Contents

Welcome to ISMP2006

On behalf of the Federal University of Rio de Janeiro - UFRJ we welcome you to ISMP2006, the 19th edition of the International Symposium on Mathematical Programming. The symposium will be held at the Praia Vermelha Campus of UFRJ and also at the nearby auditoriums of Instituto Militar de Engenharia - IME (The Military Institute of Engineering), Escola de Guerra Naval - EGN (The Naval Warfare School), Escola de Comando e Estado-Maior do Exército - ECEME (Army High Command School), and Centro Brasileiro de Pesquisas Físicas - CBPF (the Brazilian Center for Research in Physics).

The symposium features 15 state-of-the-art invited lectures, 2 sessions in memory of George Dantzig and Leonid Khachyian, respectively, and 774 contributed talks of which about 70% were organized by the participants themselves.

We are indebted to those who suggested and decisively supported the idea of having ISMP2006 held in Rio de Janeiro. We also acknowledge the volunteer work of many others in organizing it and the generous financial backing provided by our sponsors.

There is something refreshingly new about ISMP2006. It is the very first time an ISMP is held outside Europe, Japan or the United States. It is also the first time it is held in a developing country. For a number of years, Brazilian research in Mathematical Programming has been steadily increasing in volume and quality. We thus believe that the future of our field of research is bright in Brazil and expect, as an outcome of ISMP2006, that collaboration between Brazilian mathematical programmers and their counterparts from abroad be substantially enhanced. Under a broader view, if that indeed happens, the physical frontiers of Mathematical Programming will keep expanding and are likely to reach, in the near future, other countries with the potential to further contribute to our field.

We wish you a very pleasant and stimulating ISMP2006.

Abilio Lucena - Federal University of Rio de Janeiro

Nelson Maculan - Federal University of Rio de Janeiro

Celso Ribeiro - Fluminense Federal University

Committees

Program Committee

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Roberto Cominetti – Universidad de Chile (Chile)
William Cook – Georgia Tech (USA)
Masakazu Kojima – Tokyo Tech (Japan)
Abílio Lucena – UFRJ (Brazil)
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Adilson Elias Xavier - UFRJ

The local committee thanks David Pisinger (University of Copenhagen) for kindly providing a formatting system that helped in the edition of this book.

Overview of Events

Registration

Sunday, July 30, from 12h to 17h, at the Main Entrance of the Palácio Universitário, Federal University of Rio de Janeiro - UFRJ Av. Pasteur, 250 - Urca. The registration desk will also be open on Monday, July 31, from 7h to 16h and the remaining days from 7h30 to 16h30.

Opening Ceremony

Sunday, July 30, from 19h30 to 22h30, at Teatro Municipal, Praça Marechal Floriano, s/n - Centro. Welcome addresses, awarding of prizes, Brazilian music concert by Arthur Moreira Lima and Época de Ouro, and reception. See full program on page 7.

A shuttle service to Teatro Municipal will be available for those who are staying at the conference hotels. Information about departure times will be available at the registration desk.

Plenary and Semi-plenary Sessions

See program on page 8.

Parallel Sessions

See program on page 15.

Conference Dinner

Wednesday, August 2, 21h, at Porcão Rio's, Av. Infante Dom Henrique s/n - Aterro do Flamengo.

Mathematical Programming Society Business Meeting

Thursday, August 3st, 19h, at ECEME Auditorium, Praça General Tibúrcio, 125 - Urca.

A shuttle service to the restaurant will be offered for those who are staying at the conference hotels. Information about departure times will be available at the registration desk.

Social Program

Spouses / accompanying persons are offered a number of activities during the symposium. Detailed information and reservations are available on the official tour operator website http://www.blumar.com.br/ismp2006 or at Blumar's counter at the conference venue. Also, some informal activities for participants — such as a football (soccer) tournament — have been arranged. For more information, please contact the registration desk.

Overview of Program

July 30 (Sunday) - Opening Ceremony

19:30 - 21:00	Opening Session, Teatro Municipal
21:00 - 22:00	Reception, Teatro Municipal

July 31 (Monday) - Sessions

08:00 - 09:30	Plenary Session - Dantzig Memorial Session: John Birge, Ellis Johnson, and Yinyu Ye (ECEME)
09:30 - 10:15	Coffee Break
10:15 - 11:45	Parallel Sessions (UFRJ)
11:45 - 13:30	Lunch
13:30 - 14:30	Semi-plenary sessions: Vijay Vazirani (ECEME), José Mario Martínez (EGN), and Josef Hofbauer (IME)
14:30 - 15:00	Break
15:00 - 16:30	Parallel Sessions (UFRJ)
16:30 - 17:00	Coffee Break
17:00 - 18:30	Parallel Sessions (UFRJ)

August 1 (Tuesday) - Sessions

08:30 - 09:30	Plenary Session: Karl Kunisch (ECEME)
09:30 - 10:15	Coffee Break
10:15 - 11:45	Parallel Sessions (UFRJ)
11:45 - 13:30	Lunch
13:30 - 14:30	Semi-plenary sessions: Daniel Bienstock (ECEME), Yurii Nesterov (EGN), and R. Ravi (IME)
14:30 - 15:00	Break
15:00 - 16:30	Parallel Sessions (UFRJ)
16:30 - 17:00	Coffee Break
17:00 - 18:30	Parallel Sessions (UFRJ)

August 2 (Wednesday) - Sessions

08:30 - 09:30	Plenary Session: Gerard Cornuejols (ECEME)
09:30 - 10:15	Coffee Break
10:15 - 11:45	Parallel Sessions (UFRJ)
11:45 - 13:30	Lunch
13:30 - 14:30	Semi-plenary sessions: Khachiyan Memorial Session: Martin Groetschel, Michael Todd, and Tom Liebling (ECEME), Satoru Iwata (EGN), and Toh Kim-Chuan (IME)
14:30 - 15:00	Break
15:00 - 16:30	Parallel Sessions (UFRJ)
16:30 - 17:00	Coffee Break
17:00 - 18:30	Parallel Sessions (UFRJ)

August 3 (Thursday) - Sessions

08:30 - 09:30	Plenary Session: Arkadi Nemirovski (EGN)
09:30 - 10:15	Coffee Break
10:15 - 11:45	Parallel Sessions (UFRJ)
11:45 - 13:30	Lunch
13:30 - 14:30	Semi-plenary sessions: Robert Vanderbei (ECEME), Jean Lasserre (EGN), and Maria Chudnovsky (IME)
14:30 - 15:00	Break
15:00 - 16:30	Parallel Sessions (UFRJ)
16:30 - 17:00	Coffee Break
17:00 - 18:30	Parallel Sessions (UFRJ)

August 4 (Friday) - Sessions

08:30 - 09:30	Plenary Session: Alexander Shapiro (EGN)
09:30 -10:15	Coffee Break
10:15 - 11:45	Parallel Sessions (UFRJ)

Addresses:

ECEME - Escola de Comando e Estado Maior do Exército, Praça General Tibúrcio, 125 - Urca.

EGN - Escola de Guerra Naval, Av. Pasteur, 480 - Urca.

IME - Instituto Militar de Engenharia, Praça General Tibúrcio, 80 - Urca.

UFRJ - Universidade Federal do Rio de Janeiro, Av. Pasteur, 250 - Urca.

Participants should dress accordingly for plenary and semi-plenary sessions. Shorts, sandals and sleeveless shirts are strictly forbidden in the military auditoriums (ECEME, EGN and IME). Entrance will be denied to those who do not abide by this rule.

Opening Session

The Opening Ceremony of the 19th International Symposium on Mathematical Programming will take place at Teatro Municipal, Rio de Janeiro, on July 30, 2006 at 19h30. Five academic prizes will be awarded by the Mathematical Programming Society, namely:

- Tucker Prize — for an outstanding paper by a student — delivered by Thomas McCormick;
- Beale-Orchard-Hays Prize — for excellence in computational mathematical programming — delivered by Stephen Wright;
- Fulkerson Prize — for outstanding papers in discrete mathematics — delivered by Michel Goemans;
- Lagrange Prize — for outstanding works in the area of continuous optimization — delivered by Michael Todd;
- Dantzig Prize — for original research having a major impact on mathematical programming — delivered by Robert Bixby.

A Brazilian music concert featuring the renowned pianist Arthur Moreira Lima and Época de Ouro group and a reception will follow.

Concert Program

Época de Ouro

1. Picadinho à Baiana - Luperce Miranda 2. Ingênuo - Pixinguinha/Benedito Lacerda 3. Carinhoso - Pixinguinha 4. Minha Crença - Horondino Silva/Deo Loro 5. Desvairada - Garoto 6. Benzinho - Jacob do Bandolim 7. Santa Morena - Jacob do Bandolim 8. Treme Treme - Jacob do Bandolim

Arthur Moreira Lima

1. Polonaise em lá bemol maior - Chopin 2. Asa Branca - Luiz Gonzaga 3. Adiós Nonino - Astor Piazzolla 4. Tico Tico no Fubá - Zequinha de Abreu 5. Duas Peças de Radamés Gnatalli 6. Aquarela do Brasil - Tom Jobim 7. Grande Fantasia sobre o Hino Nacional Brasileiro - L.M. Gottschalk

Plenary and Semi-Plenary Sessions

Monday, 8:00 – 9:30, ECEME Auditorium (Plenary)

Dantzig Memorial Session

JOHN BIRGE, ELLIS JOHNSON, AND YINYU YE
University of Chicago, Georgia Institute of Technology and Stanford University

Part I: George Dantzig's legacy in economics, finance, and other fields

In addition to creating the basis for mathematical programming and much of operations research, George Dantzig's work has had a significant influence on many fields, particularly economics and finance. In this talk, I will describe some of his most important contributions from the concept of an objective function to characterizations of utility, asset prices, and equilibrium.

Part II: George Dantzig and the Traveling Salesman Problem

One of the seminal papers in linear programming methods for solving integer programming problems was the paper by Dantzig, Fulkerson, and Johnson on the traveling salesman problem. Despite its seemingly narrow focus, it pointed the way to several approaches to combinatorial optimization, integer programming problems, and in general the use of linear programs as a tool for solving those problems. We give some historical perspective, details of what was in the paper, and how those methods opened up rich areas of research including: solving the traveling salesman problem; combinatorial optimization more generally; separation methods for cut generation in integer programming; and combining linear programming and enumeration.

Part III: Recent applications of linear programming

Linear programming (LP) today becomes a more and more important and popular mathematical model/tool in every day and every one's decision making. Businesses, large and small, now use LP to control manufacture inventories, price commodities, design civil/communication networks, and plan investments. LP even becomes a popular subject taught in under/graduate and MBA curriculums, advancing human knowledge and promoting science education. We present a few application cases arisen from exchange market pricing and digital auction mechanism designing. LP today is proven to be an extremely effective theory-finding machine as well. We present a few such examples in coding theory and approximation algorithms for discrete optimization. We also present a few photos of George Dantzig in his 90th birthday celebration, so that his final smiling, together with LP, would live with us forever.

Monday, 13:30 – 14:30, ECEME Auditorium (Semi-plenary)

New market models and algorithms

VIJAY VAZIRANI
Georgia Institute of Technology

The notion of a "market" has undergone a paradigm shift with the Internet – totally new and highly successful markets have been defined and launched by companies such as Google, Yahoo!, Amazon, MSN and Ebay. Another major change is the availability of massive computational power for running these markets in a centralized or distributed manner.

In view of these new realities, the study of market equilibria, an important, though essentially non-algorithmic, theory within Mathematical Economics, needs to be revived and rejuvenated with new models, ideas, and an inherently algorithmic approach.

In this talk, I will give a feel for the exciting work going on on this front and present new results on resource allocation markets. Interestingly enough, this work has also contributed handsomely to the theory of algorithms itself. In particular, the highly successful primal-dual schema from exact and approximation algorithms, which was so far used for combinatorially solving special classes of linear programs, has been extended to solving nonlinear convex programs.

Monday, 13:30 – 14:30, EGN Auditorium (Semi-plenary)

Smooth optimization tools for structure alignments

JOSÉ MARIO MARTÍNEZ
Universidade Estadual de Campinas - UNICAMP

Structural Alignments are used for fold identification of proteins, structural screening on ligand databases, pharmacophore identification and other applications. In the general case, the optimization problem of superimposing two structures is nonsmooth and nonconvex, so that most popular methods do not employ derivative information. However, it will be shown that the optimization of the superposition of two structures may be addressed using continuous smooth minimization. Using a Low Order-Value Optimization approach, the nonsmoothness may be essentially ignored and classical optimization algorithms may be used. Within this context, a Gauss-Newton method is introduced for structural alignments incorporating (or not) transformations (as flexibility) on the structures. Convergence theorems are provided and practical aspects of implementation are described. Numerical experiments suggest that the Gauss-Newton methodology is competitive with state-of-the-art algorithms for protein alignment both in terms of quality and speed. Additional experiments on binding site identification, ligand and cofactor alignments illustrate the generality of this approach.

Monday, 13:30 – 14:30, IME Auditorium (Semi-plenary)

Evolutionary Game Dynamics

JOSEF HOFBAUER
University College London

Evolutionary game dynamics is at the interface of dynamical systems and game theory. The state space of such a dynamic is the mixed strategy simplex of the underlying game. It describes how the strategy distribution in a large population of players changes over time, due to selection, imitiation or some other kind of adaptation. The Nash equilibria are rest points of the dynamics. Additional conditions such as evolutionary stability often imply asymptotic stability under such dynamics. The classical examples are the replicator dynamics and the best response dynamics but recently several other "canonical" evolutionary dynamics have been found. A survey of old and recent results together with open problems will be given.

Tuesday, 8:30 – 9:30, ECEME Auditorium (Plenary)

Semi-Smooth Newton Methods in Function Spaces with Applications to Optimal Control, Mathematical Imaging and Free Boundary Value Problems

KARL KUNISCH
University of Graz

Our interest here focuses on large scale optimization problems arising in the context of partial differential equations. Problems of practical importance typically require to consider point-wise inequality constraints

or non-differentiable cost-functionals. Thus the conditions for local second order convergence of Newton methods cannot be met.

To provide a frame work for the analysis and efficient numerical treatment of such problems the concept of Newton differentiability is introduced. It implies local super-linear convergence of the Newton method, which is referred to as semi-smooth Newton method in this context. The max-function, for example, is Newton differentiable. For certain classes of problems, the semi-smooth Newton algorithm is equivalent to the primal dual active set strategy, which proved to be extremely effective for optimal control problems with constraints.

The degree of difficulty for the numerical treatment of non-differentiable problems in functions spaces can differ significantly from one class of problems to the other. It is best quantified by the regularity of the associated Lagrange multiplier. In important cases, for example in image reconstruction involving a bounded variation reconstruction term, this multiplier is only a measure. In such cases a regularization procedure is suggested. The choice of the regularization parameter is based on a path following procedure. Differently from interior point path following algorithms it involves a model function, which describes geometric properties of the path, for tuning the path parameter.

For practical realizations appropriate use of discretization is necessary. Mesh-independence and nested iterations will be discussed.

Tuesday, 13:30 – 14:30, ECEME Auditorium (Semi-Plenary)

Experiments with robust optimization

DANIEL BIENSTOCK
Columbia University
Coauthor: Nuri Ozbay

Robust Optimization is an approach to managing optimization in the presence of data uncertainty, and is typically offered as a counterpoint to Stochastic Programming, which requires known and precise information on stochastic distributions of data. In principle, the basic machinery of Robust Optimization can be extended to any form of data uncertainty, no matter what its magnitude is, or what its "geometry" might be.

The Robust Optimization framework can prove too conservative, or not conservative enough, and, in particular, has been criticized for assigning the same "weight", or importance, to all possible realizations of data in the uncertainty set. Part of this difficulty stems from the fact that the typical uncertainty sets that have been examined in the literature are "well behaved", whereas in several practical settings data can misbehave in "malformed" or "lumpy" ways.

In this talk we will present computational tests highlighting two ideas: (1) the use of Benders' decomposition (or, more generally, cutting plane algorithms) and (2) the superposition of uncertainty models. Our algorithms prove efficient in a variety of problem settings.

Tuesday, 13:30 – 14:30, EGN Auditorium (Semi-Plenary)

Global acceleration of the Newton's method

YURII NESTEROV
Université Catholique de Louvain - CORE

In this talk we propose an accelerated version of cubic regularization of Newton's method. The original version, used for minimizing a convex function with Lipschitz-continuous Hessian, guarantees a global rate of convergence of order $O(\frac{1}{k^2})$, where k is the iteration counter. Our modified version converges for the same problem class with order $O(\frac{1}{k^3})$, keeping the complexity of each iteration unchanged. We study the complexity of both schemes on different classes of convex problems. In particular, we argue that for the second-order schemes, the class of non-degenerate problems is different from the standard class.

Tuesday, 13:30 – 14:30, IME Auditorium (Semi-Plenary)

Approximation algorithms for stochastic combinatorial optimization

R. RAVI
Carnegie Mellon University
Coauthors: Anupam Gupta, Martin Pal and Amitabh Sinha

Two-stage stochastic programming with recourse is an attempt to model data uncertainty. Data for the current time (e.g. current costs, demands) are known, whereas the uncertain future is characterized by a given probability distribution. After a set of decisions are made in a first stage, the actual future is revealed (according to the probability distribution). The first-stage solution can then be augmented in a second recourse stage to obtain a feasible solution for the realized scenario. The goal is to minimize the sum of first-stage costs plus the expected costs in the second stage.

We consider several classical combinatorial optimization problems in this framework, and provide tight (up to small constants) approximation algorithms for them. In the talk, we will focus on a canonical problem in network design (Steiner trees). We consider different ways to model future uncertainty and present approximation algorithms based on boosted sampling and rounding an LP relaxation.

Wednesday, 08:30 – 09:30, ECEME Auditorium (Semi-plenary)

Valid inequalities for mixed integer linear programs

GERARD CORNUEJOLS
Carnegie Mellon University

This tutorial presents a theory of valid inequalities for mixed integer linear sets. It introduces the necessary tools from polyhedral theory and gives a geometric understanding of several classical families of valid inequalities such as lift-and-project cuts, Gomory mixed integer cuts, mixed integer rounding cuts, split cuts and intersection cuts, and it reveals the relationships between these families. The tutorial also discusses computational aspects of generating the cuts and their strength.

Wednesday, 13:30 – 14:30, ECEME Auditorium (Semi-plenary)

Khachiyan Memorial Session:

MARTIN GROETSCHEL, MICHAEL TODD, AND TOM LIEBLING
Zuse Institute Berlin, Cornell University, EPFL

Part I: Leonid Khachiyan and the polynomial-time solvability of linear programming

In 1979 the world of mathematical programming experienced a sensation. In a two-page paper Leonid Khachiyan, a young Russian mathematician, proved that linear programs can be solved in polynomial time. This was not demonstrated by a polynomial time version of the simplex method - as many expected. The surprise was that the ellipsoid method, developed for nonlinear nondifferentiable optimization by Shor, Yudin, and Nemirovkii, could be adapted to solve linear programs in polynomial time. Khachiyan's modification consisted of a few simple, but in their combination very ingenious steps. His correctness proof was based on volume shrinking, something unheard of before in linear programming. The algorithm turned out to be a failure in practice but of great impact in complexity theory, in particular, for combinatorial optimization, convexity, and many geometrical problems. This lecture will describe Khachiyan's contribution to linear programming and some of its consequences for integer programming.

Part II: Leonid Khachiyan's contributions to mathematical programming beyond LP $\in$ P

Leo Khachiyan made a number of significant contributions to mathematical programming beyond his seminal result showing that LP $\in$ P. These include work on the complexity of convex quadratic and general convex programming; on convex polynomial programming; on rounding of polytopes; on matrix scaling; on fast approximation algorithms; and on several areas of logic and combinatorics. In this talk I will highlight some of Khachiyan's research in these areas.

Part III: Why commemorate Khachiyan?

Last year, when Leo Khachiyan passed away in his prime, just a few days before George Dantzig, he again took us entirely by surprise, albeit with such a sad event. Unlike the first time in 1979, when as a wholly unknown mathematician in his twenties, he had used Shor´s ellipsoid method to show that linear programming was easy after all. Of course, without George Dantzig´s puzzlingly efficient simplex method, the impact of young Khachiyan´s contribution wouldn´t have been all that meteoric. At the latest since Klee and Minty, who in 1972 had dared ask, "How good is the simplex method?" deciding whether a polynomial variant of it exists has been dubbed one of the foremost open problems in applied mathematics. Khachiyan gave us hope that the answer might be positive and enkindled quite some research activity, however, to date the issue still remains open. With the ellipsoid method, Khachiyan quite consciously proposed an algorithm of limited practical utility; nevertheless it was one of the very few contributions in our field to make it to the front page of the New York Times. For sure, such coverage was well deserved, but not for the outlandish reasons mentioned by the journalists. Instead, his work had a twofold lasting impact. For one, it turned out to be an extremely powerful tool for analyzing and settling the complexity status of many combinatorial optimization problems. On the other hand, it opened the door to non-linear optimization approaches to linear programming, which very soon gave rise to the now well-known interior point methods. This, among other things, is why Khachiyan deserves our lasting recognition and the purpose of this memorial session is to remind us of that.

Wednesday, 13:30 – 14:30, EGN Auditorium (Semi-plenary)

Submodular function minimization

SATORU IWATA
University of Tokyo

A set function f defined on the subsets of a finite set V is said to be submodular if it satisfies

$$f(X)+f(Y) \geq f(X \cup Y)+f(X \cap Y), \qquad \forall X, Y \subseteq V.$$

Submodular functions are discrete analogues of convex functions. They arise in various branches of applied mathematics such as game theory, information theory, and queueing theory. Examples include the matroid rank functions, the cut capacity functions, and the entropy functions.

The importance of submodular functions in the context of combinatorial optimization was established by J. Edmonds. Most efficiently solvable combinatorial optimization problems such as the minimum spanning tree and maximum flow problems are related to submodular functions in various ways.

The first polynomial-time algorithm for minimizing submodular functions, due to Grötschel, Lovász, and Schrijver, relies on the ellipsoid method, which is not efficient in practice. Recently, combinatorial strongly polynomial algorithms have been developed independently by Schrijver and by Iwata, Fleischer and Fujishige. Although theoretical running time bounds of these algorithms are not very attractive, one may expect to obtain more efficient algorithms for special cases that arise in applications.

In this talk, we review algorithms and applications of submodular function minimization. In particular, we mention recent works that develop new efficient algorithms for minimizing special classes of submodular functions that arise in applications in statistical physics and in queueing theory.

Wednesday, 13:30 – 14:30, IME Auditorium (Semi-plenary)

Inexact primal-dual path following algorithms for convex quadratic SDP

TOH KIM CHUAN
National University of Singapore

We propose primal-dual path-following Mehrotra-type predictor-corrector methods for solving convex quadratic semidefinite programming (QSDP) problems of the form: $\min_X\{\frac{1}{2}X \bullet Q(X) + C \bullet X : \mathcal{A}(X) = b, X \succeq 0\}$, where Q is a self-adjoint positive semidefinite linear operator on $\mathcal{S}^n$, $b \in R^m$, and $\mathcal{A}$ is a linear map from $\mathcal{S}^n$ to R^m. At each interior-point iteration, the search direction is computed from a dense symmetric indefinite linear system (called the augmented equation) with dimension $m + n(n+1)/2$. Such linear systems are very large when n is larger than a few hundreds and can only be solved by iterative methods. We propose three classes of preconditioners for the augmented equation, and show that the corresponding preconditioned matrices have favorable asymptotic eigenvalue distributions for fast convergence under suitable nondegeneracy assumptions. We are able to solve the augmented equation efficiently via the preconditioned symmetric quasi-minimal residual iterative method with the preconditioners constructed. Numerical experiments on a variety of QSDPs with matrices of dimensions up to 1600 are performed and the computational results show that our methods are efficient and robust.

Thursday, 08:30 – 09:30, EGN Auditorium (Plenary)

Selected topics in robust optimization

ARKADI NEMIROVSKI
Technion - Israel Institute of Technology

Robust Optimization is a rapidly developing methodology for handling optimization problems affected by non-stochastic "uncertain-but-bounded" data perturbations. In the talk, we overview several selected topics in this popular area, specifically, (1) recent extensions of the basic concept of robust counterpart of an optimization problem with uncertain data, (2) tractability of robust counterparts, (3) links between RO and traditional chance constrained settings of problems with stochastic data, and (4) a novel generic application of the RO methodology in Robust Linear Control.

