq E$ and edge weights c_{ij} for $(i, j) \in E$. The parametric weight $d_{ij}(\lambda)$ of edge $(i, j) \in E$ is given by $c_{ij} + \lambda$ if $(i, j) \in P$ and by c_{ij} otherwise. The PAP is to find a perfect matching with maximum weight with respect to the parametric weights $d_{ij}(\lambda)$ for all values of λ. We present an algorithm which solves the PAP in $O(mn + n^2 \log n)$ time for a graph with $2n$ vertices and m edges.

We then show how this algorithm can be extended to solve the nonlinear parametric assignment problem which arises in the computation of $\xi_A(\lambda)$. In this manner we obtain an $O(n^3)$ algorithm for this task which improves upon the previously best-known algorithm by a factor of n.

On semidefinite relaxations for the linear ordering problem

ALANTHA NEWMAN
MIT
keywords: linear ordering problem, maximum acyclic subgraph, semidefinite programming, approximation algorithms

The linear ordering problem is easy to state: Given a complete weighted directed graph, find an ordering of the vertices that maximizes the weight of the forward edges. Although the problem is NP-hard, it is easy to estimate the optimum to within a factor of 1/2. (Take any ordering of the vertices; either the set of forward edges or the set of backward edges accounts for at least half of the total edge weight.) It is not known whether the maximum can be estimated to a better factor using a polynomial-time algorithm.

Recently it was shown that widely-studied polyhedral relaxations for this problem cannot be used to approximate the problem to within a factor better than 1/2. This was shown by demonstrating that the integrality gap for these relaxations is 2 on certain classes of random graphs. We present a new semidefinite relaxation for the linear ordering problem and show that the gap is strictly less than 2 on the classes of random graphs referred to above.

On the stabbing number of matchings, trees, and triangulations

MARCO LÜBBECKE
Braunschweig University of Technology
coauthors: Sandor Fekete, Henk Meijer
keywords: perfect matching, line stabbing number, NP-hardness, integer programming

Given a planar point set we investigate perfect matchings, spanning trees, and triangulations of minimum stabbing number. The stabbing number of a matching (tree, triangulation) is the maximal number of intersections of any line with matching edges (tree edges, triangles). A small stabbing number is a desirable property of data structures for location queries in the widest sense. We prove that minimizing the stabbing number is NP hard for all three problems. We present integer programming formulations and evaluate their performance computationally. We outline how to obtain approximation results from the LP relaxation.

TH1-302/44 COMBINATORIAL OPTIMIZATION
Counting problems
chair: Takeaki Uno

An algorithm for enumerating all substitutions a rooted ordered tree into a term tree

YASUKO MATSUI
Dept . of Mathematical Sciences, Tokai University
coauthors: Satoshi Matsumoto, Tetsuhiro Miyahara, Takayoshi Shoudai
keywords: graphs, enumeration, dynamic programming

We consider an ordered tree with internal structured variables, called a term tree. A term tree is a rooted tree that consists of tree structures with ordered children and internal variable, and it is suited for representing tree-structured data such as HTML files. In learning theory, there are many problems on term trees. In this talk, we deal with a problem on a term tree. Let a rooted ordered tree T be a term tree such that T does not including internal variable. We define a replacing operation is as follows: (1)A variable of a term tree is replaced by an edge. (2)A variable of a term tree is replaced by a subgraph of a rooted ordered tree. Then, a term tree T_1 and a rooted ordered tree T_2 are given, we consider a problem for enumerating all substitutions T_2 into T_1 where the replacing operation is permitted and an order relation of all leaves on T_1 satisfy an order relation of them on T_2 We propose an algorithm with polynomial delay for the above problem using a dynamic programming technique.

Counting the vertices of certain classes of polyhedra

SAMMANI DANWAWU ABDULLAHI
UAE University
coauthors: Martin Dyer, Les Proll
keywords: counting, approximation, randomization

The problem of counting the vertices of arbitrary polyhedra has various computational applications. The problem is known to be #P-complete. We discuss different fully polynomial randomized approximation schemes (fpras) for counting the vertices of polyhedra associated with;0-1 Permanent, 0-1 Knapsack, 2 x n transportation problems, matroids and matchings in non-bipartite graphs. We show that the vertices of a polyhedron associated with regular matroids can be exactly counted.

Fast algorithms for enumerating maximal cliques

TAKEAKI UNO
National Institute of Informatics
keywords: maximal clique, enumeration, algorithms, bipartite

A clique of a graph is a vertex subset such that any its two vertices are connected by an edge. A bipartite clique of a graph is a pair of vertex subsets such that any vertex of a vertex set of them is connected to any vertex of the other. In this talk, we propose new algorithms for enumerating cliques and bipartite cliques of a given graph $G = (V,E)$. These problems can be solved by an existing algorithm, however the algorithm takes $O(|V||E|)$ time per output clique. The time complexities of our algorithms are $O(\Delta^4)$ per clique and $O(\Delta^3)$ per bipartite clique, respectively, where Δ is the maximum degree of G. We show some result of computational experiments for both random instances and real world instances, and show that the practical computation time of our algorithm is proportional to the square of the average degree, which is quite less than Δ^4. By using this algorithm, several huge enumeration problems taken from application areas can be solved in a sufficiently short time.

TH1-302/45 INTEGER AND MIXED INTEGER PROGRAMMING
Integer and mixed integer programming V
chair: Atsushi Kawamoto

On classes of mixed integer programming problems arising in discriminant analysis

CARLO VERCELLIS
Politecnico di Milano
coauthor: Carlotta Orsenigo
keywords: classification, segmentation, support vector machines, heuristics

We consider the new concept of discrete support vector machines for solving classification problems in discriminant analysis. It is a discrete version of support vector machine (SVM) in which the error is properly expressed as the count of misclassified instances, in place of the misclassification distance considered by traditional SVMs. This results in a mixed integer programming problem whose properties are investigated, and whose approximate solution is efficiently obtained by means of a sequential LP-based heuristic. Alternative approximation algorithms based upon truncated branch and bound and tabu search methods are also discussed and compared. Further, an extension of the model is obtained by introducing an additional term in order to reduce the complexity of the discriminant rule generated. Computational tests performed on several well-known benchmark datasets indicate that our algorithm consistently outperforms other classification approaches in terms of accuracy, and is therefore capable of good generalization on future unseen data. Further testing on marketing datasets of realistic size have proven the applicability of our algorithm to massive classification tasks.

So it's facet-defining... big, fat, hairy deal!

DAVID WARME
L-3 Communications Analytics Corp.
keywords: facets

Decades of practical experience with cutting-plane algorithms has taught us that "all inequalities are *not* created equal." Certain inequalities slash away major portions of the LP/IP gap, while thousands of others collectively produce very little. (Quite fortunate then that we call them "*inequalities*"!) It is well known that facet-defining inequalities generally outperform those that are merely valid, but it is less well appreciated how wide the variance in gap-closing performance can be even within a single family of facet-defining inequalities. How do we design separation procedures that are *effective* — i.e., that produce not just violations, but very strong violated inequalities that converge rapidly?

We address this question by presenting several metrics based on intuitive properties that "strong" inequalities are likely to possess. We apply two of these metrics analytically to several families of inequalities, including subtour inequalities for both the TSP and the spanning tree in hypergraph polytopes, and the 3-toothed comb inequalities for the TSP. We present computational evidence that corroborates the predictive power of these metrics, and we show how such metrics can be used both to design more effective separation procedures, and to theoretically justify existing "constraint strengthening" methods.

Articulated mechanism designs: topology and geometry variations

ATSUSHI KAWAMOTO
MAT/DTU
keywords: mechanism design, topology optimization, geometry optimization

This paper deals with the design of articulated mechanisms using a truss-based ground-structure representation with geometric non-linearity taken into consideration. It is essential to consider both topology and geometry variations for obtaining an effective mechanism, and this research is an initial attempt at developing a systematic method for optimizing both topology and geometry of mechanisms. This can be performed sequentially or simultaneously and takes into account design requirements such as maximization of the output displacement or generation of a specified path. Research on design of compliant mechanisms using topology optimization techniques in continuum structures suggests that it should also be possible to obtain results for articulated mechanisms by applying such techniques. On the other hand, dimensional synthesis techniques based on optimization methods can provide a broad range of tools especially for mechanism path generation. However, this method often encounters non-assembly problems during the optimization process because the method employs rigid bars and their use as design variables involves the process of assembling of the mechanism in all possible configurations. The proposed method with truss representation uses cross-sectional areas and nodal positions as design variables, and thus assembly is unnecessary during the optimization process.

TH1-302/49 INTEGER AND MIXED INTEGER PROGRAMMING

Alternative methods

chair: Chuangyin Dang

An augmentation framework for integer programming

UTZ-UWE HAUS
University of Magdeburg/ FMA-IMO

coauthor: Robert Weismantel
keywords: lattice reduction, augmentation algorithm

A number of practical algorithmic building blocks that combine into an augmentation framework for solving general integer programs are presented. The main ingredients are the generation of augmentation vectors using Lovász's lattice reduction and the Integral Basis Method, which are used to find an initial feasible solution, augment to an optimal point, and prove optimality. Other techniques can be integrated seamlessly at any point, if additional information (e.g. combinatorial structure) for the problem is available. Computational experience on problems from the MIPLIB library is reported upon.

The integral basis method and extensions

MATTHIAS KOEPPE
University of Magdeburg/ FMA-IMO

coauthors: Robert Weismantel, Quentin Louveaux
keywords: primal methods, integral bases

The Integral Basis Method by Haus, Köppe, Weismantel (2001) is an exact primal-type algorithm for solving integer linear programs. It is based on the computation of integral generating sets of cones and polyhedra. Using these generating sets, the integer program to be solved is reformulated in an iterative way, until augmentation vectors are found or the optimality of the current solution is proved.

In this talk we present extensions of the algorithm to mixed integer programs. We introduce a variant of the method that uses a different kind of discrete relaxation of integer programs. Moreover, we present new computational results for the augmentation phase of the optimization process of hard integer programs from the MIPLIB.

A simplicial approach to integer programming

CHUANGYIN DANG
City University of Hong Kong

coauthor: Hans van Maaren
keywords: integer programming, simplicial approach, integer point, polytope

Integer programming is equivalent to determining whether there exists an integer point in a polytope. By increasing dimension, we show that determining whether there exists an integer point in a polytope is equivalent to determining whether there exists an integer point in a simplex. Based on an integer labeling rule and the D1-triangulation of the space, we develop a simplicial approach to determining whether there exists an integer point in a simplex in the canonical form, which is obtained from the application of a unimodular transformation. The approach consists of two phases. The first phase forms a homotopy-like simplicial method, which generates (n+1)-dimensional simplices, and the second phase forms a pivoting procedure, which generates n-dimensional simplices. Starting at an arbitrary integer point on the artificial level, the approach interchanges between those two phases and follows a finite simplicial path that either leads to an integer point of the simplex or proves no such point exists. Efficiency of the approach is demonstrated through numerical results.

TH1-306/31 INTEGER AND MIXED INTEGER PROGRAMMING

Computational methods for solving IPs II

organizers: Eva Lee and Andrew Miller
chair: Eva Lee

Strong formulations and separation for multi-level lot-sizing problems

KEREM AKARTUNALI
University of Wisconsin-Madison

coauthor: Andrew Miller
keywords: lot sizing, combinatorial optimization, integer programming, production planning

Much of the difficulty in solving practical lot-sizing problems arises because strong formulations for the underlying multi-level problems are usually not used. Such problems have been studied by Afentakis and Gavish, Tempelmeier and Derstroff, and Stadtler, among others. We discuss computational results obtained by using strong reformulations, including using efficient new methods to separate for strong valid inequalities.

Lifting, superadditivity and single node flow sets revisited

QUENTIN LOUVEAUX
CORE, Universite catholique de Louvain

coauthor: Laurence A. Wolsey
keywords: mixed integer programming, lifting, single node flow sets

This talk focuses on the lifting of valid inequalities for mixed integer programs. We review the work of Gu, Nemhauser and Savelsbergh on the lifting of valid inequalities for single node flow sets and try to give a general presentation of it. In particular, we show that the lifting can always be carried out by fixing a set of variables to 0, after an appropriate transformation of the variables. We show how to apply this theory to both particular cases and generalizations of single node flow sets. Special empahasis is placed on superadditive lifting that allows one to simultaneously lift different sets of variables.

Problems of optimization: an exact algorithm for finding a maximum clique optimized for the dense graphs

DENISS KUMLANDER
Tallinn Technical University

keywords: maximum clique, independent sets, dense graph

In this paper we present an algorithm that solves one of the problems arising from the optimization task, namely finding maximum clique from an arbitrary graph. The optimization problem is a common problem in many areas including theory of programming. Our algorithm is an optimization for dense graphs of one of the quickest algorithms for a maximum clique finding - Carraghan and Pardalos algorithm. An optimization effect starts to appear from graphs with average density and reach maximum on graphs with high density. On dense graphs maximum clique is found up to 1000 times faster than for initial algorithm.

TH1-306/32 NONLINEAR PROGRAMMING
Applications
chair: Katia Demaseure

Shape optimization in rotordynamics with eigenvalue and eigenvector constraints

FRANK STRAUSS
University of Heidelberg
coauthors: Jens Starke, Mizuho Inagaki
keywords: finite element model, sensitivity analysis, shape optimization, eigenvector constraints

We study design optimization problems for general rotating bodies including gyroscopic effects and consider a turbocharger as example. The target of our research is to reduce rotor weight and rotor vibrations leading to higher efficiency and reliability and less noise. This can be achieved by minimizing the total mass of the rotor while reducing the vibration response of the first bending mode in the resonance case below a certain threshold and at the same time increasing the critical speed on a given level. In our model the rotor is described by beam elements for the shaft and two rigid disks for impeller and turbine. Design variables are the diameters of the beam elements as well as mass and moments of inertia of the rigid disks. This leads to an optimization problem with eigenvalue and eigenvector constraints. Special attention is paid to differentiability aspects and a fast and precise calculation of the eigenvector derivatives. We will present numerical results obtained by sequential linear programming (SLP), sequential quadratic programming (SQP) and the method of moving asymptotes (MMA) which show that a substantial reduction in total mass of the rotor can be achieved.

A food problem for a predator-prey interaction model

OLEG MAKARENKOV
Department of Mathematics, Voronezh State University
keywords: nonlinear programming, cost analysis, predator-prey interaction mode, periodic solutions

Consider the following predator-prey interaction model

$$\begin{cases} \dot{N}_1 = k_1N_1 - \frac{k_2}{k_0+N_1}N_1N_2 - k_3N_1^2 \\ -\varepsilon a_1F_1(t,N_1,N_2)N_1 - ... - \varepsilon a_nF_n(t,N_1,N_2)N_1, \\ \dot{N}_2 = -k_5N_2 + \frac{k_4}{k_0+N_1}N_1N_2 \\ -\varepsilon b_1F_1(t,N_1,N_2)N_2 - ... - \varepsilon b_nF_n(t,N_1,N_2)N_2, \end{cases}$$

where N_1 and N_2 are the prey and predator species concentrations, F_i is the quantity of the food number i the species eat during the unit time and the coefficients $k_0,...,k_4$, $\varepsilon a_1,...,\varepsilon a_n$, $\varepsilon b_1,...,\varepsilon b_n$ are positive. Assume that the parameters $k_0,...,k_4$ satisfy the condition under which the system () with $\varepsilon = 0$ has a limit cicle $\tilde{N}$ and denote by T it's period. Then, we assume that the functions $F_1,...,F_n$ are T-periodic with respect to the first variable. Finally, we consider $a_1 = 0$ and the parameter $\varepsilon > 0$ small. Introduce the cost function

$$f(a_1,...,a_n,b_1,...,b_n) = (a_1+b_1)c_1 + ... + (a_n+b_n)c_n,$$

where $c_i > 0$ express the price of the food number i. In the present report we solve the following problem: To minimize the function f on the set of such $a_1,...,a_n$ and $b_1,...,b_n$ that the system () has an assimptotically stable T-periodic solution $\tilde{N}_\varepsilon$ and $\tilde{N}_\varepsilon \to \tilde{N}$ geometrically as $\varepsilon \to 0$. The work supported by RFBR, projects 02-01-00189, 02-01-00307 and 03-01-06308.

The progressive addition lens problem : an hybrid approach combining optimization and perturbation techniques

KATIA DEMASEURE
FUNDP
coauthor: Annick Sartenaer
keywords: progressive addition lenses, nonlinear optimization, perturbation tecnhiques

Progressive Addition Lenses (PAL for short) represent the best solution for presbyopia. A PAL has a far vision area with low refractive power in the upper part, and a near vision area with higher optical power in the lower part. It is important for the visual quality of the lens to have smooth transition of optical power across the PAL. Unfortunately, some optical error, know as astigmatism , is unavoidable for this kind of lenses and complicates the design of the PAL. Usually, one tries to get minimal astigmatism at the far and near vision area and on a central zone of progression which connects both areas. The non-avoidable astigmatism has to be reduced as far as possible and to be placed near the boundary of the lens. This talk will first consider the PAL design when spherical coordinates are used in the modelling of the PAL. We will compare the optimization problem and its solution in spherical coordinates with the classical frame using cartesian coordinates. A new approach for solving the PAL problem which combines nonlinear optimization and perturbation techniques will then be proposed. We conclude by testing the computational effectiveness of the new suggested strategies.

TH1-306/33 NONLINEAR PROGRAMMING
PDE-constrained optimization (1)
organizers: Michael Ulbrich and Stefan Ulbrich
chair: Stefan Ulbrich

Optimization of time-dependent partial differential equations

MATTHIAS HEINKENSCHLOSS
Rice University
keywords: dynamic programming, optimal control, nonlinear programming

The size and structure of optimization problems governed by time-dependent partial differential equations (PDEs) makes the direct application of existing optimization algorithms to the fully discretized PDE constrained problem or the adapt ion of optimization methods for ODE constrained problems impractical for realistic problems.

In this talk we discuss some of the issues arising in the optimization of time-dependent PDE constrained optimization problems. We present our solution approach, which is based on an in-between formulation of the infinite dimensional problem, solved using sequential quadratic programing methods.

Optimal design of groundwater remediation systems

CARL KELLEY
North Carolina State University
keywords: optimal design, hydrology, implicit filtering

In this talk we discuss several problems in optimal design of subsurface remediation and flow control systems. The objective functions and constraints are constructed from PDE solvers for the flow and species transport equations. We show how to implement problems using standard production codes, how these codes and the underlying physics present obstacles to the optimization algorithms, and how sampling methods, in particular implicit filtering, can overcome these problems.

The objective functions and constraints in these problems are typically non-smooth in all the design parameters and discontinuous in some of them. We will discuss the physical reasons for these properties and how optimization methods can deal with them and compare the results from several optimization algorithms.

Multilevel and preconditioning approaches for inequality constrained optimization problems governed by PDEs

MICHAEL ULBRICH
Fachbereich Mathematik, Universitaet Hamburg

keywords: optimal control, nonlinear programming, multilevel methods, preconditioning

The numerical solution of PDE-constrained optimization problems requires efficient solvers for linear or nonlinear equations of huge size. These systems are usually structured and sparse, but due to their size they cannot be solved by direct methods. We discuss reformulation approaches and interior-point techniques that are well suited for PDE-constrained optimization problems with inequality constraints. It is shown how these methods can be combined with inexact iterative solvers that are preconditioned by multilevel and other techniques. The proposed methods are applied to the solution of optimization problems in engineering and finance.

TH1-306/34 NONLINEAR PROGRAMMING

Large scale problems I

chair: Trond Steihaug

On the development of a trust-region interior-point method for large-scale nonlinear programs

CRISTINA VILLALOBOS
The University of Texas-Pan American

coauthors: Miguel Argaez, Leticia Velazquez
keywords: interior point method, trust region method, Newton method, primal-dual method

We present a new methodology for solving general nonlinear programs. We propose the use of interior-point methodology, trust-region globalization strategies and the conjugate gradient method to find a solution to large-scale problems. As a central region to guide the iterates to an optimal solution of the problem, we use the notion of the quasi-central path introduced by Argaez and Tapia.

An inexact Newton trust region interior-point algorithm for nonlinear programming problems

JAIME, JR. HERNANDEZ
University of Texas at El Paso

coauthors: Miguel Argaez, Leticia Velazquez
keywords: interior point, conjugate gradient, trust region

We present an algorithm for solving large scale nonlinear programming problems. We use interior-point methodology, a trust region globalization strategy, and the conjugate gradient method with Steihaug's ending conditions. Some preliminary numerical results are presented.

When sparsity counts: optimal direct Jacobian computation

TROND STEIHAUG
University of Bergen

coauthor: Shahadat Hossain
keywords: nonlinear programming, automatic differentiation

When Coleman and More in 1982 analyzed the Curtis-Powell-Read technique to estimate an matrix they showed that this is equivalent to a graph coloring problem. In the same paper they show that the CPR technique is a direct determination method, but they also give an example showing that the CPR technique is not equivant to direct determination. In this paper we characterize optimal direct determination and give an algorithm for computing the minimum number of function evalutions to compute a Jacobian matrix with direct determination.

TH1-306/35 NONLINEAR PROGRAMMING

NLP software - the state of the art II

organizer/chair: Hans D. Mittelmann

The state of the art in software for SDP&SOCP problems

HANS D. MITTELMANN
Arizona State University

keywords: optimization software, conic programming

For the Seventh DIMACS Implementation Challenge in SDP&SOCP we had evaluated all ten submitted codes. The results appeared in early 2003 in Mathematical Programming B. Several of the codes have not been updated since. The others, however, are under development. As part of our ongoing benchmarking effort we are evaluating those, especially on large and/or sparse problems. Several authors have been using our benchmark problems to improve their codes. We will report on the current state.

Functional versus conic optimization: what is the better

ERLING ANDERSEN
MOSEK ApS

keywords: quadratic cone, conic optimization, convex, convex quadratic constraints

Convex optimization problems can be formulated and solved on either functional or conic form. In this talk we will discuss the advantages and disadvantages of the two approaches.

Finally using the software package NOSEK we will present computational results comparing whether convex quadratically constrained optimization problems should be solved in in their traditional functional form or on conic form.

Automated performance analysis in the evaluation of nonlinear programming solvers

ARMIN PRUESSNER
GAMS Development Corp.

coauthor: Hans D. Mittelmann
keywords: performance analysis, automation server, visualization, optimization software

As part of Performance World, we describe an automation server PAVER:

http://www.gamsworld.org/performance/paver

to help facilitate reproducible performance testing and benchmarking of optimization software. Our online server automates the task of performance analysis and visualization, taking into account various performance metrics, including not only robustness and efficiency but also quality of solution. We discuss the tools and the performance metrics used and give benchmark examples using an instance of the COPS test case for nonlinear programming.

TH1-306/36 NONSMOOTH OPTIMIZATION
Bundle-based methods
chair: Marko M. Makela

An infeasible bundle method for nonsmooth convex constrained optimization without a penalty function or a filter

CLAUDIA ALEJANDRA SAGASTIZÁBAL
IMPA
coauthors: Pablo A. Rey, Mikhail Solodov
keywords: bundle methods

Global convergence in constrained optimization algorithms has traditionally been enforced by the use of penalty functions. Recently, the filter strategy has been introduced as an alternative, with the motivation to alleviate the need for estimating a suitable penalty parameter (which is often problematic). In this paper, we demonstrate that the use of a parametrized penalty function in nonsmooth convex optimization can be avoided without using the relatively complex filter methods. In particular, we propose an approach which appears to be more direct and easier to implement, in the sense that it is closer to the well-developed unconstrained bundle methods. Preliminary computational results are also reported.

Large-scale nonsmooth optimization: new limited memory bundle method

MARJO HAARALA
University of Jyvaskyla
keywords: nondifferentiable programming, large scale optimization, bundle methods, limited memory methods

Many practical optimization problems involve nonsmooth (that is, not necessarily differentiable) functions of hundreds or thousands of variables. In such problems, the direct application of smooth gradient-based methods may lead to a failure due to the nonsmooth nature of the problem. On the other hand, none of the current nonsmooth optimization methods is efficient in large-scale settings. In this presentation we introduce a new limited memory variable metric -based bundle method for nonsmooth large-scale optimization.

The new limited memory bundle method uses limited memory approach to calculate the search direction. Thus, the time-consuming quadratic direction finding problems appearing in standard bundle methods need not to be solved. Furthermore, we use only few vectors to represent the variable metric approximation of the Hessian and, thus, we avoid storing and manipulating large matrices as is the case in variable metric bundle methods. These improvements make the limited memory bundle method suitable for large-scale optimization: The number of operations needed for the calculation of the search direction is only linearly dependent on the number of variables while, for example, with variable metric bundle methods this dependence is quadratic. The efficiency of the new method is shown by giving some results from the numerical experiments.

A hybrid of simulated annealing and proximal bundle method for continuous global optimization

MARKO M. MAKELA
University of Jyvaskyla, Department of Mathematical Information Technology
coauthors: Kaisa Miettinen, Heikki Maaranen
keywords: global optimization, hybrid methods, metaheuristics

We introduce several hybrid method for global continuous optimization. They combine simulated annealing and a local proximal bundle method. Traditionally, the simplest hybrid of a global and a local solver is to call the local solver after the global one. This does not necessarily produce good results. Besides, using a gradient-based solver implies that the hybrid can only be applied to differentiable problems. We show several ways how to integrate the local solver as a genuine part of simulated annealing to enable both efficient and reliable solution processes. Using the proximal bundle method as a local solver makes it possible to solve even nondifferentiable problems. We present results of numerical experiments giving evidence of the applicability of the hybrids.

TH1-306/37 CONVEX PROGRAMMING
Robust optimization
organizer/chair: Garud Lyengar

Robust quadratically constrained quadratic programming

GARUD LYENGAR
Columbia University
coauthor: Don Goldfarb
keywords: robust optimization, QCQP

In this talk we will dicsuss robust convex quadratically constrained programs, a subset of the class of robust convex programs introduced by Ben-Tal and Nemirovski. In contrast to this previous work, where it is shown that such problems can be formulated as semidefinite programs, our focus is to identify uncertainty sets that allow this class of problems to be formulated as second-order cone programs. We propose three classes of uncertainty sets that satisfy this criterion and discuss examples from finance, classification, and signal processing where these classes of uncertainty sets are natural.

Robust optimization approach to multi-stage uncertain decision problems

AHARON BEN-TAL
Technion-Israel Institute of technology
keywords: robust optimization, multi-stage decision problems

We use the Robust Optimization(RO) approach to solve multi-stage decision problems with uncertain data. New features of the RO approach are the use of adjustable variables (recourse actions) and the employment of linear decision rules,to obtain comutationally tractable convex programs. The methodology is illustrated by studying a problem in supply-chain management.

Robust discrete optimization and network flows

MELVYN SIM
MIT & NUS Business School
coauthor: Dimitris Bertsimas
keywords: robust optimization, discrete optimization, stochastic optimization

We propose an approach to address data uncertainty for discrete optimization and network flow problems that allows controlling the degree of conservatism of the solution, and is computationally tractable both practically and theoretically. When both the cost coefficients and the data in the constraints of an integer programming problem are subject to uncertainty, we propose a robust integer programming problem of moderately larger size that allows controlling the degree of conservatism of the solution in terms of probabilistic bounds on constraint violation. When only the cost coefficients are subject to uncertainty and the problem is a 0-1 discrete optimization problem on n variables, then we solve the robust counterpart by solving at most $n+1$ instances of the original problem. Thus, the robust counterpart of a polynomially solvable 0-1 discrete optimization problem remains polynomially solvable. We also show that the robust counterpart of

an *NP*-hard α-approximable $0-1$ discrete optimization problem, remains α-approximable. Finally, we propose an algorithm for robust network flows that solves the robust counterpart by solving a polynomial number of nominal problems on a modified network.

TH1-306/38 GLOBAL OPTIMIZATION
Global optimization III
chair: Ivo Nowak

Relaxation of the semicontinuity for marginal functions

VINCENZO SCALZO
Dipartimento di Matematica e Statistica, Università di Napoli

coauthor: Jacqueline Morgan
keywords: value functions, marginal functions, maxinf problems, upper quasicontinuity

Let f be an extented real valued function defined on $X \times Y$, K be a set-valued function from X to Y and let $v_S(x) = \sup_{y\in K(x)} f(x,y)$ and $v_I(x) = \inf_{y\in K(x)} f(x,y)$. In light of the Berge Maximum Theorem, when X and Y are topological spaces, the upper semicontinuity of the function f plays a central role for the upper semicontinuity of the functions v_S and v_I. More recently (see Lignola and Morgan in Optimization (1992) for sequential spaces and in J. Math. Anal. Appl. (1990) for topological spaces), weaker sufficient conditions on the function f have been presented which also guarantee existence results for the MaxSup problem (maximize the function v_S) and the MaxInf problem (maximize the function v_I). Here, with reference to sequential spaces, we consider an other property called sequential upper quasicontinuity and we obtain new existence results for the MaxSup and the MaxInf problems. Among the others, it is shown that sequential upper quasicontinuity cannot be later weaken using the minimal condition for existence of maximum points and that the functions v_S and v_I are sequentially upper quasicontinuous if f is sequentially upper quasicontinuous.

Convex extensions and polyhedral basis

MOHIT TAWARMALANI
Purdue University

keywords: convexification, disjunctive programming, multilinear envelopes, nonlinear programming

We recently developed a theory of convex extensions. In this talk, we demonstrate that along with facial disjunctive programming techniques, a study of convex extensions enables us to constructively determine the convex and concave envelopes of many classes of nonlinear functions. We define a polyhedral basis as a set of convex extensions defined over a disjunctive set. We study conditions under which a polyhedral basis is composed of polynomial functions. Then, we develop polyhedral basis for certain classes of polytopes. Finally, we investigate applications of polyhedral basis in developing lower bounds for many classes of global optimization problems.

Rounding and partitioning heuristics for solving nonconvex minlps

IVO NOWAK
Humboldt University Berlin

coauthors: Hernan Alperin, Stefan Vigerske
keywords: nonconvex programming, convex relaxation, rounding heuristic, mixed integer programming

In this talk, we present solution approaches to nonconvex mixed integer nonlinear programs (MINLPs). First we describe decomposition methods for generating nonlinear convex relaxations and polyhedral relaxations. Both relaxations are constructed via a block-separable reformulation of a given MINLP. Then we present rounding and partitioning heuristics for retrieving solution candidates from a convex relaxation. We report numerical results on instances from the MINLPLib and on an engineering design problem using the recently developed software package LaGO.

TH1-308/11 GENERALIZED CONVEXITY/MONOTONICITY
Generalized convexity IV
organizer: Laura Martein
chair: Nicolas Hadjisavvas

Quasimonotone variational inequalities

NICOLAS HADJISAVVAS
University of the Aegean

coauthor: Didier Aussel
keywords: variational inequality, quasimonotone operator, generalized monotonicity

An existence theorem for the Stampacchia variational inequality for quasimonotone multivalued operators is shown, under very weak conditions. No assumption on the existence of inner points is made. Also, the assumptions of hemicontinuity and compactness of values of the operator are relaxed, even with respect to known theorems on pseudomonotone operators.