Thursday, 13:30 – 14:30, ECEME Auditorium (Semi-plenary)

Extreme optics and the search for Earth-like planets

ROBERT VANDERBEI
Princeton University

I will describe a new and exciting application of optimization technology. The problem is to design a space telescope capable of imaging Earth-like planets around nearby stars. Because of limitations inherent in the wave nature of light, the design problem is one of diffraction control so as to provide the extremely high contrast needed to image a faint planet positioned very close to its much brighter star. I will describe the mathematics behind the diffraction control problem and explain how modern optimization tools were able to provide unexpected solutions that actually changed NASA's approach to this problem.

Thursday, 13:30 – 14:30, EGN Auditorium (Semi-plenary)

Moments, sums of squares and semidefinite programming

JEAN LASSERRE
LAAS-CNRS

We will introduce the generalized problem of moments (GPM) and some of its many potential applications. When data are polynomials, we then show how the GPM can be approximated (and sometimes even solved) efficiently via semidefinite programming relaxations. On the way, we will develop some aspects of the duality between moments and sums of squares (s.o.s.), as well as the relationship between nonnegative and s.o.s. polynomials.

Thursday, 13:30 – 14:30, IME Auditorium (Semi-plenary)

Testing for a theta

MARIA CHUDNOVSKY
Princeton University

Recently a few new results appeared, providing polynomial time algorithms for testing if a given graph contains certain induced subgraphs (such as "pyramids", odd odd cycles and anticycles, and some others). However, some seemingly similar problems (such as testing for the presence of an induced cycle passing through two given vertices, or testing for "prisms") are known to be NP-complete. At the moment it is not clear what causes this difference.

A "theta" is a graph consisting of three vertex disjoint induced paths between two fixed vertices (the "ends"), such that there are no edges between the interiors of different paths. In joint work with Paul Seymour we were able to find a polynomial time algorithm to test if a graph contains a theta. In fact, we prove a stronger result, that provides a necessary and sufficient condition for a graph to contain a theta with a given end. We prove that a graph G does not contain a theta with a given end v, if and only if G has a certain structure; which can be tested for in polynomial time.

Friday, 08:30 – 09:30, EGN Auditorium (Plenary)

Stochastic programming approach to optimization

ALEXANDER SHAPIRO
Georgia Institute of Technology

In this talk we discuss computational complexity and risk averse approaches to two and multistage stochastic programming problems. We argue that two stage (say linear) stochastic programming problems can be solved with a reasonable accuracy by Monte Carlo sampling techniques while there are indications that complexity of multistage programs grows fast with increase of the number of stages. We discuss an extension of coherent risk measures to a multistage setting and, in particular, dynamic programming equations for such problems.

Parallel Sessions: Overview

A parallel session consists of three presentations, and has a duration of 90 minutes. In total 13 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: 10:15 – 11:45

2: 15:00 – 16:30

3: 17:00 – 18:30

On each day from Monday to Thursday there are three blocks of parallel sessions, and on Friday one block of parallel sessions. The blocks are coded according to their weekday and time: MO1, MO2, MO3, TU1, TU2, etc. Up to 21 parallel sessions are taking place simultaneously in each time block. The ISMP2006 clusters were divided into three distinct groups for the purpose of room assignment:

Group I – Rooms 1 to 9

- Airline Optimization
- Combinatorial Optimization
- Constraint Logic Programming
- Finance and Economics
- Game Theory
- Global Optimization
- Integer and Mixed Integer Programming
- Leonid Khachiyan Memorial
- Logistics and Transportation
- Networks
- Optimization in Energy Systems
- Optimization in Natural Resources
- Telecommunications and Network Design

Group II – Rooms 10 to 17

- Bioinformatics and Optimization
- Complementary and Variational Inequalities
- Generalized Convexity / Monotonicity
- Infinite Dimensional Programming and Optimal Control
- Linear, Cone and Semidefinite Progamming
- Multicriteria Optimization
- Nonlinear Programming
- Nonsmooth Optimization and Convex Programming
- Optimization Software and Modelling Systems

- Robust Optimization
- Semi-Infinite Programming
- Stochastic Programming

Group III – Rooms 18 to 21

- Approximation Algorithms
- Dynamic Programming
- Graphs and Matroids
- On-Line Optimization
- Production and Scheduling
- Tucker Prize Finalists

The location of the rooms in each group is given on the map in the end of this book. All rooms are provided with the following equipment: 1. overhead projector 2. beamer 3. computer (software installed: Power Point, Acrobat Reader and Open Office).

Room Page	Parallel Sessions: Monday 10:15 – 11:45 (MO1)		
R1 p.30	**Heuristics I**, *chair*: Dárlinton Carvalho DÁRLINTON CARVALHO, Towards a framework for heuristics based on vocabulary building	ANDRE CORDENONSI, Learning objects to heuristics teaching process	COMBINATORIAL OPTIMIZATION
R2 p.30	**Combinatorial optimization II**, *organizer/chair*: Marcia Fampa EDUARDO UCHOA, Experiments with extended capacity cuts	HONGXIA ZHAO, Branch-and-cut for robust single-machine scheduling	COMBINATORIAL OPTIMIZATION KURT ANSTREICHER, An improved algorithm for computing Steiner minimal trees in Euclidean d-space
R3 p.31	**Metaheuristics for real world applications**, *organizer*: Claudio Meneses, *chair*: Claudio Barbieri GLAYDSTON RIBEIRO, A GRASP based on conflict graph for the point-feature cartographic label placement problem	CLAUDIO CUNHA, A tabu search heuristic for the truck-load pickup and delivery problem	COMBINATORIAL OPTIMIZATION FABÍOLA NAKAMURA, A hybrid metaheuristc for the permutational flow shop problem
R4 p.31	**Optimization and geometry**, *organizer/chair*: Volker Kaibel YAEL BERSTEIN, Nonlinear bipartite matching	MARC PFETSCH, Optimizing discrete Morse functions	COMBINATORIAL OPTIMIZATION
R5 p.32	**Risk management in electricity, oil and gas market**, *organizer*: Luiz A. Barroso, *chair*: Sergio Granville NIKO ILIADIS, CVaR formulation in dynamic programming for hydroelectric portfolio risk management	LUIZ GUILHERME MARZANO, Modeling the conditional value-at-risk into the portfolio optimization of energy contracts problem for generators dispatched in a tight pool scheme	OPTIMIZATION IN ENERGY SYSTEMS GERALDO VEIGA, Short-term production planning in oil refineries: two mixed integer programming models
R6 p.32	**Mining 1**, *organizer/chair*: Alexandra Newman DOREEN THOMAS, Modelling and software design for optimal declines in underground mine development	PETER GROSSMAN, Constrained path optimisation with applications to underground mine development	OPTIMIZATION IN NATURAL RESOURCES RAFAEL EPSTEIN, Combinatorial problems in mining
R7 p.33	**Emerging network design problems**, *organizer/chair*: Gianpaolo Oriolo MARIA GRAZIA SCUTELLÁ, Hardness of robust network design	SARA MATTIA, Using mixed-integer programming to solve power grid blackout problems	TELECOMMUNICATIONS AND NETWORK DESIGN. GUIDO SCHAEFER, Simple cost sharing schemes for multicommodity rent-or-buy and stochastic Steiner tree
R8 p.33	**Voting games**, *organizer*: Dennis Leech, *chair*: Karol Zyczkowski ANTTI PAJALA, Voting games with abstentions	KAROL ZYCZKOWSKI, Critical point in voting games	GAME THEORY
R9 p.34	**Global optimization for mathematical problems**, *chair*: Tibor Csendes BALÁZS BÁNHELYI, A verified optimization technique to calculate topological entropy	TIBOR CSENDES, Global optimization and verified numerical techniques for the solution of mathematical problems	GLOBAL OPTIMIZATION PÉTER GÁBOR SZABÓ, Grid circle packings - a global optimization approach
R10 p.34	**Sensitivity analysis in multiobjective programming**, *organizer/chair*: Alejandro Balbás MERCEDES ESTEBAN-BRAVO, Generalized stochastic discount factors with applications in marketing	SILVIA MAYORAL, Balance points and duality with applications in risk analysis	MULTICRITERIA OPTIMIZATION ALEJANDRO BALBÁS, Duality and sensitivity for balance points of set valued functions
R11 p.35	**Approximately solving large scale linear programs**, *organizer/chair*: Fabian Chudak NAVEEN GARG, Fractional packing and covering	KIYOHITO NAGANO, Approximation algorithms for facility locations with submodular penalties and generalized set covering problems	LINEAR, CONE AND SEMIDEFINITE PROGRAMMING FABIAN CHUDAK, A survey of recent results on approximate algorithms for solving linear programs
R12 p.35	**Applications of LP and cone programming I**, *chair*: Hakan Umit ELENA PACHKOVA, Modeling deposits in the banking sector usig directional distance functions	HAKAN UMIT, IGP weight optimization using column generation	LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
R13 p.36	**Derivative-free optimization**, *organizer/chair*: Katya Scheinberg ANDREW CONN, Some new results in derivative free optimization	ANA CUSTODIO, Improving efficiency in pattern search methods	NONLINEAR PROGRAMMING KATYA SCHEINBERG, Study of convergence of Wedge derivative free algorithm.
R14 p.36	**Nonsmooth optimization with structure**, *organizer/chair*: Warren Hare SANGWOON YUN, A coordinate gradient descent method for nonsmooth separable minimization	ROBERT MIFFLIN, A rapidly convergent VU-algorithm for general conv	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING WARREN HARE, Identifying smooth substructure via proximal points
R15 p.37	**Convexity and monotonicity**, *chair*: Wilfredo Sosa GIOVANNI CRESPI, Strong well-posedness properties of vector quasiconvex optimization problems	PAULO OLIVEIRA, Proximal methods applied to quasi-convex programming	GENERALIZED CONVEXITY/MONOTONICITY WILFREDO SOSA, Coerciveness for equilibrium problems
R16 p.37	**Stability and sensitivity analysis**, *organizer*: Mikhail Solodov, *chair*: Muddappa Gowda MUDDAPPA GOWDA, Z-transformations on proper and symmetric cones	JAN HEERDA, Characterizing Lipschitz stability in terms of explicit limits	COMPLEMENTARY AND VARIATIONAL INEQUALITIES RUBEN MONTOYA, Sensitivity analysis for complementarity problems
R17 p.38	**Structural analysis of GSIP**, *organizer/chair*: Oliver Stein HARALD GUENZEL, On the feasible set in generalized semi-infinite programming		SEMI-INFINITE PROGRAMMING
R18 p.38	**Constraint Satisfaction and Clustering**, *organizer*: Celina Figueiredo, *chair*: Sulamita Klein ANDREI KROKHIN, Supermodular optimization on lattices and maximum constraint satisfaction	NATHALIE FAURE, New p-median formulation of multicast sessions aggregation problem	GRAPHS AND MATROIDS
R19 p.38	**Tucker Prize Committee**, *organizer/chair*: Tom McCormick		TUCKER PRIZE
R20 p.38	**Real-world problems**, *chair*: Emily Duane LUIS MIGUEL TORRES CARVAJAL, Column generation helping the Ecuadorian flower export industry	RENATA FERRARI, The use of a MIP model to identify investments in soybean storage units in the state of Mato Grosso, Brazil	PRODUCTION AND SCHEDULING EMILY DUANE, Improving crane scheduling and container handling operations at seaport container terminals
R21 p.39	**Advances in dynamic programming methodology**, *organizer/chair*: Marina Epelman JÖRG RAMBAU, LP-based local approximation for Markov decision problems	MARINA EPELMAN, Sampled fictitious play algorithms for large-scale DPs and MDPs	DYNAMIC PROGRAMMING

Parallel Sessions: Monday 15:00 – 16:30 (MO2)

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R2 p.40	**Combinat. Opt. in VLSI design I: paths and flows**, *organizer/chair*: Jens Vygen		COMBINATORIAL OPTIMIZATION
	ULRICH BRENNER, A new transportation algorithm with applications to VLSI placement	DIRK MUELLER, Optimizing yield and power in global routing	SVEN PEYER, Generalizing Dijkstra's algorithm to speed up path searches in huge grids
R3 p.40	**Topics on neighborhood search**, *organizer*: Gerhard Reinelt, *chair*: James Orlin		COMBINATORIAL OPTIMIZATION
	OZLEM ERGUN, Solving the maximum flow network interdiction problem with local search	JAMES ORLIN, Using grammars to generate very large scale neighborhoods for sequencing problems	LUCIANA BURIOL, Travel-time minimization in transportation networks by near-optimal tollbooth placement
R4 p.40	**Branch and cut and price**, *organizer*: Adam Letchford, *chair*: Marcus Poggi de Aragão		COMBINATORIAL OPTIMIZATION
	MARCUS POGGI DE ARAGÃO, Trends in robust (and non-robust) branch-cut-and-price	THIAGO NORONHA, A branch-and-cut algorithm for the Chilean soccer championship	ALEXANDRE CUNHA, A hybrid relax-and-cut / branch-and-cut algorithm for the degree constrained minimum spanning tree problem
R5 p.41	**Supply function and dispatch models in electricity**, *organizer/chair*: Andy Philpott		OPTIMIZATION IN ENERGY SYSTEMS
	PAUL STEWART, A Markov DP supply offer construction model for electricity generators with intertemporal constraints	ANIBAL AZEVEDO, Interior point methods for large scale dc optimal power flow	ADRIANO THOMAZ, Primal-dual interior point method applied to AC optimal active-reactive power flow problem
R6 p.42	**Mining 2**, *organizer/chair*: Alexandra Newman		OPTIMIZATION IN NATURAL RESOURCES
	ALEXANDRA NEWMAN, Optimization in the mining industry	VICTOR PARADA, Programming operations in a copper refining and casting process	
R7 p.42	**Real-world routing**, *organizer/chair*: Andreas Bley		TELECOMMUNICATIONS AND NETWORK DESIGN.
	HEIKO SCHILLING, Length-bounded cuts and flows	VAHAB MIRROKNI, Convergence and approximation in selfish routing.	ANDREAS BLEY, Unsplittable shortest path routing: complexity and algorithms
R8 p.43	**Computation of equilibria**, *organizer/chair*: Yinyu Ye		GAME THEORY
	XIAOTIE DENG, On algorithmic complexity issues in cooperative and non-cooperative game theoretical solution concepts	KAMAL JAIN, New market models and algorithms	BRUNO CODENOTTI, Leontief economies encode nonzero sum bimatrix games
R9 p.43	**Global optimization methods**, *chair*: Tibor Csendes		GLOBAL OPTIMIZATION
	HIME JUNIOR, Fuzzy control of stochastic global optimization algorithms and very fast simulated reannealing	RÚBIA OLIVEIRA, Global optimization algorithms for convex multiplicative programming	ISMAEL VAZ, A particle swarm pattern search method for bound constrained nonlinear optimization
R10 p.44	**Applications of MCDM**, *chair*: Mischel Belderrain		MULTICRITERIA OPTIMIZATION
	MISCHEL BELDERRAIN, Multiattribute utility theory applied to petrochemical company problem	SERGIO SILVA, Multicriteria scheduler for low performance wireless network	DIANA ROMAN, Portfolio Construction Based on stochastic Dominan
R11 p.44	**Applications of LP and cone programming II**, *chair*: Renata Sotirov		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	RENATA SOTIROV, Constructive rational approximation using semidefinite programming	MONAEL PINHEIRO RIBEIRO, Mathematical modeling for a defensive game for ROBOCUP F-180 small-size league	
R12 p.44	**Computational issues in LP and SDP II**, *chair*: Aurelio Oliveira		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	ANA PAULA TEIXEIRA, Hybrid approaches to calculate the step-lengths in a predictor-corrector method variant for semidefinite programming	FERNANDO VILLAS-BÔAS, Dynamic optimization of parameters for interior-point linear programming methods	AURELIO OLIVEIRA, A hybrid preconditioner approach for solving large-scale linear systems arising from interior point methods
R13 p.45	**Nonlinear and mixed-integer optimization**, *organizer/chair*: Christodoulos Floudas		NONLINEAR PROGRAMMING
	PANOS PARDALOS, Nonlinear integer optimization and data mining	NUNO FAISCA, A multi-parametric programming approach for constrained multi-stage optimization problems	CHRISTODOULOS FLOUDAS, Novel classes of tight convex underestimators for general nonconvex problems
R14 p.46	**Non-deterministic/novel methods in convex problems**, *organizer*: Robert Freund, *chair*: Alexandre Belloni		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	PABLO PARRILO, Numerical implementation and evaluation of SOS decompositions	ALEXANDRE BELLONI, Testing the boundedness of a convex set	RAVINDRAN KANNAN, Optimization via matrix and tensor approximations
R15 p.46	**Opt. conditions and sensitivity analysis**, *chair*: Valeriano de Oliveira		INFINITE DIMENSIONAL PROGRAMMING AND OPTIMAL CONTROL
	VALERIANO DE OLIVEIRA, Optimality and duality in infinite programming	J. FREDERIC BONNANS, Second-order optimality conditions and sensitivity analysis for state-constrained optimal control problems	
R16 p.46	**Algorithmic issues related to MPECs**, *organizer*: Mikhail Solodov, *chair*: Clovis Gonzaga		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	CLOVIS GONZAGA, A smoothing method for solving MPEC's	JEAN-PIERRE DUSSAULT, Regularization schemes for MPECs	MIKHAIL SOLODOV, On attraction of Newton-type iterates to multipliers violating second-order sufficiency conditions
R17 p.47	**Numerical aspects of SIP**, *organizer*: Oliver Stein, *chair*: Harald Guenzel		SEMI-INFINITE PROGRAMMING
	MARCO CAMPI, Robust convex optimization: the scenario approach	PANAYIOTIS LEMONIDIS, Global solution of GSIP using interval methods	OLIVER STEIN, The adaptive convexification algorithm: a feasible point method for semi-infinite programming
R18 p.48	**Algorithms for graph optimization**, *organizer/chair*: Santosh Vempala		GRAPHS AND MATROIDS
	ADAM MEYERSON, Traveling salesman with deadlines	OJAS PAREKH, Compacting cuts: a new linear formulation for minimum cut	CLAUDSON BORNSTEIN, Flow metrics
R19 p.48	**Perfect graphs**, *organizer*: Frederic Maffray, *chair*: Celina Figueiredo		GRAPHS AND MATROIDS
	KRISTINA VUSKOVIC, Square-3PC(.,.)-free Berge graphs	BENJAMIN LEVEQUE, Coloring bull-free perfectly contractile graphs	GIACOMO ZAMBELLI, Minimally infeasible set partitioning problems on balanced matrices
R20 p.49	**Constrained lot-sizing and scheduling**, *organizer/chair*: Andrew Miller		PRODUCTION AND SCHEDULING
	MIAO SONG, Robust stochastic lot-sizing using historical data	KAI HUANG, Stochastic lot-sizing problems with random lead time	DIEGO KLABJAN, Lot-sizing with minimum order quantity
R21 p.49	**Approximate dynamic programming**, *organizer/chair*: Daniela Pucci de Farias		DYNAMIC PROGRAMMING
	ADAM MERSEREAU, Relaxations of weakly coupled stochastic dynamic programs	JULIANA NASCIMENTO, An optimal approximate dynamic programming algorithm for concave single asset management	DANIELA PUCCI DE FARIAS, Performance bounds and state relevance selection in the LP approach to approximate DP

Parallel Sessions: Monday 17:00 – 18:30 (MO3)

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R1 p.51	**Trees and TSP**, *organizer*: Luis Gouveia, *chair*: Thomas Magnanti		COMBINATORIAL OPTIMIZATION
	IOANNIS GAMVROS, Network design with reload costs	THOMAS MAGNANTI, On time-dependent formulations for routing problems	ABILIO LUCENA, New formulations for the max-leaf spanning tree problem
R2 p.51	**Combinat. Opt. in VLSI design II: trees and timing**, *organizer/chair*: Jens Vygen		COMBINATORIAL OPTIMIZATION
	DIETER RAUTENBACH, Repeater trees in VLSI design	JENS MASSBERG, Distributing signals by unbalanced trees	STEPHAN HELD, Cycle time optimization in VLSI-design
R3 p.52	**Hybrid metaheuristics**, *organizer/chair*: El-Ghazali Talbi		COMBINATORIAL OPTIMIZATION
	GÜNTHER RAIDL, Combining variable neighborhood search with IP for the generalized minimum spanning tree problem	TIAGO NEVES, Adaptive memory with GRASP for the for the scheduling workover rigs for onshore oil production	TALBI EL-GHAZALI, Towards a classification of hybrid metaheuristics
R4 p.52	**Polyhedral combinatorics I**, *organizer/chair*: Francisco Barahona		COMBINATORIAL OPTIMIZATION
	HERNAN ABELEDO, Polyhedral characterizations of the Clar and Fries problems on plane bipartite graphs	FRANCISCO BARAHONA, Odd cycle inequalities and the p-median polytope of Y-free graphs	MOURAD BAIOU, The p-median polytope of restricted y-graphs
R5 p.53	**Advances in integer programming I**, *organizer/chair*: Andrea Lodi		INTEGER AND MIXED INTEGER PROGRAMMING
	DASH SANJEEB, On the strength of Gomory mixed-integer cuts as group cuts	ZONGHAO GU, Using superadditive functions with GUBs and VUBs to improve Gomory fractional and MIR cuts	ISMAEL DE FARIAS, Branch-and-cut for piecewise linear optimization
R6 p.53	**Gas models**, *chair*: Ronald Farina		OPTIMIZATION IN NATURAL RESOURCES
	RONALD FARINA, Energy, ethanol & ethics: evaluating economic and environmental arguments regarding the pros and cons of biomass ethanol as a sustainable fuel technology	YRIS OLAYA, Optimal expansion of the world liquefied natural gas market	
R7 p.53	**Spanning trees in networks**, *chair*: Andréa Cynthia		TELECOMMUNICATIONS AND NETWORK DESIGN.
	RODRIGO FRANCO TOSO, Algorithms for updating minimum spanning trees in dynamic graphs	CRISTIANE MARIA SANTOS FERREIRA, A GRASP with adaptive memory for the generalized minimum spanning tree problem	ANDRÉA CYNTHIA SANTOS, Heuristics for the diameter constrained minimum spanning tree problem
R8 p.54	**Search, assignment and matching games**, *organizer/chair*: Flip Klijn		GAME THEORY
	GUILLERMO OWEN, Tracking a moving fugitive: a game-theoretic representation of search	CARLES RAFELS, A simple procedure to obtain the extreme core allocations of an assignment market	FLIP KLIJN, Fairness in a student placement mechanism with restrictions on the revelation of preferences
R9 p.55	**Applications of global optimization**, *chair*: Leo Liberti		GLOBAL OPTIMIZATION
	LEO LIBERTI, The discretizable molecular distance geometry problem	JAVIER TREJOS, Partitioning numerical data sets by particle swarm optimization	
R10 p.55	**Theory of vector optimization**, *chair*: Lee Gue Myung		MULTICRITERIA OPTIMIZATION
	GUE MYUNG LEE, Epsilon-optimality conditions for convex infinite vector optimization problem	GRACIELA SOTTOSANTO, On regularity conditions to multiobjective optimization	MOON HEE KIM, On vector matrix game and vector dual problems
R11 p.56	**Computational challenges for large scale SDP**, *organizer/chair*: Makoto Yamashita		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	KARTIK KRISHNAN SIVARAMAKRISHNAN, A conic interior point decomposition approach for semidefinite programming	KAZUHIDE NAKATA, Computational techniques of interior-point methods for ill-conditioned semidefinite programs	MAKOTO YAMASHITA, Large-scale semidefinite programming from quantum chemistry
R12 p.56	**Extensions of SDP**, *chair*: Amir Beck		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	AMIR BECK, Quadratic matrix programming	SANGHO KUM, Penalized complementarity functions on symmetric cones	HECTOR RAMIREZ C , Filter methods for nonlinear semidefinite programming
R13 p.56	**MINLP**, *organizer/chair*: Jeff Linderoth		NONLINEAR PROGRAMMING
	MATTHIAS KOEPPE, Fully polynomial time approximation schemes for mixed-integer polynomial optimization in fixed dimension	SVEN LEYFFER, FilMINT: A new MINLP solver	ALEXANDER MARTIN, Approximation of non-linear functions in mixed integer linear programming
R14 p.57	**Robust optimization under data uncertainty**, *organizer*: Javier Pena, *chair*: Luis Zuluaga		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	FERNANDO ORDONEZ, Network design and routing with demand and travel time uncertainty	JORGE VERA, Robust optimization in supply chain management: application cases	LUIS ZULUAGA, Robust formulations for the CVaR portfolio allocation, and the newsvendor problem
R15 p.58	**Efficient Numerical Methods**, *chair*: Frank Strauss		INFINITE DIMENSIONAL PROGRAMMING AND OPTIMAL CONTROL
	FRANK STRAUSS, High performance computing for eigenvalue constrained shape optimization	LUIZ OLIVEIRA, Application of parallel computing to nonlinear optimal control problems	
R16 p.58	**Advances in monotone variational inequalities**, *organizer*: Paulo Jose da Silva e Silva, *chair*: Jonathan Eckstein		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	JONATHAN ECKSTEIN, General projective splitting for monotone operators	SUSANA SCHEIMBERG, On general variational inequalities	PAULO DA SILVA E SILVA, Exact penalties for KKT systems
R17 p.59	**Extensions of SIP**, *organizer/chair*: Juan Alfredo Gomez		SEMI-INFINITE PROGRAMMING
	JUAN ALFREDO GOMEZ, Necessary conditions and duality for inexact nonlinear semi-infinite programming problems	PAUL BOSCH, Stability of the feasible set mapping of linear inequality	WALTER BOFILL, Cutting plane algorithms for robust conic convex optimization problems
R18 p.59	**Graph algorithms**, *organizer/chair*: Celia Mello		GRAPHS AND MATROIDS
	SIMONE DANTAS, On graph sandwich problems	JOÃO NEIVA DE FIGUEIREDO, Optimal transmission tower spotting using a shortest-path algorithm with preference relationships between nodes	MARCELO CARVALHO, An O(VE) algorithm for ear decompositions of matching covered graphs
R19 p.60	**Optimization in graphs and digraphs**, *organizer/chair*: András Sebo		GRAPHS AND MATROIDS
	ZOLTAN SZIGETI, Reliable network design	YUJI MATSUOKA, Fractional packing in ideal clutters	VINCENT JOST, Minimum cost partition into cliques with submodular costs
R20 p.60	**Approximation algorithms for scheduling problems**, *organizer*: Claire Kenyon, *chair*: Baruch Schieber		APPROXIMATION ALGORITHMS
	CLIFF STEIN, Fair Scheduling in Operating Systems	MARC UETZ, Scheduling with resource dependent processing times	ALEXANDER HALL, Sequential vector packing
R21 p.61	**Stochastic dynamic programming**, *organizer/chair*: Eugene Feinberg		DYNAMIC PROGRAMMING
	WARREN POWELL, Scalable approximate dynamic programming algorithms for stochastic resource allocation	RICHARD CHEN, Non-randomized control of constrained Markov decision processes	EUGENE FEINBERG, Multiple objective nonatomic discounted dynamic programming

Parallel Sessions: Tuesday 10:15 – 11:45 (TU1)

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R1 p.62	**Matrices and optimization**, *chair*: Davaatseren Baatar		COMBINATORIAL OPTIMIZATION
	DAVAATSEREN BAATAR, Matrix decomposition problem with application in cancer radiation treatment planning	PABLO REY, On symmetric combinatorial IP models and inequalities eliminating symmetries	GEORGE STEINER, The traveling salesman problem on permuted Monge matrices
R2 p.62	**Integrated methods for optimization**, *organizer/chair*: John Hooker		COMBINATORIAL OPTIMIZATION
	PAULO BOAVENTURA NETO, A new hybrid heuristic for the quadratic assignment problem	MEINOLF SELLMANN, Disco-Novo-GoGo: integrating local search and complete search with restarts	JOHN HOOKER, Continuous relaxation of combinatorial constraints
R3 p.62	**Metaheuristics and applications I**, *organizer*: Toshihide Ibaraki, *chair*: Ana Viana		COMBINATORIAL OPTIMIZATION
	HOONG LAU, iMDF: intelligent meta-heuristics development framework	HIROTAKA ONO, DNA sequence design by dynamic neighborhood searches	ANA VIANA, Hydrothermal coordination: an integrated approach with metaheuristics
R4 p.63	**Cutting planes for MIPs and polynomial programs**, *organizer*: Michael Juenger, *chair*: Frauke Liers		COMBINATORIAL OPTIMIZATION
	LEEN STOUGIE, A linear bound on the diameter of the transportation polytope	CHRISTOPH BUCHHEIM, Efficient reduction of logic optimization problems to max-cut	FRAUKE LIERS, Polynomial binary optimization over 'easy' polytopes
R5 p.64	**Graph partitioning problems**, *organizer/chair*: Alexander Martin		INTEGER AND MIXED INTEGER PROGRAMMING
	ARMIN FÜGENSCHUH, Mixed-integer programming for topology optimization in sheet metal design	MARZENA FÜGENSCHUH, Polyhedral and semidefinite relaxations for graph bisection problems	CHRISTOPH HELMBERG, Bisection knapsack path inequalities for graph bisection problems
R6 p.64	**Mathematical models in forestry 1**, *organizer*: Andres Weintraub, *chair*: Marc MacDill		OPTIMIZATION IN NATURAL RESOURCES
	MARC MCDILL, Using column generation to solve spatially explicit forest management planning problems	HORACIO GILABERT, Optimizing inventory collection effort for forest planning	MIGUEL CONSTANTINO, A mixed integer programming model for harvest scheduling
R7 p.65	**Models and methods for network design problems**, *organizer/chair*: Anantaram Balakrishnan		TELECOMMUNICATIONS AND NETWORK DESIGN,
	RAGHAVENDRAN SIVARAMAN, Single facility network loading in hybrid telecommunication networks	LUIS GOUVEIA, Models and heuristics for minimum spanning trees with node degree dependent costs	ANANTARAM BALAKRISHNAN, Cutting plane approach for service network design
R8 p.65	**Games on graphs**, *organizer/chair*: Encarnación Algaba		GAME THEORY
	DANIEL GRANOT, Revenue management of perishable products under competition	ENCARNACIÓN ALGABA, Cooperative games restricted by augmenting systems	
R9 p.66	**Global optimization techniques I**, *chair*: Panayiotis Lemonidis		GLOBAL OPTIMIZATION
	GILSILEY DARU, Enterprise optimization - problems found, problems solved	WALTER MASCARENHAS, On the divergence of line search methods	
R10 p.66	**Integer and combinatorial problems**, *chair*: Ranga Muhandiramge		MULTICRITERIA OPTIMIZATION
	JOHN KARLOF, A branch and bound algorithm for solving the binary bilevel integer programming problem	KEISUKE HOTTA, A mathematical analysis of the political redistricting problem in Japan	RANGA MUHANDIRAMGE, Network algorithms for continuous path planning problems
R11 p.67	**Non-deterministic methods for cone programming**, *organizer/chair*: Robert Freund		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	ROBERT FREUND, Efficiency of a re-scaled perceptron algorithm for conic systems	SANTOSH VEMPALA, Logconcave functions: sampling, integration and optimization	GORAN LESAJA, Interior-point methods for linear optimization based on the new class of barrier functions
R12 p.67	**Game theoretic techniques with applications**, *organizer/chair*: Zhiquan Luo		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	MARK PETERS, A convex Parimutuel formulation for contingent claim markets	ZHIQUAN LUO, Optimal spectrum management for interference-limited multiuser communication systems	
R13 p.68	**Large scale nonlinear programming**, *organizer/chair*: Richard Waltz		NONLINEAR PROGRAMMING
	FRANK CURTIS, Utilizing quadratic programming subproblems for nonlinear optimization	JORGE NOCEDAL, Preconditioning and convergence of interior-point methods	ANDREAS WAECHTER, Smoothing noisy black box functions for nonlinear optimization
R14 p.68	**Minimum covering ellipsoids and their applications**, *organizer/chair*: E. Alper Yildirim		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	E. ALPER YILDIRIM, On the minimum volume covering ellipsoid of ellipsoids	MICHAEL TODD, On minimum volume ellipsoids: from John and Kiefer-Wolfowitz to Khachiyan and Nesterov-Nemirovski	ROMY SHIODA, Clustering via minimum volume ellipsoids
R15 p.69	**Integration with scripting languages and constraints**, *organizer/chair*: Leonardo Lopes		OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS
	LEONARDO LOPES, The model object: local or remote, producer and consumer	MARY FENELON, CPLEX indicator constraints	KEARNEY TREVOR, PROC OPTMODEL: integrating pptimization modeling with the SAS programming environment
R16 p.69	**Algorithms for LCP and NLCP**, *chair*: Jose Luis Morales		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	JOSE LUIS MORALES, Methods for the approximate and fast solution of linear complementarity problems	UWE SCHAFER, On van Bokhoven's modulus algorithm for the linear	SANDRO MAZORCHE, A new feasible point algorithm for nonlinear complementarity problems
R17 p.70	**Computational stochastic integer programming**, *organizer/chair*: David Morton		STOCHASTIC PROGRAMMING
	LEWIS NTAIMO, Disjunctive decomposition for two-stage stochastic mixed-integer programs with random recourse	CLARA NOVOA, A new recourse model for solving the vehicle routing problem with stochastic demands	DAVID MORTON, Prioritization via stochastic integer programming
R18 p.70	**Graphs, Matrices, and Optimization**, *organizer/chair*: Satoru Iwata		GRAPHS AND MATROIDS
	NICHOLAS HARVEY, Randomized algebraic algorithms for matroid and matching problems	KENJIRO TAKAZAWA, The independent even factor problem	NAONORI KAKIMURA, Solving linear programs from sign patterns
R19 p.71	**Approximation algorithms**, *organizer/chair*: Eduardo Laber		GRAPHS AND MATROIDS
	FLAVIO MIYAZAWA, Class constrained bin packing problems	ARTUR PESSOA, An approximation algorithm for constructing error detecting prefix codes	CRISTON SOUZA, On the competitive ratio of monotone boolean functions
R20 p.71	**Online optimization I**, *organizer*: Kirk Pruhs, *chair*: Susanne Albers		ON-LINE OPTIMIZATION
	SUSANNE ALBERS, Energy-efficient algorithms	JEFF EDMONDS, Cake cutting really is not a piece of cake	KIRK PRUHS, Online speed scaling for weighted flow
R21 p.72	**Multiobjective criteria in dynamic programming**, *chair*: Natashia Boland		DYNAMIC PROGRAMMING
	NATASHIA BOLAND, Simultaneous solution of related Lagrangean dual problems with iterated preprocessing for solving the weight constrained shortest path problem	RODRIGO CARDOSO, An iterated invariant-set approach for linear multi-objective dynamic programming problems	MARIA ARONNA, On some minimax optimal control problems

Room Page	Parallel Sessions: Tuesday 15:00 – 16:30 (TU2)		
R1 p.73	**Heuristics II**, *chair*: Celso Ribeiro ALEXANDRE DUARTE, Referee assignment in sports tournaments	FLÁVIO MONTENEGRO, Heuristics for the stratification problem in survey samples	COMBINATORIAL OPTIMIZATION MARCELO LISBOA ROCHA, An asynchronous team proposal for the capacitated p-median problem
R2 p.73	**Advanced methods in real world applications**, *organizer*: Marcus Poggi de Aragão, *chair*: Oscar Porto OSCAR PORTO, Optimization of the continuous casting phase in steel tubes production	LORENZA MORENO, Planning flight schedules to offshore platforms	COMBINATORIAL OPTIMIZATION MARCELO REIS, Short term iron ore pellet production planning
R3 p.74	**Distance measures and metaheuristics**, *organizer/chair*: Kenneth Sorensen KENNETH SORENSEN, Vehicle routing – the movie	PATRICK SCHITTEKAT, Coping with unquantifiable criteria by generating structurally different solutions - Application to a large real-life location-routing problem in the automotive industry	COMBINATORIAL OPTIMIZATION LIGIA BAGI, A transgenetic algorithm for the capacited traveling purchaser problem
R4 p.74	**Cutting plane methods in combinatorial opt.**, *organizer*: Abdel Lisser, *chair*: Wadie Benajam JOSE NETO, On multiple-points separation: theory and practice	RAFAEL ANDRADE, Subgradient tree optimization	COMBINATORIAL OPTIMIZATION WADIE BENAJAM, SDP relaxations for the quadratic assignment problem
R5 p.75	**Covering and matching problems**, *chair*: Jean-Marie Bourjolly GABRIELA ARGIROFFO, Properties of the covering and the matching numbers of minimally nonideal	JEAN-MARIE BOURJOLLY, Conditional covering on a line	INTEGER AND MIXED INTEGER PROGRAMMING
R6 p.75	**Mathematical models in forestry 2**, *organizer/chair*: Andres Weintraub TARA BARRETT, Math modeling for efficiency in forest inventory	MICHAEL BEVERS, Spatial control and numerical chance constraint estimation	OPTIMIZATION IN NATURAL RESOURCES ANDRES WEINTRAUB, Solving difficult forestry problems with spatial adjacency
R7 p.76	**Routing and facility location**, *organizer/chair*: Philippe Mahey ADAM OUOROU, Mathematical models of the delay constrained routing problem	RICARDO POLEY M. FERREIRA, Global optimization of capacity expansion and flow assignment of data networks	TELECOMMUNICATIONS AND NETWORK DESIGN. CÉDRIC CHAMAYOU, Capacitated facility location problem with operational constraints
R8 p.76	**Core and equilibrium**, *organizer*: Ramesh Johari, *chair*: Thomas Liebling THOMAS LIEBLING, On the core of some combinatorial games	ALBERTO PINTO, Repeated Cournot competition: Nash investment equilibrium to increase the demand	GAME THEORY MARIANA ESCALANTE, Conditions for totally balanced packing games
R9 p.77	**Global optimization techniques II**, *chair*: Ricardo Takahashi OTILIJA SEDLAK, Risk measurement for managing project financing	ELIZABETH WANNER, Constraint quadratic approximation operator for treating equality constraints with genetic algorithms	GLOBAL OPTIMIZATION ANI VELO, Stress optimality results for a Goupillaud-type layered elastic strip
R10 p.77	**Multicriteria issues in planning and scheduling**, *chair*: Luiz Alves CARLOS MANUEL TOLEDO, Generación de planes temporales de proyectos	TIBOR KIS, Modeling the development of regional units	MULTICRITERIA OPTIMIZATION LUIZ ALVES, Adoption of sub-optimal solutions for the equipment selection model
R11 p.78	**On the curvature of the central path**, *organizer*: Antoine Deza, *chair*: Yinyu Ye YURIY ZINCHENKO, On the total curvature of the central path for linear programming	TAMÁS TERLAKY, Redundant Klee-Minty Cubes	LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
R12 p.78	**Algorithms**, *organizer*: Andreas Fischer, *chair*: Stephen Wright STEPHEN WRIGHT, An accelerated Newton method for nonlinear complementarity problems	MARGARIDA MELLO, Comparative experiments regarding differentiable reformulations of the GSOCCP	COMPLEMENTARY AND VARIATIONAL INEQUALITIES
R13 p.78	**Large-scale optimization**, *organizer*: Frank Curtis, *chair*: Jorge Nocedal RICHARD WALTZ, Numerical experience With preconditioners for interior-point methods	RICHARD BYRD, Exact penalty methods and regularization	NONLINEAR PROGRAMMING MIKHAIL SMELYANSKIY, Scaling performance of interior-point method on chip multiprocessors
R14 p.79	**Semidefinite programming**, *organizer*: Christoph Helmberg, *chair*: Samuel Burer SAMUEL BURER, Handling free variables in conic optimization with application to moment relaxations	MIGUEL ANJOS, Globally optimal solutions for large single-row facility layout problems	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING FRANK GÖRING, The rotational dimension of a graph
R15 p.80	**Integration with other analytical tools**, *organizer*: Leonardo Lopes, *chair*: Irvin Lustig DAVID GAY, Random variables, an AMPL extension for stochastic programming	RADHIKA KULKARNI, SAS retail price optimization solutions: forecasting "leads the party"	OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS IRVIN LUSTIG, A practical tool for sensitivity analysis
R16 p.80	**Equilibrium and related problems**, *chair*: Mauro Passacantando HELENA RODRIGUES, A MPCC-NLP approach for an electric power market problem	MAURO PASSACANTANDO, A path-based double projection method for solving the asymmetric traffic network equilibrium	COMPLEMENTARY AND VARIATIONAL INEQUALITIES
R17 p.81	**Applications of stochastic programming**, *organizer/chair*: Pavel Popela GERSON OLIVEIRA, Reduced scenario tree generation for mid-term hydrothermal scheduling	PETR STEPANEK, Stochastic programming applications in civil engineering	STOCHASTIC PROGRAMMING RUTH LUSCOMBE, Safe transit of a marine minefield as a stochastic shortest path
R18 p.81	**Algebraic methods**, *organizer/chair*: Cristina Fernandes CLAUDIA JUSTEL, Algebraic connectivity on combinatorial optimization problems	MANOEL LEMOS, On 3-connected binary matroids with circumference 6 or 7	GRAPHS AND MATROIDS LEONIDAS PITSOULIS, On the representability of totally unimodular matrices on bidirected graphs
R19 p.82	**Graph homomorphisms and constraint satisfaction**, *organizer/chair*: Pavol Hell JAROSLAV NESETRIL, Optimal local colorings	PAVOL HELL, Generalized colourings of chordal graphs and cographs	GRAPHS AND MATROIDS VICTOR DALMAU, Deciding the existence of homomorphism by games
R20 p.83	**Bicriteria approximation algorithms**, *organizer*: Claire Kenyon, *chair*: David Shmoys BARUCH SCHIEBER, Minimizing setup and beam-on times in radiation therapy	ASHISH GOEL, Simultaneous optimization and fairness for resource allocation problems	APPROXIMATION ALGORITHMS MICHEL GOEMANS, Minimum bounded-degree spanning trees
R21 p.83	**Applications in dynamic programming**, *chair*: Nikolaos Sahinidis NIKOLAOS SAHINIDIS, An exact algorithm for the contact map overlap problem in protein structural alignment	RENÉ MEZIAT, Analysis of non convex dynamical programs and its applications	DYNAMIC PROGRAMMING JESUK KO, Network service scheduling using a dynamic program

Parallel Sessions: Tuesday 17:00 – 18:30 (TU3)

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R1 p.85	**Polyhedral combinatorics II**, *chair*: Michael M. Sorensen		COMBINATORIAL OPTIMIZATION
	SILVIA BIANCHI, Characterizing all fractional extreme points of circulant matrices	IRINA DUMITRESCU, Polyhedral results for the pickup and delivery travelling salesman problem	MICHAEL M. SORENSEN, Polyhedral computations for the simple graph partitioning problem
R2 p.85	**Integer programming for graph optimization problem**, *organizer*: Cid de Sousa, *chair*: Cid de Souza		COMBINATORIAL OPTIMIZATION
	CID DE SOUZA, Lagrangian relaxation and cutting planes for the vertex separator problem	CARLOS FERREIRA, The group Steiner tree problem	MARKUS CHIMANI, Using ILPs to tackle the crossing number problem
R3 p.85	**Metaheuristics for scheduling problems**, *organizer/chair*: Debora Ronconi		COMBINATORIAL OPTIMIZATION
	DENISE YAMASHITA, Scatter search for project scheduling with resource availability cost	ALETÉIA ARAÚJO, Towards grid implementations of metaheuristics for hard combinatorial	DEBORA RONCONI, Heuristic approaches for total tardiness minimization in a flowshop with blocking
R4 p.86	**Combinatorial optimization I**, *organizer*: William H. Cunningham, *chair*: Eric Duchene		COMBINATORIAL OPTIMIZATION
	ERIC DUCHENE, A solitaire game played on graphs	DAVID DÉFOSSEZ, Complexity of clique-coloring perfect graphs	LUERBIO FARIA, An implementation for randomized truth assignments in 3-sat / nae3sat
R5 p.87	**Applications of IP II**, *chair*: Marzena Fügenschuh		INTEGER AND MIXED INTEGER PROGRAMMING
	JOSÉ BRITO, An integer programming formulation for the stratification problem in survey samples with proportional allocation	RICARDO FUKASAWA, MIR inequalities and mixed-integer knapsack problems	
R6 p.87	**Mathematical models in forestry 3**, *chair*: Gyana Parija		OPTIMIZATION IN NATURAL RESOURCES
	GYANA PARIJA, Strategic budgeting for wildfire management	ADRIANA PIAZZA, Asymptotic convergence of optimal harvesting policies for a multiple species forest	JOHNSON MOURA, Integrated system of energy using beddings of ambient engineering
R7 p.88	**Scheduling, Steiner and ring star problems**, *chair*: Giuliana Carello		TELECOMMUNICATIONS AND NETWORK DESIGN,
	GIULIANA CARELLO, A transmission scheduling problem in wireless networks	CRISTINE SCHMIDT, A transgenetic algorithm for the prize collecting Steiner tree problem	MARCIA FAMPA, A hybrid metaheuristic for the ring star problem
R8 p.88	**Finance and economics IV**, *chair*: Hilary Paul Williams		FINANCE AND ECONOMICS
	ANDREA RONCORONI, Energy swing options with load penalty	HILARY PAUL WILLIAMS, The allocation of shared fixed costs	
R9 p.89	**Competitive energy market modeling**, *organizer/chair*: Jorge Valenzuela		OPTIMIZATION IN ENERGY SYSTEMS
	CHAN PARK, Transmission investments in competitive markets	MAINAK MAZUMDAR, Oligopoly models for the market price of electricity	JORGE VALENZUELA, Power generation expansion under cournot competition
R10 p.89	**Utility theory and games**, *chair*: Pedro Jara		MULTICRITERIA OPTIMIZATION
	LUÍS ALBERTO DUNCAN RANGEL, A variant of the UTA method	PEDRO JARA, Strategic complementarity, heterogeneity and eductive stability in a class of non-atomic games	LUIS MAURICIO GRAÑA DRUMMOND, A Newton Method for Multicriteria
R11 p.90	**Applications of LP and cone programming III**, *chair*: Fernanda Raupp		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	ALIREZA HADIGHEH, Support set sensitivity analysis in bi-parametric linear optimization	MARIA RODRIGUEZ, MILP formulation for solving the cutting stock problem in the corrugated board boxes industry	FERNANDA RAUPP, Analytic center of spherical shells applied to the analytic center machine
R12 p.90	**Stochastic variational inequalities**, *organizer/chair*: Alexander Shapiro		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	GUL GURKAN, Approximations of Nash equilibria	VINAYAK V. SHANBHAG, Algorithms for stochastic Nash and Stackelberg problems	ALEXANDER SHAPIRO, Stochastic mathematical programs with equilibrium constraints
R13 p.91	**PDE-constrained optimization and algorithms**, *organizer*: Stefan Ulbrich, *chair*: Matthias Heinkenschloss		NONLINEAR PROGRAMMING
	MATTHIAS HEINKENSCHLOSS, SQP algorithms with inexact linear system solvers for the solution of PDE constrained optimization problems	RONALD HOPPE, Path-following primal-dual interior-point methods in PDE constrained optimization	HUGO SCOLNIK, Increasing robustness of the L-BFGS method by using extra updates
R14 p.91	**Convex analysis and algorithms**, *organizer*: Raphael Hauser, *chair*: Coralia Cartis		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	CORALIA CARTIS, A new perspective on the complexity of interior point methods for linear programming	JAVIER PENA, Algorithms for computing Nash equilibria of large sequential games	
R15 p.92	**Features of large-scale optimization systems**, *organizer/chair*: Robert Fourer		OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS
	ROLAND WUNDERLING, Finding conflicting constraints with CPLEX	ALKIS VAZACOPOULOS, State-of-the-optimization using Xpress-MP v2006	FLAVIO PIZZATO, Exploiting programming capabilities of LINGO 10 in multi-model analyses
R16 p.92	**Primal-dual methods for KKT systems**, *chair*: Mikhail Solodov		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	PAUL ARMAND, A local convergence property of primal-dual methods for nonlinear programming	DAMIÁN FERNÁNDEZ, On local convergence of sequential quadratically-constrained quadratic-programming type methods, with an extension to variational problems	
R17 p.93	**Scenario generation and optimization under uncertainty**, *organizer*: Pavel Popela, *chair*: Werner Roemisch		STOCHASTIC PROGRAMMING
	WERNER ROEMISCH, Stability-based scenario tree generation for multistage stochastic programs	PAVEL POPELA, The scenario reduction for incomplete recourse	
R18 p.93	**Graphs and Matroids**, *organizer*: TBD, *chair*: Samuel Varas		GRAPHS AND MATROIDS
	MAMANE SOULEY IBRAHIM, A strengthened flow linear formulation for the shortest path problem in digraphs with negative cycles	DAVID HARTVIGSEN, The polytope for 1-restricted simple 2-matchings in trees	SAMUEL VARAS, Determining the minimum cost path in hypergraphs
R19 p.94	**Covers**, *organizer*: Siang Song, *chair*: Guillermo Durán		GRAPHS AND MATROIDS
	CRISTINA FERNANDES, Approximation results on rational objectives	LUCIENE MOTTA, The generalized covering tour problem: a computational experience with reduction rules	LOANA NOGUEIRA, A note on the size of minimal covers
R20 p.94	**Approximation algorithms for scheduling problems**, *organizer/chair*: Baruch Schieber		PRODUCTION AND SCHEDULING
	YOSSI AZAR, Multiplexing packets with arbitrary deadlines in bounded buffers	REUVEN BAR-YEHUDA, LP rounding using fractional local ratio	SAMIR KHULLER, Algorithms for vehicle routing