Generalized vector variational and quasi-variational inequalities with operator solutions

SANGHO KUM
Department of Mathematics Education/ Chungbuk National University

coauthor: Won Kyu Kim
keywords: variational inequality, monotonicity, fixed point, equilibrium

In a recent paper, Domokos and Kolumban gave an interesting interpretation of variational inequalities (VI) and vector variational inequalities (VVI) in Banach space settings in terms of variational inequalities with operator solutions (in short, OVI). They presented a general version of Yu and Yao in a Banach space as a main application and gave some other applications such as the solvability of variational inequalities defined on Hausdorff topological vector space, and that of variational inequality on $L^\infty(\Omega)$. In this paper, in the spirit of Domokos and Kolumban, we consider a multi-valued version of (OVI), i. e., the case of T being multi-valued, which is called the generalized variational inequalities with operator solutions (simply, GOVI). In addition, we introduce the quasi-version of (OVI) in multi-valued settings, i.e., the case of T and A being multi-valued called the generalized quasi-variational inequalities with operator solutions (simply, GOQVI). Some applications are also provided.

Well-posed vector variational inequalities

ANGELO GUERRAGGIO
Universita' Bocconi

keywords: well-posedness, vector optimization, vector variational inequality, convexity

The notion of well posedness of a scalar minimization problem dates back to J. Hadamard at the beginning of the past century. It has been revisited by A. Tykhonov in the early sixties. Both notions are now fully accepted in the literature and their relevance (as their motivations) is quite evident also because of the implications on the stability of the problem. More recently, by means of Ekeland variational principle, the same notion was linked to variational inequalities. As far as we know, the vector extension is less developed. However some definitions have been proposed for a vector minimization problem (a nice survey is due to J. Loridan) and few comparisons have been made between the definitions itselves and their scalar counterpart. The aim of this talk is to present a generalisation of the scalar results to the vector case. We present two suitable notions of well-posed vector variational inequalities. Moreover, by means of some vector Ekeland variational principle, we prove the relations with well-posedness of the primitive vector optimization problem. Some examples are provided to illustrate the concepts.

TH1-308/12 STOCHASTIC PROGRAMMING

Dynamic stochastic programming: theory and applications

organizer/chair: Lisa Korf

Dynamic stochastic programming: models, information structures, and duality

LISA KORF
Department of Mathematics, University of Washington

keywords: stochastic optimal control, dynamics, scenario tree, structure of information

Dynamic stochastic programming models encompass discrete time stochastic optimal control problems. To be comprehensive, these models ought to include formulations in which the controller has only partial state information, or may respond to information exogenous to the system state. In the stochastic programming setting, this would require the consideration of scenario trees in which each time stage contains not only nodes, but also the description of how information evolves withi a time stage. A general stochastic programming formulation of stochastic optimal control problems is presented that encompasses this enhanced information structure, and a general duality theory is developed for these problems.

Risk control of dynamic investment models

LEONARD MACLEAN
Dalhousie University
coauthors: Yonggan Zhao, William Ziemba

keywords: investment, risk, stochastic, control

The risk inherent in the accumulation of investment capital in a dynamic, stochastic capital market depends on the true returns distribution of risky assets, the accuracy of estimated returns, and the investment strategy. This paper considers risk control in a decision model with Value-at-Risk and Conditional Value-at-Risk constraints. The model is supplemented with control limits, which are used to signal misdirected parameter estimates,and correspondingly determine times for portfolio rebalancing. Optimal strategies and control limits are determined for a geometric Brownian motion asset pricing model with random parameters. The approaches to risk control are applied to the fundamental problem of investment in stocks, bonds, and cash over time.

Planning of supply chains under uncertainty: interworking of stochastic programming and simulation

ALEXEI GAIVORONSKI
Norwegian University of Science and Technology

keywords: supply chain management, uncertainty, stochastic programming, production planning

We consider the problem of supply chain design and related production decision for an enterprise which is engaged in production of components for a complex product. We are specifically interested in the case when demand for the product is uncertain. Stochastic programming approach based on conbination of simulation and optimization is considered and numerical experiments are reported with the use of Stochastic Quasigradient methods

TH1-308/13 STOCHASTIC PROGRAMMING

Stochastic programming: a panel discussion

organizer/chair: Gautam Mitra

panel members: Alan King, Julia Higle, Robert Fourer, Maarten van der Vlerk, H. Gassmann, A. Felt, S. Ahmed and Gautam Mitra.

The purpose of the panel will be to:

1. Identify the need for benchmarks models for Stochastic programming and Stochastic integer programming.
2. Discuss processes for collecting and adding to the bench mark library and maintaining a repository.
3. Revisit the SMPS representation standard for Stochastic programming models.
4. Discuss the role of XML and data exchange across the net.
5. Extensions to the Algebraic modelling languages, such as AMPL, GAMS, MPL, for Stochastic programming.
6. Process for collecting the models from diverse industrial domain.

Structure of session:

- Short presentation by three to four plane members (30-45 minutes). This will possibly cover the items 1...6 above.
- Open forum and discussions (30-45 minutes).
- Follow up action plan.
- Any other business.

TH1-308/T1 FINANCE AND ECONOMICS

Combinatorial auctions II

organizer/chair: Susan Powell

Secure multi-agent dynamic programming and its application to combinatorial auction

MAKOTO YOKOO
NTT

keywords: dynamic programming, information security, combinatorial auction, multi-agent systems

Combinatorial auctions have recently attracted the interests of many researchers due to their promising applications such as the spectrum auctions recently held by the FCC. In a combinatorial auction, multiple items with interdependent values are sold simultaneously and bidders are allowed to bid on any combination of items.

This paper presents a method for implementing several secure combinatorial auction protocols based on our newly developed secure dynamic programming protocol. Dynamic programming is a very effective, widely used technique for tackling various combinatorial optimization problems, including several types of combinatorial auctions. We developed two alternative methods for implementing a secure dynamic programming protocol. One method utilizes homomorphic encryption and the other method utilizes secret sharing techniques. Our secure dynamic programming protocol can obtain the optimal solution of a combinatorial optimization problem, i.e., result of a combinatorial auction, without revealing the inputs of the problem, i.e., bidding prices. We discuss the application of the method to several combinatorial auctions, i.e., multiple-unit single-item auctions, linear-goods auctions, and general combinatorial auctions.

Winner determination in combinatorial auctions: Lagrangean heuristic for a generalization of the WJISP

THOMAS ELENDNER
Inst. for Business Administration, University of Kiel

keywords: winner determination, combinatorial auctions, scheduling

We present an allocation problem an point out that combinatorial auctions are well–suited for solving it. We show that the winner determination problem can be modelled as a generalization of the Weighted Job Interval Scheduling Problem. Here, positive–weighted jobs with release and due dates compete for time–slots. The generalization is based on budgets which the bidders can additionally submit. Since the WJISP is proven to be np–hard we suggest a Lagrangean Heuristic for obtaining upper and lower bounds and give empirical results.

Branch-and-price and new test-problems for spectrum auctions

SVEN DE VRIES
Zentrum Mathematik, TU Muenchen
coauthors: Oktay Gunluk, Laszlo Ladanyi

keywords: spectrum auctions, combinatorial auctions, branch-and-price

When combinatorial bidding is permitted in Spectrum Auctions, such as the upcoming FCC auction #31, the resulting winner-determination problem can be computationally challenging. We present a branch-and-price algorithm based on a set-packing formulation originally proposed by Dietrich and Forrest (2002). This formulation has a variable for every possible combination of winning bids for each bidder. Our algorithm exploits the structure of the XOR-of-OR-bidding-language used by the FCC. We also present a new methodology to produce realistic test problems based on the round-by-round-results of FCC auction #4. We generate 2639 test problems which involve 99 items and are substantially larger than most of the previously used benchmark problems. Since there are no real-life test problems for combinatorial spectrum auctions with the XOR-of-OR language, we used these test problems to observe the computational behavior of our algorithm. Our algorithm can solve all but one test problems within ten minutes, appears to be very robust and compares favorably to the natural formulation solved using a commercial optimization package.

TH1-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Topics in mathematical programs with equilibrium constraints

organizers: Angel-Victor DeMiguel and Michael Paul Friedlander
chair: Michael Paul Friedlander

A superlinearly convergent interior-point method for MPECs

ANGEL-VICTOR DEMIGUEL
London Business School
coauthors: Michael Paul Friedlander, Francisco J. Nogales, Stefan Scholtes

keywords: MPEC, interior point method, convergence

We propose a new interior-point method for mathematical programs with equilibrium constraints (MPECs). At each iteration, a single log-barrier Newton step is derived from a nondegenerate relaxation of the MPEC. The barrier and relaxation parameters are updated simultaneously to maintain a nonempty strict interior of the relaxed MPEC at each iteration and in the limit. We discuss the convergence properties of the proposed algorithm.

Algorithms for solving EPECs

CHE-LIN SU
Stanford University

keywords: NCP, MPEC, EPEC

An equilibrium problem with equilibrium constraints (EPEC) is a mathematical program to find an equilibrium point which simultaneously solves several MPECs, each of which is parameterized by decision variables of other MPECs. EPECs often arise from noncooperative multi-leader-follower games where each leader is solving a Stackelberg game formulated as an MPEC. In this talk, we propose a new algorithm for solving EPECs by solving a sequence of nonlinear complementarity problems. Numerical results on randomly generated EPECs will be presented.

Local properties of MPCC methods

DANIEL RALPH
Cambridge University
coauthor: Stephen Wright

keywords: complementarity constraints, nonlinear programming, constraint identification

A regularisation scheme for MPCC, recently analysed by Scholtes, approximates the original problem by a nonlinear program parametrized by a nonnegative scalar t. The intent is to find B-stationary points that are local solutions of the MPCC by solving these regularized nonlinear programs for a decreasing sequence of t values. In this talk we examine several issues related to the regularization approach, including the existence of minimizers to the regularized problem near a B-stationary point of the MPCC, variants on the definition of the regularized nonlinear program, and identification of the zero components of the two complementary vectors by inspection of the solution of a regularized nonlinear program for small nonzero values of t ("finite identification").

TH1-308/T3 TELECOMMUNICATION NETWORK DESIGN

Integer programming for the design of ring networks

chair: Rosemary T. Berger

A column generation approach for a network design problem

IRENE LOISEAU
Depto. de Computación, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires
coauthors: Nelson Maculan, Gerard Plateau

keywords: column generation, integer programming, network design

We present a column generation method for a problem arising in ring architecture networks, based in a mathematical model presented in previous work by Lisser, Maculan, Passini and Brito. Studies about network dimensioning and survivability focused mainly on ring based and mesh based architectures. Most works treated both models separately. But several companies deploy networks based on rings, and at the same time they have meshed networks in operation or being built. In large metropolitan centers it is easy to identify clusters of nodes generating big data traffic among themselves If the area under study in already served by a meshed network it is possible to deal with the growth of traffic demands by superimposing self-healing rings on the existing mesh. The mesh part of the problem, can be modeled as a capacitated multicommodity flow problem with expandable arc capacities. The other way the flow can circulate on the net is on an additional net of rings where only flow between nodes on each ring is allowed. The formulation of the problem as integer linear programming problem includes a column associated with each ring. A procedure for generating these columns is proposed.

An exact algorithm for optimal routing and wavelength assignment in ring networks

HERNAN ABELEDO
George Washington University

coauthor: Rudy Kusnadi Sultana
keywords: integer programming

In this routing and wavelength assignment problem, traffic demands on a ring network must be routed on colored paths, where paths that share an edge must be colored differently and each colored path can carry one unit of traffic. Colors here represent wavelengths in an all-optical communication network based on wavelength division multiplexing (WDM). The optimization problem seeks to minimize the number of required wavelengths and is known to be NP-Hard. Our approach has two phases. The first one solves a standard network design problem that seeks a set of routes that minimizes the necessary capacity of the ring edges. The second phase determines an optimal coloring for the paths selected in the first stage. Computational results show that this approach yields optimal solutions in almost all cases. In the cases where a gap persists we use constraint aggregation to solve the problem to proven optimality.

Designing stacks of interconnected bidirectional sonet rings

ROSEMARY T. BERGER
Industrial and Systems Engineering, Lehigh University

coauthor: Karen A. Kelly
keywords: networks/graphs applications, integer programming, communications

The problem of designing stacks of interconnected bidirectional SONET rings arises in the capacity planning of telecommunications networks. Given a topology of interconnected rings and a set of demands between pairs of nodes, the objective of the problem is to determine how to route each demand and where to place add/drop multiplexers (ADMs) on each stack of each ring in such a way as to minimize the total number of ADMs required. Two linear integer programming formulations are presented. The formulations are extensions of path-based and edge-based formulations for the multi-commodity flow problem. A set of constraints that strengthens the linear programming relaxation bound is identified. Solution algorithms to solve the formulations are described, and computational results comparing the two formulations are reported. Future research directions are discussed.

TH1-341/21 INTERIOR POINT ALGORITHMS
Large scale problems
chair: Michael Alan Saunders

Smoothed analysis of condition numbers of linear programs

SHANGHUA TENG
Boston University

coauthors: John Dunagan, Daniel Spielman
keywords: smoothed analysis, linear programming, interior point algorithms

For any linear program, we show that the slight random perturbation of that linear program has small condition number with high probability. In particular, we prove that the expectation of the log of the condition number of any appropriately scaled linear program subject to a Gaussian perturbation of variance sigma squared is at most O(log nd/sigma) with high probability. By combining this result with a recent result of Spielman and Teng on the smoothed complexity of the termination phase of an interior-point method, we show that the smoothed complexity of an interior-point algorithm for linear programming is $O(m^3 \log(m/\sigma))$. In contrast, the best known bound on the worst-case complexity of linear programming is $O(m^3 L)$, where L could be as large as m.

The smoothed complexity of an algorithm is defined to be the maximum over its inputs of the expected running time of the algorithm under slight perturbations of that input. It has been proposed as an alternative to worst-case and average-case analyses, in an attempt to explaining the good practical performance many algorithms. The result of this talk may help explain the observed fast convergence of the interior-point algorithms.

A trust region inexact Newton interior-point method for solving large scale unconstrained minimization problems

LETICIA VELAZQUEZ
University of Texas at El Paso

coauthors: Miguel Argaez, Roberto Saenz
keywords: unconstrained minimization, interior point method

We present a trust region inexact Newton interior-point algorithm for solving unconstrained minimization problems. We propose to solve the linear system using conjugate gradient method with a termination test proposed by Steihaug. Some preliminary numerical results on large scale problems are reported.

Interior-point solution of large-scale entropy maximization problems

MICHAEL ALAN SAUNDERS
Stanford University

coauthor: John Tomlin
keywords: convex optimization, interior point method, entropy

We describe the application of a Primal-Dual Separable Convex Objective (PDSCO) method to a class of extremely large entropy maximization problems. Separability allows the Newton directions to be computed from (even larger) least-squares problems by the iterative solver LSQR. With the entropy objective, LSQR and PDSCO converge remarkably rapidly.

TH1-341/22 LOGISTICS AND TRANSPORTATION
Railways / public transportation
organizer/chair: Leo Kroon

Rolling stock circulations for passenger trains

LEO KROON
Netherlands Railways

coauthor: Lex Schrijver
keywords: railway systems, rolling stock circulation, public transportation, optimization

In this presentation, we describe optimization models that can be used to find high quality rolling stock circulations for passenger trains that may consist of train units of different types. Performance indicators for evaluating these rolling stock circulations are: (i) the quality of the matching of demand and supply for capacity per trip, (ii) the total number of carriage kilometers, and (iii) the number of shunting movements. Since the trains may consist of train units of different types, the positions of the train units in the trains need to be modeled explicitly. In this way, infeasible shunting movements can be excluded a priori, but this also leads to huge optimization models. Computational results are presented, based on several real-life case studies from Netherlands Railways.

Multiple-depot integrated vehicle and crew scheduling

DENNIS HUISMAN
Econometric Institute, Erasmus University Rotterdam
coauthors: Richard Freling, Albert Wagelmans
keywords: vehicle scheduling, crew scheduling, column generation, Lagrangian relaxation

This paper presents two different models and algorithms for integrated vehicle and crew scheduling in the multiple-depot case. The algorithms are both based on a combination of column generation and Lagrangian relaxation. Furthermore, we compare those integrated approaches with each other and with the traditional sequential one on random generated as well as real-world data instances for a suburban/extra-urban mass transit system. To simulate such a transit system, we propose a new way of generating randomly data instances such that their properties are the same as for our real-world instances.

Shunting passenger train units

RAMON LENTINK
Erasmus University Rotterdam
coauthor: Leo Kroon
keywords: railway transportation

In this talk, we introduce Train Unit Shunting Problem (TUSP). This problem occurs when train units are temporarily not necessary to operate a given timetable. The problem is to park the superfluous train units at a shuntyard as efficiently as possible. One element of this problem is the matching of arriving train units to departing train units. Furthermore, for each train unit, we need to find routes from it's arrival platform to it's shunt track, and from this shunt track to it's departure platform. Moreover, deciding at which shunt track a unit will be parked is a major part of the problem. Finally, there are several processes that take place during the night, such as cleaning the train units. These processes might require moving train units to dedicated tracks and therefore they can complicate the problem considerably. In this talk, we will discuss the elements of the problem and discuss an application of our solution approach to real life data of a station in the Netherlands.

TH1-341/23 APPROXIMATION ALGORITHMS

Algorithms for routing and partitioning

chair: Kimmo Tapio Nieminen

Approximation algorithms for partitioning a graph into connected subgraphs

YOSHIKO WAKABAYASHI
University of São Paulo
coauthor: Liliane R. Benning Salgado
keywords: approximation algorithms, graph partitioning, connectivity

Let $G = (V, E)$ be a connected graph with a weight function $w : V \to \mathbb{Z}_+$, and let p, q be positive integers. For $X \subseteq V$, let $w(X)$ denote the sum of the weights of the vertices in X. We consider the following two NP-hard problems on G: the *max balanced connected q-partition problem* and the *max connected* (p/q)-*partition problem*. In the first, defined for $q \geq 2$, we are interested in finding a q-partition $P = (V_1, V_2, \ldots, V_q)$ of V such that $G[V_i]$ is connected $(1 \leq i \leq q)$ and P maximizes $\min\{w(V_i) : 1 \leq i \leq q\}$. In the second, defined for $1 \leq p < q$, we want to find a partition (V_1, V_2) of V such that $G[V_1]$ and $G[V_2]$ are connected and $w(V_1)$ is maximum subject to $w(V_1) \leq (p/q)w(V)$. These two problems are equivalent when $q = 2$; for this case approximation algorithms have appeared in the literature. We consider this more general setting and present approximation algorithms with performance ratio at most 2. We show that the ratio decreases as the connectivity of G increases.

The multi-layer constrained via minimization problem: formulation andpolyhedral issues

PIERRE FOUILHOUX
Université Blaise Pascal - Clermont-Ferrand II
coauthor: Ali Ridha Mahjoub
keywords: VLSI design, bipartite induced subgraph, polytope, branch-and-cut

The multi-layer constrained via minimization problem can be seen as the last step in the design of integrated circuits and printed circuit boards. It consists in positionning wires on a card so that no two wire nets cross. For this, we should use the different card layers which can be drilled for connecting wires that are on different layers. We call these holes vias, and, for fiability reasons, we want to place a minimum number of vias. We have shown that the constrained via minimization on k layers can be reduced to the k-partite induced subgraph problem in an appropriate graph G. For the particular case when k equals 2, we study the facial structure of the bipartite (2-partite) induced subgraph polytope P(G) associated with the solutions of that problem. We describe several classes of valid inequalities for this polytope and give necessary and sufficient conditions for these inequalities to be facet defining. We also describe some lifting procedures and discuss separation heuristics. We finally describe a Branch-and-Cut algorithm based on these results and present some computational results for both the bipartite induced subgraph and the constrained via minimization problem.

A genetic algorithm for the vehicle routing problem

KIMMO TAPIO NIEMINEN
Helsinki University of Technology
coauthor: Istvan Maros
keywords: genetic algorithm, vehicle routing

In this study we present a new genetic algorithm for the capacitated vehicle routing problem (CVRP) in which a fixed fleet of delivery vehicles of uniform capacity, a common depot and several geographically scattered customer demands are given and the problem is to find the set of routes with overall minimum route cost which service all the demands. In a practical application we noticed that embedded travelling salesperson problems (TSP) problems involves less than 11 locations. It justifies the use of an exact TSP algorithm. In this way we can substantially reduced the search space of the CVRP problem. The solution space is reduced significantly because during the evolutionary process we need to focus on finding good subsets instead of ordered subsets of the set of all customers. Experimental results of this method are encouraging.

TH1-321/053 PRODUCTION AND SCHEDULING

Scheduling with complex constraints

chair: Chris Potts

A time staged linear programming model for multi-site aggregate production planning problems

YUE WU
London School of Economics
coauthor: H.Paul Williams
keywords: aggregate production planning, time stage linear programming, supply chain management

This paper is concerned with the problem of aggregate production planning (APP) for a multinational fashion company in China. The multi-site production planning problem considers the production loading plans among manufacturing factories subject to certain restrictions, such as production import/export quotas imposed by regulatory requirements of different nations, the use of manufacturing factories/locations with regard to customers' preferences, as well as production capacity, workforce level, storage space and resource conditions of the factories. A time-stage linear programming model is developed to minimize the total cost, while satisfying the different production constraints. To enhance the practical implications of the proposed model, different managerial production loading plans are evaluated according to changes in future production policy and situation. Numerical results demonstrate the effectiveness of the developed model.

Scheduling to simultaneously optimize two objectives

CLIFFORD STEIN
Columbia University

coauthors: April Rasala, Eric Torng, Pratchawat Uthaisombut
keywords: multiple criteria, approximation algorithms

Scheduling algorithms are designed to optimize many different optimality criteria in a wide variety of scheduling models. Unfortunately, an algorithm that works well for one scheduling problem/objective may perform poorly on a different scheduling problem/objective.

We give very general results about the existence of schedules which simultaneously minimize two criteria. We will focus mainly on results that apply to almost any scheduling environment, and apply to all pairs of metrics in which the first metric is one of maximum flow time, makespan, or maximum lateness and the second metric is one of average flow time, average completion time, average lateness, number of on-time jobs. We will show that for almost all such pairs of metrics there exist schedules which are simultaneously close to optimal for both metrics.

We will also discuss algorithms for simultaneously optimizing two metrics.

Rescheduling for new orders

CHRIS POTTS
Faculty of Mathematical Studies, University of Southampton

coauthor: Nicholas G. Hall
keywords: scheduling, single machine, disruption

This paper considers scheduling problems where a set of original jobs has already been scheduled to minimize some cost objective, when a new set of jobs arrives and creates a disruption. The decision maker needs to insert the new jobs into the existing schedule without excessively disrupting it. Two classes of models are considered. First, we minimize the scheduling cost of all the jobs, subject to a limit on the disruption caused to the original schedule, where this disruption is measured in various ways. In the second class a total cost objective, which includes both the original cost measure and the cost of disruption, is minimized. For both classes and various costs based on classical scheduling objectives, and for almost all problems, we provide either an efficient algorithm or a proof that such an algorithm is unlikely to exist. We also show how to extend both classes of models to deal with multiple disruptions in the form of repeated arrivals of new jobs. Our work refocuses the extensive literature on scheduling models towards issues of rescheduling which are important because of the frequency with which disruptions occur in manufacturing practice.

TH1-321/033 MULTICRITERIA OPTIMIZATION

Planning by multicriteria optimization

chair: Alexander Scherrer

An MCDM approach to portfolio optimization

KATHRIN KLAMROTH
Institute of Applied Mathematics, University of Erlangen-Nuremberg

coauthors: Matthias Ehrgott, Christian Schwehm
keywords: portfolio, multiple criteria, utility function, metaheuristics

We propose a model for portfolio optimization extending the Markowitz mean-variance model. Based on a case study in cooperation with Standard & Poor's we use five specific objective functions related to risk and return and allow the consideration of individual preferences through the construction of decision-maker specific utility functions. Numerical results using customized local search, simulated annealing, tabu search and genetic algorithm heuristics show that good solutions can be obtained quickly for problems of practically relevant size.

Optimization of debt management in uncertainty by algorithms on graph

GANNA SHYSHKANOVA
Zaporizhzhya National Technical University

keywords: decision analysis, multiple criteria, uncertainty, graphs

Multicriteria model of interchange debts repayment is considered. The mathematical formulation of the problem is caused by existing of crises of interchange non-payment in Ukraine.

Let's consider weighed oriented graph $G = \{S;U\}$. $S = \{S_1, \ldots, S_n\}$ is set of graph nodes – enterprises. The weight vector (debts values) is given on set U directed lines of orgraph. It is necessary to distribute debts among the given objects to discharge maximally the debts by transferring of some debts units through m nodes on a contour. The vector criterion function is given: $f(x) = (f_1(x), \ldots, f_5(x))$. Five criteria are proposed with its economic interpretation.

The optimization algorithms are constructed for each criterion and for two-criteria problem. The lexicographic method of multicriteria choice is applied for the problem decision in uncertainty. Estimations of the alternatives $j = 1, J$ by criteria f_i is function of uncertainty preference relation, when the criterion approaches to a maximum: $\mu_{f_{ij}}(x) = f_{ij}/\sup_j(f_{ij})$. Uncertainty information is accounted by consideration of nature conditions – bankruptcy or sudden increase of depts. The solution can also be considered with use of separating function containing potentials with weak singularity. Calculation method of the potential is also developed. Computer programs on the algorithms are made in VB.

Intensity modulated radiation therapy - a multicriteria optimization problem

ALEXANDER SCHERRER
Fraunhofer Institute for Industrial Mathematics

coauthors: Karl-Heinz Kuefer, Michael Monz, Fernando Alonso, Thomas Bortfeld, Christian Thieke
keywords: Pareto domain representation, hierarchical clustering, adaptive problem approximation, multicriteria decision support

In oncological intensity modulated radiation therapy, inverse treatment planning strives for ideal treatment plans with sufficiently high doses in the tumour and ideally low doses in the organs at risk. In general, there are no intensity profiles to realize such dose distributions, hence acceptable compromises have to be found. We model this as a convex multicriteria optimization problem, where the criteria are defined as relative deviations from the ideal doses. A representative set of several hundred clinically meaningful Pareto optimal solutions is then computed and

stored in a database, in which the physician, supported by a navigation tool, can search for a suitable treatment plan. The discrete problem formulations are large scale, but the use of a combined hierarchical clustering and local refinement strategy yields adaptive problem approximations of decisively reduced size and thus acceptably small computation times. Numerical experiments on real clinical data showed, that the problems can then be exactly solved on the basis of adapted approximations with 5-10% of the original size and the computation of the whole database requires approximately 2 hours. The talk provides a generalized mathematical embedding of the problem, gives detailed information about computational complexity and presents numerical examples.

TH1-321/133 LINEAR PROGRAMMING
Aspects of linear programming
chair: Vincent Guigues

Distance to ill-posedness for linear optimization problems: distance to insolvability

F.Javier Toledo-Melero
Operations Research Center/Miguel Hernández University
coauthors: M. J. Cánovas, M. A. López, J. Parra
keywords: distance to insolvability

This talk is concerned with the parameter space of all the linear optimization problems, in the n-dimensional Euclidean space, whose constraint systems are indexed with a fixed and arbitrary index set. In this context, the boundary of the set of solvable (resp. bounded) problems may be considered as the set of ill-posed problems. In a first stage, the paper shows that, both, the boundary of the set of solvable problems and the one of bounded problems coincide. The second stage consists of characterizing the problems in this boundary. The paper also provides a formula in terms of certain subsets of R and R^{n+1} for the distance to this boundary, provided that the nominal problem is solvable. The remaining case is also considered; lower bounds for the aimed distance are provided, and different examples show the difficulties underlying this analysis. The formula for the distance to insolvability consists of the minimum of two ingredients; the first one is the distance to infeasibility, whereas the other ingredient turns out to be the 'distance to ill-posedness' of the dual problem. This second ingredient can be also used for finding balls, centered on the origin, containing the optimal set or certain lower level sets, which constitute key ingredients in certain Lipschitz constant for the optimal value function obtained in the paper.

Gaussian elimination as a computational paradigm

Etienne Loute
CORE/UCL
keywords: parallel programming, large scale linear programming, decomposition algorithms, Cholesky factorization

An abstract view of the symmetric gaussian elimination is presented. Problems are viewed as an assembly of computational entities whose interdependence is modeled by a graph. An algorithmic transformation on the entities which can be associated with vertex removal, is assumed to exist. The elimination tree of the symmetric gaussian elimination figures the order in which these transformations are applied and captures any potential parallelism. The inherently sequential part of the computational effort depends on the height of the tree. The paradigm is illustrated by block structured LP problems with nested decomposition and basis factorization approaches, problems of blocked symmetric and unsymmetric systems of linear equations, with respectively blocked Cholesky factorization and blocked gaussian elimination. Contributions are: demonstration of the paradigm expressive power through graph concepts (eliminations sets, elimination chains, etc.); emphasis on patterns of similarity in the use of the graph concepts (with connections between nested decomposition and blocked basic factorization for the revised simplex) and finally an effective parallelization tool for blocked Cholesky factorization of matrices arising in time phased or dynamic LP models solved by interior point algorithms.

Application of robust counterpart technique to production management

Vincent Guigues
IMAG-LMC
keywords: uncertain linear programs, robust optimization, stochastic programming, AARC

The problem of production management can be often cast in the form of linear program with uncertain parameters. Typically, such problems are treated in the framework of multi-step stochastic programming. Recently, a new robust counterpart (RC) approach has been proposed in the literature, in which the decisions are optimized for the worst realizations of problem parameters. However, an application of the RC technique often results in very conservative solutions. To tackle this drawback, an adjustable robust counterpart (ARC) approach has been proposed in [1]. In ARC, some decision variables are allowed to depend on past values of uncertain parameters. A restricted version of ARC, introduced in [1], is the affinely adjustable robust counterpart (AARC). The implementation of robust programs relies on the description of parameter uncertainty sets, which can be defined using the a priori information or available past observations of problem parameters. In this paper, we consider an application of RC and AARC methodology to the problem of annual electricity production management and gas distribution management in France. We compare the quality of robust solutions obtained by polyhedral or ellipsoidal uncertainty sets which are estimated using historical data. [1] Ben-Tal, Goryashko, Guslitzer, Nemirovski. Adjustable robust solutions of uncertain linear programs.

TH2-302/41 COMBINATORIAL OPTIMIZATION

Computational methods for graph-coloring III

organizer/chair: Michael Trick

Lightpath coloring in all-optical networks

ARIE M.C.A. KOSTER
Zuse Institute Berlin (ZIB)

coauthor: Adrian Zymolka
keywords: communications, networks/graphs applications, integer programming

In optical telecommunication networks, wavelength division multiplexing (WDM) allows for the efficient usage of fibers by transmitting optical signals in parallel on different wavelengths. Optical Cross Connects provide full optical switching in the nodes. This enables ongoing optical channels across several links, so-called lightpaths. A lightpath is a path together with a wavelength associated to each of its links. At a node the wavelength of operation can be exchanged at the cost of a wavelength converter. The wavelength assignment problem consists in the conflict-free allocation of the available wavelengths to a set of lightpaths with a minimum number of converters.

In this talk, we discuss this generalized coloring problem and the relation with both vertex and edge coloring. We present integer programming formulations for the minimum converter wavelength assignment problem and discuss their properties. For the most promising formulation, we present a column generation algorithm to obtain good assignments.

Hybrid local search on two multicolouring models

STEVEN PRESTWICH
Cork Constraint Computation Centre

keywords: heuristics, stochastic

This paper describes a hybrid local search approach to pure and bandwidth multicolouring problems. It compares two models of multicolouring: a 0/1 integer linear program, and a binary constraint satisfaction model derived by transforming multicolouring problems to colouring problems. The latter approach yields smaller models and competitive results.