Room Page	Parallel Sessions: Wednesday 10:15 – 11:45 (WE1)		
R1 p.95	**Efficient IP formulations**, *chair*: Gilberto Miranda VICTOR CAMPOS, A 0-1 integer formulation for the tree decomposition problem	GILBERTO MIRANDA, Fast flow formulations for sparce QAP instances	COMBINATORIAL OPTIMIZATION
R2 p.95	**Sequences, coloring, and related applications**, *organizer*: Uwe Zimmermann, *chair*: Gabriele Di Stefano BENJAMIN LEROY-BEAULIEU, Online coloring of comparability graphs: some results	GABRIELE DI STEFANO, How to assign tracks to trains	COMBINATORIAL OPTIMIZATION FELIX KÖNIG, The stacking problem and its connection to graph coloring
R3 p.96	**New and emerging trends in metaheuristics**, *organizer*: Stefan Voss, *chair*: David Woodruff DAVID WOODRUFF, Distances between VRP solutions	MARÍA BALDOQUÍN DE LA PEÑA, Heuristic mining: a new concept and related techniques for reducing the effort and expertise to solve hard combinatorial optimization problems	COMBINATORIAL OPTIMIZATION ANDREAS FINK, Solving multi-agent resource-constrained project scheduling problems with discounted cash flows by means of a negotiation-based coordination mechanism
R4 p.96	**Advances in integer programming II**, *organizer/chair*: Andrea Lodi JEFF LINDEROTH, The football pool problem	PIETRO BELOTTI, Randomized relaxation methods for the maximum feasible subsystem problem	INTEGER AND MIXED INTEGER PROGRAMMING DIRK OLIVER THEIS, Results on the graphical relaxation of the symmetric traveling salesman problem
R5 p.97	**Multiobjective integer programming**, *organizer/chair*: Theodore Ralphs JORGEN TIND, Column generation in integer programming with applications in multicriteria optimization	SCOTT DENEGRE, Multiobjective mixed-integer Stackelberg games	INTEGER AND MIXED INTEGER PROGRAMMING
R6 p.97	**Vehicle routing**, *chair*: Ana Maria Oliveira DANIELE PRETOLANI, Adaptive routing in random time-dependent networks with real-time information	DANIEL LACERDA, Integer programming formulation for an extended Dantzig-Fulkerson fleet size and routing model	LOGISTICS AND TRANSPORTATION ANA MARIA OLIVEIRA, Railroad logistics for sugar exports departing from the state of São Paulo: implications on the location of intermodal warehouses
R7 p.98	**Network design**, *organizer/chair*: Lisa Zhang YIHAO ZHANG, Optical network design	ALESSANDRO PANCONESI, Communication and power control	TELECOMMUNICATIONS AND NETWORK DESIGN. ARAVIND SRINIVASAN, Wireless networks: algorithms for scheduling and capacity-estimation
R8 p.98	**Finance and economics I**, *organizer*: William Ziemba, *chair*: John Birge JOHN BIRGE, Continuum approximations of multiple-asset taxable portfolios	VICTOR DEMIGUEL, Portfolio optimization with robust estimates of risk	FINANCE AND ECONOMICS
R9 p.98	**Variational inequalities in energy**, *organizers*: Luiz A. Barroso, Alejandro Jofre, Danny Ralph, *chair*: Alejandro Jofre LUIZ A. BARROSO, Strategic bidding under uncertainty and Nash equilibria in electricity markets: a binary expansion approach	DANIEL RALPH, Complementarity models and the architecture of energy markets	OPTIMIZATION IN ENERGY SYSTEMS ALEJANDRO JOFRE, Optimal regulation mechanisms for electricity generation markets
R10 p.99	**Robust optimization in engineering & network optim**, *organizer*: Mustafa Pinar, *chair*: Edoardo Amaldi ALFREDO CANDIA, Minimax regret spanning arborescence under uncertain costs	DICK DEN HERTOG, Robust optimization using computer experiments	ROBUST OPTIMIZATION LAURA SANITÀ, Network design with more traffic matrices
R11 p.99	**Semidefinite programming: methods and models**, *organizer/chair*: Michael Todd RENATO MONTEIRO, Large scale semidefinite programming via a saddle point mirror-prox algorithm	MAN-CHO SO, A semidefinite programming approach to tensegrity theory and realizability of graphs	LINEAR, CONE AND SEMIDEFINITE PROGRAMMING GERT LANCKRIET, Semidefinite programming in machine learning: sparse and large-scale learning with heterogenous data
R12 p.100	**Geometric aspects of convex programming**, *organizer/chair*: Leonid Faybusovich MASAKAZU MURAMATSU, Sparse SOS and SDP relaxations for polynomial optimization problems over symmetric cones	FARID ALIZADEH, Bilinear complementary conditions for the cone of positive polynomials	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING LEONID FAYBUSOVICH, Symmetric relaxations of non-convex optimization problems
R14 p.101	**Proximal methods and convex separable optimization**, *organizer/chair*: Felipe Alvarez FELIPE ALVAREZ, Primal/dual convergence results for hybrid proximal-projection methods coupled with penalty methods in convex programming	LISANDRO PARENTE, Variable metric extensions of the HIPPM and HPDM schemes	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING JUAN VERA, Static arbitrage bounds for basket options via linear programming
R15 p.101	**Software services and distribution**, *organizer/chair*: Robert Fourer TATJANA DAVIDOVIC, Mathematical programming based approach to the multiprocessor scheduling problem with communication delays	ROBERT FOURER, Optimization via the internet: NEOS 5 and beyond	OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS BRADEN HUNSAKER, COIN-OR triennial update
R17 p.101	**Simulation methods for SP problems**, *chair*: Ozge Ozdemir TITO HOMEM-DE-MELLO, Quasi-Monte Carlo methods in stochastic optimization	OZGE OZDEMIR, Optimal threshold levels in stochastic fluid models via simulation-based optimization	STOCHASTIC PROGRAMMING SUVRAJEET SEN, Mixed integer stochastic decomposition
R18 p.102	**Packings, domination and isomorphisms**, *organizer/chair*: Luerbio Faria EDUARDO PIZA, Dominating Z_p^n and $Z_2^n \times Z_3^m$	GORDANA MANIC, Packing edges and triangles: hardness results and approximation algorithms	GRAPHS AND MATROIDS UGO PIETROPAOLI, On isomorphic 4-regular circulant graphs
R19 p.102	**Approximation algorithms for network problems**, *organizer*: Claire Kenyon, *chair*: Cliff Stein AMIT CHAKRABARTI, Unsplittable flows in line and ring networks	NEAL YOUNG, Incremental medians via online bidding	APPROXIMATION ALGORITHMS STAVROS KOLLIOPOULOS, Edge pricing of multicommodity networks for selfish users with elastic demands
R20 p.103	**Online optimization II**, *organizer*: Kirk Pruhs, *chair*: Alberto Marchetti-Spaccamela ALBERTO MARCHETTI-SPACCAMELA, Data aggregation in sensor networks with latency constraints	TAK-WAH LAM, Online deadline scheduling with energy concern	ON-LINE OPTIMIZATION KAZUO IWAMA, Online knapsack problems

Parallel Sessions: Wednesday 15:00 – 16:30 (WE2)

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R1 p.105	**Knapsack problems**, *chair*: Bala Krishnamoorthy		COMBINATORIAL OPTIMIZATION
	CHRISTOPHER FRICKE, Clique-based facets for the precedence constrained knapsack problem	BALA KRISHNAMOORTHY, A knapsack cryptosystem secure against attacks using basis reduction and integer programming	
R2 p.105	**Shortest path algorithms**, *organizer/chair*: Andrew Goldberg		COMBINATORIAL OPTIMIZATION
	ANDREW GOLDBERG, Reach for A^*: efficient point-to-point shortest path problem	CAMIL DEMETRESCU, Algorithmic techniques for path problems on dynamic graphs	ROLF MÖHRING, Fast shortest path computations on large networks
R3 p.106	**Metaheuristics for solving prac. logistics**, *organizer*: Helena Ramalhinho, *chair*: Daniel Serra		COMBINATORIAL OPTIMIZATION
	DANIEL SERRA, A DSS for locating public and private facilities in Barcelona	GERALDO REGIS MAURI, A general multi-objective model for dial-a-ride problem solved by simulated annealing	HAROLDO SANTOS, Combining metaheuristics and integer programming on school timetabling problems
R4 p.106	**Advances in integer programming III**, *organizer*: Andrea Lodi, *chair*: Sanjeeb Dash		INTEGER AND MIXED INTEGER PROGRAMMING
	EMILIE DANNA, Solution polishing and other recursive MIP heuristics	TOBIAS ACHTERBERG, Conflict analysis in mixed integer programming	ANDREW MILLER, Polynomial time algorithms for stochastic lot-sizing problems
R5 p.106	**Applications of mixed integer programming**, *organizer/chair*: Carlos Ferreira		INTEGER AND MIXED INTEGER PROGRAMMING
	JUAN PABLO VIELMA, A constructive characterization of the split closure of a mixed integer linear program	UTZ-UWE HAUS, A combinatorial optimization approach to challenging synthesis problems	DENIS CORNAZ, On forests, stable sets and polyhedras associated with clique partitions
R6 p.107	**Routing and location problems**, *chair*: Roberto Galvão		LOGISTICS AND TRANSPORTATION
	RICARDO CAMARGO, Benders decomposition for a hub location problem with economies of scale	ROBERTO GALVÃO, Interactive and hierarchical methods for location-routing problems	LUCIANA GONÇALVES, A GRASP with adaptive memory for a period vehicle routing problem
R7 p.108	**Routing, design and control in data networks**, *organizer*: David Johnson, *chair*: David Applegate		TELECOMMUNICATIONS AND NETWORK DESIGN.
	DAVID APPLEGATE, ACL optimization or compressing rectilinear pictures	MARCELO SANTOS, Distributed dual ascent for Steiner problems in graphs	HECTOR CANCELA, A model for caching mechanisms in DNS and P2P network
R8 p.108	**Finance and economics II**, *organizer*: William Ziemba, *chair*: Florian Herzog		FINANCE AND ECONOMICS
	MARKKU KALLIO, Real option valuation under imperfect markets	FLORIAN HERZOG, Stochastic model predictive control for portfolio optimizations	GABRIEL DONDI, Asset and liability management for swiss pension funds
R9 p.109	**Hydro/thermal scheduling**, *organizer/chair*: Claudia Sagastizabal		OPTIMIZATION IN ENERGY SYSTEMS
	ANDRE DINIZ, A multistage Benders decomposition approach for the security-constrained hydrothermal scheduling with transmission losses for large scale systems	ROMAIN APPARIGLIATO, Management of a hydraulic valley by robust optimization	EDUARDO FARIA, Allocation of firm-energy rights among hydro agents using cooperative game theory: an Aumann-Shapley approach
R10 p.110	**Robust optimization: dynamic models**, *organizer/chair*: Daniel Bienstock		ROBUST OPTIMIZATION
	DANIEL BIENSTOCK, Computing robust basestock levels	GEORGIA PERAKIS, Multi-period pricing of perishable products; competition, uncertainty and learning	
R11 p.110	**Duality in LP and cone programming**, *chair*: Andre Tits		LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
	GIDEON WEISS, Full symmetric duality in separated continuous linear programs	FLAVIA JACINTO, Revisiting dual results in convex semidefinite programming	ANDRE TITS, Constraint reduction for certain degenerate linear programs
R12 p.111	**Algorithms for cone programming and convex hulls**, *organizer/chair*: John Mitchell		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	JOHN MITCHELL, Conic cutting surface algorithms	ALEXANDRE CABOUSSAT, A primal-dual interior-point method for the determination of the convex hull	TAKASHI TSUCHIYA, An extension of the standard polynomial-time primal-dual path-following algorithm to the weighted determinant maximization problem and its applications
R13 p.111	**Filter methods for NLP**, *chair*: Elizabeth Karas		NONLINEAR PROGRAMMING
	CLAUDIA MARGARITA VILLAGRAN DE LEÓN, Non smooth, non convex optimization	ADEMIR RIBEIRO, Global convergence of filter methods for nonlinear programming	ELIZABETH KARAS, Numerical comparison of merit functions and filter criteria in inexact restoration algorithms using hard-spheres problems
R14 p.112	**Nonsmooth algorithms**, *organizer*: Claudia Sagastizabal, *chair*: Napsu Haarala		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	MILAGROS LORETO, Spectral projected subgradient with a momentum term for the Lagrangean dual approach	NAPSU HAARALA, Limited memory bundle method for bound constrained	
R15 p.112	**Biomolecular modeling and simulation**, *organizer/chair*: Zhijun Wu		BIOINFORMATICS AND OPTIMIZATION
	ELIZABETH ESKOW, Progress and challenges in protein structure prediction	PETER VEDELL, A shooting method with inexact boundary conditions and parameter reduction for protein dynamics simulation	ZHIJUN WU, Distance based protein modeling
R16 p.113	**Mathematical programs with equilibrium constraints**, *organizer*: Jiri Outrata, *chair*: Joydeep Dutta		COMPLEMENTARY AND VARIATIONAL INEQUALITIES
	ALEXEY IZMAILOV, Directional regularity and directional metric regularity	JOYDEEP DUTTA, Bilevel programming with convex lower level problems	
R17 p.113	**Pension and portfolio applications of SP**, *organizer/chair*: William Ziemba		STOCHASTIC PROGRAMMING
	WILLIAM ZIEMBA, The innovest austrian pension fund financial planning model InnoALM	CHANAKA EDIRISINGHE, Integrated risk control in fund management using multistage stochastic programming	ELIO CANESTRELLI, Combining stochastic programming and optimal control theory to solve multistage financial problems
R18 p.114	**Graph colorings I**, *organizer/chair*: Kristina Vuskovic		GRAPHS AND MATROIDS
	MARTIN KOCHOL, Linear algebra approach to graph coloring and flow problems	CELINA FIGUEIREDO, Even pairs in bull-reducible graphs	CHRISTIANE CAMPOS, On the colourings of powers of cycles
R19 p.114	**Approximation algorithms and SDP**, *organizer*: Claire Kenyon, *chair*: Michel Goemans		APPROXIMATION ALGORITHMS
	MOSES CHARIKAR, Near-optimal algorithms for unique games	DAVID PHILLIPS, Approximating a class of semidefinite programs	GEORGE KARAKOSTAS, A better approximation ratio for the vertex cover problem
R20 p.115	**Capacitated deterministic inventory models**, *organizer/chair*: Retsef Levi		PRODUCTION AND SCHEDULING
	DOLORES ROMERO MORALES, Existence of equilibria in a decentralized two-level economic lot-sizing model	ALISTAIR CLARK, Integrated setup-sequencing and lot-sizing in production scheduling at an animal-feed plant	ANDREA LODI, LP-based multi-item lot sizing

Room Page	Parallel Sessions: Wednesday 17:00 – 18:30 (WE3)		
R1 p.116	**Bin packing**, *chair*: Philippe Refalo PHILIPPE REFALO, A constraint programming approach to variable-sized bin packing with color constraints	NEI YOSHIHIRO SOMA, On the absolute error for solving the bin backing problems by subset sums	COMBINATORIAL OPTIMIZATION PARK SANG HYUCK, Two-dimensional bin-packing optimization model for two-stage guillotine-cutting problem
R2 p.116	**Combinatorial optimization III**, *organizer/chair*: Paolo Ventura VOLKER KAIBEL, Orbitopes	CLAUDIO GENTILE, Mod-2 cuts generate the convex hull of bounded feasible integer sets	COMBINATORIAL OPTIMIZATION GAUTIER STAUFFER, Lower bound for the Chvatal rank of polytopes: application to the stable set polytope of quasi-line graphs
R3 p.116	**Metaheuristics in facility location problems**, *organizer*: Diptesh Ghosh, *chair*: Jens Wollenweber MARCOS ROBERTO SILVA, Solving the bi-objective hub location problem with evolutionary algorithms	JENS WOLLENWEBER, Solving large-scale multi-stage facility location problems by VNS	COMBINATORIAL OPTIMIZATION I. KUBAN ALTINEL, Solving probabilistic multi-facility Weber problem by vector quantization
R4 p.117	**Computational integer programming II**, *organizers*: Alexander Martin, *chair*: George Nemhauser JAMES LUEDTKE, Planning activities with start-time dependent variable costs	RENAN GARCIA, Resource constrained shortest paths using branch-and-cut	INTEGER AND MIXED INTEGER PROGRAMMING EGON BALAS, Optimizing over the split closure
R5 p.118	**Applications of IP I**, *chair*: Andrew Felt NAN KONG, Redesigning the liver allocation hierarchy	ANDREW FELT, MILP model for university timetabling	INTEGER AND MIXED INTEGER PROGRAMMING JON WARWICK, Using mathematical programming to identify students at risk of failure
R6 p.118	**Maritime operations and transport**, *chair*: Gary Froyland GARY FROYLAND, Scheduling of rail mounted gantry cranes at port Botany, Sydney	FÉLIX MORA-CAMINO, Heuristic estimation of 3D airside capacity at airports	LOGISTICS AND TRANSPORTATION
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R9 p.120	**Energy modeling**, *organizers*: Alejandro Jofre, *chair*: Golbon Zakeri AMARO PEREIRA, Energy modeling in developing countries	CARLOS HENRIQUE SABOIA, Long-term power expansion planning: an application of mixed-integer linear programming	OPTIMIZATION IN ENERGY SYSTEMS GOLBON ZAKERI, Experiments with equilibria in the New Zealand electricity market
R10 p.120	**Industrial applications of robust optimization**, *organizer/chair*: Ralf Werner PAPA MOMAR NDIAYE, Towards a robust dynamic principal component analysis	MICHAL KOCVARA, Towards a code for robust programming	ROBUST OPTIMIZATION KATRIN SCHOETTLE, Towards robust efficient frontiers
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R12 p.121	**Cone programming**, *organizer*: Andre Tits, *chair*: Simon Schurr OLENA SHEVCHENKO, Hyperbolic polynomials, the Lax conjecture and its applications	YURII NESTEROV, Towards nonsymmetric conic optimization	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING SIMON SCHURR, Effects of inexact barrier function evaluations in interior-point methods for conic optimization
R13 p.122	**Decomposition and quadratic programs**, *chair*: María Cristina Maciel LUIS CONTESSE, On applying the Frank-Wolfe algorithm to projected nonlinear optimisation problems	MEHDI LACHIHEB, Prediction of optimal set of extreme points in parametric quadratic programming	NONLINEAR PROGRAMMING MARÍA CRISTINA MACIEL, Newton's method for minimizing quadratic matrix functions
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	KOJI NONOBE, An iterated local search algorithm for the multi-resource generalized assignment problem with flexible assignment cost	MICHEL VASQUEZ, On the queen graph coloring problem	TERESA GALVÃO DIAS, Multiobjective genetic algorithms for some relaxed versions of the set partitioning problem
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R5 p.128	**Mixing MIR inequalities**, *organizer/chair*: Ismael de Farias		INTEGER AND MIXED INTEGER PROGRAMMING
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	CRISTIAN MARTINEZ, School bus routing problem resolution with hybrid metaheuristics	RALF BORNDÖRFER, Line planning in public transport	ROBERTO DE LA LLATA, Optimal bus transit route network design in a medium sized city
R7 p.129	**Airline models and algorithms**, *chair*: Ivo Nowak		AIRLINE OPTIMIZATION
	EDUARDO SOARES, Air lines planning: crew scheduling	JUAN JOSE MIRANDA BRONT, A column generation algorithm for the choice-based linear programming	IVO NOWAK, A unified column generation approach to crew pairing and rostering
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	ANDY PHILPOTT, Solving multi-stage stochastic capacity-planning problems	YVES SMEERS, Investment issues inrestructured electricity systems	MARIO PEREIRA, Expansion planning of generation and interconnections under uncertainty
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	ELODIE ADIDA, Dynamic pricing and inventory control; uncertainty and competition through robust optimization and quasi variational inequalities	NICOLAS STIER-MOSES, Robust Wardrop equilibrium	
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R12 p.132	**Warm starting IPMs in NLP applications**, *organizer/chair*: Jacek Gondzio		NONLINEAR PROGRAMMING
	HANDE BENSON, Interior-point methods for nonlinear programming: regularization and warmstarts	LEO TENENBLAT, Zoom: A strategy for accelerating and warm-starting interior methods	ANDREAS GROTHEY, Unblocking heuristics for warm-starting interior point methods
R13 p.132	**NLP algorithms**, *chair*: Ernesto Birgin		NONLINEAR PROGRAMMING
	JOSE HERSKOVITS, Positive definite sparse quasi-Newton matrices for constrained optimization	SANDRA SANTOS, Inexact restoration methods with inequality constraints and lagrangian tangent decrease	ERNESTO BIRGIN, Augmented Lagrangian methods with arbitrary lower-level constraints: implementation and experiments
R14 p.133	**SDP-relaxations for polynomial problems**, *organizer*: Jean B. Lasserre, *chair*: Nebojsa Gvozdenovic		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
	NEBOJSA GVOZDENOVIC, Approximating the chromatic number of a graph	HAYATO WAKI, Numerical results on semidefinite programming relaxations	
R15 p.133	**Duality and conic theory**, *organizer*: Claudia Sagastizabal, *chair*: Alfredo Iusem		NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING
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R17 p.134	**Probabilistic constraints**, *organizer/chair*: Rene Henrion		STOCHASTIC PROGRAMMING
	RENE HENRION, On chance constraints with random coefficient matrix	CYRILLE STRUGAREK, Convexity of chance constraints with independent random variables	
R18 p.134	**Graph colorings II**, *organizer/chair*: Manoel Lemos		GRAPHS AND MATROIDS
	ABEL LOZANO, Balanced total coloring and algorithms for interconnecting networks	PRISCILA PETITO, The vertex coloring problem of UEH graphs	CARLOS DIEGO RODRIGUES, Lower bounds for the vertex coloring problem via columns and cuts generation
R19 p.135	**Approximation algs for stochastic optimization**, *organizer*: Claire Kenyon, *chair*: Jens Vygen		APPROXIMATION ALGORITHMS
	DAVID SIMCHI-LEVI, A fully polynomial time approximation scheme for single-item stochastic lot-sizing problem with discrete demand	RETSEF LEVI, Provably near-optimal dual-balancing policies for hard stochastic inventory control problems	DAVID SHMOYS, Provably near-optimal sampling-based algorithms for stochastic inventory control models
R20 p.135	**Online optimization III**, *organizer*: Kirk Pruhs, *chair*: Thomas Erlebach		ON-LINE OPTIMIZATION
	THOMAS ERLEBACH, Online capacitated interval coloring	WOLFGANG BEIN, Knowledge states: a tool in randomized online algorithms	RUDOLF FLEISCHER, Search and exploration of unknown graphs

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R2 p.137	**Cutting and packing problems**, *organizer*: Claudio Meneses, *chair*: Horacio Yanasse MARCOS ARENALES, On accelerating column generation for one-dimensional cutting stock problems and extensions	HORACIO YANASSE, On solving a cutting stock problem with pattern sequencing constraints	COMBINATORIAL OPTIMIZATION SOCORRO RANGEL, A heuristic method to generate productive 2D-cutting patterns for the furniture industry
R3 p.138	**Metaheuristics and applications III**, *organizer*: Toshihide Ibaraki, *chair*: Jorge Pinho de Sousa JORGE PINHO DE SOUSA, Multiobjective tabu search for a mean-rsk static stochastic knapsack problem	HIRATA TOMIO, Graph coloring via vector assignment in the plane	COMBINATORIAL OPTIMIZATION RODRIGO NOGUEIRA, A GRASP algorithm for the 0-1 quadratic knapsack problem
R4 p.138	**Stable set polytopes**, *organizer/chair*: Volker Kaibel ANNEGRET WAGLER, A Conjecture on the stable set polytope of Claw-Free graphs	PAOLO VENTURA, The stable set polytope of quasi-line graphs	INTEGER AND MIXED INTEGER PROGRAMMING GIANPAOLO ORIOLO, The stable set problem on fuzzy circular interval graphs
R5 p.139	**Decomposition methods in integer programming**, *organizer*: Matthew Galati, *chair*: Armin Fügenschuh CÉSAR BELTRÁN-ROYO, Solving the uncapacitated facility location problem by semi-Lagrangian relaxation	CARINA PIMENTEL, Application of multiple Dantzig-Wolfe decomposition to a lot sizing problem	INTEGER AND MIXED INTEGER PROGRAMMING
R6 p.139	**Traffic and routing I**, *chair*: Haldun Sural PABLO LOTITO, A hybrid-bundle decomposition method and its application to the traffic assignment problem	SERGEY SHISHKIN, Modelling and optimization of traffic	LOGISTICS AND TRANSPORTATION HALDUN SURAL, Coordinated inventory control and vehicle routing: Lagrangian relaxation based solution approach
R7 p.140	**Multi-task in networks**, *chair*: Matthieu Chardy ANDREAS KARRENBAUER, Multiline addressing by network flow	JOSE GREGORIO MEDINA CEPEDA, Design of an optimization model of the time and cost of execution for mixed projects	NETWORKS MATTHIEU CHARDY, Cooperative stochastic games for multi-service networks cost allocation
R8 p.140	**Leonid Khachiyan memorial II**, *organizer/chair*: Farid Alizadeh GABOR RUDOLF, Generating k-connected spanning subgraphs	JAN BIOCH, Nondisjoint decompositions of monotone Boolean functions	LEONID KHACHIYAN MEMORIAL
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R10 p.141	**Robust opt in networks and portfolio construction**, *organizer*: Raphael Hauser, *chair*: eha EDOARDO AMALDI, Network design under polyhedral traffic uncertainty	REHA TUTUNCU, Relative robust optimization	ROBUST OPTIMIZATION DENIS ZUEV, Robust portfolio optimization - Extreme case optimization
R11 p.142	**Geometric approaches in LP and cone programming**, *chair*: Jun-ya Gotoh KONSTANTIN KOBYLKIN, Geometrical method of representation of linear inequality system and applications to linear programming	MARCOS LINS, Orthogonally normalized simplex	LINEAR, CONE AND SEMIDEFINITE PROGRAMMING JUN-YA GOTOH, Conditional minimum volume ellipsoid and its application to multiclass classification
R12 p.143	**Mixed integer nonlinear programming**, *organizer/chair*: Andreas Waechter JON LEE, An MINLP solution method for a water-network optimization problem	PIERRE BONAMI, A new open-source solver for MINLP	NONLINEAR PROGRAMMING FRANCOIS MARGOT, A feasibility pump for mixed integer nonlinear programming
R13 p.143	**Nonlinear integer programming applications**, *chair*: José Arica TIBERIUS BONATES, Pseudo-boolean regression	FABIO FAGUNDEZ, Jetty scheduling optimal control models	NONLINEAR PROGRAMMING JOSÉ ARICA, A planning model for offshore natural gas transmission
R14 p.144	**Topics in Convex Programming**, *organizer*: Osman Guler, *chair*: Raphael Hauser RAPHAEL HAUSER, A new proof of the s-lemma	ROBERTO COMINETTI, Stochastic equilibrium and learning in traffic networks	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING FILIZ GURTUNA, Efficient, first-order methods for convex programming
R15 p.144	**Computational methods**, *chair*: Adilson Elias Xavier HÉCTOR ANDRES OSPINA, Solution of quantile regression problems by means of method ACCPM	LUIZ CARLOS DE SOUZA, New computacional results of the hyperbolic smoothing clustering method	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING RALF WERNER, Variance reduction in Monte Carlo simulation by quadratic programming
R16 p.145	**Merit function and penalty techniques**, *chair*: Barbara Stefania Panicucci ESTEVE CODINA, An algorithm for generalized bilevel programming problems using exact pennalties	BARBARA STEFANIA PANICUCCI, On gap functions for generalized variational inequalities	COMPLEMENTARY AND VARIATIONAL INEQUALITIES MARIA LAURA SCHUVERDT, Convergence of augmented Lagrangian methods with arbitrary lower-level
R18 p.145	**Colorings, factors and paths**, *organizer/chair*: Yoshiko Wakabayashi MARTIN MATAMALA, Some remarks about factors	ORLANDO LEE, Non-separating paths in 4-connected graphs	GRAPHS AND MATROIDS CLAUDIA SALES, Weighted coloring on graphs with bounded tree-width
R19 p.146	**Stochastic and online machine scheduling**, *organizer/chair*: Marc Uetz BRIAN DEAN, Approximation algorithms for deadline-constrained stochastic scheduling problems	NICOLE MEGOW, Models and algorithms for stochastic online scheduling	PRODUCTION AND SCHEDULING TJARK VREDEVELD, Approximation results for preemptive stochastic online scheduling
R20 p.146	**Production planning**, *organizer/chair*: Laurence Wolsey YVES POCHET, Single item lot-sizing with non-decreasing capacities	SIMGE KÜÇÜKYAVUZ, Lot-sizing polyhedra with backlogging	PRODUCTION AND SCHEDULING KEREM AKARTUNALI, A computational comparison of lower bounds for big bucket production planning problems

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R5 p.149	**Advances in integer programming IV**, *organizer/chair*: Francois Margot ANUREET SAXENA, Cuts from multiple-term facial disjunctions	AGOSTINHO AGRA, A polyhedral study of a mixed integer set	INTEGER AND MIXED INTEGER PROGRAMMING ALEXANDER KOLOKOLOV, Stability analysis of some integer programming algorithms
R6 p.150	**Traffic and routing II**, *chair*: João Sarubbi FREDERICO CRUZ, Algorithms for system optimum on queueing networks	JOÃO SARUBBI, A fast QAP based formulation for the minimum latency problem	LOGISTICS AND TRANSPORTATION
R7 p.150	**Constraint logic programming**, *organizer*: Krzysztof Apt, *chair*: Daniela Pavel ERIC MONFROY, Using process calculi for dynamic enumeration strategies and hybrid solvers in constraint programming	CARLOS CASTRO, A rule-based approach for constraint solving	CONSTRAINT LOGIC PROGRAMMING DANIELA PAVEL, Optimisation with fuzzy logic
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R10 p.152	**Robust optimization and probabilistic guarantees**, *organizer*: Daniel Bienstock, *chair*: Aharon Ben-Tal AHARON BEN-TAL, Some remedies for intractable robust optimization	AKIKO TAKEDA, Worst-case violation of randomized solutions for uncertain convex optimization problems	ROBUST OPTIMIZATION OLIVIER KLOPFENSTEIN, A robust approach to the chance-constrained knapsack problem
R11 p.152	**Algorithms for LP and cone programming**, *chair*: Kees Roos MARINA ANDRETTA, Augmented Lagrangian method with lower-level linear constraints	PETER RICHTARIK, Improved algorithms for convex minimization in relative scale	LINEAR, CONE AND SEMIDEFINITE PROGRAMMING KEES ROOS, Full-Newton step polynomial-time methods for LO based on locally self-concordant barrier functions
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R13 p.153	**Nonlinear programming applications**, *chair*: Lara Urdaneta ISABEL MARIA NARRA FIGUEIREDO, A sizing optimization contact rod problem	FRANCISCO SOBRAL, A tool based on nonlinear programming for minimizing the object dimensions in circle and sphere packing problems	NONLINEAR PROGRAMMING HUGO URDANETA, Bayesian approach to solve inverse problems: application to exponential sum problems
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R16 p.154	**Traffic**, *organizer*: David Watling, *chair*: Agachai Sumalee NAGAE TAKESHI, A generalized complementarity approach for optimal maintenance a deteriorating transportation facility under dynamic uncertainty	AGACHAI SUMALEE, Properties of stochastic user equilibrium model as a smoothing function and its application to network design problems	COMPLEMENTARY AND VARIATIONAL INEQUALITIES YOUNES HAMDOUCH, Congestion pricing for capacitated transit networks with loading
R17 p.155	**Stochastic integer programming**, *organizer/chair*: Shabbir Ahmed PATRIZIA BERALDI, An exact approach for solving probabilistically constrained integer problems with random technology matrix	ANDREW SCHAEFER, Totally unimodular stochastic programs	STOCHASTIC PROGRAMMING AHMED SHABBIR, Polyhedral stochastic integer programming
R18 p.155	**Optimization on graphs and hypergraphs**, *organizer/chair*: Carmen Ortiz MONICA VILLANUEVA-ILUFI, Maximal Independent Sets of Caterpillar Graphs	PEH NG, Directed hypergraphs with balanced or totally unimodular incidence matrices	GRAPHS AND MATROIDS BOTING YANG, Strong-mixed searching and pathwidth
R19 p.156	**Planning and scheduling under uncertainty**, *organizer/chair*: Marc Uetz RUDOLF MÜLLER, Decentralization and mechanism design for online machine scheduling	ALEXANDER SOUZA, An average-case view on non-clairvoyant scheduling	PRODUCTION AND SCHEDULING CHAITANYA SWAMY, Approximation algorithms for stochastic optimization
R20 p.156	**Miscellaneous**, *chair*: Sueli Cunha GUSTAVO DA GAMA TORRES, Capacity and flow assignment with additional constrains	RODRIGO SCARPEL, Market-based pricing models: a policy evaluation approach.	PRODUCTION AND SCHEDULING SUELI CUNHA, Divers applications of a task model

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R3 p.159	**Enhancements to pure metaheuristics**, *organizer*: Paola Festa, *chair*: Mauricio Resende MAURICIO RESENDE, Global optimization by continuous GRASP	WEE CHONG WAN, Intelligent hybridization of metaheuristics	COMBINATORIAL OPTIMIZATION
R4 p.159	**Column generation**, *organizer*: Eduardo Uchoa, *chair*: Christophe Duhamel FRANCOIS VANDERBECK, Branching in branch-and-price: a generic scheme	CHRISTOPHE DUHAMEL, Branch and price for the minimum cost k-splittable flow problem	COMBINATORIAL OPTIMIZATION IRENE LOISEAU, A column generation algorithm for some networks design problems
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R14 p.163	**Convex optimization**, *organizer/chair*: Joerg Fliege JOERG FLIEGE, An efficient interior-point method for convex multicriteria optimization problems	GWI SOO KIM, Boundedness of epsilon-approximate solution set	NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING MARIA GONZALEZ-LIMA, A primal-dual interior-point method for quadratic
R18 p.163	**Graph coloring: a classical problem in new applications**, *organizer/chair*: Rossella Petreschi DEO NARSINGH, An edge-coloring algorithm for placing data and parity to tolerate two disk failures in RAIDs	MARTIN SKOVIERA, Colouring of cubic graphs and partial Steiner triple systems: a new look at old problems	GRAPHS AND MATROIDS
R19 p.164	**Approximation algorithms I**, *organizer*: Claire Kenyon, *chair*: David Williamson DAN STRATILA, Strongly polynomial primal-dual algorithms for concave cost combinatorial optimization problems	MATTHIAS MUELLER-HANNEMANN, Approximation of octilinear Steiner trees constrained by obstacles	APPROXIMATION ALGORITHMS MIKHAIL KHACHAY, On the computational complexity and approximability of the minimum committee combinatorial optimization problem
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Parallel Sessions: Abstracts

MO1-R1 COMBINATORIAL OPTIMIZATION
Heuristics I
chair: Dárlinton Carvalho

Towards a framework for heuristics based on vocabulary building

DÁRLINTON CARVALHO
PUC-Rio

coauthors: Celso Ribeiro, Carlos Lucena
keywords: car sequencing problem, frameworks, vocabulary building

Vocabulary building is an adaptive memory technique for heuristic search methods. Its main idea consists in identifying common portions from good solutions, called words, and recombining them into full solutions, called phrases. Vocabulary building heuristics learn from high quality solutions from promissory regions of the solution space. At the same time, they provide an alternative neighborhood search strategy for intensifying the search in promissory regions of the solution space. There are many ways to implement vocabulary building based heuristics. Frameworks are efficient architectural software solutions for implementing and comparing algorithms and programs from the same domain. We propose a framework for developing and testing vocabulary building heuristics. As a case study, we implement vocabulary building heuristics for solving the car sequencing problem, which consists in sequencing the daily production of real-life car factory. The problem was proposed by Renault as part of the ROADEF Challenge'2005. Experimental results are presented.

Learning objects to heuristics teaching process

ANDRE CORDENONSI
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coauthors: Felipe Martins Müller, Fábio da Purificação de Bastos, Fabricio Viero de Araujo
keywords: AMEM, learning objects, travelling salesman problem, virtual educational environment

The heuristics and met heuristics teaching process is centered in a set of mathematical models definitions and algorithms, which are presented in classrooms. This traditional model of education estimates the professor as a main mentor of the transference process of the mathematical theory to define algorithmically logical steps. The students must understand the algorithms and implement it in some programming language. In this paper, we present a learning object to assist the development of the classes by the teacher, using a simple and effective interface simulation system. The learning object simulates constructive and improvement algorithms to solve the Traveling Salesman Problem and the student can observe the algorithm development step-by-step in a graphical interface. A Virtual Educational Environment (AMEM) was developed to assist the interactions between students and the professor. In the AMEM environment, the professor can include learning objects in his own classes, improving the educational process.

MO1-R2 COMBINATORIAL OPTIMIZATION
Combinatorial optimization II
organizer/chair: Marcia Fampa

Experiments with extended capacity cuts

EDUARDO UCHOA
Universidade Federal Fluminense

coauthors: Ricardo Fukasawa, Jens Lysgaard, Artur Pessoa
keywords: cuts, extended formulations, integer programming

Extended Capacity Cuts (ECCs) can be defined as family of cuts valid for a pseudo-polynomially large extended formulation of the Fixed Charge Network Flow (FCNF) problem. Several other problems, like some vehicle routing and facility location variants, or the Steiner problem, can be naturally viewed as special cases of the FCNF. Therefore, ECCs can be used on all those problems. In fact, it can be shown that several well-known families of cuts for those particular problems are equivalent or dominated by ECCs. This talk discusses the implementation of an ECC separation routine and extensive computational experiments over the capacitated minimum spanning tree problem and over the heterogeneous fleet vehicle routing problem. The use of ECCs gives significant improvements over previous algorithms.

Branch-and-cut for robust single-machine scheduling

HONGXIA ZHAO
State University of New York at Buffalo

coauthors: Ming Zhao, Ismael de Farias
keywords: branch-and-cut, cutting planes, robust optimization

We present a branch-and-cut approach to the robust single-machine scheduling problem (RSMS), where the processing times for the jobs belong to a set of possible scenarios. We give a new formulation for RSMS and three families of facets for the convex hull of its feasible set. In addition, we give computational results that demonstrate the effectiveness of the facets as cutting planes for solving difficult instances of RSMS.

An improved algorithm for computing Steiner minimal trees in Euclidean d-space

KURT ANSTREICHER
University of Iowa

coauthor: Marcia Fampa
keywords: Euclidean Steiner problem, Steiner tree, strong branching

We describe improvements to Smith's branch-and-bound (B &B) algorithm for the Euclidean Steiner problem in $\Re^d$. Nodes in the B &B tree correspond to full Steiner topologies associated with a subset of the terminal nodes, and branching is accomplished by "merging" a new terminal node with each edge in the current Steiner tree. For a given topology we use a conic formulation for the problem of locating the Steiner points to obtain a rigorous lower bound on the minimal tree length. We also show how to obtain lower bounds on the child problems at a given node without actually computing the minimal Steiner trees associated with the child topologies. These

lower bounds reduce the number of children created and also permit the implementation of a “strong branching" strategy that varies the order in which terminal nodes are added. Computational results demonstrate substantial gains compared to Smith’s original algorithm.

MO1-R3 COMBINATORIAL OPTIMIZATION

Metaheuristics for real world applications

organizer: Claudio Meneses
chair: Claudio Barbieri

A GRASP based on conflict graph for the point-feature cartographic label placement problem

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Instituto Nacional de Pesquisas Espaciais

coauthors: Gildásio Cravo, Luiz Antonio Lorena
keywords: conflict graph, GRASP, heuristics, label placement

The point-feature cartographic label placement problem (PFCLP) is NP-hard and has been defying researchers both in theoretical aspects and in what concerns computational results.

Text labels convey information about points in graphical displays like cartographic maps. Thus, the PFCLP consists in placing labels to points on a map, in such a manner to maximize the legibility.

Several heuristics have been presented searching approximated solutions. Following this idea, we present a greedy randomized adaptive search procedure (GRASP) for the PFCLP that is based on its conflict graph. It has produced better solutions than all those reported in the literature in reasonable computational times.

A tabu search heuristic for the truckload pickup and delivery problem

CLAUDIO CUNHA
University of Sao Paulo

coauthor: Frederico A. Mourad
keywords: metaheuristics, tabu search, truckload pickup and delivery

Truckload carriers are constantly faced with the problem of shipping full truck loads of goods at minimum cost between pairs of cities or customers, using a fleet of trucks located at one or more depots. Thus, we consider the problem of routing and scheduling a homogeneous fleet of vehicles for truckload pickup and delivery in the presence of time windows as well as other constraints found in practice. We also allow the possibility of assigning third-party drivers that own their vehicles and are hired on a trip-to-trip basis, aiming to minimize the total transportation costs. Our approach for solving this problem is based on a simple and fast construction heuristic, followed by an improvement heuristic based on tabu search. We investigate some different tabu settings, including a variable tabu tenure mechanism for search diversification, as well as a simple granular restricted neighborhood. Results of computational experiments are also reported.

A hybrid metaheuristc for the permutational flow shop problem

FABÍOLA NAKAMURA
UFMG

coauthors: Martin Gómez Ravetti, Claudio Meneses, Mauricio Resende, Geraldo Robson Mateus, Panos Pardalos
keywords: flow shop problems, GRASP with ILS, memetic algorithms, metaheuristics

The Flow Shop Problem (FSP) is known to be NP-hard when considering more than 3 machines. Thus, for non-trivial size problem instances, heuristics are needed in order to find good orderings. In this work, we consider the permutational case of this problem (PFSP). In this case, the sequence of jobs has to remain the same at each machine, and the objective is to minimize the completion time (makespan), F/prmu/Cmax. We implement a hybrid metaheuristic combining elements from the standard Greedy Randomized Adaptive Search Procedure (GRASP), Iterative Local Search (ILS), and Memetic algorithms. The results thus obtained are shown to be competitive compared to existing algorithms.

MO1-R4 COMBINATORIAL OPTIMIZATION

Optimization and geometry

organizer/chair: Volker Kaibel

Nonlinear bipartite matching

YAEL BERSTEIN
Technion - Israel Institute of Technology

coauthor: Shmuel Onn
keywords: bipartite matching, Birkhoff polytope, combinatorial optimization, convex optimization

We consider a generalization of the standard linear bipartite matching problem defined as follows. For each edge in a complete bipartite graph there is a given d-dimensional weight vector. A functional on d-space is also given. The sum of the weight vectors of all edges in a matching defines the weight of the corresponding matching. The objective value of a matching is the value of the functional on its weight vector. The problem is to find a perfect matching optimizing the objective value. While it is generally intractable, using the projection of the Birkhoff polytope of bistochastic matrices by the given weights, we develop several efficient algorithms for solving the nonlinear bipartite matching problem, including a deterministic algorithm for maximizing convex objectives, approximative algorithms for norm optimization, and a randomized algorithm for optimizing arbitrary objectives. In particular, for binary weights, our results imply polynomial-time algorithms.

Optimizing discrete Morse functions

MARC PFETSCH
Zuse Institute Berlin

coauthor: Michael Joswig
keywords: acyclic matchings, Morse matchings

Discrete Morse functions where introduced by Forman in 1998 as a combinatorial analogy of classical smooth Morse theory and have many applications in combinatorial topology. Their essential structure is captured by so-called Morse matchings and one wants to maximize their cardinality. A Morse matching M consist of arcs in the Hasse diagram of a simplicial complex, such that two conditions are fulfilled: the arcs in M form a matching and if the arcs in M are reversed the result is still an acyclic digraph. Finding Morse matchings is related to the acyclic subgraph and the linear ordering problem.

The computation of optimal Morse matchings is an NP-hard problem, which we treat by a branch-and-cut method. To this end, I will present an integer programming formulation, investigate the corresponding polyhedral properties, and

present computational results. One core problem is the separation of so-called cycle inequalities, which amounts to finding a shortest cycle in an undirected graph with a conservative weighting (no cycle of negative length exists), which can be solved by T-join methods. We treat this problem by solving shortest paths problems in a related graph with nonnegative weights.

MO1-R5 OPTIMIZATION IN ENERGY SYSTEMS

Risk management in electricity, oil and gas market

organizer: Luiz A. Barroso
chair: Sergio Granville

CVaR formulation in dynamic programming for hydroelectric portfolio risk management

NIKO ILIADIS
EPFL

coauthors: Mario Pereira, Sergio Granville, Luiz A. Barroso
keywords: CVaR stochastic optimisation, hydroelectric assets optimisation, portfolio and risk management, stochastic dynamic programming

The objective of this paper is to formulate an optimisation model for hydro scheduling and risk management in deregulated electricity markets where hydropower companies face stochastic inflows, spot prices and forward prices in a portfolio subject to risk constraints. This portfolio management problem, which includes physical and financial assets, is formulated as a stochastic revenue maximization problem subject to risk constraints which is defined using Conditional Value at Risk constraints. As hydroelectric portfolio optimisation with multiple reservoirs is a large scale problem, a hybrid stochastic dynamic programming (SDP)/stochastic dual dynamic programming (SDDP) formulation is adopted where the future benefit function is approximated through Benders decomposition. Since the CVaR risk constraint is coupling all the states at every stage, a Lagrangian Relaxation was used. Spot price and hydrologic uncertainties are captured through scenarios.

Modeling the conditional value-at-risk into the portfolio optimization of energy contracts problem for generators dispatched in a tight pool scheme

LUIZ GUILHERME MARZANO
CEPEL - Centro de Pesquisas em Energia Elétrica

coauthors: Albert Cordeiro Geber de Melo, Claudia Sagastizabal
keywords: energy commercialization, portfolio optimization, risk management, stochastic programming

In this paper the portfolio optimization concept is applied to the energy commercialization area. The objective is to present an approach for the portfolio optimization problem of energy contracts in order to determine the energy commercialization strategy that maximizes the revenue of a generating company subject to the control of its risk exposure. The risk measure adopted is the Conditional Value-at-Risk. The system dispatch is performed by an Independent System Operator in a tight pool scheme, i.e., the generating company does not define its own dispatch. Among the risks faced by the generating company, we deal explicitly with the spot price and generators output uncertainties. Candidate contracts are divided into two sets: those of immediate decision and those that can be contracted in the future. This modeling leads to a large-scale two-stage stochastic programming problem that is solved by a decomposition method. Numerical results for the Brazilian system are discussed.

Short-term production planning in oil refineries: two mixed integer programming models

GERALDO VEIGA
RN Ciência & Tecnologia

coauthors: Abilio Lucena, Luidi Simonetti, Sérgio Monteiro
keywords: mixed-integer programming, oil refineries, production planning

We introduce two mixed integer programming formulations for the solution of short term planning problems in oil refineries. Starting with a heuristic procedure, the model pre-selects candidate productions chains. The tasks belonging to the production chains are assigned to each equipment, inducing a decomposition of the scheduling constraints. The first formulation is a continuous-time model, where the scheduling constraints are expressed as a linear ordering subproblem. The second is a discrete time model using a finite set of event/inspection points where tasks can be started and scheduling constraints enforced. The resulting models offer great flexibility and can be customized for a variety of production planning problems in multi-product batch plants.

MO1-R6 OPTIMIZATION IN NATURAL RESOURCES

Mining 1

organizer/chair: Alexandra Newman

Modelling and software design for optimal declines in underground mine development

DOREEN THOMAS
University of Melbourne

keywords: decline, optimization

In underground mining, the declines used for trucking ore to the surface typically have to satisfy a gradient and turning circle constraint to make them navigable for the large haulage trucks. In this talk we describe a method of modelling the problem of designing a least cost decline as a constrained path optimisation problem in 3-space and demonstrate a software tool DOT2 that we have developed to design such navigable paths. Another important constraint in this problem is that the access and haulage infrastructure should avoid certain regions, such as old workings, poor quality ground or the ore body itself. This "obstacle problem" is a well known hard problem in the area of shortest networks and is an important one to analyse and solve. We discuss our plans for new versions of DOT2 that take such obstacles into account.

Constrained path optimisation with applications to underground mine development

PETER GROSSMAN
University of Melbourne

keywords: underground mining

We study the problem of designing a minimum cost path connecting a given set of points in 3-space, where the path must satisfy a given gradient bound and a given curvature bound. We show that, using a dynamic programming approach, we can reduce the problem to one of computing an optimal planar path (a planar

path that is either of minimal length or of a given length) with bounded curvature between two points with given directions of travel. We are further able to show that nice geometric characterisations of such paths exist. This has important applications to the design of haulage and access declines for underground mines. We also discuss the problem of incorporating other key constraints relating to mine design into such an optimisation strategy.