TH2-302/42 COMBINATORIAL OPTIMIZATION

Combinatorial optimization VIII

chair: Sonoko Moriyama

Reconstructing (0,1)-matrices using Lagrangean decomposition

TRULS FLATBERG
Department of Informatics, University of Oslo

coauthor: Geir Dahl
keywords: integer programming, discrete tomography

We consider a variant of the NP-hard problem of reconstructing hv-convex (0,1)-matrices from known row and column sums. Instead of requiring the ones to occur consecutively in each row and column, we maximize the number of neighboring ones. This is reformulated as an integer programming problem. A solution method based on variable splitting is proposed and tested with good results on moderately sized test problems.

A new class of matrices for half-integrality

BALAZS KOTNYEK
INRIA

coauthor: Gautam Appa
keywords: networks/graphs, matrices, generalized networks

We present a class of matrices, called binet matrices, that ensure half-integral optimal solutions. They furnish a direct generalisation of totally unimodular network matrices and arise from the node-edge incidence matrices of bidirected graphs in the same way as the network matrices do from directed graphs. Network matrices are shown to be a special case of binet matrices, as are the two important non-network but totally unimodular matrices. We discuss ways in which binet matrices preserve the advantages of network matrices, and provide theorems revealing the structure of these matrices. Connections are made to signed graphs, monotone inequalities and subspaces with well-scaled frames respectively. Finally, for the LP or IP problem defined over a binet constraint matrix, we provide adaptations of algorithms for generalised networks and matching as well as a proof that the strong Chvatal rank of the relevant polytope is one.

Shellability of simplicial complexes and optimization in acyclic orientations

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coauthor: Masahiro Hachimori
keywords: simplicial complex, shellability, acyclic orientation

Shellability is one of basic properties in the field of topological and geometric combinatorics, and it has been studied extensively by many researchers until today. However, it is hard to decide whether a given simplicial complex is shellable or not. Deciding shellability of a simplicial complex is one of difficult problems which are unknown to be solved in polynomial time or not. Shellability is a concept asking whether a simplicial complex has a shelling or not, where a shelling is a total ordering $F_1 < F_2 < \cdots < F_t$ of the facets satisfying that $(F_1 \cup \cdots \cup F_{k-1}) \cap F_k$ is a pure $(\dim F_k - 1)$-dimensional simplicial complex for every $2 \leq k \leq t$. Instead of using such kind of total ordering, we characterize the shellability of simplicial complexes in terms of acyclic orientations of the Hasse diagram of their face posets. We show that shellability is described by a problem of minimization of an objective function among acyclic orientations satisfying some conditions. We also show that this characterization gives a simple integer programming type formulation of shellability.

TH2-302/44 COMBINATORIAL OPTIMIZATION

Paths in graphs

chair: L. Sunil Chandran

NP-hardness of some maximum edge-disjoint paths problem

EUGENE BARSKY
NACE(Negev Academic College of Engineering)

coauthor: Ilani Hagai
keywords: edge-disjoint paths

Given a graph $G = (V, E)$, a set of terminals $T \subseteq V$ and a demand graph $H = (T, F)$, we call a path in G an H-path if its ends are adjacent terminals in H. We prove that if H is fixed and has 3 intersecting maximal stable sets , A , B , C , such that $A \cap B \neq A \cap C$ then, the problem of finding maximum number of edge-disjoint H-paths in an Eulerian graph G is NP-Hard.

Two edge-disjoint hop-constrained paths and polyhedra

DAVID HUYGENS
Université Libre de Bruxelles

coauthors: Ali Ridha Mahjoub, Pierre Pesneau
keywords: survivable network, edge-disjoint paths, hop-constraints, polyhedron

Given a graph G with distinguished nodes s and t, a cost on each edge of G, and a fixed integer $L \geq 2$, the Two edge-disjoint Hop-constrained Paths Problem (THPP for short) consists in finding a minimum cost subgraph such that, between s and t, there exist at least two edge-disjoint paths of length at most L. In this talk, we consider the problem from a polyhedral point of view. We give an integer programming formulation for the problem and discuss the associated polytope, $P(G,L)$, when $L = 2,3$. In particular, we show that in this case the linear relaxation of $P(G,L)$, $Q(G,L)$, given by the trivial, the st-cut, and the so-called L-path-cut inequalities, is integral. As a consequence, we obtain a polynomial time cutting plane algorithm for the problem when $L = 2,3$. We also give necessary and sufficient conditions for these inequalities to define facets of $P(G,L)$ for $L \geq 2$. We finally investigate the dominant of $P(G,L)$ and give a complete description of this polyhedron for $L \geq 2$, when $P(G,L) = Q(G,L)$.

Isoperimetric inequalities and the width parameters of graphs

L. Sunil Chandran
Max Planck Institute for Informatik

keywords: graph theory, treewidth, path width, hypercube

We relate the isoperimetric inequalities with many width parameters of graphs: treewidth, pathwidth and the carving width. Using these relations, we deduce 1. A lower bound for the treewidth in terms of girth and average degree 2. The exact values of the pathwidth and carving width of the d–dimensional hypercube, H_d 3. That treewidth $(H_d) = \Theta\left(\frac{2^d}{\sqrt{d}}\right)$.

Moreover we study these parameters in the case of a generalization of hypercube, namely the Hamming graphs.

TH2-302/45 INTEGER AND MIXED INTEGER PROGRAMMING

Generalized assignment

chair: Alberto Ceselli

An LP-based heuristic procedure for the generalized assignment problem with special ordered sets

John Wilson
Loughborough University

coauthor: Alan French

keywords: assignment, generalized assignment, heuristics, special ordered sets

The generalized assignment problem with special ordered sets (GAPS2), is the problem of allocating a set of jobs to a set of machines, where each job must be assigned to a machine, or shared between two adjacent machines, and there are constraints on the availability of resources for job allocation. For reasonably large values of m and n the NP-hard combinatorial problem GAPS2 becomes intractable for standard mathematical programming software, hence there is a need for heuristic algorithms to solve such problems. It will be shown how an LP-based heuristic developed previously for the well-established generalized assignment problem can be modified and extended to solve GAPS2. Encouraging results, in terms of speed and accuracy, in particular when compared to an existing heuristic for GAPS2, are described.

Cut-and-branch for the generalized assignment problem

Andreas Drexl
University of Kiel

coauthor: Andreas Klose

keywords: generalized assignment problem, extended cover inequalities, cut and branch

The generalized assignment problem (GAP) examines the maximum profit assignment of jobs to agents such that each job is assigned to precisely one agent subject to capacity restrictions on the agents. The GAP has many applications and several algorithms have been proposed for solving this NP-hard optimization problem. Recently, Gabrel and Minoux (2002) have developed an algorithm for the exact separation of extended cover inequalities (ECI). Furthermore, they have shown that ECI speed-up the convergence of Cplex when solving the multidimensional knapsack problem. In this research we adapt the generation of ECI to the GAP. Additionally, ECI are embedded within a cut-and-branch algorithm for solving the GAP. We show by means of a computational study that ECI improve convergence of Cplex substantially.

A branch-and-price algorithm for the multilevel generalized assignment problem

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University of Milano, Department of Information Technologies

coauthor: Giovanni Righini

keywords: generalized assignment, column generation, branch-and-bound

The multilevel generalized assignment problem (MGAP) is a variation of the generalized assignment problem, in which agents can perform tasks at different efficiency levels. MGAP arises, for example, in the context of manufacturing systems. As reported in the literature, due to the large number of binary variables involved, it is impractical to use standard ILP software to achieve optimal solutions to these problems. A tabu search algorithm (Laguna et al., 1995), obtained good results for instances with up to 40 tasks, 4 agents and 4 efficiency levels. Two recent heuristic algorithms (French and Wilson, 2002) obtained good approximations on problems with up to 200 tasks, 30 agents and 5 efficiency levels. We present a branch-and-price algorithm that, at the best of our knowledge, is the first exact algorithm for MGAP. We report computational experience on many sets of randomly generated instances, with different kind of correlations between cost and resource consumption for each agent-task-level assignment, and with different ratio between the number of agents, tasks and levels. Experimental results show that our method is very effective, and it solves to proven optimality instances of the maximum size proposed in the literature.

TH2-302/49 INTEGER AND MIXED INTEGER PROGRAMMING

Routing in networks

chair: Bruce Shepherd

A prize collecting connected subgraph problem

Per Olov Lindberg
Department of Mathematics, Linköping University

coauthor: Nima Golbaharan

keywords: prize collecting, subgraph, routing

We consider a new (?) NP-hard optimization problem, the Prize Collecting Connected Subgraph Problem, which appears as a subproblem in routing of snow plows during snow fall. In this problem we have a set of arcs $a \in A$ in a network with arc "costs" c_a, and arc times t_a. Moreover there is a time budget b. The problem is to find a connected subset $\underline{A} \subseteq A$ (corresponding to a snow plow tour) such that $\sum c_a$ is minimized subject to the budget constraint $\sum t_a <= b$. This problem can be modeled by introducing multicommodity constraints or adding valid inequalities. We have mainly used the second approach. We will present results for the classical Sioux Falls network, and for a real life case of the region of Eskilstuna in Sweden.

The quadratic selective travelling salesman problem

TOMMY THOMADSEN
Technical University of Denmark

coauthor: Thomas Stidsen
keywords: traveling salesman, branch-and-cut, ring networks, multicommodity

A well-known extension of the Travelling Salesman Problem (TSP) is the Selective TSP: Each node has an associated profit and instead of visiting all nodes, only profitable nodes are visited. The Quadratic Selective TSP (QSTSP) adds the additional complication that each pair of nodes have an associated profit which can be gained only if both nodes are visited. The QSTSP problem is motivated by being a subproblem when constructing hierarchical ring networks.

We describe a mixed integer linear program model for the QSTSP. The problem is solved by Branch and Cut using the COIN/BCP framework. Computational results are presented.

Maximum multicommodity demand flows

BRUCE SHEPHERD
Bell Laboratories

coauthors: C. Chekuri, M. Mydlarz
keywords: integrality gap, knapsack, integer multicommodity flow, b-matching

We consider requests for capacity in a tree network $T=(V,E)$ where each edge of the tree has a bounded capacity u_e. Each request consists of an integer demand d_f and a profit w_f which is obtained if the request is satisfied. The objective is to find a set of demands that can be feasibly routed in the tree and which provide a maximum profit. This generalizes well-known problems including the knapsack and *b*-matching problems.

When all demands are 1, we have the integer multicommodity flow problem. In this case, Garg, Vazirani, and Yannakakis had shown an integrality gap of 2 for the cardinality version of the problem. We establish factor 4 gap for the case of arbitrary profits.

For arbitrary demands (with maximum demand at most the minimum capacity) we show that the integrality gap of the LP is at most 48. This is obtained by showing that the integrality gap for demand version of such problems is at most 12 times that for their unit demand version.

TH2-306/31 — INTEGER AND MIXED INTEGER PROGRAMMING

Open-source software for mathematical programming

organizer/chair: Robin Lougee-Heimer

The COIN-OR open solver interface: a progress report

MATTHEW SALTZMAN
Clemson University

keywords: software, integer programming, linear programming, open source

When the COIN-OR project debuted at ISMP 2000, a key component of the project was the Open Solver Interface (OSI). The OSI is intended to be a common application program interface (API) for calling any of a variety of embedded solvers in an algorithm. The current version includes support for CPLEX, XPRESS-MP, Soplex, the GNU LP Kit, Hafer's DyLP, and COIN-OR native solvers CLP (the COIN-OR LP solver), SBB (Simple Branch and Bound), and Vol (an implementation of Barahona and Anbil's volume algorithm). A user can write a single implementation of an algorithm calling any of these solvers through the same interface.

This presentation describes features of the OSI and an outline of the design of a new version of the OSI (under development). The new design will improve flexibility and efficiency and simplify the process of embedding new solvers. It will offer a consistent (solver-independent) problem representation and access to a broad set of solver capabilities through an efficient, open, standard, portable API.

The COIN-OR initative: open-source tools for mathematical programmers

ROBIN LOUGEE-HEIMER
IBM Research

keywords: software, optimization, mixed integer programming, open source

Much of the mathematical programming research and application relies on software. And yet, there is relative low number of reference implementations, common interfaces, re-usable frameworks, and open standards for the specific software needs of the mathematical programming community. Open source is an alternative style of software development with some attractive benefits. Three years ago at ISMP 2000, the COIN-OR project was launched as an experiment with the mission of promoting open-source software for the mathematical programming community. In this talk, we report on the progress of COIN-OR and its future direction. We will announce the winners of the COIN-OR Open Source Coding Contest. The contest was a joint effort of INFORMS, MPS, and COIN-OR with prizes donated by IBM.

Prox-Accpm: a cutting plane solver for convex optimization

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University of Geneva

coauthors: Jean-Philippe Vial, Frédéric Babonneau, Cesar Beltran, Olivier du Merle
keywords: convex, cutting planes, non smooth, analytic center

Prox-Accpm is an extension of the analytic center cutting plane method to solve general (nondifferentiable) convex optimization problems, whose components (objective and constraints) are described by first order oracles. The addition of a proximal term allows a better control of the algorithm behavior. Prox-Accpm applies to problems arising from decomposition approaches (Benders, Lagrangian, Column generation) or to equilibrium problems, or to cutting plane approaches to difficult mathematical programming problems (e.g., some SDP's). In view of the wide range of applications, Prox-Accpm is conceived as a parametizable solver. It is written in MATLAB, but some routines are written in C. All developments are tested against families of benchmark problems: Column generation (cutting stock, linear separation in data mining), Lagrangian relaxations (p-median, unit commitment, nonlinear multi-commodity flow), equilibria (two-person games, traffic equilibria), nonlinear convex problems (optimization on positive polynomials, quadratically constrained problems) etc. Prox-Accpm can be used as a standalone binary version to be included in any standard program for user-specific purposes.

TH2-306/32 — NONLINEAR PROGRAMMING

Surrogate modelling for engineering optimization I

organizer/chair: Kaj Madsen

On multivariate polynomial interpolation and its use in derivative-free optimization (parts I and II)

ANDREW CONN
IBM T.J. Watson Research Center

coauthors: Katya Scheinberg, Luís N. Vicente

keywords: multivariate interpolation, derivative-free optimization, trust region method, bilevel optimization

We will introduce a new, comprehensive approach for multivariate polynomial interpolation under which it is possible to derive appropriate bounds for the error between the function being interpolated and its interpolating polynomial. This derivation is based on a new concept of well-poisedness for the interpolation set, directly connecting the accuracy of the error bounds with the geometry of the points in the set. Our approach includes error bounds for function values as well as for derivatives. We show how to design algorithms to build sets of well-poised interpolation points or to modify existing interpolation sets to ensure well-poisedness.

We will also talk about derivative-free optimization techniques, relating geometrical concepts like well-poisedness to the key ingredients for attaining global convergence. A new approach to solve derivative-free bilevel optimization problems based on interpolation-based models for both upper and lower level objective functions is also presented. The underlying algorithms are of trust-region type and the setting is such that both function and gradient values can be inexact.

On multivariate polynomial interpolation and its use in derivative-free optimization (parts I and II)

LUÍS N. VICENTE
University of Coimbra

coauthors: Andrew Conn, Katya Scheinberg

keywords: multivariate interpolation, derivative-free optimization, trust region method, bilevel optimization

We will introduce a new, comprehensive approach for multivariate polynomial interpolation under which it is possible to derive appropriate bounds for the error between the function being interpolated and its interpolating polynomial. This derivation is based on a new concept of well-poisedness for the interpolation set, directly connecting the accuracy of the error bounds with the geometry of the points in the set. Our approach includes error bounds for function values as well as for derivatives. We show how to design algorithms to build sets of well-poised interpolation points or to modify existing interpolation sets to ensure well-poisedness.

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Constrained global optimization with radial basis functions

JAN-ERIK KÄCK
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coauthor: Kenneth Holmström

keywords: global optimization, response surface, costly constraints

Response surface methods show promising results for global optimization of costly nonconvex objective functions, i.e. the problem of finding the global minimum when there are several local minima and each function value takes considerable CPU time to compute. Such problems often arise in industrial and financial applications, where a function value could be a result of a time-consuming computer simulation or optimization. Derivatives are most often hard to obtain. The problem is here extended with linear and nonlinear constraints, and the nonlinear constraints can be costly or not. A new algorithm that handles the constraints, based on radial basis functions (RBF), and that preserves the convergence proof of the original RBF algorithm is presented. The algorithm takes advantage of the optimization algorithms in the Tomlab optimization environment (http://tomlab.biz). Numerical results are presented for standard test problems.

TH2-306/33 NONLINEAR PROGRAMMING

PDE-constrained optimization (2)

organizers: Michael Ulbrich and Stefan Ulbrich
chair: Michael Ulbrich

Optimal control of PDEs with mixed control-state constraints

FREDI TROELTZSCH
TU Berlin, Institut fuer Mathematik

keywords: optimal control, Lagrange multiplier, regularity

A class of quadratic optimization problems with pointwise box constraints and constraints ofbottleneck type is considered in Hilbert spaces. The main subject is the existence of regular Lagrange multipliers in L^2-spaces is proven under natural assumptions. This question is answered by investigating a Lagrange dual quadratic problem. The theory is applied to different optimal control problems for elliptic and parabolic partial differential equations with mixed pointwise control-state constraints.

Space mapping for optimal control of partial differential equations

MICHAEL HINTERMÜLLER
Department of Mathematics / University of Graz

coauthor: Luís N. Vicente

keywords: space mapping, optimal control of PDEs, trust regions

Numerically solving optimal control problems for nonlinear partial differential equations represents a significant challenge due to the tremendous size and possible model difficulties (e.g., nonlinearities) of the discretized problems. In this talk, a novel space-mapping technique for solving the aforementioned problem class is introduced, analyzed, and tested. The advantage of the space-mapping approach compared to classical multigrid techniques lies in the flexibility of not only using grid coarsening as a model reduction but also employing (perhaps less nonlinear) surrogates. The space mapping is based on a regularization approach which, in contrast to other space-mapping techniques, results in a smooth mapping and, thus, avoids certain irregular situations at kinks. A new Broyden update formula for the sensitivities of the space map is also introduced. This quasi-Newton update is motivated by the usual secant condition combined with a secant condition resulting from differentiating the space-mapping surrogate. The overall algorithm employs a trust-region framework for global convergence. We highlight some of the issues involved in the computations and we report a few illustrative numerical tests.

Software for rapid source location in chemical/biological defense

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Sandia National Laboratories

coauthors: Kevin R. Long, Stephen Margolis

keywords: PDE-constraints, nonlinear optimization, software

The problem to be discussed is to find the source of a toxic release in a large building, e.g., an airport. In such cases, time is of the essence and is clearly more important than accuracy, since even a relatively crude approximation of the source will allow timely response by emergency managers to contain the release and to take appropriate crowd control actions. At the beginning, we are unsure of many of the aspects of the problem, e.g., how many sensors are needed, how much accuracy is needed in the prediced locations, how much accuracy is needed in the flow models, and what is the sensitivity of the predictions with respect to these questions. Our approach has been to start with something relatively simple and move to more complex models. To do this, we used several software tools that made changing the models and doing the analyses much easier. We report specifically on Sundance, a tool that allows symbolic description of the PDE and related constraints as well as easy connection to the optimization software.

TH2-306/34 NONLINEAR PROGRAMMING
Large scale problems II
chair: Jacek Gondzio

Approximation of optimum sets of extreme points in a SQP integrated simple decomposition

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Département de Génie Civil, ENIT
coauthor: Hichem Smaoui
keywords: simple decomposition, large scale, SQP, extreme point

Sacher's simple decomposition, originally developped for large scale quadratic programming problems, has recently been integrated into a sequential quadratic programming (SQP) algorithm in order to handle large nonlinear programming problems. The resulting algorithm is particularly efficient when the number of passive constraints is a small fraction of the number of variables and the total number of constraints. However, when the standard simple decomposition is applied, the number of extreme points that are generated throughout the SQP iterations is usually very large, with many points leaving and entering the set. In order to reduce the computational effort devoted to the generation of extreme points, a procedure is developped for initiating the simple decomposition with a whole set of extreme points that approximates the optimum set. This set is determined at the start of each new iteration of the SQP sequence, based on the results of the preceding one, bypassing the solution of many master problems and subproblems. Furthermore, computation of Lagrange multipliers for the quadratic programming problems is performed based on any available non degenerate extreme point of the optimum set. Numerical results for several nonlinear programming example problems demonstrate computational saving up to 60% due to the proposed procedure.

Dynamic scaling based preconditioning for truncated Newton methods in large scale unconstrained optization

MASSIMO ROMA
Universita' di Roma "La Sapienza"
keywords: truncated Newton methods, conjugate gradient method, preconditioning, row-column scaling

This work deals with the preconditioning of truncated Newton methods for the solution of large scale nonlinear unconstrained optimization problems. We focus on preconditioners which can be naturally embedded in the framework of truncated Newton methods, i.e. which can be built without storing the Hessian matrix of the function to be minimized, but only based upon information on the Hessian obtained by the product of the Hessian matrix times a vector. In particular we propose a diagonal preconditioning which enjoys this feature and which enables us to examine the effect of diagonal scaling on truncated Newton methods. In fact, this new preconditioner carries out a scaling strategy and it is based on the concept of equilibration of the data in linear systems of equations. An extensive numerical testing has been performed showing that the diagonal preconditioning strategy proposed is very effective. In fact, on most problems considered, the resulting diagonal preconditioned truncated Newton method performs better than both the unpreconditioned method and the one using an automatic preconditioner based on limited memory quasi–Newton updating (PREQN) recently proposed.

Parallel solution techniques in financial planning problems

JACEK GONDZIO
School of Mathematics, University of Edinburgh
coauthor: Andreas Grothey
keywords: financial engineering, parallel computing, interior point method, large scale optimization

Financial planning problems by their very nature involve uncertainty and therefore lead to very large-scale optimization problems. Their solution requires carefully designed optimization techniques and the use of high performance computing. These optimization problems display exploitable structure: the blocks corresponding to scenarios are linked through common variables corresponding to earlier stage investment decisions.

Financial planning problems are often solved by decomposition methods. However, decomposition approaches tend to be slower than any direct approach (if the latter can handle the large problem).

An alternative to a development of a parallel implementation of a decomposition method is to exploit structure directly in the linear algebra operations. We explore such alternative in this paper. We have developed a structure-exploiting parallel interior-point solver for nonlinear programming problems. Its design uses object-oriented programming techniques. The program OOPS (Object-Oriented Parallel Solver:

http://www.maths.ed.ac.uk/
~lkgondzio/parallel/solver.html)

can efficiently handle very large nonlinear problems and achieves scalability on a number of different computing platforms.

We illustrate its performance on a collection of quadratic programming problems with sizes over 50 million decision variables arising from asset liability management and portfolio optimization.

TH2-306/35 NONLINEAR PROGRAMMING
Newton-like algorithms I
chair: Oleg Burdakov

Newton-like search directions

JELENA NEDIC
Oxford University
coauthor: Raphael Hauser
keywords: Newton method, q-quadratic convergence, flux lines, stiffness of vector field

We consider problems of nonlinear continuous unconstrained optimization. New approximations of the local minimiser are obtained via the updating rule $x_{k+1} = x_k + v(x_k)$, $k = 0,1,2,\ldots$ where $v(x_k)$ is a given vector field. It is a well known fact that the sequence of iterates obtained by using the Newton method converges to an optimal solution q-quadratically if the initial approximation is in some neighbourhood of a local minimiser x^*. But are there other conceptually different direction vector fields that will also lead to

q-quadratic convergence? To answer this question, necessary and sufficient conditions for q-quadratic convergence of such methods are derived. They are given in terms of the Jacobian of the direction field and are very simple to check. Moreover, we analyse the convergence rates of the direction from which x_k approaches x^* to give deeper insight into the problem. In particular, we are interested in providing conditions that will completely determine whether the given direction field is actually the Newton one for some function or not.

Value function and error bounds of a basic trust region model

JIAN-ZHONG ZHANG
City University of Hong Kong
coauthor: Chang-Yu Wang
keywords: trust region method, error bounds, constrained optimization

We study some properties of a trust region model for solving constrained minimization problems. We first consider the optimal value function defined by the predicted reduction of the trust region subproblem and the ratio between the value function and the trust region radius. We expose the close relationship between this ratio and the projected gradient of the objective function. We then show under different conditions that this ratio and the value function provide global or local error bounds for the distances from the projected gradient to the origin, and from the iterative point to the solution set of the minimization problem. Using these error bounds, we give a condition for convergence of the iterative sequence generated from the trust region model. Especially, we give a new equivalent condition for finite convergence.

On limited memory methods with shape changing trust region

OLEG BURDAKOV
Linkoping University
coauthor: Ya-xiang Yuan
keywords: large scale optimization, limited memory, quasi-Newton methods, trust region

We consider a trust-region (TR) approach. In this approach, the TR-subproblem is defined by a limited memory model function and a trust region, which shape depends on the model function. This special shape allows to solve efficiently the TR-subproblem. We prove global convergence for our limited memory methods with shape changing trust region.

TH2-306/36 NONSMOOTH OPTIMIZATION
Covering problems
chair: Frits Spieksma

Global optimality conditions for discrete and nonconvex optimization, with applications to Lagrangian heuristics and column generation

MICHAEL PATRIKSSON
Department of mathematics
coauthor: Torbjörn Larsson
keywords: integer programming, Lagrangian relaxation, Lagrangian heuristics, set covering problems

The well-known and established global optimality conditions based on the Lagrangian formulation of an optimization problem are consistent if and only if the duality gap is zero. We develop a set of global optimality conditions which are structurally similar but which are consistent for any size of the duality gap. This system characterizes a primal-dual optimal solution by means of primal and dual feasibility, primal Lagrangian ε-optimality, and, in the presence of inequality constraints, δ-complementarity, that is, a relaxed complementarity condition. At an optimal solution the value of $\varepsilon+\delta$ equals the size of the duality gap. The characterization is further equivalent to a near-saddle point condition which generalizes the classic saddle point characterization of a primal-dual optimal solution in convex programming. The system developed can be used to explain, to a large degree, when and why Lagrangian heuristics for discrete optimization are successful in reaching near-optimal solutions. Further, experiments on a set covering problem illustrate how the new optimality conditions can be utilized as a foundation for the construction of Lagrangian heuristics. Finally, we outline possible uses of the optimality conditions in column generation algorithms.

Optimum order p covering of plane domains by circles via hyperbolic smoothing method

ADILSON ELIAS XAVIER
COPPE/Federal University of Rio de Janeiro
coauthor: Antonio Alberto Fernandes de Oliveira
keywords: non differentiable programming, semi infinite programming, location, smoothing

In this work, we will consider the particular problem of obtaining an optimum order p coverage of a plane region by q circles. The mathematical modeling of that problem leads to a $min-max-min_p$ problem, where min_p denotes the p^{th} least value. That problem, in addition to its intrinsic multi-level nature, has the significant characteristic of being strongly non-differentiable. To address that difficulty we smooth the $min-max-min_p$ problem by using a special family of smoothing function of class C^∞. The use of this technique, called Hyperbolic Smoothing, permits to overcome the main difficulties presented by the original problem. The final solution is obtained by solving a sequence of differentiable sub-problems which gradually approaches the original problem. Preliminary computational results obtained for real test problems are also presented to illustrate the potentiality of the method.

An approximation algorithm for an interval stabbing problem

FRITS SPIEKSMA
Katholieke Universiteit Leuven
coauthor: Sofia Kovaleva
keywords: combinatorial optimization

We consider the following problem. Given is a grid consisting of columns and rows. The grid contains intervals; each interval intersects a set of consecutive columns and lies on a single row. We say that, if interval *i* intersects column *j*, column *j* *stabs* interval *i*. We also say that, if interval *i* lies on row *j*, row *j* *stabs* interval *i*. The aim is to select as few rows and columns as possible such that each interval is stabbed at least once. This problem is known to be APX-hard. We describe a polynomial-time algorithm, called STAB, that always outputs a solution with a value that is bounded by $e/(e-1) \approx 1.582$ times the optimal value of the problem. This algorithm is based on solving the LP-relaxation of an integer programming formulation of the problem described above. We also give extensions to weighted variants of the problem.

TH2-306/37 CONVEX PROGRAMMING
Conic programming and positive polynomials
organizer/chair: Javier Pena

A conic programming approach to generalized Tchebycheff inequalities

LUIS ZULUAGA
Carnegie Mellon University
coauthor: Javier Pena
keywords: Tchebycheff bounds, cones of moments, positive polynomials, semidefinite programming

Consider the problem of finding optimal bounds on the expected value of piecewise polynomials over all measures with a given set of moments. This is a special class of Generalized Tchebycheff Inequalities in probability theory. We study this problem within the framework of conic programming. Relying on a general approximation scheme for conic programming, we show that these bounds can be numerically computed or approximated via semidefinite programming. We also describe some applications of this class of Generalized Tchebycheff Inequalities in probability, finance, and inventory theory.

Global optimization of rational functions: a semidefinite programming approach

ETIENNE DE KLERK
Delft University of Technology
coauthor: Dorina Jibetean
keywords: semidefinite programming, global optimization, rational functions

We consider the problem of global minimization of rational functions on R^n (unconstrained case), or on a connected semi-algebraic subset of R^n. We show that in the univariate case ($n = 1$), these problems have exact reformulations as a semidefinite programming problems (SDP), by using reformulations introduced in the PhD thesis of Jibetean. This extends the analogous results by Nesterov for global minimization of univariate polynomials.

For the bivariate case ($n = 2$), we obtain a fully polynomial time approximation scheme (FPTAS) for the unconstrained problem, if an a priori lower bound on the infimum is known, by using results by De Klerk and Pasechnik.

For the NP-hard multivariate case, we discuss semidefinite programming-based heuristics for obtaining lower bounds on the infimum, by using results by Lasserre.

Using algebraic geometry in 0-1 programming

JUAN VERA
Carnegie Mellon University
coauthors: Javier Pena, Luis Zuluaga
keywords: integer programming, relaxation hierarchies, algebraic geometry

Recently, Algebraic Geometry has been successfully applied to develop new solution schemes for a large class of optimization problems. Motivated by this, we study several well-known relaxation hierarchies for mixed and pure 0-1 programming from an algebraic geometry point of view. As a result, we obtain a general approximation scheme from which these relaxation hierarchies arise as special cases. For specific mixed and pure 0-1 programs, this generalization can be applied to strengthen the sequence of relaxations obtained by any of the known relaxation hierarchies. Moreover, from this general setting, both new relaxation hierarchies and natural generalizations of the existing ones are obtained.

TH2-306/38 GLOBAL OPTIMIZATION

Global optimization IV

chair: Tibor Csendes

Global optimization methods for approximation by consistent matrices

JÁNOS FÜLÖP
Computer and Automation Institute, Hungarian Academy of Sciences
keywords: global optimization, branch-and-bound, decision theory, pairwise comparison

The lecture considers a classic problem of decision theory, when the priority weights of alternatives are determined by using pairwise comparisons. We review the methods proposed for the approximation of a pairwise comparison matrix by consistent matrices. We consider then a special problem, when a consistent matrix with the least sum of squares of differences is to be determined to an inconsistent pairwise comparison matrix. This is a nonconvex optimization problem, and multiple global optimal solutions are possible. We propose two approaches to solve the problem. First, we formulate the problem as a generalized convex multiplicative problem solvable as a concave minimization subject to convex constraints. The classic branch-and-bound approach is also applied, where the partition elements are rectangles, and to compute bounds, a convex underestimation and the concave envelope of the ratio function are also used. Computational experience is presented.