This seminar, which focuses on the underlying theoretical issues in optimal decline design, is a companion talk to the previous paper by Doreen Thomas.

Combinatorial problems in mining

RAFAEL EPSTEIN
University of Chile

coauthor: Andres Weintraub
keywords: mining modeling

We present combinatorial problems related with the extraction of copper mines in both: underground and open pit operations. The main problem consists of finding the optimal sequence of investment projects and the associated long term operation plan. We show different formulations and algorithms to efficiently solve these problems. The methodology was tested in CODELCO, the Chilean State own company and the largest copper producer in the world, with significant improvements compared with traditional approaches.

MO1-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.

Emerging network design problems

organizer/chair: Gianpaolo Oriolo

Hardness of robust network design

MARIA GRAZIA SCUTELLÁ
Dipartimento di Informatica, Universitá di Pisa, Italy

coauthors: Chandra Chekuri, Gianpaolo Oriolo, Bruce Shepherd
keywords: network design, robust optimization, single-source hose model

We settle the complexity status of the robust network design problem in undirected graphs. In our model, the routing can vary as the traffic demand changes. The fact that the flow-cut gap in general graphs can be large, poses some difficulty in establishing a hardness result. So, we introduce a single-source version of the problem where the flow-cut gap is known to be one. We then show that this restricted problem is coNP-Hard. This version also captures, as special cases, the fractional relaxations of several problems including the spanning tree problem, the Steiner tree problem, and the shortest path problem.

Using mixed-integer programming to solve power grid blackout problems

SARA MATTIA
DIS - Università di Roma "La Sapienza"

coauthor: Daniel Bienstock
keywords: network design

During the last decade, several large-scale failures of national power transmission networks took place. We consider optimization problems related to the prevention of large-scale cascading blackouts in power transmission networks subject to multiple scenarios of externally caused damage. We present computation with networks with up to 600 nodes and 827 edges, and many thousands of damage scenarios.

Simple cost sharing schemes for multicommodity rent-or-buy and stochastic Steiner tree

GUIDO SCHAEFER
Technical University Berlin

coauthors: Lisa Fleischer, Jochen Konemann, Stefano Leonardi
keywords: approximation algorithms, network design problems, Steiner forest, stochastic programming

In the multicommodity rent-or-buy network design problem (MRoB) we are given a network together with a set of k terminal pairs $R = \{(s_1,t_1),\ldots,(s_k,t_k)\}$. The goal is to install capacities on the edges of the network so that a prescribed amount of flow f_i can be routed between all terminal pairs s_i and t_i simultaneously. We can either *rent* capacity on an edge at some cost per unit flow or *buy* infinite capacity on an edge at some larger fixed cost. The overall objective is to install capacities at a minimum total cost.

The version of the stochastic Steiner tree problem (SST) considered here is the Steiner tree problem in the model of two-stage stochastic optimization with recourse. In stage one, there is a known probability distribution on subsets of vertices and we can choose to buy a subset of edges at a given cost. In stage two, a subset of vertices T from the prior known distribution is realized, and additional edges can be bought at a possibly higher cost. The objective is to buy a set of edges in stages one and two so that all vertices in T are connected, and the expected cost is minimized.

Gupta et al. (FOCS '03) give a randomized scheme for the MRoB problem that was both used subsequently to improve the approximation ratio for this problem, and extended to yield the best approximation algorithm for SST. One building block of this scheme is a good approximation algorithm for the Steiner forest problem.

We present a surprisingly simple 5-approximation algorithm for MRoB and 6-approximation for SST, improving on the best previous guarantees of 6.828 and 12.6, and show that no approximation ratio better than 4.67 can be achieved using the above mentioned randomized scheme in combination with the currently best known Steiner forest approximation algorithms. A key component of our approach are cost shares that are 3-strict for the *unmodified* primal-dual Steiner forest algorithm.

MO1-R8 GAME THEORY

Voting games

organizer: Dennis Leech
chair: Karol Zyczkowski

Voting games with abstentions

ANTTI PAJALA
Doc. Pol. Sci., Researcher / University of Turku

keywords: abstain, algorithm, computation, voting power

The measurement of voting power, when voter abstention is allowed, is more complicated compared to the traditional yes-no voting. The literature suggests two basic intuitions for the measurement under abstention. A close investigation reveals there to be at least three distinctive computation algorithms producing different results. We present and discuss the algorithms and provide guidelines to implement the algorithms into computer software.

Critical point in voting games

KAROL ZYCZKOWSKI
Jagiellonian University, Cracow, Poland

coauthor: Wojciech Slomczynski
keywords: critical quota, Penrose - Banzhaf index, voting games, voting power

We study majority voting games and investigate the dependence of the voting power measured by the Penrose-Banzhaf index on the threshold for the qualified majority. A system based on the law of Penrose, in which each representative in the voting body receives voting weight proportional to the square root of the population he represents is analysed.

We demonstrate that for a generic distribution of the population there exists a critical point (an optimal quota) for which the voting power of any state is proportional to its weight. The optimal quota is shown to decrease with the number of players. This observation based on numerical results is supported by analytical model obtained for a particular class of population distributions.

MO1-R9 GLOBAL OPTIMIZATION

Global optimization for mathematical problems

chair: Tibor Csendes

A verified optimization technique to calculate topological entropy

BALÁZS BÁNHELYI
University of Szeged, Institute of Informatics

coauthors: Tibor Csendes, Barnabas M. Garay
keywords: topological entropy, verified optimization technique

First we show how topological entropy is definied. This technique is based on the covering property, and the covering matrix, which gives a lower bound for the entropy. Then we present a computer assisted proof of the covering property.

To find a region that fulfills the respective conditions, the program combines a global optimization procedure and our interval arithmetic based checking technique. We define a nonnegative penalty function, which is zero if and only if the structure does not hurt any given condition. When the program finds the optimum and it is zero, then the search is successful.

We applied this technique to a Henon map. The conjectured entropy value of this map is 0.465. We were able to improve the earlier, published result (0.338) to 0.382. In a recently published paper by Zbigniew Galias gave a better result (0.430).

Global optimization and verified numerical techniques for the solution of mathematical problems

TIBOR CSENDES
University of Szeged, Institute of Informatics

keywords: global optimization, interval methods, theorem prooving, validated numerics

The talk will summarize the results achieved recently at the University of Szeged investigating optimization models and validated numerical methods that allow us to prove theoretical statements of open mathematical problems. The first problem considered was the circle packing in the unit square. Mihaly Csaba Markot could refine earlier numerical techniques, and he has provided a reliable computational procedure that were successful in proving the optimality of some approximate solutions for the problem instances regarding 28, 29, and 30 circles. A general overview is given in a book in press describing the the state of the art on this field. The present talk will explain the most important new ideas that were necessary for the breakthrough.

The second set of results is related to the qualitative theory of differential equations, especially to chaos detection. Balazs Banhelyi composed a branch-and-bound based checking algorithm based on verified differential equation solver to prove the chaotic behaviour of the forced damped pendulum. We report on the full proof together with new details. Finally an optimization model and an adaptive reliable checking algorithm is described that can find chaotic regions for difficult mappings, such as some iterates of the Henon mapping.

Grid circle packings - a global optimization approach

PÉTER GÁBOR SZABÓ
University of Szeged, Dpt. Applied Informatics

keywords: discrete geometry, global optimization, stochastic algorithms

The problem is to place n equal and non-overlapping circles in a square, such that the common radius of the circles is maximal. The optimal solutions of this geometrical problem are known up to $n = 30$ circles using a reliable computer aided global optimization method. For higher n values stochastic optimization algorithms can find good approximate circle packings. The numerical results can then be validated by interval arithmetic computations.

On comparing the structures of the optimal and the best known packings, we can classify some packings into pattern classes. In this talk we study a special pattern class: the grid packings. Based on these arrangements we consider some infinite packing sequences from a number theoretically point of view too.

MO1-R10 MULTICRITERIA OPTIMIZATION

Sensitivity analysis in multiobjective programming

organizer/chair: Alejandro Balbás

Generalized stochastic discount factors with applications in marketing

MERCEDES ESTEBAN-BRAVO
Universidad Carlos III de Madrid

coauthors: Alejandro Balbás, Jose M. Vidal-Sanz
keywords: imperfections, marketing, stochastic discount factors

The paper draws on some optimization problems and representation theorems in order to introduce the concept of Stochastic Discount Factor in markets characterized by significant frictions. The generalized stochastic discount factors allow us to extend the Arbitrage Pricing Theory and its links with several notions of "Non Dominated Strategy". Some applications in Finance and Marketing are presented.

Balance points and duality with applications in risk analysis

SILVIA MAYORAL
Universidad de Navarra

coauthor: Alejandro Balbás
keywords: balance points, duality, multicriteria optimization, risk analysis

Several authors recently showed that the balance space approach may be an interesting alternative to address several topics concerning vector optimization. Indeed, this new look yields new theoretical results and algorithms, as well as new

economic interpretations. The present paper presents two duality and sensitivity theories linked to the balance space, showing that the use of balance points allows us to establish saddle-point-like conditions or subgradient-linked conditions that could apply in practice much more easily than those generated by more classical analyses. We draw on the practical possibilities of our duality results in order to address portfolio choice problems that simultaneously optimize several risk measures. In this sense we extend and generalize those recent analyses optimizing a single measure. As it is known there is no consensus in the literature when choosing the most appropriate measure of risk, since all of them may present some special drawback. Therefore, our extension could be an adequate alternative when dealing with modern portfolio choice problems.

Duality and sensitivity for balance points of set valued functions

ALEJANDRO BALBÁS
University Carlos III of Madrid

keywords: balance points, duality, sensitivity analysis, set valued function

The concept of balance point, introduced by Professor Galperin in 1990 for multiobjective optimization problems, is extended to set valued functions. Both finite and infinite dimensional frameworks are considered. Optimization problems involving balance points of set valued functions are addressed, as well as computational methods, duality theories and sensitivity analyses. Some relationships with more classical approaches in vector optimization are also studied.

MO1-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Approximately solving large scale linear programs

organizer/chair: Fabian Chudak

Fractional packing and covering

NAVEEN GARG
IIT DELHI

coauthor: Rohit Khandekar
keywords: approximation algorithms, fractional covering, fractional packing, Lagrangian relaxation

We present a unified framework to compute (1+ε approximation algorithms for fractional packing and covering problems. Our framework yields faster algorithms for computing the fractional optimum of many combinatorial optimization problems.

Approximation algorithms for facility locations with submodular penalties and generalized set covering problems

KIYOHITO NAGANO
Univ. of Tokyo

coauthor: Fabian Chudak
keywords: approximation algorithms, convex optimization, submodular functions

We provide new approaches to the facility location with submodular penalty and design (1+ε)-approximation algorithms for the relaxation of this problem without using the ellipsoid method. We extend the smooth minimization method of Nesterov and give an algorithm whose running time dependence on ε is ε^{-1}. Alternatively, by extending the subgradient method proposed by Nesterov, we substantially improve the comlexity of each iteration in general, although the dependence on ε becomes ε^{-2}. Furthermore by rounding a fractional solution we can give a constant factor approximation algorithm for facility location with penalties. We also consider the set covering problem with submodular costs.

A survey of recent results on approximate algorithms for solving linear programs

FABIAN CHUDAK
IFOR, RTH

keywords: approximation schemes, gradient and subgradient algorithms, primal-dual algorithms for convex optimization

In this talk, I will review some very recent results on provably good approximation algorithms for solving linear programs. The objective is to tackle large scale problems that cannot be solved using currently available commercial software. During most of the talk I will adopt the non-linear programming point of view since most of the algorithms are based on solving the non-smooth Lagrangian dual problem. Examples will be given mostly for linear programming relaxations of combinatorial optimization problems, such as network design and scheduling jobs on unrelated parallel machines.

MO1-R12 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Applications of LP and cone programming I

chair: Hakan Umit

Modeling deposits in the banking sector usig directional distance functions

ELENA PACHKOVA
University of Copenhagen

coauthor: Natalia Konstandina
keywords: deposits, directional distance functions, efficiency

Since deposits in the banking sector both has input and output features it has not been clear how to model it when calculating the efficiency og a banking unit. Thus, there exist two main approaches, the intermediation and the production approach, where the deposits are treated as inputs and outputs respectively. Here we present an alternative approach based on directional distance functions that takes both the input and the output characterictics of deposits into consideration.

IGP weight optimization using column generation

HAKAN UMIT
Université catholique de Louvain

coauthor: Bernard Fortz
keywords: column generation, internet traffic engineering

Interior Gateway Protocol (IGP) is one of the most popular protocols used by Internet Service Providers (ISP). In order to support drastically growing internet traffic with minimal network congestion and packet delay several traffic engineering techniques are deployed, such as IGP weight optimization. In an Autonomous System (AS), links that connect IGP routers have certain metric (weight or cost of transferring an IP packet) that can be modified by network administrators. However, finding an optimum combination of these integer weights is NP-Hard due to hard protocol constraints, e.g. a flow is evenly distributed among the shortest paths of its origin and destination routers. Therefore, heuristic techniques have become essential to obtain near optimal solutions. In this study we present a column generation approach to generate fast and efficient IGP weights. We present experimental results that were done using real and synthetic internetworks.

MO1-R13 NONLINEAR PROGRAMMING

Derivative-free optimization

organizer/chair: Katya Scheinberg

Some new results in derivative free optimization

ANDREW CONN
IBM T J Watson Research Center

coauthors: Katya Scheinberg, Luis Vicente
keywords: derivative free optimization

Some new results on derivative free methods will be presented. We present a general framework for a trust region derivative free algorithm that, for the models, assumes only that they can be made to satisfy Taylor-like error bounds. Under the assumptions that need to be satisfied by the function and the algorithm a suitable second order convergence proof is given. This has broader implications for, for example, second-order trust-region methods and is of both theoretical and practical interest.

Improving efficiency in pattern search methods

ANA CUSTODIO
New University of Lisbon

coauthor: Luis Vicente
keywords: derivative free optimization, pattern search methods, poisedness, simplex gradient

Pattern search methods are widely used in practice but have the major drawback of sometimes being very slow. In this talk we will introduce a number of ways of making pattern search more efficient by reusing previous evaluations of the objective function, based on the computation of simplex derivatives (e.g., simplex gradients).

At each iteration, one can attempt to compute an accurate simplex gradient by identifying a sampling set of previous evaluated points with good geometrical properties. The simplex gradient can then be used to reorder the evaluations of the objective function associated with the directions used in the poll step or to update the mesh size parameter according to a sufficient decrease criterion, neither of which requires new function evaluations. A search step can also be tried along the negative simplex gradient at the beginning of the current pattern search iteration.

We will present these procedures in detail and apply them to a set of problems which includes test problems from the CUTEr collection and two applications problems (one related to the simulation of a mechanical system and another resulting from the adjustment of stellar modeling parameters). Numerical results show that these procedures can enhance significantly the practical performance of pattern search methods.

Study of convergence of Wedge derivative free algorithm.

KATYA SCHEINBERG
IBM T.J. Watson Research Center

coauthors: Andrew Conn, Luis Vicente
keywords: derivative free optimization, global convergence, trust region methods

All existing derivative free algorithms based on polynomial interpolation have to balance the quality of the geometry of the interpolation set and the number of the objective function evaluations. Derivative free optimization (DFO) algorithm poposed by Conn, Scheinberg and Toint generates special geometry improving sample points, when the model is suspected to be poor. This algorithm enjoys global convergence property. Wedge derivative free algorithm, proposed Marazzi and Nocedal, has a different and unique approach to geometry handling. It imposes the geometry constraints on the iterates, which are, otherwise, generated solely to improve the objective function. Thus the algorithm attempts to maintain the quality of the polynomial models at all times. So far this algorithm, although successful in practice, was lacking convergence theory. We will use our recently developed general framework for convergence proofs for DFO algorithms to show how to modify Wedge algorithm so that we can obtain global convergence results. Joint work with A.R. Conn and L.N. Vicente.

MO1-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Nonsmooth optimization with structure

organizer/chair: Warren Hare

A coordinate gradient descent method for nonsmooth separable minimization

SANGWOON YUN
University of Washington

coauthor: Paul Tseng
keywords: gradient descent method, nonsmooth optimization, separable optimization

We consider the problem of minimizing the sum of a smooth function and a *separable* convex function. This problem includes as special cases bound-constrained smooth optimization and smooth optimization with ℓ_1-regularization. We propose a (block) coordinate gradient descent method for solving this class of nonsmooth separable problems. The method is simple, highly parallelizable, and suited for large-scale applications in signal/image denoising, regression, and data mining/classification. We establish global convergence and, under a local Lipschitzian error bound assumption, local linear rate of convergence for this method. The local Lipschitzian error bound holds under assumptions analogous to those for constrained smooth optimization, e.g., the convex function is polyhedral and the smooth function is (nonconvex) quadratic or is the composition of a strongly convex function with a linear mapping. We report numerical experience with solving the ℓ_1-regularization of unconstrained optimization problems from Moré et al. Comparison with L-BFGS-B and MINOS, applied to a reformulation of the ℓ_1-regularized problem as a bound-constrained smooth optimization problem, is also reported.

A rapidly convergent VU-algorithm for general conv

ROBERT MIFFLIN
Washington State University

coauthor: Claudia Sagastizabal
keywords: bundle methods, convex optimization, proximal points, VU-decomposition

This talk describes a modification of a recently published VU-algorithm for minimizing convex functions including "infinitely-defined" ones resulting from inner maximization or integration. The change allows for a certain "prox-parameter" to go to infinity. We show global convergence of the modified algorithm and provide a strategy for prox-parameter variation which reduces the number of function evaluations needed to solve some numerical test problems.

The algorithm exploits natural (VU-decomposition) structure of a function

without having to know it explicitly and without adding extraneous structure from barrier or smoothing functions. The method employs a bundle subroutine that collects subgradients for constructing a V (cutting-plane)-model of the function and a corresponding U-gradient needed for the method's U-Newton predictor-steps that alternate with its V-corrector-steps. When the function has a "primal-dual track" leading to a (minimizing point, zero subgradient) pair the algorithm follows this track in a superlinear manner.

Identifying smooth substructure via proximal points

WARREN HARE
McMaster University

keywords: proximal points

Recent developments in nonsmooth optimization have provided several classes of functions which, although nonsmooth themselves, contain an underlying smooth substructure. Recent work has not only shown surprising relationships between each of these classes, but also shown a strong relationship between these classes and the classical proximal point mapping. More specifically, for each of these classes the underlying smooth substructure can be (theoretically) identified by the proximal point mapping. The beauty of this approach is that for many functions the proximal point mapping can be computed to any desired accuracy via simple algorithms which require only black-box information of the function value and gradient values as individual points. In this talk we discuss these results, and new techniques for computing proximal points for nonconvex functions.

MO1-R15 GENERALIZED CONVEXITY/MONOTONICITY
Convexity and monotonicity
chair: Wilfredo Sosa

Strong well-posedness properties of vector quasiconvex optimization problems

GIOVANNI CRESPI
Université de la Vallée d'Aoste

coauthors: Matteo Rocca, Angelo Guerraggio
keywords: generalized convexity, vector optimization, well-posedness

Well-posedness of a scalar minimization problem is a classical notion and plays a crucial role in the stability theory for optimization problems. The notion of well-posedness for vector valued problems is less developed. However some definitions have been proposed for vector minimization problems and some comparisons have been made among these definitions and with their scalar counterparts. In this talk we investigate well-posedness properties of vector optimization problems with quasiconvex objective functions. In particular we show that such problems are well-posed in the strongly extended sense. This well-posedness notion has been introduced in and reveals to be the strongest among the existing ones. Further, from these results we derive some stability properties of vector quasiconvex optimization problems.

Proximal methods applied to quasiconvex programming

PAULO OLIVEIRA
COPPE/UFRJ

coauthors: Erik Quiroz, João Cruz Neto, Francisco Cunha
keywords: proximal point algorithm, quasiconvex programming

In this talk, we present some new results on proximal algorithms applied to continuous quasiconvex programming in finite dimensional spaces, and Hadamard manifolds. Let λ_k the multiplicative regularization parameter at k iteration. In a Hadamard setting, so, also Euclidian, we get the convergence to an optimal solution, whose existence is supposed, for a class of proximal-Bregman methods, when $\lambda_k \to 0$. In the same setting and hypothesis on λ_k, we get the convergence for proximal algorithms, associated with the manifold distance. In Euclidian spaces, we get, for unconstrained problems and continuously differentiable functions, the convergence to a critical point of the problem, for λ_k bounded, of the classical proximal algorithm. We also consider the minimization for C^1 functions, on the positive octant, through a proximal point algorithm with $\varphi-$divergence of log type. We obtained the convergence to a critical point, for λ_k bounded.

Coerciveness for equilibrium problems

WILFREDO SOSA
Instituto de Matematica y Ciencias Afines

keywords: convex analysis, equilibrium problems, recession cones

Based on the notion of coerciveness in optimization theory, we introduce coerciveness and weakly coerciveness for equilibrium problems and using its, we comments some necessary and/or sufficient condictions for the existence of equilibrium points.

MO1-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES
Stability and sensitivity analysis
organizer: Mikhail Solodov
chair: Muddappa Gowda

Z-transformations on proper and symmetric cones

MUDDAPPA GOWDA
University of Maryland, Baltimore County

coauthor: Jiyuan Tao
keywords: Euclidean Jordan algebra, proper/symmetric cone, quadratic representation, stability/diagonal stability

A Z-matrix is a real square matrix whose off-diagonal entries are nonpositive. Extending this notion, we introduce Z-transformations on proper cones and symmetric cones (in Euclidean Jordan algebras). Examples include Lyapunov and Stein transformations. In this talk, we show that many properties of Z-matrices extend to Z-transformations. In particular, we describe P, Q, positive stability, and diagonal stability properties.

Characterizing Lipschitz stability in terms of explicit limits

JAN HEERDA
Humboldt University Berlin, Department of Mathematics

keywords: Lipschitz stability, perturbed stationary solutions

Generalized equations may describe solutions of various problems: They may be used for the analysis of Karush-Kuhn-Tucker or stationary points of perturbed nonlinear problems, which for instance play a role if solutions of some problems are involved in another one. They also reflect solutions of parametric variational conditions or describe equilibria in games, solutions in mathematical programs of equilibria problems (MPECs) or multilevel models.

We are interested in local Lipschitz stability of related solutions. In current literature it is standard to reformulate Lipschitz stabilities with aid of generalized derivatives. In this way one gets a different prospect to the problem. Recent research showed that it is also possible to characterize several types of Lipschitz stability – namely strong Lipschitz stability, Aubin property and calmness – explicitly in terms of some limits which do not appear in the context of known generalized derivative concepts. It is an aim of future research to examine those limits in greater detail and hopefully get a deeper insight into stability. Particular results for concrete mappings will be presented in the talk.

Sensitivity analysis for complementarity problems

RUBEN MONTOYA
Universidad Catolica de la Santisima Concepcion

keywords: asymptotic analysis, coercive existence sets, complementarity problem, sensitivity analysis

In this work we develop a sensitivity theory for multivalued complementarity problems in finite-dimensional spaces. This topic has wide range of applications in optimization, nonlinear analysis, economics, etc. We employ an asymptotic technique based on the approximation of the initial problem by a sequence of approximate problems. To this end we choose suitable metrics on the space of sets and mappings. Firstly, we obtain coercive existence results which are given in terms of some sets termed coercive-existence-sets. Secondly, we employ such sets in order to obtain new sensitivity/stability results and bounds for the solution sets. Finally, we deal in particular with the piecewise polyhedral and nonlinear complementarity problems.

MO1-R17 SEMI-INFINITE PROGRAMMING
Structural analysis of GSIP
organizer/chair: Oliver Stein

On the feasible set in generalized semi-infinite programming

HARALD GUENZEL
RWTH Aachen University

keywords: marginal functions, parametric optimization, semi-infinite programming

Passing (from ordinary) to generalized semi-infinite programming one observes that the feasible set M need not to be closed anymore. Thus, insisting on feasibility, there need not exists any optimal point, even if the feasible set is bounded. This drawback could easily be removed by considering the *closure* of the feasible set rather than the feasible set itself. But how can the closure of a set such complex as the feasible set in generalized semi-infinite programming be described in explicit terms? The present paper gives an answer to this question under mild conditions. Surprisingly enough, the closure $\overline{M}$ of M is obtained, if the varying index set $Y(x)$ in the description of M is replaced by its interior.

As a side result, we present a "symmetric" description of $\overline{M}$. In fact it turns out, that $\overline{M}$ is independent of where a g_i appears in its description: as the constraint on x for all $Y(x)$ or as a constraint on the index y in the definition of $Y(x)$.