Box region in which the local minimizer is global

YOUKANG FANG
University of Botswana & Shenyang Institute of Technology,China
keywords: global minimizer, quadratically constrained QP, box region

Using information from computing a local minimizer of quadratially constrained nonconvex quadratic programming, a box region is easy to get in which this local minimizer is global. Research on such method using for general global nonlinear programming is presented too.

A new interval selection technique for global optimization

TIBOR CSENDES
University of Szeged
keywords: global optimization, interval selection

The convergence properties of interval global optimization algorithms are studied that select the next subinterval to be subdivided with the largest value of the indicator $pf(f_k, X)$. This time the more general case is investigated, when the global minimum value is unknown, and thus its estimation f_k in the iteration k has an important role. We present a new technique to ensure convergence to global minimizer points even for this case.

Extensive numerical tests will be completed on 40 problems to clear the positive efficiency impact of this new technique.

Csendes, T.: Convergence properties of interval global optimization algorithms with a new class of interval selection criteria, J. Global Optimization 19(2001) 307-327.

TH2-308/11 GENERALIZED CONVEXITY/MONOTONICITY

Generalized convexity V

organizer: Laura Martein
chair: Piera Mazzoleni

Generalized convexity and dependence structures in equilibrium problems

PIERA MAZZOLENI
Catholic University, Milan
keywords: generalized convexity, interval orders, equilibrium problems

Ambiguous and imprecise knowledge often affect economic problems and they can be formalized by using fuzzy numbers. In this approach there are difficulties to estimate the membership functions. Therefore the theory of interval orders is applied to give a more flexible tool in order to represent a whole range of values and to compare them. The role of order relations is fundamental to develop monotonicity and concavity properties and several applications can be given to state a qualitative analysis for parametric optimization problems. Studies in this area are now in progress and new results are suggested by several fields. It is well known the generalization from complementarity problems to variational inequalities up to equilibrium problems: indeed, solvability conditions are weakened and the range of applications is growing. Interval orders offer a fruitful tool to make comparisons more flexible. New monotonicity and concavity properies can be stated and an application is given to a vector equilibrium problem.

On generalized equilibrium points

GABOR KASSAY
Eastern Mediterranean University

coauthor: Peter Kas
keywords: approximate equilibrium points, approximate saddlepoints, perturbed convex functions

Generalizations of the usual definitions of saddlepoint and equilibrium point are introduced. The existence of these points is proved using the Ky Fan's minimax inequality theorem and shown to be related to a class of functions that we call perturbed convex functions. First and second order conditions regarding the existence of these points are also proved.

On generalized convexity for set valued maps

DAVIDE LA TORRE
Department of Economics

keywords: generalized convexity, set valued analysis

It is well known that convexity and generalized convexity play a crucial role in many fields. Recently, some papers deal with some extensions of these notions to set valued maps. In this talk some definitions of convexity and generalized convexity are considered and compared. Some characterizations are given by Dini and Dini-Hadamard first order generalized derivatives. Applications of these concepts in optimization problems and variational inequalities are shown.

TH2-308/12 STOCHASTIC PROGRAMMING

Risk issues in stochastic programming

organizer: COSP (Stephan Tiedemann)
chair: Stephan Tiedemann

Risk modeling in stochastic programming

SHABBIR AHMED
Georgia Institute of Technology

coauthor: Andrzej Ruszczynski
keywords: stochastic programming, risk, stochastic dominance, decomposition

This talk addresses various risk modeling paradigms for two-stage stochastic programming models. We show that traditional mean-variance approach may lead to non-convex optimization models and severe computational difficulties. On the other hand, many risk paradigms that are consistent with second order stochastic dominance lead to tractable convex optimization problems. Furthermore, the original decomposability property of the stochastic program is preserved. A computational comparison of several risk modeling paradigms will be presented.

Risk aversion in stochastic programs with mixed-integer recourse, Part I

ANDREAS MAERKERT
University Duisburg-Essen

coauthors: Ruediger Schultz, Stephan Tiedemann
keywords: stochastic programming, mean-risk models, mixed integer programming

Many decision problems involving random data can be regarded as ordering problems of random variables. We review the concept of stochastic dominance and several related mean-risk models. When turning to specific random variables induced by two-stage random mixed-integer programs, besides consistency with stochastic dominance, structural properties of risk measures become crucial. We investigate two properties which yield, when satisfied, well-defined and algorithmically amenable stochastic programs.

The material is presented in two consecutive talks.

In this talk we associate two-stage stochastic mixed-integer programs with stochastic ordering principles, in particular, with stochastic dominance. We use the mean-variance model to illustrate that the choice of the risk measure requires special care when integer variables enter stochastic programs.

Risk aversion in stochastic programs with mixed-integer recourse, Part II

STEPHAN TIEDEMANN
University Duisburg-Essen

coauthors: Andreas Maerkert, Ruediger Schultz
keywords: stochastic programming, mean-risk models, mixed integer programming

Many decision problems involving random data can be regarded as ordering problems of random variables. We review the concept of stochastic dominance and several related mean-risk models. When turning to specific random variables induced by two-stage random mixed-integer programs, besides consistency with stochastic dominance, structural properties of risk measures become crucial. We investigate two properties which yield, when satisfied, well-defined and algorithmically amenable stochastic programs.

The material is presented in two consecutive talks.

In this talk we investigate mean-risk models, which are consistent with stochastic dominance, for the specific random variables induced by two-stage random mixed-integer programs. We present structural results, an algorithm, and computational experience with academic and real-world problems.

TH2-308/T1 DYNAMIC PROGRAMMING AND OPTIMAL CONTROL

Dynamic programming and optimal control

chair: Julien Laurent-Varin

Robust dynamic programming for polytopic systems with piecewise linear cost

MORITZ DIEHL
University of Heidelberg

keywords: dynamic programming, robust optimization, polytopic systems, convex programming

We present a new method for robust dynamic programming that is suitable for polytopic linear systems and piecewise linear convex cost functions. The method performs exact dynamic programming without any discretization of the state space by a using piecewise linear representation of the cost-to-go function. It is shown that the robust dynamic programming recursion preserves this piecewise linear representation. Inclusion of linear inequality constraints on controls and states leads to a simultaneous recursion of the cost-to-go and of feasible sets in state space. It is shown that a polyhedral representation of the feasible sets is preserved as well under the robust dynamic programming recursion.

Finally, we show how the method can be applied to an example problem, namely a parking car with uncertain mass that shall quickly reach the end of a garage and stop there without hitting the wall. We also discuss the involved computational costs and possible dynamic programming approximations based on this approach.

A relaxation theorem for nonlinear control systems with sliding modes

ANDREI DMITRUK
Russian Academy of Sciences, CEMI

keywords: nonlinear operator, metric regularity, control system, sliding modes

On a fixed time interval we consider a nonlinear control system with additional equality constraints on the endpoints of trajectory, and also consider a relaxed (convexified) system with so-called sliding modes. The question is, when the passage to the relaxed system is valid, i.e., when a given trajectory of relaxed system can be approximated by trajectories of initial system? We prove that if the operator of relaxed system is nondegenerate, i.e., its derivative at a given relaxed trajectory is surjective (the Lyusternik condition), and the weight coefficients of sliding modes are essentially positive, then the relaxed trajectory can be approximated (uniformly in state and control variables, and weakly-* in weight coefficients) by trajectories whose weight coefficients take only two values: 0 or 1. These new trajectories actually present trajectories of the initial system. This theorem strengthens the known results of Bogolyubov, Warga, Gamkrelidze et al, related to systems without additional terminal equality constraints.

The proof is based on a nonlocal estimate to the level set of a nonlinear operator, which in turn is based on a generalization of the known Lyusternik theorem on the tangent subspace.

An interior points algorithm for optimal control problems

JULIEN LAURENT-VARIN
CNES/ONERA/INRIA

coauthors: Frederic Bonnans, Nicolas Berend, Mounir Haddou, Christophe Talbot
keywords: interior point, optimal control, discretization

In this talk we will analyze interior-point algorithms for solving optimal control problems, and their application to aerospace problems. The algorithm is based on a Runge Kutta discretization of the problem and its approximation using logarithmic penalties.

An important feature is that all linear systems to be solved involve band matrices, for which efficient solvers are available. Equally important is the quality of the discretization. The interior-point algorithm allows easily to introduce additional points at any iteration of the algorithm, the process being monitored by a local error estimate.

We will present numerical results showing how behaves the automatic refinement procedure for some flight mechanics problems such as the atmospheric reentry. The extension of these techniques for future space launcher trajectory optimization, involving multi-arc problems, will be discussed.

TH2-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Mathematical programs with equilibrium constraints

organizers: Sven Leyffer and Richard Waltz
chair: Sven Leyffer

Solution and application of MPECs in process engineering

LORENZ BIEGLER
Carnegie Mellon University

coauthor: Arvind Raghunathan
keywords: process engineering, MPEC, barrier methods, phase equilibrium

The talk focuses on the development of nonlinear programming methods for the solution of MPECs in process engineering. Complementarity constraints for these problems arise from nested optimization problems due to phase equilibrium, feedback control or phenomenological models. The addition of these features leads to richer optimization models that cover a wider range of process behavior.

We apply an approach that extends directly from the IPOPT barrier method with a filter line search algorithm. The extended algorithm, called IPOPT-C, has desirable local and global convergence properties and performs very well on numerical comparisons. Several examples drawn from metabolic flux analysis, distillation optimization and two phase flow behavior will be presented.

Interior point methods for MPECs

GABRIEL LOPEZ-CALVA
Northwestern University

coauthors: Sven Leyffer, Jorge Nocedal
keywords: MPEC, interior point method, L1 penalty, nonlinear programming

We discuss different interior-point approaches for solving MPECs, paying particular attention to an L1-penalty formulation. We present global and local convergence results and compare them with classical results for nonlinear programming. Numerical experiments on large-scale MPECs are presented. We identify problem characteristics that cause difficulties in practice.

Solving complementarity constraints via nonlinear optimization

SVEN LEYFFER
Argonne National Laboratory

keywords: complementarity constraints, nonlinear programming

An exciting new application of nonlinear programming techniques is mathematical programs with complementarity constraints (MPCC). Problems of this type arise in many engineering and economic applications. Recently, it has been shown that MPCCs can be solved efficiently and reliably as nonlinear programs.

We examine several different nonlinear formulations of the complementarity constraints. Unlike traditional smoothing techniques, our reformulations do not require the control of a smoothing parameter. Thus they have the advantage, that the smoothing is exact in the sense, that Karush-Kuhn-Tucker points of the reformulation correspond to strongly stationary points of the MPCC.

We show how the formulations can be integrated into an SQP method and report on numerical experience on a large range of test problems.

TH2-308/T3 TELECOMMUNICATION NETWORK DESIGN

Scheduling and routing in networks

chair: Hans-Florian Geerdes

Design of survivable IP-over-optical networks

SYLVIE BORNE
Université Blaise Pascal - Clermont-Ferrand II

coauthors: Eric Gourdin, Bernard Liau, Ali Ridha Mahjoub
keywords: IP-over-optical network, survivability, integer programming

In the past years, telecommunication networks have seen an important evolution wih the advances in optical technologies and the explosive growth of the Internet. Several optical systems allow a very large transport capacity, and data traffic has dramatically increased. Telecommunication networks are now moving toward a model of high-speed routers interconnected by intelligent optical core networks. Moreover, there is a general consensus that the control plan of the optical networks should utilize IP-based protocols for dynamic provisioning and restoration of lightpaths. The interaction of the IP routers with the optical core networks permits to achieve end-to-end connections. And the lightpaths of the optical networks provide the topology of the virtual network interconnecting the IP routers. This new infrastructure has to be sufficiently survivable, so that network services can be restored in the event of a catastrophic failure. This paper addresses survivability issues that may be of practical interest for IP-over-optical neworks. We consider some optimization problems concerning the topology of these networks. We give integer programming formulation of the problem. We also present some computational results and discuss some extensions.

The potential of relaying cellular wireless computer networks

HANS-FLORIAN GEERDES
Konrad-Zuse-Zentrum für Informationstechnik Berlin

coauthor: Holger Karl
keywords: telecommunication, integer programming, scheduling

Bandwidth is a scarce resource in wireless computer networks. Relaying is a protocol extension designed for utilizing radio resources more efficiently in a cellular setting: several hops are allowed within one cell. In traditional networks only direct transmission between base station and mobile terminals is feasible. It has been shown that relaying can increase data throughput significantly for special cases, but the average potential is an open question.

In our work we discuss the general potential of relaying. We approach this question by defining the optimization problem of finding a feasible transmission schedule that maximizes the data throughput under fairness conditions. A special mathematical model and a column-generation based algorithm is presented for this problem. This enables us to quantitatively compare the data transmission capacity with and without relaying of concrete networks consisting of multiple cells.

We apply our methodology to example networks and assess the average potential of relaying under the assumption of uniform node placement. This yields statistical evidence that relaying increases the average data throughput in an example network class by 30%. In addition, the method presented here can serve as an engineering benchmark for any concrete scheduling/routing algorithm for relaying.

TH2-341/21 INTERIOR POINT ALGORITHMS

Recent development in interior-point methods

organizer/chair: Jiming Peng

What is special with the logarithmic barrier function in optimization?

KEES ROOS
TU Delft

coauthors: Y. Bai, M. Elghami
keywords: primal-dual method, interior point method, barrier function

After its introduction by Frisch in 1955, the logarithmic barrier function (LBF) has played a major role in the field optimization. The revolutionary developments of the past two decades in this field, which gave rise to the subfield of interior-points (IP) methods, has re-emphasized its importance. The search directions in all state-of-the-art IP-solvers for linear, and also for second-order cone and semidefinite optimization problems are explicitly or implicitly based on an LBF, and the analysis of these methods strongly depends on properties of such functions. Other barrier functions have been proposed, but both from a theoretical and computational viewpoint LBF's always were winning, at least surviving. It has often been asked what makes LBF so special. In this talk we deal with this question. We focus on primal-dual methods for linear optimization. It is probably for the first time that alternative barrier functions have been found that in some cases provide better theoretical complexity results than the LBF. The results can be extended to other conic optimization problems; it is an open question if the new barrier functions can be adapted to primal methods and dual methods, respectively.

A homogeneous model for p_0 and p_* nonlinear complementarity problems

AKIKO YOSHISE
Institute of Policy and Planning Sciences, University of Tsukuba

keywords: homogeneous model

The homogeneous model for linear programs provides a most simple and firm theory in interior point algorithms, and several computational experiences report its practical efficiency. In 1999, Andersen and Ye generalized this model to monotone complementarity problems (CPs) and showed that the model inherits most of desirable properties under the monotonicity of the problems. However, in contrast to primal-dual interior point methods for CPs, the analysis deeply depends on the monotonicity and the extension to more general classes of CPs, e.g., P_* CPs or P_0 CPs, is difficult as it is. In this paper, we propose a new homogeneous model which can be applied to P_0 CPs, and show that (i) there exists a trajectory which leads to a complementarity solution of the homogeneous model, (ii) from the solution, we can obtain a complementarity solution of the original problem, under the assumption that the original problem is a strictly feasible P_* CP and (iii) any positive point, feasible or infeasible, can be set as a starting point of the trajectory and it does not need to use any big-$\mathcal{M}$ parameter.

Self-regular proximity based dynamic large-update primal-dual ipms for linear optimization

TAMAS TERLAKY
Dept. of Computing and Software, McMaster University

coauthor: Maziar Salahi
keywords: linear optimization, large update, interior point method

Primal-Dual Interior-Point Methods (IPMs) are the method of choice when one solves large scale optimization problems. The gap between large-update and small-update IPMs was narrowed recently by Peng, Roos and Terlaky by introducing and analyzing a novel class of so-called Self-Regular IPMs (SR-IPMs).

In this paper a family of dynamic, large-update primal-dual IPM is proposed where the proximity functions and the search directions are defined by one of the specific families of SR functions. The results are generalizations of the dynamic SR-IPM algorithm proposed recently by Peng and Terlaky. An $O(qn^{\frac{q+1}{2q}} \log \frac{\varepsilon}{n})$ worst case iteration bound is established, where q is the barrier degree of the SR proximity. For the special case $q = \log(n)$ the so far best known complexity $O(n \log(n) \log \frac{\varepsilon}{n})$ of large-update IPMs is established.

TH2-341/22 LOGISTICS AND TRANSPORTATION

Routing by mixed integer programming

chair: Jean-Francois Cordeau

Modelling of road investments

JENNY KARLSSON
Linkøping University

coauthors: Mikael Rönnqvist, Mathias Henningsson
keywords: forestry, road investments, modeling, mixed integer programming

Public and private roads, which have an insufficient bearing capacity or blocking due to thawing or heavy rains, annually contribute to a considerable loss in Swedish forestry sector. The forestry is forced to build up large stocks of raw material in order to secure a continuous supply during periods of uncertain accessibility to parts of the road network. One method to reduce costs related to road blocks, is to made investments, i.e. upgrade the road network, to a standard that will guarantee accessibility. We consider the road investment problem from the perspective of Swedish forest companies. The objective is to minimize the investment and overall transportation costs, given that demanded volumes of raw material must be accessible along roads of a certain bearing class. This problem is strategic. The planning period is typically one decade. We present a mathematical model for this problem. The problem becomes a mixed integer problem or a network design problem. Preliminary numerical results will be presented.

A ship routing problem in the pulp industry

HENRIK ANDERSSON
Department of Science and Technology / Linköping University

coauthor: Peter Värbrand
keywords: ship routing, column generation

In this presentation, a ship routing problem in the pulp industry is introduced. This year, the Swedish forest company Södra will produce around two million tons of pulp in over 20 different qualities. The pulp is produced in five different mills, three in Sweden and two in Norway. The companies buying the pulp are located all over the world, but most of them are located in Europe. This study concerns the distribution of pulp to European customers. The distribution of pulp from the mills is done either by trains or trucks to domestic customers, or by ships to harbor terminals in Europe. At the harbors, the pulp is either picked up by the customers or delivered to the customers by Södra. The distribution planning problem is to combine demands from different customers into shiploads and to decide where to load and land the ships and how to coordinate the land and sea transports. Another question is when and where to use the own fleet of ships and when to buy transports on the spot market. The problem is modeled as a column based mixed integer program. A solution approach based on column generation and some computational results are presented.

A branch-and-cut approach for the dial-a-ride problem

JEAN-FRANCOIS CORDEAU
HEC Montreal

keywords: dial-a-ride, branch-and-cut, vehicle routing, time windows

In the dial-a-ride problem, users formulate transportation requests between an origin and a destination. Transportation is carried out by a fleet of vehicles that provide a shared service. The problem is to design a set of minimum cost vehicle routes satisfying capacity, duration, time window, pairing, precedence and ride time constraints. We propose a mixed-integer programming formulation of the problem. We then describe a branch-and-cut approach that uses new valid inequalities for the problem as well as known valid inequalities for the TSP with precendence constraints and the VRP with time windows.

TH2-341/23 APPROXIMATION ALGORITHMS
Approximation and trees
chair: Abdel Lisser

The double-tree approximation for metric TSP: is the best good enough?

VLADIMIR DEINEKO
The University of Warwick

coauthor: Alexander Tiskin
keywords: traveling salesman problem, double-tree algorithm

The Metric Traveling Salesman Problem (TSP) is a classical NP-hard optimization problem. The double-tree heuristic allows one to approximate the solution of the Metric TSP within a factor of 2, by picking an arbitrary solution from a restricted space of solutions to the original problem. Such an approach raises two natural questions: can we find efficiently a solution that is optimal in the restricted space? will this optimal solution provide a better approximation ratio than an arbitrary solution? Paper R.E Burkard et al. (1999), "The traveling salesman problem and the PQ-tree", Mathematics of Operations Research, 24(1), answers the first question in the affirmative, by presenting an algorithm that finds the optimal double-tree solution to Metric TSP in time $O(2^d n^3)$ and space $O(n^2)$, where d is the maximal vertex degree in the corresponding minimal spanning tree. We improve these bounds to time $O(2^d n^2)$ and space $O(2^{2d} n)$. We also give a partial answer to the second question, by presenting a lower bound of 1.666 on the approximation ratio of the optimal double-tree solution. Computational experiments show that the optimal double-tree algorithm is practical, providing one of the best known tour-constructing heuristics.

Covering minimum spanning trees of induced subgraphs

MICHEL GOEMANS
M.I.T.

coauthor: Jan Vondrak
keywords: combinatorial optimization, minimum spanning trees, probabilistic analysis

In a variety of optimization settings, one has to repeatedly solve instances of the same problem in which only part of the input is changing. It is important in such cases to perform a precomputation involving only the static part and assumptions on the dynamic part, allowing to speed-up the repeated solution of instances.

We consider here the minimum spanning tree problem, when instances are repeatedly drawn either randomly or deterministically from a given graph. The goal is to prove the existence and exhibit a sparse subgraph of edges guaranteed to contain the MST of all (or almost all) subgraphs generated. The two random models that we consider are subgraphs induced by a random subset of vertices or edges, each present with probability p. In both random cases, we prove that there is a covering set Q of cardinality $O(n \log_b n)$ where $b = 1/(1-p)$ and this is asymptotically optimal. We also derive a randomized algorithm which calls an MST subroutine only a polylogarithmic number of times, and finds such a sparse covering set with high probability. The random results also imply results in the deterministic setting.

Robust minimum spanning tree

ABDEL LISSER
LRI, Universite de Paris IX

coauthors: Lisser Abdel, Kenyon Claire
keywords: robust optimization, approximation algorithms, minimum spanning trees

We Propose a new randomized algorithm for solving the robust spanning tree problem, hereafter called $RSTP$. The robustness in our problem is expressed by the means of a set of weights for each edge of the underlayer graph. We model $RSTP$ as a $\{0-1\}$ linear programming problem. As the size of the LP is very large, we use

Benders Decomposition to solve its relaxation in order to get the lower bounds. We then apply our randomized algorithm to compute the upper bounds. Complexity as well as Numerical results are given for instances with up to 100 nodes fully meshed graphs.

TH2-321/053 PRODUCTION AND SCHEDULING

Scheduling AND/OR constraints

chair: Valery Gordon

Scheduling with or-precedence constraints

BERIT JOHANNES
Technische Universität Berlin

keywords: scheduling, OR networks, computational complexity

In various scheduling contexts, AND/OR-networks are a relevant generalization of ordinary precedence constraints (AND constraints). Accordingly, scheduling problems with AND/OR-constraints inherit the computational complexity of their classic ancestors with AND-constraints. On the other hand, the complexity status of various scheduling problems with OR-constraints has remained open. In this talk, we present a couple of complexity results for scheduling unit-time jobs subject to OR-precedence constraints. In particular, we give a polynomial-time algorithm for minimizing the makespan and the total completion time on identical parallel machines. However, minimizing the total weighted completion time is NP-hard, even on a single machine.

Scheduling with AND/OR-networks

VANESSA KAEAEB
Technische Universitaet Berlin

keywords: networks, sensitivity analysis, scheduling, approximation

In contrast to standard digraphs, an AND/OR-network has two different sorts of nodes, AND- and OR-nodes, which represent the following precedence constraints. An AND-node is just a normal node with the meaning that the job it represents can be processed as soon as every job preceding it in the graph has been completed. An OR-node on the other hand can be scheduled as soon as at least one of its predecessors has been finished.

First, we define four versions of critical sets in AND/OR-networks. The systems of critical sets of an AND/OR-network form two pairs of blocking clutters. It follows that in each case two of the concepts are equivalent but all four of them are not equivalent in general. It is NP-complete to decide whether a single job is critical, whereas it is easy to find a critical set.

We also focus on scheduling AND/OR-networks on identical parallel machines. For the objective of minimizing the makespan, the problem with AND/OR precedence constraints can be reduced to the problem with standard precedence constraints. In contrast to this, a reduction from a special disassembly problem provides us with a strong inapproximability result for the total weighted completion time objective.

Assignment of due dates in scheduling partially ordered jobs

VALERY GORDON
United Institute of Informatics Problems, National Academy of Sciences of Belarus

coauthors: Jean-Marie Proth, Vitaly Strusevich
keywords: scheduling, due date assignment, precedence constraints, single machine

A single machine due date assignment and scheduling problem is considered where due dates are determined by increasing the processing times of jobs by a common positive slack and jobs are partially ordered according to the given precedence constraints. The objective is to explore the trade-off between the size of the slack and the arising holding costs for the early jobs, and to find an optimal schedule that minimizes holding costs provided that there are no tardy jobs and precedence constraints are respected. A polynomial-time solution is proposed for the series-parallel and somewhat wider class of precedence constraints.

TH2-321/033 MULTICRITERIA OPTIMIZATION

Convexity and generalized convexity in multicriteria optimization

chair: Andreas Loehne

Efficiency conditions and duality for multiobjective fractional variational programming problems

KHADIJA KHAZAFI
Université Hassan II, faculté des sciences Ain Chock, Casablanca, Morocco

keywords: multiobjective fractional, variational programming, duality, optimality

We are concerned with multiobjective fractional variational programming problems. A class of generalized convexity functions are introduced. Based upon this concept of generalized convex, optimality conditions and duality results are established.

A projected gradient method for vector optimization

LUIS MAURICIO GRAÑA DRUMMOND
Rio de Janeiro Federal University

coauthor: Alfredo Noel Iusem
keywords: vector optimization, weak efficiency, projected gradient method, k-convexity

We propose a method for solving constrained vector optimization problems in a finite dimensional linear space, with preference order induced by a closed convex cone. When the objective is scalar-valued, the procedure coincides with the classical projected gradient method. For convex objectives (respect to the cone), we show that the algorithm generates sequences which converge to weak efficient points, no matter how poor is the initial guess.

On convex functions with values in semi-linear spaces

ANDREAS LOEHNE
Martin-Luther-Universitaet Halle-Wittenberg

keywords: set valued optimization, semi linear spaces, convex programming

It holds the following well–known result of convex analysis: *If the function* $f : X \to [-\infty, +\infty]$ *is convex and some* $x_0 \in \operatorname{core}(\operatorname{dom} f)$ *satisfies* $f(x_0) > -\infty$, *then* f *never takes the value* $-\infty$. From a corresponding theorem for convex functions with values in semi–linear spaces a variety of results are deduced, among them the mentioned theorem, a theorem of Deutsch and Singer on the single–valuedness of convex set–valued maps as well as a result on the compact–valuedness of convex set–valued maps.

TH2-321/133 LINEAR PROGRAMMING

Numerical approaches I

chair: Neelam Gupta

Solving DEA models by the Fourier Motzkin elimination method

GAUTAM APPA
London School of Economics

coauthor: H.Paul Williams
keywords: data envelopment analysis, linear programming, Fourier Motzkin method

When solving Data Envelopment Analysis (DEA) models it is usual to solve a Linear Programme (LP) many times, with different right-hand-side (RHS) vectors: once for each Decision Making Unit (DMU) being evaluated. This iterative approach gives little insight into the overall structure of the model for the organisation. Instead, by projecting out all the variables of the LP which are common to all LP runs, we obtain a formula into which we can substitute the inputs and outputs of each DMU in turn to obtain its efficiency number and efficient comparators. In addition we also obtain the best weightings which the DMU would choose to put on its inputs and outputs. The method of projection, which we use, is Fourier-Motzkin Elimination. This provides us with a finite number of extreme rays of the elimination cone. These rays give the dual multipliers which can be interpreted as weights which will apply to the inputs and outputs for particular DMUs. As the approach provides all the extreme rays of the cone, multiple sets of weights, when they exist, are explicitly provided. In addition it is possible to construct the skeleton of the efficient frontier of efficient DMUs.

A simplex algorithm for separated continuous linear programs

GIDEON WEISS
University of Haifa

keywords: simplex, continuous linear programming

We consider the separated continuous linear programming problem (SCLP) with linear data as formulated originally by Bellman 1953 and by Anderson 1979 and investigated by Pullan 1993. We characterize the form of its optimal solution, and present an algorithm which solves it in a finite number of steps, using simplex pivot operations. To do so we: (a) Formulate a symmetric dual problem. (b) Find that a finite sequence of LP bases plays the role of a basis for SCLP. (c) Define neighboring base-sequences through their validity regions. (d) Construct an algorithm to pivot between neighboring base-sequences. (e) Find an algorithm to solve SCLP by a sequence of pivots analogous to the parametric simplex algorithm of LP.

Una: a simple numerical algorithm to solve linear constraints in real variables

NEELAM GUPTA
The University of Arizona
coauthors: YongJun Cho, Mohammad Z. Hossain

keywords: solving linear constraints, numerical algorithms, linear programming

In this paper, we present a strikingly simple numerical algorithm called UNA for computing a feasible solution or detecting infeasibility of linear constraints in real variables. We show that UNA converges for solving linear constraints in real variables. We present experimental comparison of the average time performance of UNA, with two commercial linear programming packages XA and CPLEX, for solving randomly generated constraint sets.

In our experiments, CPLEX performed better than UNA, and UNA performed better than XA in solving larger feasible constraint sets. As the size of constraint sets increases, the average time taken by UNA is only about 2 to 3 times the average time taken by CPLEX, whereas the time performance of XA becomes much worse than both UNA and CPLEX. In experiments with detecting infeasibility of large constraint sets, CPLEX performed far better than UNA and XA.

Our experiments indicate that UNA is a simple but practical algorithm to solve linear constraints. Most of its computation time is spent when it is already very close to a feasible solution. It would be worthwhile to explore variants of UNA that cut down the computation time after it is in close proximity to a feasible solution.

TH3-302/41 COMBINATORIAL OPTIMIZATION

Semidefinite liftings in combinatorial optimization

organizer/chair: Miguel Anjos

Solving the satisfiability problem using semidefinite programming

MIGUEL ANJOS
Faculty of Mathematical Studies

keywords: semidefinite programming

The satisfiability (SAT) problem is a central problem in mathematical logic, computing theory, and artificial intelligence. An instance of SAT is specified by a set of boolean variables and a propositional formula in conjunctive normal form. Given such an instance, the SAT problem asks whether there is a truth assignment to the variables such that the formula is satisfied. The general SAT problem is well known to be NP-complete, although several important special cases can be solved in polynomial time.

We propose semidefinite programming relaxations for the satisfiability problem within a paradigm of “higher liftings” for combinatorial optimization problems. We first discuss the ability of these relaxations to prove whether or not a given instance of SAT is satisfiable. Then, from a more practical point of view, we explore the amenability of these relaxations to practical computation.

Semidefinite relaxations for sparse max-cut problems

ANGELIKA WIEGELE
University of Klagenfurt

coauthor: Franz Rendl
keywords: semidefinite programming

Let be given an edge-weighted undirected graph. The Max-Cut Problem consists in finding a partition S and V§ of the vertex set V in such a way that the total weight of the edges joining S and V§ is maximized. The Max-Cut Problem is known to be NP-complete.

We investigate semidefinite relaxations of the Max-Cut problem, which are formulated in terms of the edges of the graph, thereby exploiting the (potential) sparsity of the problem. We show how this is related to higher order liftings of Anjos and Wolkowicz and Lasserre. Contrary to the basic semidefinite relaxation, which is based on the nodes of the graph, the present formulation leads to a model which is significantly more difficult to solve.

We present preliminary computational results where we combine interior point methods with the bundle concept. These results indicate that this model is manageable for sparse graphs on a few hundred nodes and yields very tight bounds.