As another side result we present a strong theorem on marginal functions. For the special case of free optimization problems this theorem reads as follows. Marginal functions of parametric free optimization problems are differentiable at values of the parameter, where the optimizer is unique.

MO1-R18 GRAPHS AND MATROIDS
Constraint Satisfaction and Clustering
organizer: Celina Figueiredo
chair: Sulamita Klein

Supermodular optimization on lattices and maximum constraint satisfaction

ANDREI KROKHIN
University of Durham

coauthor: Benoit Larose
keywords: constraint satisfaction, finite lattice, supermodular function, tractability

We consider the problem of maximizing a supermodular function defined on the product of n copies of a fixed finite (not necessarily distributive) lattice. In the simplest case, when the lattice is a two-element chain, this problem is the standard problem of maximizing a supermodular set function. We describe a large class of lattices for which this problem is solvable in polynomial time in n, assuming that functions are given by an oracle.

We will also describe a recently discovered strong link between supermodularity on lattices and tractability of optimization problems known as maximum constraint satisfaction problems (Max CSP). An instance of Max CSP is given by a collection of weighted constraints on overlapping sets of variables, and the goal is to find values for the variables that maximize the total weight of simultaneously satisfied constraints.

New p-median formulation of multicast sessions aggregation problem

NATHALIE FAURE
France Telecom R&D & LIP6

coauthor: Eric Gourdin
keywords: clustering, integer programming, p-median problem

We consider a family of p-median problems where symmetries in the cost function allow to choose any element of a cluster to be its center. We propose an Integer Programming formulation exploiting the symmetry which outperforms the usual formulations. Such situations often occur in the context of clustering problems. These problems can also be used to model situations where several multicast sessions must be aggregated into p clusters. More precisely, each one of customers requires some of the possible sessions. Network constraints force to use a limited number of clusters (for instance p) to route sessions so it is necessary to group the sessions. In such a cluster, every session required by some of its customers must be sent to all the customers of the cluster, even to those that did not require the session. The problem consists in aggregating the sessions into p clusters to limit the number of unnecessary information sent to customers.

MO1-R19 TUCKER PRIZE
Tucker Prize Committee
organizer/chair: Tom McCormick

MO1-R20 PRODUCTION AND SCHEDULING
Real-world problems
chair: Emily Duane

Column generation helping the Ecuadorian flower export industry

LUIS MIGUEL TORRES CARVAJAL
Escuela Politécnica Nacional

coauthors: Diego Recalde, Sandra Gutiérrez, Fernanda Salazar, Ramiro Torres
keywords: column generation, integer programming, production planning

An Ecuadorian rose export company cultivates about 60 varieties of roses, and combines them into several dozens of products that are sold to customers in the United States and some European countries. Size of flower, length of stem and age are factors used to further classify the flowers into more than 600 categories. A set of acceptance rules defines which of these flowers may be used in each product. Moreover, flowers may also be sold to / bought from other local producers at the so-called "open market". Standing orders that have to be satisfied in any case, prices changing frequently, and narrow deadlines for selling cultivated flowers before they get too old are additional aspects to be taken into account. We present an integer programming model designed for the daily production planning that aims at maximizing global revenue, and a solution algorithm based on column generation.

The use of a MIP model to identify investments in soybean storage units in the state of Mato Grosso, Brazil

RENATA FERRARI
ESALQ/USP

coauthor: José Vicente Caixeta-Filho
keywords: agriculture, bulk grains, soybean

To define the spatial rearrangement of the static capacity of soybean storage in the state of Mato Grosso in Brazil, a mixed-integer programming model was specified, seeking for the reduction of logistic costs involved in transporting the grain production to warehouses and from there to the main harbors in Brazil. Assuming the transportation from warehouses to harbors would be occur through the most economical option (which meant - basically - intermodal connections), the results obtained from the model confirm that there was a tendency to expand the capacity of storage of that state up to 1.4 million tons, specially in the regions of the North and Northeast of Mato Grosso. Besides, the regions of Alto Paraguai (Center-South), Alto Araguaia (Southeast), Nova Lacerda and Tangara da Serra (Southwest) presented high gaps in their capacity of storage - with relation to their grain production levels - revealing themselves as potential places to get expansion investments.

Improving crane scheduling and container handling operations at seaport container terminals

EMILY DUANE
The University of Melbourne

coauthors: Natashia Boland, Andre Costa, Gary Froyland
keywords: gantry crane scheduling

Sea freight containers are used to transport goods from one location to another. With increasing competition between seaport container terminals and greater containerization of cargo, there is great demand to improve container handling.

In this talk we highlight the problem of scheduling rail-mounted gantry cranes. The crane scheduling problem can be modeled as a discretized time-expanded network. The single crane scheduling problem can also be viewed as the Generalized Asymmetric Traveling Salesman Problem with Time Windows. We present some recent results from our investigations of these and other model formulations.

MO1-R21 DYNAMIC PROGRAMMING

Advances in dynamic programming methodology

organizer/chair: Marina Epelman

LP-based local approximation for Markov decision problems

JÖRG RAMBAU
University of Bayreuth

coauthors: Stefan Heinz, Volker Kaibel, Matthias Peinhardt, Andreas Tuchscherer
keywords: column generation, large scale linear programming, Markov decision problems, online optimization

The standard computational methods for computing the optimal value functions of Markov Decision Problems (MDP) require the exploration of the entire state space. This is practically infeasible for applications with huge numbers of states as they arise, e.g., from modeling the decisions in online optimization problems by MDPs. Exploiting column generation techniques, we propose and apply an LP-based method to determine an ε-approximation of the optimal value function at a given state by inspecting only states in a small neighborhood. In the context of online optimization problems, we use these methods in order to evaluate the quality of concrete policies with respect to given initial states. Moreover, the tools can also be used to obtain evidence of the impact of single decisions. This way, they can be utilized in the design of policies.

Sampled fictitious play algorithms for large-scale DPs and MDPs

MARINA EPELMAN
University of Michigan

coauthors: Archis Ghate, Robert Smith
keywords: dynamic programming, fictitious play

Sampled Fictitious Play (SFP) is a recently proposed technique for solving large-scale discrete optimization problems. In this talk, we focus on applications of SFP to large-scale discrete finite-horizon dynamic programs and Markov decision problems. We will describe several versions of the algorithm, discuss their theoretical convergence guarantees, and demonstrate their computational efficiency on various examples.

MO2-R2 COMBINATORIAL OPTIMIZATION

Combinat. Opt. in VLSI design I: paths and flows

organizer/chair: Jens Vygen

A new transportation algorithm with applications to VLSI placement

ULRICH BRENNER
Uni-Bonn

keywords: minimum-cost flows, transportation problem, VLSI placement

We present a new algorithm for the HITCHCOCK TRANSPORTATION PROBLEM. On instances with n sources and k sinks, our transportation algorithm has a worst-case running time of $O(nk^2(\log n + k\log k))$. This algorithm closes a gap between algorithms which have a running time linear in n but exponential in k and a polynomial-time algorithm with running time $O(nk^2\log^2 n)$. The HITCHCOCK TRANSPORTATION PROBLEM has an important application in the placement of VLSI chips where a large number of modules has to be arranged in a given area. We describe how our transportation algorithm is used as a main ingredient of the leading-edge VLSI placement tool BONNPLACE.

Optimizing yield and power in global routing

DIRK MUELLER
Uni-Bonn

keywords: global routing, network flows, tree packing, VLSI design

We present the first efficient approach to global routing of VLSI chips that takes spacing-dependent costs into account and provably finds a near-optimum solution including these costs. We show that this algorithm can be used to optimize power consumption and manufacturing yield. The core routine is a parallelized fully polynomial approximation scheme, scaling very well with the number of processors. We present results on state-of-the-art industrial chips, showing that our algorithm reduces power consumption and the expected number of defects in wiring significantly.

Generalizing Dijkstra's algorithm to speed up path searches in huge grids

SVEN PEYER
Uni-Bonn

keywords: Dijkstra's algorithm, VLSI routing

We generalize Dijkstra's algorithm to compute shortest paths in huge undirected graphs with non-negative edge lengths. The main idea is to cover the vertex set V by l subsets and label these subsets instead of individual vertices. With some natural assumptions on the subsets V_i we get a running time of $O(l\log l)$. We apply this algorithm to 3-dimensional grid graphs in order to speed up path search in VLSI routing. Here we use two different granularities of the sets V_i. This enables us to find millions of exact shortest paths in a graph with billions of vertices on current industrial chips in a few hours.

MO2-R3 COMBINATORIAL OPTIMIZATION

Topics on neighborhood search

organizer: Gerhard Reinelt
chair: James Orlin

Solving the maximum flow network interdiction problem with local search

OZLEM ERGUN
Georgia Tech

coauthors: Doug Altner, Nelson Uhan
keywords: local search, maximum flow network interdiction

We investigate the effectiveness of local search for the Maximum Flow Network Interdiction Problem (MFNIP) for the deterministic, single commodity case. Although this problem has gained much attention during the last few years, very little work on local search based approaches has been documented. In practice, the computational difficulty of this problem is very sensitive to the interdiction resource budget. Our goal is to develop methods that consistently obtain good solutions over a wide range of budgets in a timely fashion. Two main kinds of variable-depth neighborhoods are developed: neighborhoods based on cut-sets and neighborhoods based on simple arc exchanges. The former works with minimum cuts and the latter employs maximum flows to define and search the respective neighborhoods. Various implementations for the these methodologies are tested. We present computational results, and discuss how well these approaches generalize to natural extensions of MFNIP.

Using grammars to generate very large scale neighborhoods for sequencing problems

JAMES ORLIN
Massachusetts Institute of Technology

coauthor: Agustin Bompadre
keywords: sequencing problems

Local search heuristics are among the most popular approaches to solve hard optimization problems. Among them, Very Large Scale Neighborhood Search techniques present a good balance between the quality of local optima and the time to search a neighborhood. We show how context free grammars can generate exponentially large neighborhoods for sequencing problems. Moreover, we show that theneighborhoods can be efficiently searched by "generic" dynamic programs for the Traveling Salesman Problem, the Linear Ordering Problem, as well as other sequencing problems. This framework unifies and extends a variety of previous results on exponentially large neighborhood for the Traveling Salesman Problem.

Travel-time minimization in transportation networks by near-optimal tollbooth placement

LUCIANA BURIOL
UFRGS

coauthors: Mauricio Resende, Tania Querido, Michael Hirsch, Don Hearn, Panos Pardalos
keywords: memetic algorithms, tollbooth, transportation network

We present a memetic algorithm to place K tollbooths and set corresponding tolls on a capacitated transportation network such that when travelers take a least-cost route, their expected travel time is minimized. We illustrate the algorithm on five real networks: Sioux Falls, Anaheim, Stockholm, Barcelona, and Winnipeg.

MO2-R4 COMBINATORIAL OPTIMIZATION

Branch and cut and price

organizer: Adam Letchford
chair: Marcus Poggi de Aragão

Trends in robust (and non-robust) branch-cut-and-price

MARCUS POGGI DE ARAGÃO
PUC-RIO

coauthor: Eduardo Uchoa
keywords: branch-cut-and-price, column generation, mixed-integer programming

We first discuss the concept of robustness in BCP algorithms, revising the previous definitions towards a higher degree of formalization. Representative examples of robust and non-robust BCP's on problems such as Vehicle Routing, Graph Coloring, Bin Packing / Cutting stock and Capacitated Minimum Spanning Tree are analyzed, showing that robustness in the proposed technical sense is indeed quite correlated to robust algorithms in the practical sense. Next, we discuss and present some new results on robust BCPs. On these we try to take full advantage of robust pricing methods by introducing a large number of additional extended variables in the Master. Cuts over those variables may be stronger and/or easier to separate. Finally, we try to give some insights about decomposition choices.

A branch-and-cut algorithm for the Chilean soccer championship

THIAGO NORONHA
PUC-RIO

coauthors: Guillermo Durán, Celso Ribeiro, Andres Weintraub, Sebastian Souyris
keywords: branch-and-cut, integer programming, sport scheduling

The Chilean soccer championship follows the structure of a compact single round robin. Good schedules for the games are of major importance for the success of the tournament, making them more balanced, profitable, and attractive. The schedules were randomly prepared until 2004. The main drawbacks of such schedules were addressed in 2005, when the problem was tackled by a first integer programming model. Although the new schedules were better than the previous ones, the computation times were high and the solutions produced by the model had high gaps. In this work, we tackle the problem of scheduling the games of Chilean championship with the two new objective functions. The original integer programming formulation is improved. Valid inequalities are derived and appended to the model. A new branch-and-cut strategy is used to speedup convergence. Preliminary results on a real-life instance are reported, illustrating the effectiveness of the approach and the improvement in solution quality.

A hybrid relax-and-cut / branch-and-cut algorithm for the degree constrained minimum spanning tree problem

ALEXANDRE CUNHA
COPPE/UFRJ

coauthor: Abilio Lucena
keywords: branch-and-cut, Lagrangian shortcuts to linear programming, relax-and-cut algorithms

In this work, we introduce a new exact algorithm for the Degree Constrained Mnimum Spanning Tree Problem (DCMST) based on two phases. The first one is a Lagrangian Relax-and-Cut method, while the second is a Branch-and-Cut algorithm. Both relies on formulatilons strengthened by Blossom Inequalities. An important feature of the proposed algorithm is that whenever optimality is not proven by Relax-and-Cut alone, an atractive set of valid inequalities is carried from Lagrangian Relaxation to a warm Linear Programming Relaxation, as an attempt to obtain an initial LP lower bound at least as good as the best Lagrangian one, without the need of separation algorithms. Although it was proposed in the context of the DCMST, the approach for obtaining such bound may be extended to other problems which admit relaxations defined over matroids. Our computational experiments show that the use Blosssom inequalities and the advanced LP basis constribute to reduce CPU times.

MO2-R5 OPTIMIZATION IN ENERGY SYSTEMS

Supply function and dispatch models in electricity

organizer/chair: Andy Philpott

A Markov DP supply offer construction model for electricity generators with intertemporal constraints

PAUL STEWART
University of Canterbury, New Zealand

coauthors: Read Grant, James Ross
keywords: dynamic programming, electrical supply function, electricity, intertemporal

This paper presents a multi-dimensioned DP for constructing optimal offers for generators operating in a wholesale electricity market. The algorithm uses a two-stage approach whose computational time increases at a substantially slower rate than previously published algorithms as the problem size increases, thus being able to solve more practical problems. The DP considers many complexities together (such as limited fuel, uncertain inflows, uncertain and correlated residual market scenarios, and unit operating rules) which previously were only considered independently.

Interior point methods for large scale dc optimal power flow

ANIBAL AZEVEDO
UNICAMP

coauthors: Aurelio Oliveira, Secundino Soares
keywords: dc optimal power flow, interior-point methods, large scale

This work presents a predictor-corrector interior point method that solve a DC optimal power flow, where the Kirchhoff laws are represented by a network flow with side constraints and was applied to Brazilian power systems with up to 4000 bars. Some modifications are introduced such to consider phase shifters and loss calculation. The interior point method was implemented in Matlab and shows robustness with fast convergence for all test cases. Another important part of this work was the analysis for the large quantities of results obtained by the optimization process. Without any geographical information (like latitude or longitude coordinates), special visualization software in Java was employed that permitted the graphical inference for power flow violation in some transmission branches. In addition to this, we may present an extension for the original predictor corrector interior point method such that DC optimal power flow with security constraints is solved.

Primal-dual interior point method applied to AC optimal active-reactive power flow problem

ADRIANO THOMAZ
Unicamp

coauthors: Aurelio Oliveira, Secundino Soares

keywords: interior-point methods, nonlinear programming, optimal power flow

The primal-dual interior point method is developed to the AC optimal active and reactive power flow problem. The representation of the tensions through cartesian coordinates is adopted, once that Hessian of the problem is constant and the expansion in Taylor is accurate for the second order term. The advantage of working with polar coordinates, that easily model the tension magnitudes, lose importance due to the efficient treatment of inequalities proportionated by the interior point methods. Before the application of the method, the number of variables of the problem is reduced through the elimination of free dual variables. This reduction does not modify the sparse pattern of the problem. The linear system obtained can be reduced to the dimension of twice the number of buses. Moreover, such matrix is symmetric in structure. This feature can be explored reducing the computational effort per iteration.

MO2-R6 OPTIMIZATION IN NATURAL RESOURCES

Mining 2

organizer/chair: Alexandra Newman

Optimization in the mining industry

ALEXANDRA NEWMAN
Colorado School of Mines

keywords: integer programming, mining application, production planning, scheduling

LKAB's Kiruna mine is an underground sublevel caving mine located above the Arctic circle in northern Sweden. The iron ore mine currently uses a long-term production scheduling model to strategically plan its ore extraction sequence. We describe how we modify this model to incorporate both short- and long-term decisions, and present an optimization-based heuristic, whose efficacy we support with numerical results.

Programming operations in a copper refining and casting process

VICTOR PARADA
Universidad de Santiago de Chile

coauthors: Pradenas Lorena, Nuñez Gino, Jacques Ferland

keywords: copper smelter, heuristics, parallel machines, scheduling

In this paper we describe the scheduling problem in a refining and casting copper smelter plant. A mathematical model represents the daily operation of the plant. The Gantt chart corresponding to the solution of maximum production is obtained by means of a heuristic procedure. Numerical results show that the heuristics procedure generates solutions having smaller total flow times and considering less equipment than those produced by an expert manager.

MO2-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.

Real-world routing

organizer/chair: Andreas Bley

Length-bounded cuts and flows

HEIKO SCHILLING
TU Berlin

coauthors: Georg Baier, Thomas Erlebach, Alexander Hall, Ekkehard Koehler, Martin Skutella

keywords: approximation algorithms, hardness of approximation, length-bounded cuts, length-bounded edge-disjoint paths

An L-length-bounded cut in a graph G with source s, and sink t is a cut that destroys all s-t-paths of length at most L. An L-length-bounded flow is a flow in which only flow paths of length at most L are used. We show that the minimum length-bounded cut problem in graphs with unit edge lengths is NP-hard to approximate within a factor of at least 1.1377 for $L \geq 5$ in the case of node-cuts and for $L \geq 4$ in the case of edge-cuts. We also give approximation algorithms of ratio $\min\{L, n/L\}$ in the node case and $\min\{L, n^2/L^2, \sqrt{m}\}$ in the edge case, where n denotes the number of nodes and m denotes the number of edges. We discuss the integrality gaps of the LP relaxations of length-bounded flow and cut problems, analyze the structure of optimal solutions, and present further complexity results for special cases.

Convergence and approximation in selfish routing.

VAHAB MIRROKNI
Microsoft Research

keywords: algorithmic game theory, convergence, network congestion games/selfish routing, price of anarchy

In this talk, we survey related results in the price of anarchy and convergence for selfish routing games. Our main goal is to compare the average delay incured on a set of selfish users compared to the optimal average delay enforced by a central entity. I will present focus on convergence results, but will mention the related approximation results. We will cover both on atomic and non-atomic games and will generalize the setting to all congestion games. We will conclude by some open problems.

Unsplittable shortest path routing: complexity and algorithms

ANDREAS BLEY
Zuse Institute Berlin (ZIB)

keywords: computational complexity, mixed-integer programming, network design, shortest paths

Most data networks nowadays employ shortest path routing protocols to control the flow of data packets. With these protocols, all end-to-end traffic streams are routed along shortest paths with respect to some administrative routing weights. Dimensioning and routing planning are extremely difficult for such networks, because end-to-end routing paths cannot be configured individually but only jointly and indirectly via the routing weights. Additional difficulties arise if the communication demands must be sent unsplit through the network - a requirement that is often imposed to ensure tractability of end-to-end traffic flows and to prevent package reordering in practice. In this case, the lengths must be chosen such that the shortest paths are uniquely determined for all communication demands.

In this talk, we consider the problem of finding an unsplittable shortest path routing routing (USPR) that minimizes the maximum link congestion in a communication network: Given a capacitated digraph and traffic demands, the task is to find arc lengths, such that the shortest (s,t)-path is unique for each commodity (s,t) and the maximum arc congestion (flow/capacity ratio) is minimal.

We discuss the relation of USPR to other routing schemes, review several results concerning the approximability of USPR problems, and illustrate an integer linear programming solution approach for the congestion minimization problem, which relies on an independence system

characterization of the path sets that form USPRs. Finally we report on computational results for the German research network and other real-world instances, which demonstrate the efficiency of this approach.

MO2-R8 GAME THEORY
Computation of equilibria
organizer/chair: Yinyu Ye

On algorithmic complexity issues in cooperative and non-cooperative game theoretical solution concepts

XIAOTIE DENG
City University of Hong Kong

coauthors: Xi Chen, Shanghua Teng, QiZhi Fang, Xiaoxun Sun
keywords: algorithm and complexity, cooperative and non-cooperative game theory

At this talk, we discuss some recent development on algorithmic issues in cooperative and non-cooperative game theoretic solution concepts and potential applications, as well as new problems arisen in the interface of computer science and game theory.

New market models and algorithms

KAMAL JAIN
Microsoft Research

coauthor: Vijay Vazirani
keywords: combinatorial algorithms, computation, market

The notion of a "market" has undergone a paradigm shift with the Internet – totally new and highly successful markets have been defined and launched by companies such as Google, Yahoo!, Amazon, MSN and Ebay. Another major change is the availability of massive computational power for running these markets in a centralized or distributed manner.

In view of these new realities, the study of market equilibria, an important, though essentially non-algorithmic, theory within Mathematical Economics, needs to be revived and rejuvenated with new models, ideas, and an inherently algorithmic approach.

In this talk, I will give a feel for the exciting work going on on this front and present new results on resource allocation markets. Interestingly enough, this work has also contributed handsomely to the theory of algorithms itself. In particular, the highly successful primal-dual schema from exact and approximation algorithms, which was so far used for combinatorially solving special classes of linear programs, has been extended to solving nonlinear convex programs.

Leontief economies encode nonzero sum bimatrix games

BRUNO CODENOTTI
IIT-CNR

coauthors: Amin Saberi, Yinyu Ye, Kasturi Varadarajan
keywords: computational complexity, Leontief economy, market equilibrium, Nash equilibrium

We show that there is a one-to-one correspondence between Nash equilibria in bimatrix games and market equilibria in certain Leontief economies. We use this correspondence to prove hardness results for economies. In particular, we show that it is NP-hard to say whether a Leontief economy has an equilibrium.

MO2-R9 GLOBAL OPTIMIZATION
Global optimization methods
chair: Tibor Csendes

Fuzzy control of stochastic global optimization algorithms and very fast simulated reannealing

HIME JUNIOR
IBMEC-RJ

coauthor: Maria Augusta Soares Machado
keywords: fuzzy control, fuzzy logic, global optimization, simulated annealing

This paper presents a fuzzy control approach for improving convergence time in stochastic global minimization algorithms .We show concrete results when the method is applied to an efficient algorithm based on ideas related to Simulated Annealing.We describe a well-succeeded approach to accelerate ASA (Adaptive Simulated Annealing) algorithm using a simple Mamdani fuzzy controller that dynamically adjusts certain user parameters related to quenching. It is shown that, by increasing the algorithm's perception of slow convergence, it is possible to speed it up significantly and to reduce enormously (perhaps eliminate) the user task of parameter tuning . That is done without changing the original ASA code . The algorithm was sucessfully applied to neurofuzzy (data driven) synthesis of Takagi-Sugeno-Kang and Mamdani fuzzy systems and MLE (Maximum Likelihood Estimation).

Global optimization algorithms for convex multiplicative programming

RÚBIA OLIVEIRA
UNICAMP-FEEC

coauthor: Paulo Augusto Valente Ferreira
keywords: convex analysis, global optimization, multiplicative programming, numerical methods

We propose new global optimization algorithms for convex multiplicative programs. Elements of convex analysis and multiobjective programming are used for dealing with multiplicative programming problems exhibiting a product or a sum of products of positive convex functions in their objective functions. A global minimum in the first case is obtained by solving a sequence of quasi-concave minimizations on polytopes through vertex enumeration. A global minimum in the second case is obtained by solving a sequence of special indefinite quadratic problems through constraint enumeration. The algorithms proposed are easily implemented and their computational performances have been compared with alternative algorithms from the literature with basis on test problems. Better performances have been obtained with the algorithms proposed in this paper.

A particle swarm pattern search method for bound constrained nonlinear optimization

ISMAEL VAZ
Minho University

coauthor: Luis Vicente
keywords: derivative free optimization, direct search, particle swarm, pattern search methods

In this paper we develop, analyze, and test a new algorithm for the global minimization of a function subject to simple bounds without the use of derivatives. The underlying algorithm is a pattern search method, more specifically a coordinate search method, which guarantees convergence to stationary points from arbitrary starting points.