Semidefinite representations for finite varieties

MONIQUE LAURENT
CWI

keywords: semidefinite relaxation, sum of squares of polynomials

We propose a semidefinite formulation, involving combinatorial moment matrices, for the problem of optimizing a polynomial function over a semi-algebraic set defined by polynomial equalities ($h_j(x) = 0,\ j = 1,..,m$) and inequalities, in the case when the polynomials $h_1,..,h_m$ have a finite number of common zeroes with single multiplicities. In the 0/1 case ($h_j(x) = x_j^2 - x_j$) and ± 1 case ($h_j(x) = x_j^2 - 1$), we find the semidefinite representation underlying lift-and-project methods (Sherali-Adams, Anjos-Wolkowicz,..) and algebraic methods via sums of squares of polynomials (Nesterov, Lasserre, Parrilo,..). Semidefinite approximations are obtained by considering truncated moment matrices; we present rank conditions ensuring that the approximation solves the original problem at optimality, with applications to max-cut and the maximum stable set problem.

TH3-302/42 COMBINATORIAL OPTIMIZATION

Combinatorial optimization IX

chair: Safia Kedad-Sidhoum

Controlled rounding and other new statistical disclosure limitation methods for tabular data

JUAN JOSÉ SALAZAR GONZÁLEZ
University of La Laguna

keywords: statistical disclosure control

Rounding methods are common techniques in many statistical offices to protect sensitive information when publishing data in tabular form. These methods do not consider protection levels while searching patterns with minimum information loss, and therefore typically the so-called auditing phase is required to check the protection of the proposed patterns. This work addresses new versions of the classical Controlled Rounding Methodology which guarantee protection levels implicetely. We will also presents a mathematical model for the whole problem of finding a protected pattern with minimum loss of information, and proposes a branch-and-cut algorithm to solve it. It also describes a new methodology closely related with the classical controlled rounding methods but with several advantages. The new methodology leads to a different optimization problem which is simpler to solve than the previous problem. We present a cutting-plane algorithm for finding an exact solution of the new problem, which is a pattern guaranteeing the same protection level requirements but with smaller loss of information when compared with the classical controlled rounding optimal patterns. Considering the solutions of the here-introduced two problems, the auditing phase is unnecessary. We conclude with computational results on randomly generated instances proving the good performance of the proposal.

The graph disconnectivity problem: an improved algorithm and new models

YOUNG-SOO MYUNG
Dankook University

keywords: graph disconnectivity

The graph disconnectivity problem is to find a set of edges such that the total cost of removing the edges is no more than a given budget and the weight of nodes disconnected from a designated source by removing edges is maximized. Martel et al. have shown that the problem with unit capacity and unit demand is NP-hard and Myung and Kim present an integer programming formulation and develop an algorithm that includes a preprocessing procedure and lower and upper bounding strategies. In this talk, we present new findings on the properties of the optimal solution, based on which a new algorithm is developed. We also introduce new models that have different objectives and required conditions.

A new lower bound for the one machine problem with earliness andtardiness penalties

SAFIA KEDAD-SIDHOUM
LIP6 - Pierre Marie Curie University

keywords: one machine scheduling, earliness/tardiness, weighted stable set, interval graphs

We address the one-machine problem in which the jobs have distinct due dates, earliness costs and tardiness costs. More precisely, a set of jobs has to be scheduled on a single machine. Each job has a processing time. A schedule is a sequence of the starting times of all the jobs subject to disjunctive constraints, that is two jobs cannot be processed at the same time by the machine. A job is then scheduled, without preemption, from its starting time to its completion time. A cost function is attached to each job including the earliness and tardiness penalties. The total cost of the schedule is the sum of the costs of all the jobs. The problem is to find a schedule with a minimum cost. This problem arises in just-in-time production environment. A time-indexed formulation is considered and a new lower bound based on lagrangian relaxation is proposed. This bound is based on the observation that the lagrangian relaxation of a set of job constraints leads to a minimum weighted stable set problem on an interval graph. This problem is efficiently solvable by dynamic programming. Computational results will be reported.

TH3-302/44 COMBINATORIAL OPTIMIZATION
Minimum trees
chair: Francisco Barahona

A 2-paths approach for odd-diameter-constrained minimum spanning and Steiner trees

CRISTINA REQUEJO
University of Aveiro
coauthors: Luis Gouveia, Thomas Magnanti
keywords: diameter-constrained trees, network flows, hop-indexed models

Using underlying graph theoretical properties, Gouveia and Magnanti (2003) described several network flow-based formulations for diameter-constrained tree problems. Their computational results showed that, even with several enhancements, models for situations when the tree diameter D is odd proved to be more difficult to solve than those when D is even. We provide an alternate modeling approach for situations when D is odd. The approach is based on a new (although easily proved) graphical property and views the diameter-constrained minimum spanning tree as being composed of a variant of a directed spanning tree (from an artificial root node) together with two constrained paths, a shortest and a longest path, from the root node to any node in the tree. We show how to tighten the resulting formulation to develop a model with a stronger linear programming relaxation. The linear programming gaps for the tightened model are very small, typically less than 0.5%, and are usually one third to one tenth of the gaps of the best model previous described in Gouveia and Magnanti (2003). Moreover, using the new model, we are able to solve large Euclidean problem instances that are not solvable by the previous approaches.

Flexibility of Steiner minimum trees in uniform orientation metrics

MARCUS BRAZIL
The University of Melbourne
coauthors: Pawel Winter, Martin Zachariasen
keywords: geometric network design, networks, combinatorial optimization, VLSI design

We present some fundamental flexibility properties for minimum length networks (known as Steiner minimum trees) interconnecting a given set of points in an environment in which edge segments are restricted to λ uniformly oriented directions. We refer to these networks as λ-SMTs. They will play an increasingly important role in the future of optimal wire routing in VLSI physical design, particularly for the next generation of VLSI circuits, which will make pervasive use of "diagonal" interconnects.

In this paper we develop the concept of an extremal polygon for a λ-SMT, which is a region representing the union of all λ-SMTs with the same topology on a given set of points. We show that this polygon can be constructed, for a given point set and given topology, in linear time. We the discuss the applications of this polygon, which can be thought of as a geometric representation of the amount of flexibility inherent in a given λ-SMT. In particular, we show that it can be used to develop more powerful pruning techniques for exactly constructing a λ-SMT for a given set of points. We also discuss the ways in which it can be used to solve multi-objective optimisation problems in VLSI physical design, involving minimising congestion or signal delay as a secondary objective.

Network reinforcement

FRANCISCO BARAHONA
IBM Research
keywords: spanning trees

Given a graph $G = (V, E)$ with edge-weights, and a number k, we study the problem of finding an edge set of minimum weight that partitions into k disjoint spanning trees. We give an algorithm whose complexity is dominated by $V|$ applications of the minimum cut algorithm of Goldberg and Tarjan.

TH3-302/45 INTEGER AND MIXED INTEGER PROGRAMMING
Industrial applications
chair: Ken McKinnon

An integer programming solution to optimally locating radioactive waste facilities

JOHN KARLOF
University of North Carolina at Wilmington
keywords: integer programming, applications

The American 1980 Low-level Radioactive Waste (LLRW) Policy Act suggests several constraints for choosing LLRW dump sites, such as three states containing dump sites, single sourcing, and equally distributing the waste between the three sites. The optimization criteria is to minimize the number of ton-miles of LLRW transported. There is an extremely large number of ways to choose the three states for sites and the site each state will send its waste to. We model this problem as an integer programming problem and present a branch and bound algorithm using penalty fathoming for its solution.

Optimal routing of oil and gas from wells to separators

BJØRN NYGREEN
NTNU
coauthor: Ken McKinnon
keywords: mixed integer programming, petroleum/natural gas

Networks of pipelines are used to connect oil and gas wells to central production plants where the oil, gas and water are separated. We consider networks where there are alternative routings between the wells and the separation plants. The outputs of wells depend nonlinearly on the pressure in the gathering pipelines.

We discuss the problem finding the valve setting which maximize the output from the network and show how to model this as a MILP. We describe how to obtain sharper formulations of parts of the problem.

Branch-and-price to solve a MILP feed mill problem

KEN MCKINNON
Edinburgh University

coauthor: Andreas Grothey
keywords: branch-and-price, MILP, decomposition, feed mill

This talk will describe a problem which arises in feed mills of producing minimum cost diets when there are some discrete constraints on the use of raw materials.

A Branch and Price method for the problem in which the price step is solved as a MILP will be described. This allows the problem to be decompose so that each diet can be treated separately. A comparison will be given of this with a standard MILP approach to the non-decomposed problem. MILP

TH3-302/49 INTEGER AND MIXED INTEGER PROGRAMMING

Theory of 0/1 and integer programming

organizer/chair: Friedrich Eisenbrand

Fast integer programming in fixed dimension

FRIEDRICH EISENBRAND
MPI-Informatik

keywords: integer programming, lattice basis reduction

It is shown that the optimum of an integer program in fixed dimension with a fixed number of constraints can be computed with $O(s)$ basic arithmetic operations, where s is the binary encoding length of the input. This improves on the quadratic running time of previous algorithms, which are based on Lenstra's algorithm and binary search.

It follows that an integer program in fixed dimension, which is defined by m constraints, each of binary encoding length at most s, can be solved with an expected number of $O(m+\log(m)\,s)$ arithmetic operations using Clarkson's random sampling algorithm.

The graph-density of random 0/1-polytopes

VOLKER KAIBEL
TU Berlin

coauthor: Anja Remshagen
keywords: combinatorics, polytope, random

One of the discoveries that were especially exciting for the early polyhedral combinatorialists was the observation that many 0/1-polytopes associated with combinatorial optimization problems have graphs with very small diameters. Particularly striking examples are the cut-polytopes of complete graphs with graph-density equal to one. In this talk, we demonstrate that high density is not a feature that is special to 'combinatorial' 0/1-polytopes. In fact, the graph density of a d-dimensional random 0/1-polytope with $n(d)$ vertices tends to one (with d going to infinity) if $n(d) \le (\sqrt{2}-\varepsilon)^d$ holds for some $\varepsilon > 0$, while it tends to zero in case of $n(d) \ge (\sqrt{2}+\varepsilon)^d$. The cut-polytopes have $n(d) \le \mathrm{const}^{\sqrt{d}}$ vertices.

Point containment in the integer hull of a polygon

ERNST ALTHAUS
Max-Planck Institute

coauthors: Friedrich Eisenbrand, Stefan Funke, Kurt Mehlhorn
keywords: integer programming, complexity, fixed dimension, separation

We provide a $O(m+(\log m)s)$ time algorithm to decide whether a given rational point is contained in the integer hull of a two-dimensional convex polygon, defined by m constraints, each involving coefficients of binary encoding length $O(s)$. For comparison, the equivalence of separation and optimization yields a running time of $O(ms+(\log m)s2)$ for this task.

We certify containment with a feasible unimodular triangle. This can be applied to obtain a faster algorithm for multiprocessor scheduling with two job lengths, previously studied by McCormick, Smallwood and Spieksma.

TH3-306/31 CONSTRAINT LOGIC PROGRAMMING

Constraint programming

chair: Irvin Lustig

Optimizing TV-break packages offered by satellite channels

ERIC BOURREAU
Bouygues e-lab

coauthors: Bourreau Eric, Rottembourg Benoit, Benoist Thierry
keywords: constraint programming, linear relaxation, combinatorial optimization

The TV breaks packing problem consists, for a TV channel, in building spot packages satisfying marketing constraints whilst maximizing the total selling price. A package is a fixed amount of messages satisfying both campaign shapes constraints and audience requirement (minimum number of forecasted spectators). This problem is modelled with a single flow together with additional covering constraints that make it NP-hard. We compare several resolution techniques such as linear programming (standard linear relaxation, lagrangian relaxation) and constraint programming schemes (standard constraints, global constraint). Finally we present an innovative way of hybridizing global constraints and local search making use of incremental flow algorithm.

A combined mixed integer programming and constraint programming approach to planning and scheduling in a paint company

MIGUEL CONSTANTINO
University of Lisbon

keywords: production planning, scheduling, mixed integer programming, constraint programming

We consider the integrated planning and scheduling of production lots in a paint company. While the production plan establishes the production lots for a horizon of 1 to 2 weeks, the scheduling of the lots (tasks) on the machines is done daily. The approach considered uses a Mixed Integer Programming model to obtain solutions for the planning problem, and uses Constraint Programming to check for the existence of daily feasible schedules. In case such a schedule does not exist, this information is incorporated in the MIP model, and the procedure is iterated. We present results with real data from the paint company.

Scheduling the national football league with constraint programming

IRVIN LUSTIG
ILOG Direct

keywords: constraint programming, sports scheduling

The National Football League (NFL) consists of 32 teams, with each team playing a predetermined set of 16 games and one bye over 17 weeks. The NFL has to schedule these games to meet the demands of the teams as well as the television networks. We describe how constraint programming has been successfully applied to solve this problem.

TH3-306/32 NONLINEAR PROGRAMMING

Surrogate modelling for engineering optimization II

organizer/chair: Kaj Madsen

Surrogate modelling by Kriging

HANS BRUUN NIELSEN
IMM

coauthors: Søren N. Lophaven, Jacob Søndergaard
keywords: surrogate modeling, response surface, Kriging

The Kriging method has wide applications in statistics, and was introduced as a tool for modelling response surfaces about 15 years ago.

In the talk we present the Kriging method in a common framework with radial basis functions and multivariate interpolating polynomials. Further, we give a numerical analyst's view of some of the problems that we had to cope with during the development of DACE: a Matlab toolbox for Design and Analysis of Computer Experiments. By proper choice of a correlation model it is possible get very good approximations, but you have to work with a very ill conditioned matrix.

Finally, we give some preliminary results from the use of the Kriging model as surrogate model in connection with optimization of "expensive functions".

A derivative-free algorithm based on radial basis functions (RBF)

RODRIGUE OEUVRAY
ROSO-IMA-SB-EPFL

coauthor: Michel Bierlaire
keywords: derivative-free algorithm, trust region method, radial basis functions, DFO

Derivative-free optimization involves all the methods used to minimize an objective function when its derivatives are not available and when the function is expensive. We present here a trust region algorithm based on radial basis functions instead of the classical second order polynomials. Actually, our surrogate of the objective function is a mixed radial and polynomial model. We present encouraging preliminary results. The overall efficiency of the algorithm is comparable to DFO. On some instances, the new algorithm performs even better.

Gradient estimation using Lagrange interpolation polynomials

DICK DEN HERTOG
Tilburg University

coauthors: Ruud Brekelmans, Lonneke Driessen, Herbert Hamers
keywords: gradient estimation, Lagrange interpolation, nonlinear optimization, noisy function

In this paper we use Lagrange interpolation polynomials to obtain good gradient estimations when the underlying function is noisy. Good gradient estimation is e.g. important for nonlinear programming solvers. As an error criterion we take the mean squared error. This error can be split up into a deterministic and a stochastic error. We analyze these errors using (N times replicated) Lagrange interpolation polynomials. We show that the MSE is of order $N^{-1+\frac{1}{2d}}$ if we use $2d$ evaluations in each replicate. The value $d = 1$ corresponds with finite forward differencing, and the corresponding MSE order $N^{-\frac{1}{2}}$ is well-known in the literature. Moreover, note that as a result the order of the MSE converges to N^{-1} if the number of evaluation points increases to infinity. Moreover, we show that our approach is also useful for deterministic functions in which numerical errors are involved. Finally, we consider the case of a fixed budget of evaluations. For this situation we provide an optimal division between the number of replicates and the number of evaluations per replicate.

TH3-306/33 NONLINEAR PROGRAMMING

PDE-constrained optimization (3)

organizers: Michael Ulbrich and Stefan Ulbrich
chair: Stefan Ulbrich

A generalized discretization concept for control constrained optimal control problems and its numerical realization

MICHAEL HINZE
TU Dresden

keywords: discretization concept, control of PDEs, primal-dual active set method, control constraints

In my talk I will discuss a new discretization concept for abstract control problems with control constraints which extends the common discrete approaches. Discretization only is applied to the state variables, which in turn implicitly yields a discretization of the control variables by means of the first order optimality condition. For discrete controls obtained in this way an optimal error estimate in terms of the state-discretization parameter is presented.

Applied to control of partial differential equations combined with finite element discretization of the state the key features of the new control concept include

-decoupling of finite element grid and discrete active set -numerical implementation requires only small additional overhead compared to commonly utilized methods (discretization of state AND of admissible controls) -Approach applicable in 1,2 and 3 spatial dimensions, and also for Galerkin type discretization schemes of time dependent state equations -Numerical analysis seriously simplifies compared to the common approach

As numerical solution algorithms primal-dual active set strategies and semi-smooth Newton methods are discussed. Several numerical examples will be presented that confirm the theoretical investigations.

References: M. Hinze: A generalized discretization concept for optimal control problems with control constraints, Preprint Math–NM–02-2003, Institut für Numerische Mathematik, TU Dresden, Germany.

Adaptive finite elements for control of convection-diffusion equation

ROLAND BECKER
Universitaet Heidelberg

keywords: finite elements, a posteriori error estimates, optimal control

We consider selve-adaptive construction of appropriate meshes for the optimal control of scalar elliptic equations. A general framework for deriving a posteriori error estimates is presented. With the help of such an estimator we construct an adaptive algorithm which combines optimization and local mesh refinement allowing for quantitative error control and efficiency. We further focus on the additional difficulties introduced by stabilization of the Galerkin finite element scheme.

Very large scale nonlinear programming by scp methods

CHRISTIAN ZILLOBER
University of Bayreuth

keywords: nonlinear programming, applications, very large scale problems, convex approximations

We consider the general nonlinear programming problem with smooth objective function and constraints. Sequential convex programming (SCP) methods have been developed in the context of structural optimization problems where the methods are known to work well since some kind of frequently used constraints are approximated very well. The most important properties of these first order approximations which are applied for the objective function and inequality constraints are convexity and separability. The convex subproblems that arise in this framework are solved by a primal-dual interior point method. The main advantage is that sparsity of the Jacobian can be exploited very efficiently. The method had has been applied to very large scale nonlinear programming problems with up to one million variables arising in topology optimization. For these applications one could expect good performance of SCP methods. But most recently the methods have been applied to very large scale nonlinear programming problems from optimal control for which the motivation for the special approximation does not hold. Nevertheless, SCP methods perform superior to other methods that have been tested in a benchmark study by Maurer and Mittelmann. The largest problem that has been solved in this context has about 720000 variables and 360000 constraints.

TH3-306/34 NONLINEAR PROGRAMMING

Large scale problems III

chair: Ernesto G. Birgin

Issues on conjugate gradient-type algorithms within truncated Newton methods, in large scale unconstrained optimization

GIOVANNI FASANO
University of Rome
coauthor: Massimo Roma
keywords: large scale optimization, conjugate gradient method, truncated Newton methods

In this work we aim at studying some new features of conjugate gradient type methods based on planar schemes. The latter algorithms are used for solving the Newton's equation within truncated Newton methods. The interest on planar conjugate gradient algorithms has been recently rekindled, since they have a twofold advantage. On one hand they avoid the well known shortcomings of the standard conjugate gradient methods, in dealing with indefinite problems. On this purpose we investigate the possibility to overcome these drawbacks and to extend the relationship between the Lanczos and the planar conjugate gradient type methods, in the indefinite case. On the other hand, planar conjugate gradient methods provide a set of conjugate directions which seem to be promising, in defining effective preconditioning strategies.

An $o(n^2 \log n)$ algorithm for projecting a vector on the intersection of two hyperplanes and a box in r^n

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Universidade Federal do Rio de Janeiro
coauthors: Nelson Maculan, Claudio Prata Santiago
keywords: orthogonal projection, computational linear algebra, computational complexity

The orthogonal projection of a vector on the intersection of two hyperplanes and a box arises as a subproblem of some optimization methods, for example, the solution of the dual Lagrangian problem in integer programming using e-subgradient techniques. In this work, for this projection we present an $O(n^2 \log n)$ time algorithm . We extend a previous result of Maculan et al. [1], with similar approach relating to the complexity of the algorithm . With reference to projection, the solution is based in finding Lagrange multipliers associated with the hyperplanes. Details of the complexity of the algorithm for this quadratic programming problem are presented. Computational results are also presented in order to evaluate the algorithm and its time complexity.

[1] MACULAN N.,SANTIAGO C.P., MACAMBIRA,E.M.and JARDIM,M.H., An O(n) algorithm for projecting a vector on the intersection of a hyperplane and a box in Rn- Journal of Optimization and Applications , Vol117, N3 pp553-574 (2003)

[2] MINOUX,M., Mathematical Programming, John Wiley(1986)

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Inexact spectral projected gradient methods on convex sets

ERNESTO G. BIRGIN
Computer Science Dept. - IME - University of Sao Paulo
coauthors: J. M. Martinez, M. Raydan
keywords: projected gradient, convex constrained, nonmonotone line search, spectral gradient

A new method is introduced for large scale convex constrained optimization. The general model algorithm involves, at each iteration, the approximate minimization of a convex quadratic on the feasible set of the original problem and global convergence is obtained by means of nonmonotone line searches. A specific algorithm, the Inexact Spectral Projected Gradient method (ISPG) uses inexact projections computed by Dykstra's alternating projection method and generates interior iterates. This algorithm is implemented and tested and numerical results are shown. The ISPG method is a generalization of the Spectral Projected Gradient method (SPG), but can be used when projections are difficult to compute. Convergence properties and numerical results are presented.

TH3-306/35 NONLINEAR PROGRAMMING

Newton-like algorithms II

chair: Mehiddin Al-Baali

A nonmonotone line search technique and its application to unconstrained optimization

HONGCHAO ZHANG
University of Florida
coauthor: William Hager
keywords: nonmonotone line search, r-linear convergence, unconstrained optimization, L-BFGS method

A new nonmonotone line search algorithm is proposed and analyzed. In our scheme, we require that an average of the successive function values decreases, while the traditional nonmonotone approach of Grippo, Lampariello, and Lucidi [*A nonmonotone line search technique for Newton's method,* SIAM J. Numer. Anal., 23 (1986), pp. 707–716] requires that a maximum of recent function values decreases. We prove global convergence for nonconvex, smooth functions, and R-linear convergence for strongly convex functions. For the L-BFGS method and the unconstrained optimization problems in the CUTE library, the new nonmonotone line search algorithm used fewer function and gradient evaluations, on average, than either the monotone or the traditional nonmonotone scheme.

High order Newton-penalty algorithms

JEAN-PIERRE DUSSAULT
Université de Sherbrooke
keywords: quadratic penalty function, Newton method, predictor-corrector methods

Recent efforts in differentiable non-linear programming have been focused on interior point methods, akin to penalty and barrier algorithms. In this paper, we address the classical equality constrained program solved using

the simple quadratic loss penalty function/algorithm. The suggestion to use extrapolations to track the differentiable trajectory associated with penalized subproblems goes back to the classic monograph of Fiacco & McCormick. This idea was further developed by Gould who obtained a two-steps quadratically convergent algorithm using prediction steps and Newton correction. Dussault interpreted the prediction step as a combined extrapolation with respect to the penalty parameter and the residual of the first order optimality conditions. Extrapolation with respect to the residual coincides with a Newton step.

We explore here higher order extrapolations, thus higher order Newton-like methods. We first consider high order variants of the Newton-Raphson method applied to non-linear systems of equations. Next, we obtain improved asymptotic convergence results for the quadratic loss penalty algorithm by using high order extrapolation steps.

Quasi-Wolfe conditions for Newton-like methods

MEHIDDIN AL-BAALI
Sultan Qaboos University

keywords: nonlinear optimization, Newton-like methods, inexact line searches

Quasi-Wolfe conditions for practical Newton-like methods of nonlinear optimization will be introduced. These conditions suggest a modification technique to these methods to rectify certain difficulties which usually arise when the Wolfe line-search conditions are either weak or not satisfied at some iterations. It will be shown, in particular, that the modification technique speeds up several quasi-Newton algorithms and maintains their useful properties.

TH3-306/36 NONSMOOTH OPTIMIZATION
Nonsmooth optimization
chair: Robert Mifflin

Max-min separability and its applications

ADIL BAGIROV
School of Information Technology and Mathematical Sciences, University of Ballarat

keywords: nondifferentiable optimization, data analysis, pattern analysis

We consider the problem of discriminating between two or more finite point sets in the n-dimensional space by the finite number of hyperplanes generating piecewise linear function. If the intersection of these sets is empty then they can be strictly separated by a function represented as a max-min of linear functions. The problem of max-min separability is reduced to a certain nonsmooth optimization problem. We propose an algorithm for solving max-min separability problem and apply it to solve supervised data classification problems. Results of numerical experiments are presented.

Large-scale Lagrangian decomposition problems solved by cutting plane methods

MATTHIAS KNOBLOCH
Chemnitz University of Technology

keywords: nonsmooth programming, convex programming, cutting plane methods

We consider general convex programs with binding constraints suitable for Lagrangian decomposition. The proposed oracle-type method is capable to manage infinite function values of the dual function. For linear and convex quadratic programming problems a complete realization of the oracle will be described. Several generalizations for generic convex programs will be given.

Properties of functions with primal-dual gradient structure

ROBERT MIFFLIN
Washington State University
coauthor: Claudia Alejandra Sagastizábal

keywords: second order derivatives, VU-decomposition, nonsmooth analysis, convex minimizaton

This talk concerns further developments for nonsmooth functions with primal-dual gradient (pdg) structure[SIOPT 13(2003) 1174-1194]. Such functions have an underlying C^2 substructure which differs from that of fully amenable functions, because the class contains maximum eigenvalue functions and other "infinitely-defined" functions. Under certain conditions, including "primal feasibility", such a function has "U-subspace" Hessians that give second-order epi-derivatives in U-space directions. With the addition of a "dual feasiblity" condition at a point the function is partly smooth relative to a certain manifold. The pdg structure at a point of a nonconvex partly smooth example function due to Lewis is interesting because it has two U-Hessians whose eigenvalues indicate that the point is locally neither a minimizer nor a maximizer. For a convex function of the above type there exists a "fast track" to a minimizer which an algorithm can follow by alternating "V-steps" (each produced by a bundle algorithm subprocess) with orthogonal "U-quasi-Newton-steps" (each based on a VU-decomposition and a U-gradient that depends on cutting-plane subgradients generated by the bundle subroutine).

TH3-306/37 CONVEX PROGRAMMING
Geometry and duality in convex optimization
organizer/chair: Gabor Pataki

The D-induced duality and its applications

SHUZHONG ZHANG
The Chinese University of Hong Kong
coauthor: Jan Brinkhuis

keywords: dual cone, robust optimization

In this talk we introduce the notion of D-induced duality for a convex cone, using a pre-described conic ordering induced by the convex cone D and a fixed bilinear mapping. This is an extension of the standard definition of dual cones, in the sense that the nonnegativity of the inner-product is replaced by the conic ordering, and the inner-product itself is replaced by a general multi-dimensional bilinear mapping. The resulting cone is called the D-induced dual cone. Furthermore, this notion is extended to the D-induced polar set. Basic properties of the D-induced duality, including the extended bi-polar theorem, are proven. We shall further show that this notion of duality is an essential ingredient in optimization. As examples, we mention its applications in robust optimization and multiple-objective programming.

On the block-structured distance to infeasibility

JAVIER PENA
Carnegie Mellon University

keywords: distance to infeasibility, Eckart and Young identity, sparse matrices, conic systems

We show that the block-structured distance to infeasibility of a conic system of constraints equals the reciprocal of a suitable block-structured norm of a certain inverse operator. This gives a natural generalization of the classical Eckart-Young identity, which states that the (unstructured) distance to singularity of a square matrix equals the reciprocal of the norm of its inverse. We also discuss our results in the equivalent context of set-valued sublinear mappings, where a dual counterpart of the generalized Eckart-Young identity is revealed.

Our results unify and extend the Eckart and Young identity, Renegar's characterization of the distance to infeasibility, Cheung and Cucker's characterization of the normalized distance to ill-posedness, and Rohn's characterization of the componentwise distance to singularity. We also present some connections with the mu-number in robust control, and the sign-real spectral radius.

Bad semidefinite systems: they look all the same

GABOR PATAKI
Operations Research, University of North Carolina at Chapel Hill

keywords: semidefinite programming, second order cone programming, conic duality, exact characterization

We give a surprisingly simple, exact, "excluded minor" type characterization of semidefinite systems that have a badly behaved dual for some objective function. We also prove that a semidefinite system has a well behaved dual for all objectives, iff the constraint matrices can be made block-diagonal; the block structure is given by the maximum rank semidefinite slack.

The characterization is based on new results in convex analysis about the closedness of the linear image of a closed convex cone. These results lead to exact characterizations for other badly behaved convex inequality systems as well, most notably second order conic systems.

TH3-306/38 GLOBAL OPTIMIZATION

Global optimization techniques via reformulations, smoothing approaches and DC programming

organizer/chair: Tao Pham Dinh

A difference of convex functions programming approach to image restoration via Markov model

HOAI AN LE THI
National Insitute for Applied Sciences-Rouen
coauthors: Pham Dinh Tao, Pham Tien Son

keywords: Gibbs energy, Markov model, DC programming, DCA/GNC

Image restoration problems can be solved using optimization techniques. They lead often to the solution of a nonconvex and nondifferentiable minimization problem. In this paper, to carry out image restoration, we apply DC programming and DC algorithms (DCA), introduced by T. PHAM DINH in 1986 and extensively developed by H. A. LE THI and T. PHAM DINH since 1992, to globally minimize the Gibbs energy function in a Markov random field model. Numerical simulations show the efficiency, reliability and robustness of DCA with respect to the standard GNC method.

DC programming and DCA approaches to variational inequality problems

TAO PHAM DINH
National Institute for Applied Sciences-Rouen
coauthor: Hoai An Le Thi

keywords: DC programming/DCA, variational inequality problem, nonconvex programming, global optimization

DC programming and DCA have been introduced by T. Pham Dinh and extensively developed by the authors to solve dc programs. DCA are based on local optimality conditions and dc duality and their constructions depend on dc decompositions. Our approaches have been successfully applied to solve real-world dc programs for which DCA converge quite often to global solutions. By using gap functions, variational inequality problems can be reformulated either as problems of finding critical points of dc functions or as those of globally solving dc programs with known optimal values. In this talk, we will present dc reformulations of variational inequality problems and our DC programming and DCA approaches to solving the resulting dc programs. Numerical simulations are reported. References Pham Dinh Tao, Le Thi Hoai An : Convex analysis approach to dc programming: Theory, Algorithms and Applications. Acta Mathematica Vietnamica, Vol. 22, Number 1 (1997), pp. 289-355 Pham Dinh Tao, Le Thi Hoai An: DC Optimization Algorithm for Solving The Trust Region Problem. SIAM Journal on Optimization, Vol. 8, Number 2, (1998), pp. 476-505 Pham Dinh Tao, Le Thi Hoai An: Large Scale Molecular Optimization From Distance Matrices by a DC Optimization Approach. (40 pages), To appear in SIAM Journal on Optimization.

D.C. and smooth optimization methods for solving minimum maximal network flow problem

JIANMING SHI
Muroran Institute of Technology
coauthor: Le Dung Muu

keywords: maximal flow, D.C. optimization, global optimization

In this talk, we consider the minimum maximal flow problem, i.e., minimizing the flow value among maximal flow, which is an $\mathcal{NP}$-hard problem. After formulating the problem, we introduce a dualformulation and cast the problem into a minimization of a concave functionover a convex set. We propose a D.C. optimization algorithm for solving the problem

TH3-308/11 GENERALIZED CONVEXITY/MONOTONICITY

Generalized convexity VI

organizer: Laura Martein
chair: Matteo Rocca

On a dual method for quasi-variational inequalities

MARIELLA ROMANIELLO
Università della Calabria, facoltà di Economia, Dip. di Organizzazione Aziendale e Amministrazione Pubblica
coauthor: Jacqueline Morgan

keywords: quasi-variational inequalities, dual method

In "Generalized Quasi-Variational Inequalities and Duality" (J. Morgan - M. Romaniello, to appear on JIPAM) a duality scheme and Generalized Kuhn-Tucker conditions have been presented. This scheme allows to solve the primal and the dual problems in the spirit of the classical Lagrangian duality for constrained optimization problems and extends, in non necessarily finite dimentional spaces, the duality approach obtained by A. Auslender for generalized variational inequalities. Stability of the dual problem with respect to perturbations on the data will be investigated.

Minty variational inequalities and vector optimization

MATTEO ROCCA
University of Insubria, Department of Economics
coauthors: Giovanni Paolo Crespi, Ivan Ginchev

keywords: vector variational inequality, vector optimization, pointwise well-posedness

Vector extensions of Stampacchia and Minty variational inequalities have been introduced by F. Giannessi and have revealed useful in vector optimization. In this talk we focus on Minty variational inequalities.
Starting from classical results for scalar variational inequalities, stating that Minty variational inequality is a sufficient optimality condition for a primitive

minimization problem (that is the problem of minimizing a function f such that $f' = F$, where F is the function involved in the inequality), we remark that for vector optimization this result holds only under C-convexity assumption.
Therefore, since solutions of a Minty vector variational indeed are solution of a linearly scalarized problem (under convexity assumption), we use the oriented distance function, introduced, to obtain a scalar Minty variational inequality related to the vector optimization problem. We prove that the solutions of the former variational inequality characterize weakly efficient and efficient solution (without need for convexity) and, under convexity assumption, are equivalent to the solution of the classical Minty vector variational inequality. Furthermore, we deduce also pointwise well-posedness of vector optimization problem which admits solutions to this inequality.

Minty variational inequalities and well-posedness in scalar optimization

GIOVANNI PAOLO CRESPI
Université de la Vallée d'Aoste - Faculty of Economics
coauthors: Matteo Rocca, Ivan Ginchev
keywords: Minty variational inequality, optimization, generalized convexity, well-posedness

Minty Variational Inequalities are widely studied in relation to minimization problems. When the function involved in the inequality has a primitive f this is naturally the objective function of the primitive minimization problem over the feasible region K and Minty inequality is a sufficient optimality condition. We deal with a more general case, namely when f admits lower Dini derivative. In this setting we define a Generalized Minty Variational Inequality as refered to the minimization of (non differentiable) f. The main result of the talk is that, if the set K is star-shaped at x^* and f is radially lower semicontinuous in K along rays starting at x^*, then x^* is a solution of the genralized $GMVI(f', K)$ if and only if f is increasing along rays (starting at x^*). The relevance of Increasing Along Rays function (which can be viewed as a generalization of convex functions) is stressed porving some properties they have with regards to optimization and well-posedness.

TH3-308/12 — STOCHASTIC PROGRAMMING

Scenario tree generation

organizer: COSP (David Morton)
chair: David Morton

Monte Carlo scenario tree generation for stochastic programming

DAVID MORTON
The University of Texas at Austin
coauthor: Anukal Chiralaksanakul
keywords: stochastic programming, Monte Carlo simulation, scenario tree generation

Solving a multi-stage stochastic program with a large number of scenarios and a moderate-to-large number of stages can be computationally challenging. We develop Monte Carlo-based methods that exploit special structures to generate feasible policies. To establish the quality of a policy, we use a Monte Carlo-based lower bound (for minimization problems) in constructing a confidence interval on the policy's optimality gap. We allocate sample sizes in generating nonuniform scenario trees in order tighten the lower bound and hence the resulting confidence interval. Computational results are presented for a stochastic lot-sizing problem and for pricing an American-style option.

Scenario generation in stochastic programming - what can we reasonably ask for?

STEIN W. WALLACE
Molde University College
coauthor: Michal Kaut
keywords: stochastic programming, scenarios

As stochastic programming matures, the focus is shifting in the direction of applications. It then becomes clear that optimal solutions can be very sensitive to how randomness is described, in particular, how the random variables are discretized in the form of scenario trees. On one hand, there is a need to have a tree that properly describes the important aspects of the underlying random variables. On the other hand, we must realize that the actual distributions are rarely known with any large degree of accuracy. This talk will discuss, from a very practical perspective, how we can determine if we have a good scenario generation procedure at the same time as we try to take into account that there is a limit to how much we can know about future stochastic events. Examples will be given.

Generating scenario trees for multidimensional stochastic processes

MATTHIAS PETER NOWAK
SINTEF
coauthors: Frode Rømo, Asgeir Tomasgard, Lars Harald Vik
keywords: stochastic programming, scenario generation, principal component analysis

This paper presents an approach of generating scenariotrees for multidimensional stochastic processes. Multidimensional processes appear in real world applications for example as inflow in water magazines, electricity and gas prices, and gas demands. Typically many of the stochastic variables are highly correlated.

We present an approach for generating multidimensional scenrio trees based on the following following steps:

- Forcasting the uncertainty for these multidimensional variables
- Principal component analysis and dimension reduction to identify uncertain factors
- Generating samples for uncertainty factors
- Combining the forecasts and the samples in order to build a scenario tree.

First numerical results will be presented.

TH3-308/13 — SEMI-INFINITE AND INFINITE DIMENSIONAL PROGRAMMING

Complexity in semi-infinite programming

chair: Klaus Meer

Distance to ill-posedness for linear semi-infinite inequality systems: applications to lipschitzian analysis

MARCO A. LÓPEZ-CERDÁ
Aicante University
coauthors: M. J. Cánovas, J. Parra, F.Javier Toledo-Melero
keywords: semi infinite programming, stability, metric regularity, distance to ill-posedness

We consider the parameter space of all the linear inequality systems, in the n-dimensional Euclidean space, with a fixed and arbitrary (possibly infinite) index set, and endowed with the uniform convergence topology. Since the parameter space is not a normed space, a special subset arises, formed by those systems whose distance to ill-posedness is infinite. This fact gives rise to a generalized concept of ill-posedness, which has been characterized in terms of the so-called associated hypographical set, allowing for an explicit formula of the 'distance to generalized ill-posedness'. On the other hand, the consistency value of a system, also introduced in the talk, provides an alternative way to determine its distance to ill-posedness (in the original sense). This talk is also devoted to some applications of the 'distance to ill-posedness', in relation to some Lipschitzian properties (pseudolipschitz, calmness) of the feasible set mapping, the corresponding regularity concepts of the inverse multifunction, and some associated Hoffman type inequalities. From an algorithmic point of view, the distance to ill-posedness allow us to analyze, in our semi-infinite context, the complexity of the ellipsoid algorithm.

An outer approximation method for general semi-infinite programming without discretization

OLIVER STEIN
Aachen University

keywords: interior point method, Stackelberg game, optimality condition, convexity

Today applications of semi-infinite programming range from approximation, robust optimization and minimax problems to design centering, disjunctive optimization, data envelopment analysis and defect minimization for operator equations.

In many of these examples the index set of the inequality constraints inevitably depends on the decision variable, yielding a *general* semi-infinite optimization problem, as opposed to *standard* semi-infinite problems, where this index set is assumed to be fixed. For problems of the latter type optimality conditions and solution methods are well-known, including discretization methods for the index set which naturally lead to outer approximations of the feasible set. On the other hand, *general* semi-infinite programs have turned out to be surprisingly difficult to treat theoretically as well as computationally.

Recent results admit to solve a large subclass of these problems by a numerical method which bases on a reformulation of the semi-infinite problem as a Stackelberg game. Although then an *interior point* approach is used in the lower level problem, it turns out that one obtains an *outer approximation* of the feasible set for the semi-infinite problem.

We give convergence properties for the method and illustrate it with a number of numerical examples. The presented algorithm is easy to implement, and our examples indicate that it works well even for high dimensional index sets.

On the complexity of some problems in interval arithmetic

KLAUS MEER
University of Southern Denmark

keywords: computational complexity, interval arithmetic, semi infinite optimization

We study some problems in interval arithmetic treated by *Kreinovich et al.* First, we consider the best linear approximation of a quadratic interval function (a semi-infinite optimization problem). Whereas this problem (as decision problem) is known to be *NP*-hard in the Turing model, we analyze its complexity in the real number model and the analoguous class $NP_{\mathbb{R}}$. Our results substantiate that most likely it does not any longer capture the difficulty of $NP_{\mathbb{R}}$ in such a real number setting. More precisely, we give upper complexity bounds for the approximation problem for interval functions by locating it in $\Sigma^2_{\mathbb{R}}$ (a real analogue of Σ^2).

This result allows several conclusions:

- the problem is not (any more) $NP_{\mathbb{R}}$-hard under so called weak polynomial time reductions and likely not to be $NP_{\mathbb{R}}$-hard under (full) polynomial time reductions;
- for fixed dimension the problem is polynomial time solvable; this extends results by Koshelev et al. and answers a question left open by Kreinovich et al.

We also study several versions of interval linear systems and show similar results as for the approximation problem. Our methods combine structural complexity theory with issues from semi-infinite optimization theory.

TH3-308/T1 DYNAMIC PROGRAMMING AND OPTIMAL CONTROL

Linear programming approaches to dynamic and stochastic optimization

organizer/chair: Jose Nino-Mora

(Parametric) linear programming for Markovian control problems

LODEWIJK KALLENBERG
Mathematical Institute, University of Leiden

keywords: Markov decision processes, parametric linear programming

It is well known that discrete time, finite Markov decision problems with discounted or average rewards can be solved by linear programming. This talk consists of two parts. In the first part we consider some special models for which algorithms with complexity of order n^3 can be derived, where n is the number of states. In the second part we consider other problems, like mean-variance trade-offs and multi-armed bandit problems. The mean-variance problem can be formulated as a nonlinear programming problem. Fortunately, using the structure of the problem, this nonlinear program can efficiently be solved by parametric linear programming. The multi-armed bandit problem is a high-dimensional problem, say of dimension m with in each dimension n states, which generate an LP-formulation with m^n variables and constraints. It is known that the multi-armed bandit problem can be solved as a sequence of m one-dimensional problems. We show that each of these problems can be solved with complexity of order $n3$ by parametric linear programming.

Scheduling jobs with uncertain processing times on parallel machines

MARC UETZ
Uni Maastricht / FdEWB/ Quantitative Economics
coauthors: Rolf H. Möhring, Andreas S. Schulz, Martin Skutella

keywords: stochastic scheduling, dynamic scheduling policy, linear programming relaxations, approximation

We consider scheduling problems where the processing times of jobs are uncertain, and scheduling decisions have to be made dynamically over time. In contrast to the pessimistic assumptions in on-line optimization, we assume that job characteristics, particularly their expected processing times as well as an upper bound on their variability are known to the scheduler. In this scenario, we talk of a non-anticipatory scheduling policy if, at any point in time, only the available information about the past is anticipated. The goal is to find a non-anticipatory scheduling policy that minimizes expected performance. We derive the first approximation results for this setting. Our results are based on two main ingredients: On the one hand, this is a linear programming relaxation that is formulated in terms of the expected processing times of jobs. On the other hand, we use certain list scheduling algorithms that have been used before also in deterministic settings. Our results lead to constant performance guarantees whenever the coefficients of variation of the jobs' processing times are bounded by a constant.

Dynamic allocation indices for restless projects and queueing admission control: a polyhedral approach

JOSE NINO-MORA
Depto. de Estadistica, Universidad Carlos III de Madrid

keywords: stochastic scheduling, Markov decision processes, index rules, polyhedral methods

This work develops a polyhedral approach to the design, analysis and computation of dynamic allocation indices for scheduling binary-action (engage/rest) Markovian stochastic projects that can change state when rested (restless projects/bandits), based on the framework of partial conservation laws (PCLs). Satisfaction of PCLs by performance measures implies that the achievable performance region admits a tight polyhedral relaxation having strong structural and algorithmic properties (F-extended polymatroid). This allows to identify a class of projects (PCL-indexable) that are optimally controlled by an index policy having a postulated structure, where the indices are efficiently computed by an adaptive-greedy algorithm. PCL-indexability is shown to represent a form of the classic economic law of diminishing marginal returns, with the indices representing optimal marginal cost/reward rates. The approach is deployed to give a novel analysis of a versatile queueing admission control model.

TH3-308/T2 — COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Linear complementarity problems

chair: Vitalij Zhadan

On polyhedral games, linear complementarity problems, and interior point methods

SIMON SCHURR
University of Maryland at College Park
coauthors: Dianne O'Leary, Andre Tits

keywords: game theory, linear programming, linear complementarity problem, interior point method

It is known that a two-person zero-sum game with linear constraints, can be formulated as a linear programming problem (LP), and therefore a linear complementarity problem (LCP). We use the equivalence between different forms of LCP, to induce special structure in the aforementioned LP. Such structure allows for a more efficient solution via interior point methods.

We also discuss extensions to semidefiniteness constraints.

Nonsmooth matrix valued functions defined by singular values

DEFENG SUN
National University of Singapore
coauthor: Jie Sun

keywords: semismoothness, FB function, SVD, complementarity

A class of matrix valued functions defined by singular values of nonsymmetric matrices are shown to have many properties analogous to matrix valued functions defined by eigenvalues of symmetric matrices. In particular, the (smoothed) matrix valued Fischer-Burmeister function is proved to be strongly semismooth everywhere. This result is also used to show the strong semismoothness of the (smoothed) vector valued Fischer-Burmeister function associated with the second order cone. The strong semismoothness of singular values of a nonsymmetric matrix is discussed and used to analyze the quadratic convergence of Newton's method for solving the inverse singular value problem.

Finite Newton's methods for LP and LCP

VITALIJ ZHADAN
Dorodnicyn Computing Centre of Russian Academy of Sciences

keywords: linear programming problem, linear complementarity problem, Newton method, finite convergence

We consider the primal-dual technique for linear programming problem in which the non-perturbed system of optimality conditions is solved by Newton's method. We suppose that starting points and all cosequent points are feasible. The step length is chosen from the steepest descent approach basing on minimization of the dual gap. We have not introduced the safity factor and allow trajectories in primal and dual spaces to move along the boundaries of feasible sets. In the case where the Newton system is underdetermined the auxiliary linear complementarity problem (LCP) is solved for obtaining unique search directions. Conditions for local and non-local finite convergence of the method are presented. The generalization of the method for solving LCP with a positive definite matrix is given.

TH3-308/T3 — TELECOMMUNICATION NETWORK DESIGN

Optimization problems in wireless telecommunications

organizer/chair: Federico Malucelli

Optimization of pilot power in 3G mobile networks

PETER VÄRBRAND
Linköping University
coauthor: Di Yuan

keywords: mobile communications, resource management, relaxation, heuristics

In 3G mobile networks, a cell uses a pilot signal to provide channel estimation to the mobile terminals. The problem of choosing the power levels of the pilot signals involves the trade-off between service coverage and power consumption. In this presentation, we consider the optimization problem of minimizing the total pilot power subject to coverage constraints. We present two linear integer formulations for the problem, and describe a Lagrangean-based solution approach. We present computational results using real-life data. The results show that the proposed method finds optimal or near-optimal solutions.

Scheduling of spatial time division multiple access in multi-hop radio networks

DI YUAN
Linköping University
coauthor: Peter Värbrand

keywords: wireless communications, scheduling, column generation, heuristics

We consider resource optimization in multi-hop radio networks that use Spatial Time Division Multiple Access (STDMA). In STDMA, transmission must be scheduled to avoid access collisions and interference. We consider two scheduling problems, where the objectives are minimizing the schedule length and maximizing the network throughput, respectively. We provide linear integer formulations for the two problems. We then present a column generation method for solving the LP-relaxations, and heuristic algorithms for generating feasible schedules. Computational results for real instances are presented.

Planning of a wireless LAN

FEDERICO MALUCELLI
DEI - Politecnico di Milano
coauthors: Antonio Capone, Matteo Cesana

keywords: set covering, quadratic programming, combinatorial optimization, telecommunication

Wireless LANs are assuming a growing importance either in firm organization, or in public areas like airports and railway stations. Their planning (indoor or outdoor) is usually made by means of empirical methods and experience. However the diffusion of this kind of networks foreseen in the next future and the need of efficiency both in terms of cost and of service quality suggests the use of quantitative methods. Considering the rather simple transmission protocol, the maximization of the network capacity gives rise to two contrasting objectives: on one hand we aim at covering the service area with as many access points (antennas) as possible to increase the parallelism in transmissions, on the other hand we would like to minimize the overlapping between adjacent antennas to minimize the interference. We propose a mathematical model based on a particular set covering formulation with a quadratic objective function to account for the interference. We will propose ad hoc heuristics and bounds. Some preliminary computational results will be also presented on a set of realistic data.

TH3-341/21 INTERIOR POINT ALGORITHMS

Advances in interior point methods

organizer/chair: Tamas Terlaky

Exploiting sparsity in sum of squares of polynomials

MASAKAZU KOJIMA
Tokyo Institute of Technology

coauthors: Sunyoung Kim, Hayato Waki
keywords: sum of squares, polynomial optimization, sparsity, semidefinite program

In recent developments of sum of squares optimization and SDP (semidefinite programming) relaxation of polynomial optimization problems, representing a given nonnegative multivariate polynomial in terms of sum of squares of polynomial has become an important subject. We discuss effective methods to get a simpler representation of a “sparse” polynomial in sum of squares of sparse polynomials by eliminating redundancy.

Hybrid primal-dual interior-point methods based on self-regular functions

JIMING PENG
Department of Computing and Software, McMaster University

keywords: interior point method, large update methods, large neighborhood, polynomial complexity

Lartge-update interior-point methods (IPMs) working in a large neighborhood of the central path are among the most efficient IPMs for linear optimization (LO) problems. The best known worst-case complexity of this type of methods based on the standard Newton search direction is $O(n \log \frac{(x^0)^T s^0}{\varepsilon})$. Recently, the author, with his co-coauthors, proposed another kind of large-update IPMs on the notion of self-regular functions with an improved $O\left(\sqrt{n} \log n \log \frac{(x^0)^T s^0}{\varepsilon}\right)$ iteration bound. In this paper, we suggest a hybrid method, which employs the standard Newton search direction or the self-regularity induced search direction alternatively, depending on the position of the current iterate. We show that the hybrid IPMs enjoy an $O\left(\sqrt{n} \log n \log \frac{(x^0)^T s^0}{\varepsilon}\right)$ iteration bound, matched the best know complexity result for IPMs.

Introducing interior-point methods into the first operations research course

GORAN LESAJA
Georgia Southern University

keywords: interior point method, operations research

In recent years the introduction and development of Interior-Point Methods has had a profound impact on optimization theory and practice, and therefore, has impacted the field of Operations Research as a whole. Thus, there has been an increasing need to introduce theory and methods of this new area in optimization into introductory Operations Research and/or Linear Programming courses. The objective of this paper is to discuss the ways of simplifying the introduction of Interior-Point Methods for students who have various backgrounds or who are not necessarily math majors.

TH3-341/22 LOGISTICS AND TRANSPORTATION

Supply chain optimization

chair: Huifu Xu

Ship routing and scheduling in the pulp mill industry

DAVID BREDSTRÖM
Division of Optimization / Department of Mathematics / Linköping University

coauthor: Mikael Rönnqvist
keywords: ship routing, ship scheduling, real world application, supply chain optimization

We consider the delivery problem for a large pulp producer in Sweden and present solution methods based on optimization. The company has five pulp mills in Scandinavia. On each pulp mill they produce several different pulp types that they deliver to customers mostly located in Europe. The transport is done mainly by cargo vessels that they hire on long term contracts, but also by railway, trucks and spot vessels. It is a ship routing and scheduling problem where the constraints are to satisfy demand given production, storage and transport capacities, and the objective to minimize the overall cost. We present optimization models and compare the results from different heuristic solution approaches.

Inventory placement problem for a serial supply chain with the satisficing objective

CHIA-SHIN CHUNG
Cleveland State University

coauthors: James Flynn, Piotr Stalinkki
keywords: inventory, supply chain, single period, budget

Along a long supply chain, it is certainly unnecessary and wasteful to store inventory in every stage of the chain. In stead, a more efficient policy is to place inventory in only a few strategic locations. This paper addresses this problem in a serial supply chain facing a stochastic demand for a single planning period. All customer demand is served from stage 1, which contains the product in its final form. If the demand exceeds the supply at stage 1, then stage 1 is resupplied from stocks held at the upstream stages 2 through N, where the product may be stored in finished form or as raw materials or sub-assemblies. All stocking decisions are made before the demand occurs. All unsatisfied demand is lost. The objective is to select the stock quantities that should be placed at different stages so as to maximize the probability of achieving a budgeted profit level B. For the case of positive lost sales costs, we prove that it is optimal to consider at most three stocking locations. We also characterize its properties, and provide an algorithm for its computation.

Optimal supply functions in electricity markets with piecewise continuously differentiable profit functions

HUIFU XU
University of Southampton

coauthor: Edward J. Anderson
keywords: optimal supply function, electricity market, one way contracts, piecewise marginal costs

Optimal supply functions for generators who sell electricity into wholesale spot markets have been investigated over the past few years. In previous work a generator's profit function has been assumed to be continuously differentiable. However in some interesting instances, a generator's profit function may not be differentiable. In this paper we consider the optimal supply function when the generator's profit function is merely piecewise continuously differentiable. This allows us to deal with one-way hedging contracts that a generator may sign before bidding into the spot market, as well as a situation in which a generator owns several generation units with different marginal costs. We derive globally optimal supply functions under these circumastances.

TH3-341/23 APPROXIMATION ALGORITHMS

Approximation algorithms for scheduling problems

chair: David Shmoys

Approximation schemes for the open shop scheduling problem with non-availability constraints

VITALY STRUSEVICH
University of Greenwich

coauthors: Mikhail Kubzin, Joachim Briet, Guenter Schmidt
keywords: scheduling, open shop, approximation

We consider the two-machine open shop scheduling problem to minimize the makespan in which the machines are not continuously available during the planning period. The location of each non-availability interval, also called a hole, is known in advance. We study the resumable scenario which allows the operation affected by a hole be resumed from the point of interruption as soon as the machine becomes available again. The problem is NP-hard even for a single hole, and is not approximable within a constant ratio in polynomial time if there is at least one hole on one machine and at least two holes on the other machine. In this talk we present polynomial-time approximation schemes for the problem with one hole on each machine and with any fixed number of holes on one of the machines.

Computational experience on approximation algorithms for scheduling unrelated machines

FLAVIO KEIDI MIYAZAWA
State University of Campinas

coauthor: Eduardo C. Xavier
keywords: scheduling problems, computational experience, approximation algorithms

In this paper we consider a computational study of approximation algorithms for scheduling problems in unrelated machines minimizing the average weighted completion time. We implemented two known approximation algorithms for the problems $R||\sum w_jC_j$ and $R|r_j|\sum w_jC_j$. The first is a 2-approximation algorithm presented by Skutella using a semidefinite program and the second is a $(2+\varepsilon)$-approximation algorithm presented by Schulz and Skutella using linear programming. We also present a modified algorithm based on the algorithm of Schulz and Skutella.

We generated computational instances using 2, 5, 7 and 10 machines. For all instances, the practical performance of the algorithms was very satisfactory. When there are no presence of release dates, the algorithms perform very well. In many cases, the solutions have value very close to the optimum. For problems with release dates, solutions with value under 10 percent from the optimum was generated. The modified algorithm generates solutions with better quality in almost all instances considered.

Approximation algorithms for the joint replenishment problem

DAVID SHMOYS
Cornell University

coauthors: Retsef Levi, Robin Roundy
keywords: inventory/production, analysis of algorithms, combinatorial optimization

We consider the joint replenishment problem (JRP) in discrete time, with a finite horizon and deterministic non-stationary demand. For each of N items and T time periods, we have a given demand that must be satisfied on time. In each time period we can order any subset of the items, paying a joint fixed cost in addition to an individual fixed cost for each item ordered. We can also hold inventory while incurring an item-dependent linear holding cost. The goal is to find a policy that satisfies all demands on time and minimizes the overall fixed and holding cost.

This classical deterministic inventory model is known to be NP-hard; many heuristics for finding optimal and near-optimal solutions have been developed. We will show how LP-based techniques yield efficient approximation algorithms with constant performance guarantees significantly improving on previously known results. We give both LP rounding and primal-dual algorithms that build upon techniques recently applied to facility location problems. These methods have natural extensions to more general variants of the JRP and other inventory models.

TH3-321/053 PRODUCTION AND SCHEDULING

Industrial scheduling problems

chair: Johannes Hatzl

Optimal machine scheduling in a shipyard

JENS BUCHHOLZ
Universität Duisburg-Essen

coauthor: Ruediger Schultz
keywords: machine scheduling, machine groups, shift schedules

The talk deals with real-life machine scheduling in the manufacturing unit of a major german shipyard. Standard problems are often strongly influenced by additional restrictions which arise from the application. In this case the standard job shop scheduling problem is modified due to the fact that we have a machinery consisting of several machine groups with identical machines. Furthermore the solution has to fulfil a given shift schedule. The shift schedule can differ from machine group to machine group. The optimization goal is non-standard, too. We are heading for a schedule including as many jobs completed in due time as possible. We present a linear mixed integer model for the described problem. Moreover we report first computational experience with real data and compare our results with schedules obtained by an inhouse heuristic of the shipyard.

Industrialising the application of mathematical models and methods

JESPER HANSEN
Carmen Consulting AB
keywords: software development, methodology, packing, crane scheduling

The purpose of the CIAMM project has been to industrialise the application of mathematical models and methods for solving these models within the manufacturing industry. Two problem cases has been considered in the project posed by the industrial partners and a methodology for developing combinatorial optimization software has been proposed based on the experiences gained from the cases.

The first case was an investigation of possible improvements for handling the storage of steel plates at Odense Steel

Shipyard. The second case was posed by Bang & Olufsen concerning packing of 3-dimensional packets in boxes and boxes on pallets. The talk will introduce the problem cases and discuss the experiences gained in the project leading to the proposed methodology.

Makespan minimization for chemical batch processes

JOHANNES HATZL
TU Graz Institut für Mathematik B
coauthor: Rainer Burkard
keywords: heuristics, applications

In this talk we discuss different optimization methods for batch processing problems occurring in the chemical industry, where the objective is to minimize the make-span. Up to now, most papers formulate this kind of problem as a MILP model based on a discrete time representation. However, due to the large number of binary variables various LP-based heuristics do not obtain good results within reasonable computational time. We propose a new greedy type algorithm which produces solutions of a good quality within very short computation times. Finally, we suggest ideas how the fastness of the greedy approach can be exploited to devise iterated greedy algorithms and improved heuristics.

TH3-321/033 MULTICRITERIA OPTIMIZATION
Scalarized functions and functionals in multicriteria optimization
chair: Christiane Tammer

A method for calculating tradeoffs in multicriteria optimization

PETRA WEIDNER
FH Hildesheim/Holzminden/Göttingen
keywords: multiple criteria

In the paper, we present a scalarization for multicriteria optimization problems with the following property: The parameters of the scalarization allow one to calculate the tradeoffs in the optimal solution of the scalar problem under rather mild assumptions. Here, tradeoffs are understood to be the efficient points of the contingent cone.

For this scalarization, we give a geometrical interpretation and discuss the control of parameters taking into consideration the reachability of each efficient point and numerical difficulties.

Scalarizations in multiobjective combinatorial optimization

MATTHIAS EHRGOTT
The University of Auckland
keywords: multiple criteria, combinatorial optimization, scalarization

Multiobjective programming problems are generally solved using a scalarization. Most scalarization methods use an aggregation of the objectives or/and transform some of the objectives into constraints. Both techniques have drawbacks when applied to combinatorial problems: not all Pareto optimal solutions can be found or the scalarized problems are much harder to solve than the original (single objective) problems. We discuss these issues and point out how the difficulties can be overcome at least to some extent.

A new density result in multicriteria optimization

CHRISTIANE TAMMER
University Halle-Wittenberg, Dept. Mathematics and Computer Science
keywords: multiple criteria programming, density theorem, variational principle, properly efficient point

Arrow, Barankin and Blackwell (1953) presented a deep density assertion in multicriteria optimization concerning the approximation of the efficient points of a compact convex subset of a finite dimensional space by points that are maximizers of some strictly positive functional on this set. We give a new version of the Arrow-Barankin-Blackwell theorem in normed vector spaces. The novelty of our result is represented by the fact that we do not assume compactness of the set; in fact it can be an unbounded asymptotically compact set. Our result subsumes several generalizations of this important theorem.

TH3-321/133 LINEAR PROGRAMMING
Numerical approaches II
chair: Karl Heinz Borgwardt

A sparse implementation of the LP dual active set algorithm

WILLIAM HAGER
University of Florida
coauthor: Timothy A. Davis
keywords: dual active set algorithm, linear programming, numerical experimentation

We present a factorization-based implementation of the LP Dual Active Set Algorithm. This implementation exploits a proximal approximation to the dual function, a multilevel solution strategy, and recently developed algorithms for updating a sparse Cholesky factorization after a small rank change. We compare solution times for our implementation to those of simplex and barrier algorithms, as implemented in CPLEX, using the Netlib LP Test Problems.

An enhanced piecewise linear dual phase-1 algorithm for the simplex method

ISTVAN MAROS
Imperial College
keywords: linear programming algorithms, dual simplex method, phase-1

A dual phase-1 algorithm for the simplex method that handles all types of variables is presented. In each iteration it maximizes a piecewise linear function of dual infeasibilities in order to make the largest possible step towards dual feasibility with a selected outgoing variable. The algorithm can be viewed as a generalization of traditional phase-1 procedures. It is based on the multiple use of the expensively computed pivot row. By a relatively small amount of extra work per iteration, the progress it can make is equivalent to many iterations of the traditional method. While this is its most important feature, it possesses some additional favorable properties, namely, it can be efficient in coping with degeneracy and numerical difficulties. Both theoretical and computational issues are addressed. Some computational experience is also reported which shows that the potentials of the method can materialize on real world problems.

Average-case-behaviour of three convex-hull-algorithms under rotation-symmetry

KARL HEINZ BORGWARDT
University of Augsburg
keywords: convex hull, average case complexity, linear programming, polyhedra

We analyze three different algorithms (Beneath-Beyond, Gift-Wrapping and Fukuda-Avis), which can all be applied to answer the following question: "Given m points $a_1, \ldots, a_m \in R^n$, which are the vertices of the polyhedron $X := \{x \in R^n | {a_1}^T x \leq 1, \ldots, {a_m}^T x \leq 1\}$? We compare their expected number of calculations under the Rotation-Symmetry-Model: $a_1, \ldots, a_m$ are distibuted independently, identically and symmetrically under rotations. The incremental Beneath-Beyond-Algorithm determines sequentially m-n+1 auxiliary polyhedra $X_k =$

$\{x \in R^n | a_1{}^T x \leq 1, \ldots, a_k{}^T x \leq 1\}$ $\forall k = n, \ldots, m$, which causes an expected effort of $C(n)[m^2 n^2 (n + ln(m))]$. The sequential Gift-Wrapping-Algorithm moves on the surface ov X from vertex to adjacent vertex until every vertex is discovered. Its expected effort is $C(n)[m^2 n + mn^2 ln(m)]$. The Fukuda-Avis-Algorithm avoids storing the data of the traversed path (by exploiting the fact that the collection of Simplex-Paths starting from any vertex and running to the optimal vertex forms a sspanning tree). This algorithm causes an expected effort of $C(n)[m^2 n]$.

FR1-302/41 COMBINATORIAL OPTIMIZATION
Packing, partitioning and trees
chair: Michal Penn

Phi-functions for complex 2d-objects

GUNTRAM SCHEITHAUER
Dresden University of Technology

keywords: cutting and packing

Within two-dimensional cutting and packing problems with irregular shaped objects, the concept of Phi-functions has been proven to be very helpful for several solution approaches. Based on Phi-functions for pairs of so-called primary objects, now Phi-functions are constructed for pairs of objects which can be represented as a finite combination (union, intersection, complement) of primary objects which allows the handling of many arbitrary shaped objects by appropriate approximations of sufficient accuracy.

The densest packings of 28, 29 and 30 congruent circles in the unit square - a reliable optimality proof

MIHALY CSABA MARKOT
University of Szeged
coauthor: Tibor Csendes
keywords: interval analysis, branch-and-bound, circle packing, computer-assisted proofs

We present a new verified optimization method for the problem of finding the densest packing of non-overlapping equal circles within a square. In order to provide reliable numerical results, the developed algorithm is based on interval analysis. As a demonstration of the capabilities of the new algorithm the problems of packing 28, 29, and 30 circles were solved within very tight tolerance values. For all the above problem instances we stated that - apart from symmetric configurations - all the global optimizers are located within a very small box. Moreover, we have proved that the exact global optimum differs from the currently best known packing value by at most 7e-15, 2e-14, and 3e-15, respectively. Our verified procedure decreased the uncertainty in the location of the optimal packings by more than 700 orders of magnitude in all cases.

An approximation algorithm for the group Steiner network problem

MICHAL PENN
Technion
coauthor: Stas Rozenfeld
keywords: Steiner, group, approximation algorithms

In this talk we study the group Steiner network problem, which is the following. Given a graph G=(V,E), a partition of its vertices into K groups and connectivity requirements between the groups the aim is to find simultaneously a set of representatives, one for each group, and a minimum cost connected subgraph that satisfies the connectivity requirements between the groups (representatives). This problem is a generalization of the Steiner network problem (termed also the survivable network design problem) and the group Steiner tree problem (called also the generalized minimum spanning tree problem), two known NP-complete problems.

We present an approximation algorithm for the group Steiner network problem with an approximation ratio of min2(1+2x),2I where I is the cardinality of the largest group and x is a parameter that depends on the cost function.

FR1-302/42 COMBINATORIAL OPTIMIZATION
Combinatorial optimization X
chair: Bjarne Toft

K-edge-connected graphs and positive semidefiniteness

ALEXANDRE LAUGIER
France Telecom Recherche & Developpement
keywords: edge-connectivity, positive semi-definite matrix, cut metrics, cones of semi-metrics

It is well known that the problem of finding a minimum weight k-edge-connected subgraph of a given graph G is NP-hard. In this work we modelise the problem of finding a k-edge-connected subgraph as a problem over the cone of the cut metrics, then we embed this formulation into the cone of negative type metrics. This embedding defines a positive semi-definite relaxation of the original problem, then we exploit this relaxation in order to design a heuristic for the minimum weight k-edge-connected subgraph problem. At last we extend the formulation to the multicommodity flow problem in the case where the demand graph satisfies some given properties.

Bounds for greedy type algorithms for the k-dimensional assignment problem

LEONIDAS PITSOULIS
London School of Economics
keywords: multidimensional assignment, matroid intersection, greedy

The k-dimensional assignment problem is a natural extension of the well known 2-dimensional assignment problem, where a matching of optimum weight is sought in a k-partite hypergraph. In this talk the problem is formulated as an independence system arising from the intersection of k partition matroids. Worst case bounds of greedy type algorithms for finding a minimum weight basis and various properties of the set of bases of the resulting independence system are investigated.

Scheduling without waiting periods

BJARNE TOFT
University of Southern Denmark
keywords: graph-coloring, interval coloring

The problem of scheduling parent consultations at a school without waiting periods was first presented to me by Jesper Bang-Jensen around 1990. It had been studied a couple of years earlier by Asratyan, Karmalyan and Sevastyanov in the Sovjet Union. We stated the problem as 12.23 in the book [Jensen and Toft, Graph Coloring Problems, Wiley 1995]. The purpose of the present talk is to give an overview and update of the problem.

FR1-302/44 COMBINATORIAL OPTIMIZATION
Maximum feasible subsystem problem
organizer/chair: Edoardo Amaldi

The maximum feasible subsystem problem and related polyhedra

MARC PFETSCH
Konrad-Zuse-Zentrum
coauthors: Edoardo Amaldi, Jr. Leslie E. Trotter
keywords: infeasible linear systems, feasible subsystem polytope, alternative polyhedron

Given an infeasible linear inequality system, the maximum feasible subsystem problem (MaxFS) is to find a feasible subsystem of maximum cardinality. MaxFS is NP-hard, has many interesting applications, and generalizes well-known combinatorial optimization problems, as we will briefly present.

For the investigation of the 0-1 polytope corresponding to MaxFS, i.e., the convex hull of the incidence vectors of feasible subsystems, results about independence system polyhedra can be specialized. For example, facets arising from generalized antiwebs, which generalize cliques, odd holes, and antiholes in graphs, only occur under very special circumstances. The tools used for such results are based on a (combinatorial) connection between the minimal infeasible subsystems and the support of vertices of an alternative polyhedron.

Finally, we will also report on computational results to solve MaxFS by branch-and-cut.

Generalized boundedness of the relaxation method with an explicit bound in terms of a condition number

RAPHAEL HAUSER
Oxford University Computing Laboratory
coauthor: Edoardo Amaldi
keywords: infeasible linear systems, relaxation methods, condition number, MAX FS

We study the behavior of relaxation methods when applied to infeasible systems of linear inequalities. We show that the sequence of iterates generated by the algorithm remains confined within a ball whose radius is a function of a condition number of the input data. This radius plays a key role as a complexity measure that determines the convergence rates of an interesting class of algorithms for solving the MaxFS problem. Our result does not depend on the order in which inequalities are considered and requires only very weak assumptions on the step lengths. This generalizes a classical theorem by Block and Levin (1970) and answers their long-standing open question to give an explicit bound as a function of the input data.

Randomized relaxation methods for the maximum feasible subsystem problem

EDOARDO AMALDI
DEI, Politecnico di Milano
coauthors: Raphael Hauser, Pietro Belotti
keywords: infeasible linear systems, randomized relaxation methods, convergence analysis

In the MaxFS problem, given an infeasible system of linear inequalities, one wishes to find a Feasible Subsystem containing as many inequalities as possible. This combinatorial optimization problem, which is approximable within a factor 2 but does not admit a polynomial time approximation scheme unless P=NP, has interesting applications in a variety of fields such as computational biology, linear programming, machine learning and telecommunications. To tackle medium-to-large scale instances of MaxFS, we consider randomized and thermal variants of the classical relaxation method for solving systems of linear inequalities. Based on the generalized boundedness theorem and the condition number presented in the previous talk, we establish an upper bound on the expected number of iterations needed by these randomized relaxation methods to find an optimal solution of MaxFS. This implies, in particular, that they are guaranteed to determine within a finite number of iterations a solution which is optimal with probability one. Some computational results are also reported for instances arising in planning digital video broadcasts and in modeling the energy function underlying the folding of proteins.

FR1-302/45 — INTEGER AND MIXED INTEGER PROGRAMMING

Improved algorithms for mixed-integer programming

organizer/chair: John W. Chinneck

Pivot, cut, and dive: a class of heuristics for general MIP

JONATHAN ECKSTEIN
Rutgers University
coauthor: Mikhail Nediak
keywords: heuristics, mixed integer programming, intersection cuts, branch-and-bound

The pivot, cut, and dive heuristic framework for general mixed integer programming was originally intended for use within exact branching methods, but may also "stand alone". The heart of the method is a simple integrality merit function which is concave when all integer variables are binary. We consider various multi-objective pivoting and Frank-Wolfe schemes to locate local minima of this merit function without excessively degrading the original objective. To escape local minima of the merit function that are not integer feasible, several additional levels of the heuristic can come into play: probing of adjacent vertices, intersection cuts which may be a natural consequence of probing, and a method of diving simultaneously on multiple variables and introducing vertex/facial cuts.

Exploring relaxation induced neighborhoods to improve MIP solutions

EMILIE DANNA
ILOG
coauthors: Edward Rothberg, Claude Le Pape
keywords: mixed integer programming, heuristics

Given a feasible solution to a Mixed Integer Programming (MIP) model, a natural question is whether that solution can be improved using local search techniques. Local search has been applied very successfully in a variety of other combinatorial optimization domains. Unfortunately, local search relies extensively on the notion of a solution neighborhood, and this neighborhood is almost always tailored to the structure of the particular problem being solved. A MIP model typically conveys little information about the underlying problem structure. We consider a new approach, which we call Relaxation Induced Neighborhood Search (RINS), to exploring interesting, domain-independent neighborhoods in MIP. It constructs a promising neighborhood using information contained in the continuous relaxation of the MIP model. Neighborhood exploration is then formulated as a MIP model itself and solved recursively. Extensive computational experiments on very difficult MIP models show that RINS outperforms default CPLEX MIP and two other recent strategies (local branching and guided dives) with respect to several different metrics: quality of the best integer solution produced within a time limit, ability to improve a given integer solution (of both good and poor quality), and time required to diversify the search in order to find a new solution.

Faster MIP solutions through better variable ordering

JOHN W. CHINNECK
Carleton University
coauthor: Jagat Patel
keywords: mixed integer programming, branch-and-bound, branching variable selection

The selection of the branching variable can greatly affect MIP solution speed. We present new algorithms for choosing the branching variable based on the impact of each variable on the active constraints in the current LP relaxation. This constraints-oriented approach is a significant departure from the traditional objective-oriented approach. We focus on improving the speed to the first integer-feasible solution. Empirical comparisions to solvers such as Cplex are presented.

FR1-302/49 INTEGER AND MIXED INTEGER PROGRAMMING
Integer programming
organizer/chair: Ismael de Farias

Semi-continuous cuts for mixed-integer programming

ISMAEL DE FARIAS
GSIA, Carnegie Mellon University

keywords: mixed integer programming, branch-and-cut, polyhedral combinatorics, semi continuous constraints

We study the convex hull of the feasible set of the semi-continuous knapsack problem, in which the variables belong to the union of two intervals. Besides being important in its own right, the semi-continuous knapsack problem is a relaxation of general mixewd-integer programming, problems with partial integer variables, and discrete optimization. We show how strong inequalities can be generated and used in a branch-and-cut scheme to solve these problems efficiently.

A polyhedral approach to robust integer programming

ALPER ATAMTURK
University of California at Berkeley

keywords: cutting plane/facet

The min-max robust optimization models aim to find solutions minimizing the maximum damage by the randomness of data. In this talk we present a polyhedral approach to robust integer programming.

Improving the performance of mixed integer Gomory cuts

KENT HØJ ANDERSEN
GSIA, Carnegie Mellon University
coauthors: Gerard Cornuejols, Yanjun Li

keywords: mixed integer Gomory cuts, split cuts, intersection cuts, distance cut off

In the seventies, Balas introduced intersection cuts for a Mixed Integer Linear Program (MILP), and showed that these cuts can be obtained by a closed form formula from a basis of the standard linear programming relaxation. In the same paper, Balas demonstrated that the well-known mixed integer Gomory cuts can be viewed as intersection cuts. In the early nineties, Cook, Kannan and Schrijver introducet the split closure of an MILP, and showed that the split closure is a polyhedron. It was shown recently that the split closure can be obtained using only intersection cuts. We use these facts to improve the performance of mixed integer Gomory cuts. Mixed integer Gomory cuts are an integral part of state-of-the-art solvers for MILP problems. Any improvement in the performance of these cuts is therefore of great practical value.

FR1-306/31 CONSTRAINT LOGIC PROGRAMMING
Hybrid methods
organizer/chair: John Hooker

Constraint and integer programming for the orthogonal latin squares problem

DIMITRIS MAGOS
Technological Educational Institute of Athens
coauthors: Gautam Appa, Ioannis Mourtos

keywords: orthogonal latin squares, constraint programming, integer programming

Constraint programming (CP) and Integer programming (IP) constitute two generic frameworks dealing with hard problems of combinatorial nature. IP has been developed within the Operational Research discipline, whereas CP is considered to fall into the field of Artificial Intelligence. In many cases, similar problems have been addressed by CP and IP, independently. Consequently, the integration of CP and IP methods deserves further investigation. Along this line of research, we present a hybrid algorithm, incorporating constraint and integer programming techniques, for the Orthogonal Latin Squares (OLS) problem. We briefly introduce some definitions. A Latin square is a square matrix of order n where each value $1,\dots,n$ appears exactly once in each row and column. Consider two Latin squares and the set $\mathbb{L}$ of all the pairs each of which consists of the elements of the two squares in the same row and column. The two Latin Squares are called Orthogonal if each of the n^2 pairs $(1,1),\dots,(n,n)$ appears exactly once in $\mathbb{L}$. Finding such a structure constitutes the OLS problem. As a general result we report that the hybrid method performs substantially better than "pure" CP and IP schemes, especially, as the size of the problem grows.

A relaxation of the cumulative constraint for resource-constrained scheduling

JOHN HOOKER
Carnegie Mellon University
coauthor: Hong Yan

keywords: constraint programming, machine scheduling, hybrid methods

We provide a continuous relaxation for the cumulative constraint, one of the most important global constraints used in constraint programming (CP) systems. The constraint is used to formulate resource-constrained scheduling problems. We apply the relaxtion to solve a multiple-machine scheduling problem with a hybrid CP/MILP method, based on a generalized Benders decomposition in which the subproblem separates into cumulative constraints. Previous work suggests that a suitable relaxation of the subproblem could result in dramatic speedups relative to CP and MILP acting alone. Since the cumulative constraint is difficult to formulate with integer variables, we provide valid inequalities solely in terms of the original continuous variables.

FR1-306/32 NONLINEAR PROGRAMMING
Surrogate modelling for engineering optimization III
organizer/chair: Kaj Madsen

Motivations and applications of the space mapping technique

KAJ MADSEN
Technical University of Denmark

keywords: non linear programming, surrogate modeling, space mapping

The space mapping technique is a useful tool for pre-processing an optimization of engineering models which involve very cpu-intensive function evaluations. We use two different models of the same physical system: Besides the cpu-intensive model of primary interest (denoted the fine model), access to a less expensive (coarse) model is assumed which may be less accurate. We use the coarse model to gain information about the fine model - thus quickly finding a rough estimate of the solution sought. For engineering purposes the rough estimate is often sufficient - otherwise the method is considered a pre-prossing technique for one of the traditional optimization methods. The Space Mapping principle has been used by engineers for many years, but the automatic way to do it - utilizing Broyden updates for estimating a connection between the two models - has only been known since the first paper by Bandler et al. in 1994. Since then a lot of applications have been published within the engineering society, and recently mathematicians have shown interest in the theoretical aspects of the method.

Space mapping: engineering modeling and optimization exploiting surrogates

JOHN BANDLER
McMaster University

keywords: engineering, space mapping, surrogate modeling, trust regions

The space mapping approach to engineering model enhancement and design optimization intelligently links companion "coarse" (ideal or low-fidelity) and "fine" (practical or high-fidelity) models of different complexities. Examples include full-wave electromagnetic (fine) simulations with empirical circuit-theory based (coarse or surrogate) simulations, or an engineering device under test coupled with a suitable simulation surrogate. Our methodology has been adopted for diverse design applications: electronic components, magnetic systems, civil and mechanical engineering structures. Space mapping facilitates efficient optimization while avoiding direct optimization of the fine model. It is a simple CAD methodology, which closely follows the traditional experience and intuition of engineers, yet is amenable to rigorous mathematical treatment. Following the original concept of Bandler in 1993, algorithms have utilized Broyden updates, trust regions, and artificial neural networks. New developments include (1) implicit space mapping, in which we allow preassigned parameters not used in optimization to change in the coarse model, and (2) output space mapping, where a transformation is applied to the response of the model. We present illustrative examples such as the cheese-cutting problem, and new results applicable to RF, wireless and microwave circuit design, integrating electromagnetic simulations.

Space mapping optimization using interpolating surrogates

FRANK PEDERSEN
Civil Engineering Department

keywords: non linear programming, trust region method, space mapping optimization, interpolating surrogates

Designing a system in an optimal way can be done by applying numerical optimization methods to a mathematical model of the system. Using a time consuming, high fidelity (fine) model of the system when optimizing it, is problematic since solving an optimization problem requires a potentially large number of fine model evaluations to be performed.

The Space Mapping Optimization (SMO) method specifically aims at bringing the number of fine model evaluations down, required to find the optimal model parameters. The method forms a parameter mapping that links a low fidelity (coarse) model to the fine model. Using the parameter mapping together with the coarse model when performing the optimization saves fine model evaluations.

SMO usually converges to a parameter set close to the fine model optimizer. Convergence can be ensured by either performing a switch to a direct optimization method, or if the surrogates generated by the method interpolate with the fine model function value and first derivatives.

This talk introduces work aimed at generating interpolating surrogates using a Space Mapping approach. Results showing significant increase in the performance of the method will be presented. More practical ways of generating interpolating surrogates will be discussed.

FR1-306/33	NONLINEAR PROGRAMMING
Semidefinite problems	
chair: Joachim Dahl	

A global algorithm for nonlinear semidefinite programming

HECTOR RAMIREZ CABRERA
INRIA-Rocquencourt
coauthor: Rafael Correa

keywords: nonlinear semidefinite prog., sequentially programming, global convergence

In this paper we propose a global algorithm for solving nonlinear semidefinite programming problems. This algorithm, inspired in the classic SQP (Sequentially Quadratic Programming) method, modifies the S-SDP (Sequentially Semidefinite Programming) local method by using a nondifferentiable merit function combined with a line search strategy.

Covariance matrices calibration via semidefinite least-squares

MALICK JEROME
INRIA

keywords: matrix calibration, Lagrangian duality, semidefinite optimization

We present a method to solve the following problem, called semidefinite least-squares: to project a matrix onto the intersection of the cone of positive semidefinite matrices and an affine subspace. An important application of semidefinite least-squares is the so-called calibration of covariance matrices, which arises for example in portfolio risk analysis: to find a "good" approximation covariance matrix between some assets, from a first estimate. We propose a Lagrangian dualization which yields a convex differentiable dual problem. Numerical results assess the method, even for very large matrices.

Gabor frames with optimal time and frequency localization

JOACHIM DAHL
Aalborg University, Dept. of Comm. Tech.
coauthors: Søren V. Andersen, Søren. H. Jensen

keywords: Gabor frames, localization, global optimization

We consider the design of Gabor analysis and synthesis filterbanks with oversampling (Gabor frames). We design Gabor frames with optimal trade-off between time- and frequency localization. This is a difficult non-convex optimization problem, but suprisingly it can be solved globally and efficiently via a dual problem using semidefinite programming. As an interesting consequence of the problem formulation, the optimal analysis and synthesis frames become identical which is appealing in many engineering applications.

FR1-306/34	NONLINEAR PROGRAMMING
Large scale problems IV	
chair: Gerardo Toraldo	

PENNON - a code for large-scale nonconvex npl and SDP: algorithm, theory, numerial results

MICHAEL STINGL
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coauthor: Michal Kocvara

keywords: nonlinear programming, semidefinite programming, augmented Lagrangian method

A class of iterative methods for convex nonlinear programming problems was introduced by Ben-Tal and Zibulevsky and named PBM. The framework of the algorithm is given by the augmented Lagrangian method; the difference to the classic algorithm is in the definition of a special penalty/barrier function satisfying certain properties. A generalization of the PBM method for convex semidefinite programming problems was recently proposed by the authors. The algorithm was implemented in the code PENNON, that proved to be very efficient for convex NLP and linear SDP problems.

In this talk, we present a generalization of the algorithm for large-scale nonconvex optimization problems with

NLP and(generally nonlinear) SDP constraints. We propose two strategies for treatment of nonconvexity. In the first one, we replace the Newton method, used for approximate minimization of the augmented Lagrangian, by the Levenberg-Marquardt algorithm. In the second one, we propose to use for this purpose the full trust region method. For the latter approach we will give a convergence theory.

Both approaches were implemented in a code PENNON. We will compare PENNON to state-of-the-art codes on a large set of standard NLP problems. Results for nonconvex SDP problems will be presented in a separate talk.

A parallel NPL code for optimal control problems with bounded states

JOAO-LAURO FACO´
Universidade Federal do Rio de Janeiro

keywords: dynamic systems, nonlinear optimization, parallel computing, reduced gradient

Nonlinear dynamic systems are considered as discrete-time optimal control problems with bounded state variables. A specialized Generalized Reduced Gradient method that exploits the staircase structure of the jacobian matrix of the dynamic equations by using some priority principles in the choice of the basic variables generating factorized representations of the GRG basic matix. Linear systems of equations are solved by parallel computing techniques for the LU-decompositions of the diagonal blocks in the basic matrix factorization improving efficiency and numerical stability. In the reduced dimension space of the independent variables we have a differentiable nonlinear objective-function. The minimization search directions can be computed by an adapted parallel conjugate-gradient method or a limited-memory quasi-Newton method. A computer code is presented, and numerical experiments with practical optimal control problems are discussed.

An hybrid algorithm for large-scale quadratic programs

GERARDO TORALDO
University of Naples
coauthor: Marco D'Apuzzo

keywords: hybrid algorithms, interior point method, gradient-projection method, adaptive termination rule

We present an hybrid algorithm for solving convex quadratic programming problems. The algorithm suitably combines an interior-point method and a gradient-projection strategy. The basic idea is to perform interior-point iterations until a point sufficiently close to the solution is obtained. Starting from this point, gradient-projection steps are performed in order to refine the final computed solution. We focus on the large and sparse case, and on the use of iterative techniques to solve the linear system arising at each iteration of the algorithm. In order to deal with the increasing ill-conditioning of such systems when the iterates get close to the boundary of the feasible region, we use preconditioning techniques based on incomplete factorizations with predictable memory requirements. Moreover, we propose suitable termination rules allowing to adapt the accuracy requirement in solving the linear systems on the quality of the current iterate. We show some results of computational experiments carried out an a IBM SP system and on a cluster of PC's, variyng the accuracy requirements for both methods. We also compare the proposed algorithm, with the package MOSEK.

FR1-306/35 NONLINEAR PROGRAMMING

Semidefinite programming and nonnegative polynomials

organizer/chair: Etienne de Klerk

Optimization subject to a fixed number of quadratic constraints in polytime

DMITRII V. PASECHNIK
Theoretische Informatik, FB 15, Universitaet Frankfurt
coauthors: Etienne de Klerk, Dima Grigoriev

keywords: quadratic constraints, polynomial time, symbolic computation, real algebraic geometry

It is shown that quadratic programming in n variables subject to k quadratic constraints has time complexity $n^{O}(k)$. More generally, given a quadratic map $Q : R^n \to R^k$, optimization over a semialgebraic set specified by s polynomial inequalities $f_i(Q(X)) \geq 0$, and any number of polynomial equations $f_i(Q(X)) = 0$, has time complexity $(snd)^{O}(k)$, where d is the maximal degree of the f_i's.

The described procedure reports the range of the objective function on the feasible region. For any value of the objective function in its range the algorithm can find a feasible point with this prescribed value. Optimal points and values are algebraic numbers represented by the algorithm in a symbolic way. For this purpose the tools of quantifier elimination over real closed fields with infinitesimals are involved. The latter are used to bring the problem into general position, in certain well-defined sense.

In contrast, the best previously known procedure only works in the homogeneous case, and needs $n^{O}(k^2)$ operations just for deciding feasibility, while no polynomial-time procedure previously known is able to find a feasible point with prescribed precision.

Our result implies a complexity bound for semidefinite programming announced in 1997 by Khachiyan and Porkolab without a proof.

On the rank-reducibility of barrier functions

YVAN HACHEZ
Université catholique de Louvain
coauthor: Yurii Nesterov

keywords: semidefinite programming, nonnegative polynomials, spectral factorization

In this talk, we present a new class of convex (dual) barrier functions, which permit low-rank representations in the (primal space. These barrier functions are obtained from "rank-reduced" self-concordant barrier functions, but they do not to enjoy this important property in general. Although our results are strongly related to spectral factorization of nonnegative matrix polynomials, they can be applied to other convex cones as well. Because these barrier functions are obtained from specific linear matrix inequalities, low-rank representations can be efficiently computed using any semidefinite programming solver.

Sum of squares decompositions for structured polynomials

PABLO PARRILO
ETH Zürich

keywords: sum of squares, algebraic optimization, semidefinite programming, convex optimization

The decomposition of a multivariate polynomial as a sum of squares is a basic question in applied mathematics. It is also one with important consequences, as such decompositions can be used via the Positivstellensatz as easily verifiable suboptimality certificates in optimization. Particularly exciting is the recent availability of efficient techniques, based on semidefinite programming, for its effective computation. In this talk, we present an overview of the available algorithms, emphasizing our recent developments oriented towards the exploitation of additional algebraic properties, such as symmetries and ideal structure. The ideas and algorithms will be illustrated with examples from a broad range of domains, and the use of the SOSTOOLS software (developed in collaboration with Stephen Prajna and Antonis Papachristodoulou).

FR1-306/36 NONSMOOTH OPTIMIZATION

Nonsmooth optimization II

chair: José Herskovits

Twice differentiable spectral functions

HRISTO SENDOV
University of Guelph

coauthor: Adrian S. Lewis
keywords: spectral functions, eigenvalue optimization, symmetric functions, Hessian

A function, F, on the space of $n \times n$ real symmetric matrices is called *spectral* if it depends only on the eigenvalues of its argument, that is $F(A) = F(UAU^T)$ for every orthogonal U and symmetric A in its domain. Spectral functions are in one-to-one correspondence with the symmetric functions, f, on $\mathbb{R}^n$, those invariant under permutations of their arguments. We show that a spectral function is twice (continuously) differentiable at a matrix if and only if the corresponding symmetric function is twice (continuously) differentiable at the vector of eigenvalues. We give a concise and usable formula for the Hessian. In the case of convex functions we also show that a positive definite Hessian of f implies positive definiteness of the Hessian of F.

Characterization of error bounds for lower semicontinuous functions

DOMINIQUE AZÉ
University Paul Sabatier, Toulouse, Laboratoire MIP

keywords: error bounds, Hoffman type estimates

We give a characterization of the existence of an error bound for lower semicontinuous functions. More precisely, given a l.s.c. function $f : X \longrightarrow \mathbb{R} \cup \{+\infty\}$ defined on a complete metric space X and given $\alpha \in \mathbb{R}$, we characterize the existence of $\tau > 0$ such that $\tau d(x, [f \leq \gamma]) \leq (f(x) - \gamma)^+$ for all $x \in X$ and $\gamma \geq \alpha$ where $d(x, [f \leq \gamma])$ denotes the distance function to the upper-level set of f at height γ. Several applications are given to metric regularity of multifunctions and to the existence of a Hoffman type estimate in semidefinite programming.

A new feasible directions algorithm for nonsmooth convex optimization

JOSÉ HERSKOVITS
COPPE/Federal University of Rio de Janeiro

coauthors: Wilhelm Passarella, Susana Scheimberg, Regina Burachik
keywords: nonsmooth optimization, nonlinear programming, nonlinear optimization

We consider the Problem

$$\min F(x),\ x \in \mathbb{R}^n,$$

where F is convex and not necessarily differentiable. Let be the Equivalent Problem EP:

$$\min z \in \mathbb{R}, \text{ such that } F(x) \leq z.$$

We present an algorithm that builds a sequence $\{(x_k, z_k)\}$ at the interior of the epigraph of F, such that $z_{k+1} < z_k$.

Our method employs the Feasible Directions Interior Point Algorithm, FD-IPA, for constrained smooth optimization, [1]. At each iteration, by solving two linear systems, FD-IPA computes a Feasible Descent Direction. Making a line search, a new interior point with a lower objective is obtained.

The present algorithm defines a sequence of Auxiliary Problems AP, where the constraints of EP are approximated by cutting planes.

At each iteration a Search Direction for EP is obtained by computing with FD-IPA a Feasible Descent Direction of AP. If the step length is "short", AP is updated and a new search direction is computed. This procedure is repeated until a "good" step is obtained. When this happens, the search direction is a Feasible Descent Direction of EP. We prove global convergence and solve several test problems very efficiently.

[1] Herskovits J. "A Feasible Directions Interior Point Technique For Nonlinear Optimization", JOTA, v99-1, 1998.

FR1-306/37 CONVEX PROGRAMMING

Large-scale semidefinite programming

organizer/chair: Madhu Nayakkankuppam

Solving large scale semidefinite programming via Krylov subspace methods

KIM-CHUAN TOH
National University of Singapore

keywords: large scale SDP, preconditioners

We present preconditioned Krylov subspace methods for the augmented and Schur complement equations arising from interior-point methods for solving large scale semidefinite programming. When the SDP is primal-dual non-degenerate and strict complementarity condition holds, the preconditioned matrices are shown to have bounded condition numbers even when the barrier parameter decreases to 0. Numerical experiments on some large scale SDPs arising from maximum clique problems show that the preconditioners are effective. In particular, we are able to solve such an SDP with more than 100,000 constraints in under 10 hours to a relative accuracy of less than 10^{-6}.

A conic bundle approach to linear programming over symmetric cones

CHRISTOPH HELMBERG
Chemnitz University of Technology

keywords: Lagrangean relaxation, primal aggregation, cutting models, software

In combinatorial optimization and stochastic programming Lagrangean relaxation is frequently employed to exploit structural properties of the underlying problem. Bundle methods allow to optimize over the multipliers while generating, at the same time, approximate primal solutions via primal aggregation. Convergence properties of the bundle method and the quality of this primal approximation largely depend on the quality of the cutting model. For linear programming and general convex optimization via first order oracles the linear cutting plane model is state of the art. For semidefinite programming a specialized model was introduced in the spectral bundle method. Recently, we proposed a similar model for second order cone programming. We report on our efforts to combine these features (primal aggregation, linear, semidefinite, and second order models) in a "Conic Bundle Package" for linear programming over symmetric cones and present some preliminary numerical results.

Solving large-scale SDP's in parallel

MADHU NAYAKKANKUPPAM
Department of Mathematics & Statistics, UMBC

coauthor: Yevgen Tymofyeyev
keywords: semidefinite programming, subgradient bundle methods, Lanczos method, parallel computing

We describe a portable, parallel and distributed implementation of the spectral bundle method for semidefinite programs (SDP) with the usual block diagonal structure. Subgradients are computed via a Lanczos method with implicit restarts, but specially tailored to handle block structure. Based on the Message Passing Interface, this code exploits parallelism to solve (to low accuracy) problems larger than previously possible. (For instance, a Lovasz theta function SDP on a graph with 2000 nodes and 20,000 edges is solved to about 3 digits of accuracy in under 12 minutes on 16 processors). Our current efforts are directed towards improvements necessary to achieve scalability and superior parallel performance on very large-scale problems.

FR1-306/38 GLOBAL OPTIMIZATION

Quadratic optimization

chair: Andreas Brieden

Solving nonconvex quadratic programming problems with simple bound constraints

JOHANNES J. DE NIJS
Old Dominion University

keywords: quadratic programming, unconstrained optimization, Newton method, quadratic spline

A nonconvex quadratic programming problem with simple bound constraints can be reformulated as an unconstrained minimization problem with a (onconvex) quadratic spline as the objective function. Newton-type methods can be used to define descent directions for finding minimizers of unconstrained optimization problems, but this usually requires a positive definite Hessian, as is an $O(n^3)$ algorithm for finding a solution through a Cholesky factorization. In this paper we propose an algorithm that uses a global line search method to find a stationary point satisfying the secon order necessary optimality condition, using modifications to the Cholesky factorization. The method can be considered as an implicit active set method with the novel feature of a mixed primal-dual approach for identifying active indices, and a global exact line search strategy for global solutions. The first feature provides a dynamic balance between the need of minimizing the original function and the need of forcing the iterates to stay in the feasible region. Directions of negative curvature at stationary points and global search help to find a global solution of the nonconvex quadratic programming problem.

A solution algorithm for a class of box constrained quadratic programming problem

CLAUDIO SODINI
University of Pisa
coauthor: Riccardo Cambini
keywords: quadratic programming, optimal level solutions, D.C. optimization

The aim of this paper is to suggest an algorithm to solve a box constrained quadratic problem where the objective function is given by the sum of a quadratic strictly convex separable function and the square of an affine function multiplied by a real parameter.

Depending on the value of the real parameter, the problem might be convex or not. The particular structure of the problem allows to suggest an efficient parametric algorithm solving the problem in a finite number of steps.

Clustering in agriculture by means of quadratic optimization

ANDREAS BRIEDEN
TU München
keywords: quadratic optimization, randomized approximation, convex maximization

In the process of passing farmland to heirs a formerly large piece of land has under the heritage laws of certain countries been split over the centuries into small lots. In fact, for this and other reasons today's farmers may own a number of small sized lots that are distributed over a wide range leading to high agricultural production costs.

For various reasons classical forms of land consolidation become less and less feasible. It has hence been suggested to support the voluntary lend-lease based exchange of agricultural acreage. Due to combinatorial explosion the underlying combinatorial optimization problem becomes hard to solve for almost all sample regions. Hence, in order to fully exploit the potential of the method mathematical optimization is required.

In this talk a quadratic optimization model is presented that also intractable in theory, is successfully solved by means of a randomized approximation algorithm for Euclidean norm-maximization in practice.

FR1-308/11 GENERALIZED CONVEXITY/MONOTONICITY

Generalized convexity/monotonicity

chair: Evgeny G. Gol'shtein

Convex- and monotone-transformable mathematical programming problems and a proximal-like point method

ORIZON FERREIRA
Federal University of Goias
coauthors: Joao Xavier da Cruz Neto, Luis Roman Lucambio Perez, Sandor Z. Nemeth
keywords: monotone vector fields, Hadamard manifolds, non convex constrained problem, proximal point algorithm

The problem of finding singularities of monotone vectors fields on Hadamard manifolds will be considered and solved by extending the well-known proximal point algorithm. For monotone vector fields the algorithm will generate a well defined sequence, and for monotone vector fields with singularities it will converge to a singularity. It will be also shown how tools of convex analysis on Riemannian manifolds can solve non-convex constrained problems in Euclidean spaces. To illustrate this remarkable fact examples will be given.

A projection-type method with variational metric for solving a general variational inequality problem

SUSANA SCHEIMBERG
Universidade Federal do Rio de Janeiro,UFRJ/COPPE-PESC
coauthor: Paulo Sergio Santos
keywords: general variational inequality, projection method, variational metric, cocoercivity

In this work we consider the General Variational Inequality problem in a Hilbert space, (GVI), introduced by M. A. Noor in 1988. We present an iterative scheme based in a projection on an interior approximation of the constraint set, that can be interesting from a practical point of view. The convergence analysis requieres the existence of a solution of (GVI) and a usual cocoercivity condition of the underlying operator. We also consider a variational metric introduced by H. Attouch and R. J. B. Wets in 1986. Preliminary computational experience is reported. We compare our method with the algorithms given by M. A. Noor et al. and by B. He using test problems.

A method for solving monotone variational inequalities

EVGENY G. GOL'SHTEIN
Central Economics @ Mathematics Institute of Russian Academy of Sciences
keywords: monotone mapping, oracle, measure of proximity

We consider a class of variational inequalities each of which is defined by a monotone mapping with convex values and by a convex polyhedron comprising the domain of the mapping. In the paper, we describe an oracle-type algorithm solving the variational inequalities of the above-mentioned class. Under the assumption of the mapping being upper semi-continuous, the algorithm's convergence is established. We also present a way to calculate the measure of proximity of the current iteration point to the set of solutions of the variational inequality. This way is an extension of the functional proximity measure used in the optimization problems. In terms of the proposed proximity measure, we obtain the algorithm's convergence rate that proves its optimality on the considered class of variational inequalities.

FR1-308/12 — STOCHASTIC PROGRAMMING
Sensitivity and stability
chair: Alexey Izmailov

Nonparametric kernel estimation via nonstationary stochastic optimization

VLADIMIR NORKIN
Institute of Cybernetics of the Ukrainian Academy of Sciences
coauthors: Y. M. Ermoliev, M. A. Keyzer
keywords: kernel estimation, stochastic optimization, density/regression estimation, tracking

The report considers nonparametric kernel density/regression estimation from stochastic optimization point of view. The estimation problem is represented through a family of stochastic optimization problems. Recursive constrained estimators are obtained by application of stochastic (quasi)gradient methods to these problems, classical kernel estimates are derived as particular cases. Accuracy and rate of convergence of the obtained estimates are established, asymptotically optimal estimation procedure parameters are found. The case of moving density/regression is particularly studied.

Stability theory for systems of ineaqualities at abnormal points

ARAM ARUTYUNOV
People's Friendship University of Russia
keywords: abnormal point, cone, inverse function

We consider the equation whith unknown variables varying in a given convex closed cone. This cone defines the enequality type constraints. The corresponding nonlinear mapping is assumed to be sufficiently smooth. The inverse function and implicit function theorems are proved. The main distinction of presented results from wellknown is that the point under consideration may be abnormal. In other words we don't a'priori assume that Robinson's constrained qualification are satisfyed.

Sensitivity analysis for abnormal optimization problems

ALEXEY IZMAILOV
Moscow State University
coauthor: Aram Arutyunov
keywords: sensitivity analysis, parametric optimization, cone-constrained problem, constraint qualifications

For the parametric cone-constrained optimization problem, we consider the case when the customary (Robinson's, directional) regularity conditions can be violated at solution of the unperturbed problem. Under the assumptions substantially weaker than those previously used in the literature in this context, we develop a reasonably complete local sensitivity theory for this class of problems, including upper and lower bounds for the rate of change of the optimal value function subject to parametric perturbations, as well as the estimates and the description of asymptotic behavior of solutions of the perturbed problems. This development relies on certain genaralization of Robinson's stability theorem, extending the latter to the nonregular case.

FR1-308/13 — SEMI-INFINITE AND INFINITE DIMENSIONAL PROGRAMMING
Semi-infinite and infinite dimensional programming
chair: Tatyana Stepanchuk

The obstacle problem for water tanks

RADHIA BESSI
ENIT
coauthors: Frederic Bonnans, R. Bessi Fourati, Hichem Smaoui
keywords: obstacle problem, nonconvex variational problems, sensitivity analysis, finite elements

Abstract In this work we discuss the problem of computing and analyzing the static equilibrium of a non rigid water tank. Specifically, we fix the amount of water contained in the tank, modelled as a membrane. In addition, there are rigid obstacles that unilaterally limit the deformation. This gives rise to a constrained, non convex variational problem. We derive the optimality system and its interpretation in terms of equilibrium of forces. A second order sensitivity analysis, allowing to compute derivatives of solutions and a second order Taylor expansion of the cost function, is performed, in spite of the fact that the cost function is not twice differentiable. We also study the finite elements discretization, introduce a decomposition algorithm for the numerical computation of the solution, and display numerical results.

Solution of the optimal set partitioning problem as problem of minimization the sets function

TATYANA STEPANCHUK
Phd. student /Department of applied mathematics and mathematical cybernetics/Dnepropetrovsk national university
coauthor: Elena Kiseleva
keywords: minimization the sets function, optimal set partitioning

The problem of optimal set partitioning of the set Ω from an n -dimensional Euclidean space E_n into its disjoint subsets with unknown in advance subset center coordinates with constraints of the form of equalities and/or inequalities is considered. This problem is the novel problem of the theory of optimization the sets function. The necessary conditions for the extremum that are generalized well-known fundamental Neyman-Pearson lemma are obtained based on the mathematical tools of the theory of optimization the sets function. The algorithms for numerical solution of the above-mentioned problem are constructed, programmed and evaluated on a set of test problems.

FR1-308/T1 — DYNAMIC PROGRAMMING AND OPTIMAL CONTROL
Large-scale dynamic programming - algorithms and approximation
organizer/chair: Marina Epelman

Efficient average-cost optima for infinite horizon optimization

IRWIN SCHOCHETMAN
Oakland University
coauthor: Robert L. Smith
keywords: average-cost, efficient, state reachability, existence

Those infinite horizon optimization problems which do not admit a minimum-cost (strong) optimum, may also not admit a (minimum-) average-cost optimum. Furthermore, if an average-cost optimum does exist, there will exist many such in general because of instability over finite horizons. Thus, it is desirable to seek average-cost optima which are also efficient (finite optimal) over finite horizons, i.e., attain each of their states optimally. We show that efficient optima exist in our broad context and, under a general state-reachability condition, conclude that efficient optima are also average-cost optimal.

Solution acceleration through nested aggregation

MATTHEW BAILEY
University of Pittsburgh

keywords: dynamic programming, aggregation, deterministic

Dynamic Programming is a powerful, robust modeling mechanism for sequential decision processes. A significant deterrent to its use is the computation time and computer storage requirements resulting from the exponential growth in the state space of most models. One of the methods for mitigating this problem is aggregation. The creation of aggregate states results in the loss of information and hence an error in the resulting solution. This results in an approximate solution technique. Typically aggregation techniques have three steps: aggregation, solution, and disaggregation to find the associated feasible solution. We discuss an extension of sequential aggregation disaggregation to included a nested hierarchy of aggregated macronodes in a possibly cyclic network.

Aggregation in stochastic dynamic programming

MARINA EPELMAN
University of Michigan
coauthors: Theodore J. Lambert III, Robert L. Smith

keywords: dynamic programming, Markov: finite state, aggregation

We present a general aggregation method for Markov decision problems under which the aggregate solution is immediately applicable to the original problem (i.e., no disaggregation step is required). The method is based on selecting a collection of "distinguished" states. We provide error bounds for general time dependent "distinguished" state selection method. The aggregation scheme also provides a method to incorporate action space restrictions which have dependencies across states, a modification which generally results in the loss of the Markovian property. We demonstrate the aggregation method on a radiation treatment planning problem.

FR1-308/T2 COMPLEMENTARITY AND VARIATIONAL INEQUALITIES

Nonlinear complementarity problems

chair: Natasa Krejic

An investigation of a nonlinear obstacle plate optimization problem

JOAO PATRICIO
Escola Superior de Tecnologia de Tomar
coauthors: Joaquim Judice, Isabel Figueiredo, Luis Merca Fernandes

keywords: variational inequalities, nonlinear programming, complementarity problem, obstacle problem

We discuss the solution of a nonlinear obstacle plate problem which describes the equilibrium of a thin elastic clamped plate, that may come into contact with a rigid obstacle, by the action of external forces. The discrete formulation of the problem is based on the finite element method, using the Bogner-Fox-Schmit and the Melosh rectangle, with 16 and 8 degrees of freedom, respectively, to approximate the vertical and horizontal displacements of the middle plane of the plate. Due to the symmetry of the associated function of the variational inequality, it is possible to solve the corresponding discrete model as a nonlinear program with simple bounds on the variables. A number of algorithms exploiting the structure of the optimization problem is investigated. Numerical results of the application of these algorithms are included to highlight their efficiency in practice.

Mixed nonlinear complementarity problems via nonlinear optimization: numerical results on multi-rigid-body contact problems with Coulomb friction

SANDRA AUGUSTA SANTOS
State University of Campinas - UNICAMP
coauthors: Roberto Andreani, Ana Friedlander, Margarida P. Mello

keywords: complementarity problem, bound-constrained minimization, multi-rigid-body contact prob., Coulomb friction

In this work we show that the mixed nonlinear complementarity problem may be formulated as an equivalent nonlinear bound-constrained optimization problem that preserves the smoothness of the original data. One may thus take advantage of existing codes for bound-constrained optimization. This approach is implemented and tested by means of an extensive set of numerical experiments, showing promising results. The mixed nonlinear complementarity problem considered in the tests arises from the discretization of a motion planning problem concerning a set of rigid 3D bodies in contact in the presence of friction. For each time frame one needs to solve a complementarity problem in order to calculate the accelerations of the bodies involved.

On a quasi-Newton method for complementarity problems

NATASA KREJIC
Department of Mathematics and Informatics, University of Novi Sad
coauthor: Zorana Luzanin

keywords: complemetarity problems, quasi-Newton methods

Nonlinear complementarity problems appear in many engineering and economic applications. Such problems are often solved by iterative methods based on generalization of classical Newton method and its modifications for smoorh equations. We consider the Modification of the Right-Hand Side Vector (MRV) quase-Newton method for a semismooth reformulation of NCP. The local convergence is proved and some numerical results are presented.

FR1-308/T3 TELECOMMUNICATION NETWORK DESIGN

Models and simulations for planning and control of UMTS (momentum)

organizer/chair: Arie M.C.A. Koster

Challenges in UMTS radio network planning

ANDREAS EISENBLÄTTER
ZIB
coauthors: Alexander Martin, Thorsten Koch, Roland Wessäly

keywords: radio network planning, UMTS, momentum

The Universal Mobile Telecommunications System (UMTS) is a 3rd generation cellular system for mobile telecommunications. In UMTS cell coverage and cell capacity are inversely coupled in UMTS. The radio transmissions for different mobiles are not separated in time or frequency (unlike in GSM), but they

are separated by means of coding. For a proper decoding, a minimum ratio, called CIR, between the carrier's strength at the receiver and the interference has to be achieved. The network's capability to serve users' demand depends on the transmission powers required to satisfy all CIR requirements.

The typical network planning process cycles in a time consuming trial-and-error fashion through tentative network designs and simulation-based network performance analysis. An automatic search for a low-cost network design, achieving the required quality standard is therefore in high demand.

This talk introduces the context of network planning. Service and source models, spatial load distributions, and hardware characteristics are explained. The mathematical modelling and solving of the radio network planning challenge are addressed in the two companion talks by Roland Wessäly and Alexander Martin.

Models for UMTS radio network planning

ROLAND WESSÄLY
Konrad-Zuse-Zentrum
coauthors: Andreas Eisenblätter, Alexander Martin, Thorsten Koch
keywords: radio network planning, UMTS, momentum, mixed integer programming

The Universal Mobile Telecommunications System (UMTS) is a 3rd generation cellular system for mobile telecommunications. Even though UMTS networks are currently being deployed in many European countries, the development of planning and optimization methodologies which cover the many particularities of these networks is still in its beginnings. The project MOMENTUM, which is supported by the European Union under the Information Society Technologies (IST) Programme is one of the driving forces to push these developments ahead.

This presentation focuses on modeling aspects related to planning and optimizing the radio interface of UMTS networks. It is accompanied by the preceding presentation of Andreas Eisenblätter introducing principles of the UMTS radio interface and the succeeding of Alexander Martin one explaining optimization methods. The presented mixed-integer linear programming model has been developed within MOMENTUM and covers a broad range of planning issues: site selection for the UMTS base stations, cell sectorization, antenna selection and configuration (height, tilt, azimuths). The objective is to minimize the total cost of the network.

Optimisation methods for UMTS radio network planning

ALEXANDER MARTIN
TU Darmstadt
coauthors: Andreas Eisenblätter, Roland Wessäly, Thorsten Koch
keywords: UMTS, radio network planning, momentum, mixed integer programming

The Universal Mobile Telecommunications System (UMTS) is a 3rd generation cellular system for mobile telecommunications. The planning of UMTS networks is a challenging problem. One key issue is to select base station locations and to configure base stations including antenna types, heights, azimuths, and tilts such that the required services are met. The problem leads to a huge mixed integer program the modelling of which has been discussed in the preceding presentations by Roland Wessäly and Andreas Eisenblätter. In this talk we deal with solution methods of this model. We demonstrate success and limits of general MIP solvers, we present model reformulations including valid and heuristic inequalities, and we discuss primal metaheuristics. Computational results on realistic data conclude the presentation.

FR1-341/21 INTERIOR POINT ALGORITHMS

Second-order cone optimization and extensions

organizer/chair: Erling Andersen

The simplex method for semidefinite and second-order cone programming

DON GOLDFARB
Columbia University
keywords: conic programming, simplex method, semidefinite programming, second order cone programming

A vast array of convex optimization problems can be formulated as semidefinite and second-order cone programs. We present a natural and straightforward extension of the simplex method to these classes of problems and discuss how to efficiently implement various "pivot rules". We also present numerical results to illustrate the performance of these variants of our simplex method.

Second-order cone optimization with a single second-order cone

FRANÇOIS GLINEUR
CORE / UCL
keywords: second order cone optimization, conic optimization, convex optimization

We consider the standard conic optimization problem involving only a single second-order cone and do not assume any type of constraint qualification (e.g. Slater) condition.

We first tackle the associated feasibility problem, which amounts to deciding whether the problem is strictly feasible, weakly feasible, weakly infeasible or strongly infeasible. We show that this can be determined without any iterative process by solving a few linear equality systems.

We then outline how this procedure can be generalized to solve the original second-order cone optimization problem. In particular, we obtain a proof of the fact that such second-order cone problems can never exhibit a duality gap.

We also discuss the algorithmic complexity viewpoint and possible generalizations of this procedure.

Uniform boundedness of a preconditioned normal matrix used in interior point methods

JEROME O'NEAL
Georgia Institute of Technology
coauthors: Renato Monteiro, Takashi Tsuchiya
keywords: linear programming, interior point method, network flow problems, condition number

Solving systems of linear equations with "normal" matrices of the form AD^2A^T is a key ingredient in the computation of search directions for interior-point algorithms. In this article, we establish that a well-known basis preconditioner for such systems of linear equations produces scaled matrices with uniformly bounded condition numbers as D varies over the set of all positive diagonal matrices. In particular, we show that when A is the node-arc incidence matrix of a connected directed graph with one of its rows deleted, then the condition number of the corresponding preconditioned normal matrix is bounded above by $m(n-m+1)$, where m and n are the number of nodes and arcs of the network.

FR1-341/22 LOGISTICS AND TRANSPORTATION

Logistics and transportation

chair: Maria Daneva

A robust optimization model for empty container allocations

KIN KEUNG LAI
City University of Hong Kong
coauthors: Y. Wu, Stephen C. H. Leung
keywords: empty container, robust optimization, distribution planning

Shipping companies pay substantial operational expenses to maintain its container fleet. It is important that shippers plan and schedule efficiently the movement and inventory of containers. Owing to a trade imbalance, shipping lines accumulate a large number of unnecessary empty containers in the Middle East, whilst some export ports such as Hong Kong and Japan often face a shortage of empty containers. In this paper, a well-known container shipping line that provides scheduled sea transportation services covering the Far East, the Middle East and Europe is studied. We develop an optimisation model to dispatch empty containers from the Middle East to various export ports in the Far East region and reposition surplus empty containers from any port to shortage ports in anticipation of future demand in subsequent periods. A set of real data from one of the largest shipping companies in Hong Kong is used to test the efficacy and robustness of the model. To enhance the practical implications of the proposed model, different logistics plans are evaluated according to changes of future policy and situation, which are demonstrated by numerical results.

Conjugate direction Frank-Wolfe methods with applications to the traffic assignment problem

MARIA DANEVA
MAI/Linköping University
coauthor: Per Olov Lindberg
keywords: traffic assignment problem, Frank-Wolfe method, conjugate directions

We present versions of the classical Frank-Wolfe method for linearly constrained convex programs, in which consecutive search direction are made conjugate to each other. We apply the new algorithms to the Traffic Assignment Problem and present preliminary computational studies in a Matlab environment. In a limited set of computational tests Conjugate direction Frank-Wolfe and Bi-conjugate Frank-Wolfe turn out to be quite efficient, outperforming pure and "PARTANized" Frank-Wolfe methods. Attempts to compare the new methods with the recent origin-based algorithms, indicate that they are competitive for accuracy requirements suggested by Boyce et al.

FR1-341/23 APPROXIMATION ALGORITHMS

Priority algorithms: models and approximation bounds for greedy-like algorithms

organizer/chair: Joan Boyar

What is a greedy (approximation) algrorithm

ALLAN BORODIN
University of Toronto
keywords: greedy algorithms, scheduling, priority algorithm, facility location

Many undergraduate algorithms courses and texts often organize the material in terms of "algorithmic paradigms", such as greedy algorithms, dynamic programming, local search, primal-dual, etc. We seem to be able to intuitively describe what we have in mind when we discuss these classes of algorithms but rarely (if ever) do we (or any of the standard texts) attempt to define precisely what we mean by greedy, dynmaic programming, etc.

In a paper co-authored with Nielsen and Rackoff, we proposed a definition for greedy-like approximation algorithms, called priority algorithms. We did so in the context of classical scheduling problems. Angelopoulos and Borodin then applied the priority algorithm framework to the facility location and set cover problems. Impagliazzo and Davis have applied the framework to a number of traditional graph theoretic optimization problems.

Similar to online algorithms, we want to derive limitations on the (approximation) power of priority algorithms based only on the structure of the algorithm (allowing unbounded time complexity). Hopefully such a study will also lead to new algorithms. We motivate the priority algorithm framework by discussing some well known greedy algorithms and the corresponding lower bounds provable within this framework. We also discuss some extensions of the model such as the "one-pass" framework of Erlebach and Spieksma.

Models of greedy algorithms for graph problems

RUSSELL IMPAGLIAZZO
UCSD
coauthor: Sashka Davis
keywords: approximation algorithms, greedy algorithm, priority algorithm, graph problems

Borodin, Nielsen, and Rackoff introduced the notion of priority algorithms. Priority algorithms are an abstract model which capture the intrinsic power and limitations of greedy algorithms. The original paper was limited to scheduling problems; but subsequent workextended the model to other domains.

We generalize their notion to general optimization problems, and apply it, in particular, to graph problems. We characterize the best performance of algorithms in each model in terms of a combinatorial game between a Solver and an Adversary.

We prove bounds on the approximation ratio achievable by such algorithms for basic graph problems such as shortest path, metric Steiner trees, independent set and vertex cover. For example, we show no fixed priority algorithm can achieve any approximation ratio for shortest paths (even a function of the graph size). In contrast, the well-known Dijkstra's algorithm shows that an adaptive priority algorithm can be optimal for this problem. We show that the known upper bound of 2 for the approximation ratio of an adaptive priority algorithm for vertex cover is tight. We also give an example of a problem where memoryless algorithms are less powerful than general adaptive priority algorithms.

Restricted models for priority algorithms on graphs

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coauthors: Allan Borodin, Joan Boyar
keywords: approximation algorithms, greedy algorithms, priority algorithm, graph problems

In the topic of priority algorithms, one explores the limits of greedy-like techniques for solving approximation problems by establising general lower bounds. To capture the notion of greedy-like, where irrevocable decisions must be made for each input item without knowledge of unprocessed items, very precise specifications of the input format must be given. We focus on graph algorithms where this modelling aspect is particularly interesting. Among other things, the models must clarify if the identity of the other endpoint is revealed when presenting the edges of a vertex (vertex-adjacency) or if the edges are given by some edge identifier (edge-adjacency). In addition, we distinguish between fixed priorities and adaptive priorities, where the algorithms may reconsider their priorities before each new item is chosen.

We study unweighted vertex cover, independent set, and vertex coloring. For independent set, we obtain non-constant results: No fixed priority algorithm can obtain an approximation ratio better than order of $1/\sqrt(n)$, where n is the number of vertices. The same bound holds for adaptive algorithms which accept all vertices that they are going to accept before rejecting any.

FR1-321/053 PRODUCTION AND SCHEDULING
Scheduling with variable parameters
chair: Mohamed Haouari

Scheduling problems with controllable processing times and preemption

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keywords: scheduling, controllable processing times, preemption

We consider the problem of optimal scheduling a set of jobs on a single machine or on a set of parallel machines. The processing time for each job may vary within certain limits and it depends on the amount of a resource consumed. Compressing processing times decreases the completion times of the jobs but incurs additional costs. It is assumed that preemption is allowed, i.e., the processing of any job can be interrupted and resumed later. The objective is to minimize a function depending on job completion times (such as the makespan or maximum lateness) together with the total compression cost. We describe a unified approach that is based on reducing the scheduling problem to minimization of a linear function over a polymatroid. The approach is applicable to solve a range of scheduling problems with controllable processing times: with a single machine or several parallel machines, with equal or different release dates, with or without deadlines, etc. We conclude with a comprehensive overview of the results on optimal processing jobs with controllable processing times when preepmtion is allowed.

Optimizing job sequening and tool replacement decisions

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keywords: scheduling, modeling, tabu search

Much research related to just-in-time (JIT) production has been carried out. However, in most of the previous studies, the processing times and tool lives are treated as constant and deterministic. The decisions are often made without considering detailed tool replacement decisions. It is well known that tool life is probabilistic which leads to probabilistic processing time. Schedules made without considering the probabilistic nature of the tool life may lead to excessive in-process tool failures, prolonged waiting time, and delayed product delivery. For this reason, we propose an integrated approach to solving the tool replacement and JIT scheduling problems. The integrated problem is formulated as a probabilistic non-linear integer model. The objective is to minimize the total expected production costs. The model aimed to provide an optimal job sequence and the associated tool replacement intervals. Due to the combinatory and probabilistic nature of the model, optimal solution cannot be obtained in polynomial time. We therefore propose an efficient tabu search approach to provide near optimal solutions. A problem with 30 operations and 20 tools has been solved the performance of the proposed tabu search algorithm.

Optimal parallel machines scheduling with availability constraints

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keywords: parallel machines scheduling, machine availability, release date

We address a generalization of the classical multiprocessor scheduling problem with non-simultaneous machine availability times, release dates, and delivery times. We develop new lower and upper bounds as well as a branching strategy which is based on an original representation of a schedule as a permutation of jobs. We show that embedding a semi-preemptive lower bound based on max-flow computations in a branch and bound algorithm yields very promising performance. Computational experiments demonstrate that randomly instances with up to 700 jobs and 20 machines are solved within moderate CPU time. Moreover, the versatility of the proposed approach is assessed through its ability to solve large instances of two important particular cases $P,NC_{inc}||C_{\max}$ and $P|r_j,q_j|C_{\max}$

FR1-321/033 MULTICRITERIA OPTIMIZATION
Efficiency analysis in multicriteria optimization II
chair: Irina Pospelova

On a new concept of proper approximate Pareto efficiency

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keywords: approximate solutions, ε-Pareto solutions, proper ε-solutions, ε-subdifferential

Kuhn-Tucker type rules are basic in optimization because they describe conditions for solutions in mathematical programs. Different authors have extended these rules to approximate solutions in optimization problems.

In convex scalar optimization, it is possible to obtain multipliers rules for approximate solutions using the ε-subdifferential. In nonconvex scalar optimization, the general method to obtain multipliers rules for approximate solutions is based on variational principles.

Multiobjective optimization problems add an additional detail since in this programs the notion of approximate efficiency is not unique. The concept more used in the bibliography is due to Kutateladze (1979) and Loridan (1984).

We analyze some connections between the notions of approximate efficiency introduced by Kutateladze-Loridan and Helbig (1992). As a consequence of that we introduce a new notion of proper approximate Pareto efficiency. We establish a characterization for proper approximate Pareto solutions when the multiobjective problem is convex. We provide a general method to transform a multiobjective optimization problem into a scalar optimization problem in such a way that approximate Pareto solutions for the first problem are approximate solutions for the second problem. Finally, in convex multiobjective optimization we deduce multipliers rules for approximate Pareto solutions in the sense of Helbig using the ε-subdifferential.

Second order optimality criteria in nonsmooth vector optimization

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keywords: multicriteria optimization, nonsmooth analysis, second order incremental ratio

Second order optimality conditions are studied for a vector optimization problem without supposing twice differentiability. The standard approaches are componentwise since they try to employ nonsmooth analysis for real-valued functions also in this framework, relying directly on components or on suitable weighted sums. Recently, a global approach based on the well-known concept of generalized Hessian has been investigated too. In this paper we consider a different kind of global approach: set-valued directional derivatives of vector-valued functions are introduced relying on Kuratowski type limit of vector second order parabolic ratios. We develop second order necessary and sufficient optimality conditions for vector problems subject to either abstract constraints or inequality and equality constraints and we show that this approach gives sharper results than the previous ones.

Existence conditions of game solution in multicriteria case

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keywords: game theory, multicriteria game, vector payoff function

We investigate games with opposite purposes and vector payoff function. The presence of vector criteria generates ambiguity in interpretation of opposite purposes. In the case of all partial criteria of one player are opposite to all partial criteria of the other we come to the game that is conventionally called vector zero-sum game. Here one player maximizes the payoff function and the other minimizes it.

In the case of opposite goals of the players, we come to the game conventionally called antagonistic (following D. Blackwell, G. Jentzsch and R.J. Aumann). Here if the goal of one player is to maximize the vector payoff function then the goal of the other is to minimize an arbitrary partial criterion, which is nonfixed before.

We analyze the problem of determination of the described games' values. The possibility of generalization of the concepts known for scalar games to vector games is investigated. In particular, we consider saddle points and mixed strategies; solution existence conditions of the normal form games and properties of the games with fixed order of moves.

FR1-321/133 LINEAR PROGRAMMING

Mathematical programming techniques in data envelopment analysis

organizer/chair: Niels Christian Petersen

A new algorithm for DEA

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coauthor: Jose Dula
keywords: DEA, computational geometry, polyhedral sets

Data Envelopment Analysis (DEA) is essentially a clustering tool for data sets that identifies geometric outliers. Many of the insights about the geometry of polyhedral sets from convex analysis and computational geometry are available for DEA. These insights and other computational contributions have been used to design a new algorithm for DEA. This algorithm is faster than the traditional approach. In addition, its results provide additional useful information that can be used to accelerate complex analyses as well as eschew some of the complications inherent to some of the more standard approaches. We present the new algorithm and report on computational results.

Identification and use of efficient faces and facets in DEA

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keywords: data envelopment analysis, efficiency analysis, polyhedral convex analysis

Data Envelopment Analysis (DEA) can be seen as a mathematical programming technique designed for an identification of the efficient production frontier in an empirical production data set. The empirical production possibility set is constructed in a three step procedure involving i) the identification of the convex hull of observed input-output data, ii) an expansion of this convex hull justified by a maintained hypothesis of (strong) disposability of inputs and outputs, eventually followed by iii) a radial scaling of input-output configurations in the expanded convex hull. The faces and facets of the resulting polyhedral production possibility set define the efficient production frontier. The paper demonstrates the use of some of the available (exponential) convex hull algorithmn for an explicit identification of the facial structure of the efficient frontier in fairly large empitical DEA data sets, An outline of the use of this type of information in a productivity analysis is given.

How to bootstrap DEA efficiency scores by using the slice model approach

TOR BELTOV
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keywords: DEA, slice models, bootstrap

Calculating Data Envelopment Analysis (DEA) Efficiency Scores can be a very time consuming task. The time involved is especially high when standard modelling systems like GAMS are used. One approach to deal with this issue is to use a callable library like the one supplied by CPLEX. Another approach is to observe that a complete DEA model in fact consists of multiple linear programs, each of which has the same structure but different data. It is known that all DEA models fits the definition of the socalled slice model approach. Thinking DEA models as slice models reduces the time involved for solving the problems significantly. This issue is prominent when we turn to an estimation of confidence intervals for DEA Efficiency Scores by bootstrapping, since this procedure involves the solution of an LP each DMU more than 500 times. The paper considers how to use the slice model approach for bootstrapping in DEA.

Index of Keywords

Speakers, Coauthors and Chairpersons

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