In the optional search phase of pattern search we apply a particle swarm scheme to globally explore the possible nonconvexity of the objective function. Our extensive numerical experiments showed that the resulting algorithm is highly competitive with other global optimization methods also based on function values.

MO2-R10 MULTICRITERIA OPTIMIZATION
Applications of MCDM
chair: Mischel Belderrain

Multiattribute utility theory applied to petrochemical company problem

MISCHEL BELDERRAIN
Instituto Tecnológico de Aeronáutica - ITA

coauthor: Eduardo Magalhães Samuel
keywords: decision analysis, multiattribute utility theory, sensitivity analysis

The objective of this work is to analyze a real-world decision problem of a petrochemical company using the Multiattribute Utility Theory. The business case presented, a decision problem with multiple objectives, considered utility function assignments using both proportional scores and ratio methods, as well as swing weighting, AHP and ordinal methods for weights assignments. Sensitivity analysis has shown that the final solution greatly depends on the weight assignment method; moreover, it also made clear how such weights can be changed without affecting the final result. In addition, this work includes the Decision Analysis theory needed to understand the methodology that was applied to the real business case. Although such methodology points out very interesting insights and directions to reach the best solution, the Decision Analysis Process by itself cannot replace the decision maker.

Multicriteria scheduler for low performance wireless network

SERGIO SILVA
IME

coauthor: Ronaldo Salles
keywords: multicriteria, network, scheduling, wireless networks

In rescue operations, both military and civil defence, it is common the employment of wireless communication networks which are mobile, easy to set and robust, but are often of low performance. In such cases it is mandatory the use of priorities to guarantee to the most valuable information the available communication resources to accomplish the mission. A traditional way to implement that is to use precedence levels and classify information flows into the levels according to their importance. High precedence flows are then serviced first following a strict and static discipline. Such naive scheme has several side effects, e.g. starvation of lower priority flows during congestion. We propose a multiple criteria decision approach which uses not only precedence levels but also several parameters to make a decision. Moreover, we investigate the optimal way of scheduling information in order to attend the largest number of messages that arrive in the system.

Portfolio Construction Based on stochastic Dominan

DIANA ROMAN
Brunel University

coauthors: Ken Darby-Dowman, Gautam Mitra
keywords: multicriteria, portfolio selection, reference points, stochastic dominance

We consider the problem of constructing a portfolio, which is non-dominated with respect to second order stochastic dominance and thus optimal for risk-averse investors. In addition, this portfolio has a return distribution close to a user-specified, target distribution. Thus, this return distribution can be shaped and "crafted" to a desirable form, to the extent that is achievable. The problem is multi-objective and is transformed into a single objective problem by using the reference point method, in which target levels, known as aspiration points, are specified for the objective function values. Several models, all of them LP solvable, are proposed, in which the aspiration points relate to ordered return outcomes of the portfolio return. The theoretical properties of the models are studied. The performance of the models on real data drawn from the FTSE 100 index is also investigated.

MO2-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
Applications of LP and cone programming II
chair: Renata Sotirov

Constructive rational approximation using semidefinite programming

RENATA SOTIROV
Tilburg University

coauthor: Etienne de Klerk
keywords: positive operators, rational approximations, semidefinite programming

We construct "optimal" rational approximations of continuous functions by minimizing suitable error bounds from approximation theory, like the Korovkin error bound for positive operators, over a class of rational operators. Our class of rational operators is determined by weight functions that are constants or sum-of-squares polynomials, and include rational Bernstein operators and Shepard operators as special cases. The optimal choice for the weight functions is made using semidefinite programming.

Mathematical modeling for a defensive game for ROBOCUP F-180 small-size league

MONAEL PINHEIRO RIBEIRO
Instituto Militar de Engenharia

coauthor: Julio Cezar Silva Neves
keywords: linear programming, robocup F-180, robotics, system modeling

Nowadays, groups of autonomous robots are more and more involved with social behavior, attempting to find a common goal for the group in a collaborative way in order to accomplish the individual task of each robot. In this context the Robocup, a robot soccer competition, becomes a broad field for many different experiments, looking for a integration of the robots from each group becoming a true team. This paper proposes an implemented and tested linear programming model, which has the goal of defining the team member position in a game, playing in a defensive way; where the ball position and the action coverage of each opponent are considered in the mathematic model.

MO2-R12 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
Computational issues in LP and SDP II
chair: Aurelio Oliveira

Hybrid approaches to calculate the step-lengths in a predictor-corrector method variant for semidefinite programming

ANA PAULA TEIXEIRA
UTAD / CIO

coauthor: Fernando Bastos
keywords: determinant function's interpolation, interior-point methods, semidefinite programming, step-length

We intend to present some approaches to estimate the maximum step-length in a predictor-corrector method variant for semidefinite programming. One of the approaches uses the value of the determinant in conjunction with the backtracking method, while the others use linear or quadratic interpolation in conjunction, also, with the backtracking method, to control the distance of the iterates to the boundary of the semidefinite cone. In this variant the predictor is calculated as an iteration of a primal-dual algorithm and the corrector is calculated in the classical way. All the implementations were based on the source code of the package CSDP. We will present extensive computational experience.

Dynamic optimization of parameters for interior-point linear programming methods

FERNANDO VILLAS-BÔAS
University of Campinas

coauthors: Aurelio Oliveira, C. Perin
keywords: implementation, interior-point methods, linear programming

In this work, we study and implement a predictor-corrector interior point method for linear programming, choosing the primal and dual step-lengths α and β and the penalty parameter μ in a non-heuristic way. At each iteration and after obtaining the Cholesky factor, we can "predict" the "merit" of the next point for each value of α, β and μ using a real polynomial of total degree 12 in these variables, thus optimally choosing these parameters. The merit functions are analytical and consider the squared Euclidean norm of the scaled residue of both the original and the penalized KKT systems. Computing the polynomials requires the solution of up to 5 linear systems using the same Cholesky factor, but this number of systems is decided at each iteration, allowing a reduction of the computational time instead of the number of iterations. Preliminary implementations are already competitive as compared to PCx.

A hybrid preconditioner approach for solving large-scale linear systems arising from interior point methods

AURELIO OLIVEIRA
Unicamp

coauthors: Silvana Bocanegra, Frederico Campos
keywords: interior-point methods, large-scale linear systems, preconditioners

A hybrid approach for solving linear systems arising from interior point methods applied to linear programming problems is developed. The systems are solved by the preconditioned conjugate gradient method in two phases. During phase I a kind of incomplete Cholesky preconditioner such that fill-in can be controlled is used. As an optimal solution is approached, the linear systems become highly ill-conditioned and the method changes to phase II. In this phase, a specialized preconditioner based upon the LU factorization is found to work better near a solution of the linear programming problem. Numerical experiments reveal that the iterative hybrid approach works better than direct methods on some classes of large-scale problems.

MO2-R13 NONLINEAR PROGRAMMING

Nonlinear and mixed-integer optimization

organizer/chair: Christodoulos Floudas

Nonlinear integer optimization and data mining

PANOS PARDALOS
University of Florida

coauthors: Oleg Prokopyev, Stanislav Busygin
keywords: biclustering, data mining, fractional 0-1 programming, integer optimization

In this presentation we consider fractional 0-1 programming with the related application in data mining. We discuss computational complexity issues, linear mixed 0-1 reformulations as well as some heuristic approaches. This research is motivated in part by a new fractional 0-1 model for biclustering, which consists in a simultaneous partition of the set of samples and the set of their attributes (features) into subsets (classes). Samples and features classified together are supposed to have a high relevance to each other. Biclustering has a great significance for biomedical applications. Performing it with high reliability, we are able not only to diagnose conditions represented by sample classes, but also identify features (e.g., genes) responsible for them, or serving as their markers. Encouraging computational results on DNA microarray data mining problems are reported.

A multi-parametric programming approach for constrained multi-stage optimization problems

NUNO FAISCA
Imperial College

coauthors: Vivek Dua, Stratos Pistikopoulos
keywords: multi-stage problems

This paper presents an algorithm for multi-stage decision problems with hard constraints. The algorithm is based upon the concepts of dynamic programming and multi-parametric programming. The multi-stage problem is considered within a framework of dynamic programming where each echelon of problem is formulated and solved as a multi-parametric program. The state-space of a given stage constitutes the parametric space whereas the state-space of the next stage represents the space of control or optimization variables. The solution of the resulting multi-parametric program is given by the control or the optimization variables as a set of explicit functions of the parameters. The dynamic recursive nature of the multi-stage problem is preserved and a set of sequential and simpler multi-parametric programs which are constrained by a reduced number of inequalities is obtained. This results in a reduction in the complexity of the overall problem. The underlying theory is described in detail and numerical examples are presented to illustrate the potential of this new approach.

Novel classes of tight convex underestimators for general nonconvex problems

CHRISTODOULOS FLOUDAS
Princeton University

coauthor: Chrysanthos Gounaris
keywords: convex underestimators, global optimization

A novel technique for deriving convex underestimators of arbitrary C2-continuous functions is introduced. The new convex understimators are based on the alpha-BB principles, and employ a piecewise approach that takes advantage of the fact that the alpha-BB underestimators benefit from smaller domains. An overall valid piecewise linear underestimator is computed through suitable projections into one-dimensional spaces and proper identification of tangential supports. The results are further improved, both in quality of lower bound and in tightness of underestimator across the whole domain, by applying the method on an orthonormal transformation of the function. The new method requires additional computational resources compared to the alpha-BB method, but it can provide very tight lower bounds, sometimes eliminating the need for any branching at all.

MO2-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Non-deterministic/novel methods in convex problems

organizer: Robert Freund
chair: Alexandre Belloni

Numerical implementation and evaluation of SOS decompositions

PABLO PARRILO
Massachusetts Institute of Technology

coauthor: Jia-Li Sun
keywords: polynomial bases, semidefinite programming, sum of squares

We present a detailed comparison of several different approaches for the implementation of sum-of-squares decomposition of polynomials via SDP. For this, we explore different bases for the space of polynomials, including the monomial, Chebyshev, and Lagrange bases, for both the univariate and multivariate case. The results show the notable advantages of using a mixed Chebyshev/Lagrange approach, that is amenable to the exploitation of the low-rank structure, as described earlier by Lofberg and Parrilo.

Testing the boundedness of a convex set

ALEXANDRE BELLONI
MIT

keywords: complexity, convexity, probabilistic methods

The goal is two fold. The first one is to explore relations between a variety of geometric quantities associated with convex sets and norm-induced probability densities. The second is to develop an efficient algorithm to test if a given convex set $K \subset R^n$ is bounded or unbounded.

Optimization via matrix and tensor approximations

RAVINDRAN KANNAN
Yale University

keywords: polynomial optimization, tensor approximation

We survey recent progress in using low rank approximations to matrices and analogous computable low-rank approximations to tensors and the applications of these techniques to both numerical problems as well as combinatorial and nonconvex optimization problems like maximizing low-degree polynomials over n-dimensional convex sets.

MO2-R15 INFINITE DIMENSIONAL PROGRAMMING AND OPTIMAL CONTROL

Opt. conditions and sensitivity analysis

chair: Valeriano de Oliveira

Optimality and duality in infinite programming

VALERIANO DE OLIVEIRA
UNICAMP

coauthor: Marko Rojas-Medar
keywords: duality, infinite programming, invexity, optimality conditions

In this talk we present optimality conditions and duality theorems for the infinite programming problem. This optimization problem consists in to minimize a functional subject to an infinite number of constraints. The functions involved in the programm are defined on a real Banach space.

Concerning to the optimality conditions, we give first and second order necessary conditions and also sufficient conditions. The first and second order necesary conditions are obtained using the theory given in the paper [A. Ben-Tal, J. Zowe: A unified theory of first and second order con- ditions for extremum problems in topological vector spaces, Math. Programming Study 19 (1982) 39-76]. The first order conditions obtained are of Fritz John type. We define adequately, for the infinite problem, the Slater and the Mangasarian-Fromovitz constraint qualifications and obtain conditions of Karush-Kuhn-Tucker type. The sufficient conditions are obtained via generalized convexity: invexity. With respect to the optimality conditions, we go further and generalize for the infinite problem an interesting result by Martin [D. H. Martin: The essence of invexity, J. Optim. Theory Appl. 47 (1985) 65-76]. Martin introduced a weaker notion of invexity, called KT-invexity, and showed that every stationary point of the mathematical programming problem (in finite dimension) is a global minimizer if and only if the problem is KT-invex.

Concerning to the duality theorems, we regard a Wolfe dual problem and get the weak, the strong and a converse duality theorems. These results are established by making use of the concept of invexity.

Second-order optimality conditions and sensitivity analysis for state-constrained optimal control problems

J. FREDERIC BONNANS
INRIA

coauthor: Audrey Hermant
keywords: optimal control, second-order optimality conditions, shooting algorithm, state constraints

No-gap second order optimality conditions allowing to characterize quadratic growth, have been obtained in several fields, in particular polyedric problems and semidefinite optimization. We show in this talk that it is possible to obtain no-gap conditions for state-constrained optimal control problems. These no-gap conditions imply the well-posedness of the shooting algorithm under standrad conditions.

MO2-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Algorithmic issues related to MPECs

organizer: Mikhail Solodov
chair: Clovis Gonzaga

A smoothing method for solving MPEC's

CLOVIS GONZAGA
Federal University of Santa Catarina

coauthor: Rafael Casali
keywords: complementarity constraints, MPEC

We study the nonlinear programming problem with complementarity constraints of the form $\min\{x_i, y_i\} = 0$. These constraints are written as $x_i + (y_i - x_i)^+ = 0$, and we smooth the map $z^+ = \max\{z, 0\}$ by approximating it by the double integral of a continuous probability function $p(\cdot)$. By making $p(\tau) = 0$ for $|\tau| > \varepsilon$, we generate a sequence of $\varepsilon-$parameterized problems with smoothed complementarity constraints of class C^2 which differ from the original problem only in an $\varepsilon-$neighborhood of the origin. We discuss the optimality conditions and the convergence properties for the method.

Regularization schemes for MPECs

JEAN-PIERRE DUSSAULT
Université de Sherbrooke

coauthors: Abdeslam Kadrani, Abdelhamid Benchakroun
keywords: MPEC, regularization, stationarity

We present a new regularization scheme for MPECs. We present comparisons with previously proposed schemes. Our discussion will refer to several stationarity conditions (strong, M-stationarity, weak stationarity, etc.) and we will compare the assumptions required to prove the convergence of the regularization scheme to stationary points of the original MPEC; our new scheme requires weaker assumptions than previous schemes.

On attraction of Newton-type iterates to multipliers violating second-order sufficiency conditions

MIKHAIL SOLODOV
IMPA

coauthor: Alexey Izmailov
keywords: degenerate constraints, Newton methods, second-order optimality conditions, superlinear convergence

Assuming that the primal part of the sequence generated by a Newton-type (e.g., SQP) method applied to an equality-constrained problem converges to a solution where the constraints are degenerate, we investigate whether the dual part of the sequence is attracted by those Lagrange multipliers which satisfy second-order sufficient condition (SOSC) for optimality, or by those multipliers which violate it. This question is relevant at least for two reasons: one is speed of convergence of standard SQP methods; the other is applicability of some recently proposed approaches for handling degenerate constraints. In the case of degeneracy the multiplier set is not a singleton. Typically, SOSC may hold with some multipliers but not with others. In the case of standard Newton/SQP methods, if the dual sequence were to converge to multipliers with needed properties then primal superlinear convergence could still be expected despite degeneracy. As for methods designed for degenerate problems, they rely on the assumption that the dual part of the sequence approaches specifically those multipliers which satisfy SOSC. While convergence of the primal sequence (to a strict local minimizer satisfying SOSC with *some* associated multipliers) is natural, convergence of the dual sequence to "good" multipliers is by no means a given. We show that for the class of damped Newton methods, convergence of the dual sequence to multipliers satisfying SOSC is, in a certain sense, unlikely to occur. In particular, we demonstrate that the dual iterates are naturally attracted to certain special multipliers violating SOSC. We support our findings by some examples and numerical experiments on degenerate quadratically constrained quadratic programs. We also suggest a simple auxiliary procedure for computing multiplier estimates, which does not have the undesirable attraction property. Finally, possible implications for problems with complementarity constraints (MPCC) will be discussed.

MO2-R17 SEMI-INFINITE PROGRAMMING
Numerical aspects of SIP
organizer: Oliver Stein
chair: Harald Guenzel

Robust convex optimization: the scenario approach

MARCO CAMPI
University of Brescia

coauthor: Giuseppe Calafiore
keywords: convex programming, risk-adjusted robustness, robust optimization

Many decision problems in control, engineering, and finance can be cast as robust convex optimization, that is as optimization problems where a convex cost has to be minimized subject to convex constraints that are parameterized by an uncertainty parameter. This includes for instance the wide class of problems representable by means of parameter-dependent linear matrix inequalities (LMIs). Unfortunately, however, robust convex optimization is computationally prohibitive in many cases.

We consider a 'randomized' or 'scenario' approach for dealing with uncertainty in convex optimization, based on constraint sampling: the original robust optimization problem is replaced by one where only a finite set of N randomly chosen constraints is taken into account. We show that the resulting solution generalizes well, i.e. it automatically satisfies all unseen constraints but a small fraction of them, provided that N is suitably selected. A rich family of robust optimization problems which are in general hard to solve in a deterministically robust sense is therefore amenable to polynomial-time solution, if robustness is intended in the proposed risk-adjusted sense.

Global solution of GSIP using interval methods

PANAYIOTIS LEMONIDIS
Chemical Engineering, MIT, USA

coauthor: Paul Barton
keywords: global optimization, GSIP, nonlinear programming, stochastic integer programming

A novel algorithm on the global solution of Generalized Semi-Infinite Programs (GSIP) is presented. The method is based on constructing a restriction and a relaxation of the lower-level feasible set using interval arithmetic. The resulting lower and upper bounds are formulated as ordinary Semi-Infinite Programs (SIP) and are solved using discretization and the interval constrained reformulation (ICR) respectively. Convergence, within å-optimality, is achieved by implementing the algorithm in a branch-and-bound framework. The necessary assumptions for convergence are presented, a novel test set is introduced and the performance of the algorithm on the test set is analyzed

The adaptive convexification algorithm: a feasible point method for semi-infinite programming

OLIVER STEIN
RWTH Aachen University

keywords: alphaBB, bilevel programming, MPCC, semi-infinite programming

We present a new numerical solution method for semi-infinite optimization problems. Its main idea is to adaptively construct convex relaxations of the lower level problem, replace the relaxed lower level problems equivalently by their Karush-Kuhn-Tucker conditions, and solve the resulting mathematical programs with complementarity constraints. This approximation produces *feasible iterates* for the original problem.

The convex relaxations are constructed with ideas from the *alpha*BB method of global optimization. The necessary upper bounds for functions on box domains can be determined using the techniques of interval arithmetic, where our algorithm already works if only one such bound is available for the problem.

We show convergence of stationary points of the approximating problems to a stationary point of original semi-infinite problem within arbitrarily given tolerances. Numerical examples from Chebyshev approximation and design centering illustrate the performance of the method.

MO2-R18 GRAPHS AND MATROIDS
Algorithms for graph optimization
organizer/chair: Santosh Vempala

Traveling salesman with deadlines

ADAM MEYERSON
UCLA

coauthors: Nikhil Bansal, Avrim Blum, Shuchi Chawla
keywords: approximation algorithms

Scheduling tasks in order to meet deadlines is a key problem in both computer science and operations research. If the tasks need to be performed at various locations (or in various machine configurations), then determining the best schedule is an NP-Hard problem similar to Traveling Salesman. Given a graph where each node is labeled with a reward value and a deadline, and each edge is labeled with a length, the goal is to select a route (or schedule) to maximize the reward value of nodes visited prior to their deadlines.

In the operations research community this problem is known under the name "Vehicle Routing with Time Windows." Many heuristics have been tried, but large instances remain computationally intractable.

This talk will present recent work in approximation algorithms for this problem, under the name "Deadline TSP." This work results in performance guarantees of $O(\log n)$ if the deadlines must be respected, and $O(\log 1/e)$ if the deadlines may be violated by a $1+e$ factor for some small e. These results first appeared in STOC of 2004.

Compacting cuts: a new linear formulation for minimum cut

OJAS PAREKH
Emory University

coauthors: Robert Carr, Goran Konjevod, Greg Little, Venkatesh Natarajan
keywords: connectivity, cut polytope, minimum cut, travelling salesman problem

For a graph (V,E), existing compact linear formulations for the minimum cut problem require $\Theta(|V||E|)$ variables and constraints and can be interpreted as a composition of $|V|-1$ polyhedra for minimum *s-t* cuts in much the same way as early approaches to finding globally minimum cuts relied on $|V|-1$ calls to a minimum *s-t* cut algorithm. We present the first formulation to beat this bound, one that uses $O(|V|^2)$ variables and $O(|V|^3)$ constraints. An immediate consequence of our result is a compact linear relaxation with $O(|V|^2)$ constraints and $O(|V|^3)$ variables for enforcing global connectivity constraints. This relaxation is as strong as standard cut-based relaxations and have applications in solving traveling salesman problems by integer programming as well as finding approximate solutions for survivable network design problem. Another application is a polynomial time verifiable certificate of size n for for the NP-complete problem of l_1-embeddability of a rational metric on an n-set (as opposed to one of size n^2 known previously).

Flow metrics

CLAUDSON BORNSTEIN
UFRJ

coauthor: Santosh Vempala
keywords: approximation algorithms, spreading metrics

We introduce flow metrics as a relaxation of path metrics (i.e. linear orderings). They are defined by polynomial-sized linear programs and have interesting properties including spreading. We use them to obtain relaxations for several NP-hard linear ordering problems such as minimum linear arrangement and minimum pathwidth. Our approach has the advantage of achieving the best-known approximation guarantees for these problems using the same relaxation and essentially the same rounding algorithm for all the problems while varying only the objective function from problem to problem. This is in contrast to the current state of the literature where each problem either has a new relaxation or a new rounding or both.

MO2-R19 GRAPHS AND MATROIDS
Perfect graphs
organizer: Frederic Maffray
chair: Celina Figueiredo

Square-3PC(.,.)-free Berge graphs

KRISTINA VUSKOVIC
University of Leeds

coauthors: Frederic Maffray, Nicolas Trotignon
keywords: combinatorial algorithms, maximum weight clique, perfect graphs, star decompositions

We consider the class of graphs containing no odd hole, no odd antihole, and no configuration consisting of three paths between two nodes such that any two of the paths induce a hole, and at least two of the paths are of length 2. This class of graphs generalizes claw-free Berge graphs and 4-hole-free Berge graphs. We obtain a structural characterization of this class, that enables us to obtain a combinatorial polynomial time algorithm for solving the maximum weight clique problem on this class.

Coloring bull-free perfectly contractile graphs

BENJAMIN LEVEQUE
Leibniz - IMAG - Grenoble - France

coauthor: Frederic Maffray
keywords: bull-free graph, coloring, LexBFS, perfect graphs

We consider the class of graphs that contain no bull, no odd hole, and no antihole of length at least 5. We present a new algorithm that colors optimally the vertices of every graph in this class. This algorithm is based on the existence in every such graph of an ordering of the vertices with a special property. More generally we prove, using a variant of Lexicographic Breadth-First Search, that in every graph that contains no bull and no hole of length at least 5 there is a vertex that is not the middle of a chordless path on five vertices. This latter fact also generalizes known results about chordal bipartite graphs, totally balanced matrices and strongly chordal graphs.

Minimally infeasible set partitioning problems on balanced matrices

GIACOMO ZAMBELLI
University of Padova

coauthors: Michele Conforti, Marco Di Summa
keywords: balanced matrices

We consider the set partitioning polytope $SP(A) = \{x : Ax = 1, x \geq 0\}$ associated to 0,1 matrices A in a certain class (balanced matrices) for which $SP(A)$ has all integer-valued vertices.

We first give some properties of general minimally infeasible systems of linear inequalities, and then we use a result of Conforti, Cornuejols, Kapoor, and Vuskovic (that extends Hall's Theorem to the more general problem of perfect matchings in balanced hypergraphs) to infer combinatorial properties of minimally infeasible set partitioning problems associated to balanced matrices.

MO2-R20 PRODUCTION AND SCHEDULING
Constrained lot-sizing and scheduling
organizer/chair: Andrew Miller

Robust stochastic lot-sizing using historical data

MIAO SONG
Massachusetts Institute of Technology

coauthors: Diego Klabjan, David Simchi-Levi
keywords: robust optimization, stochastic lotsizing

We consider the single-item multi-period periodic review stochastic lot-sizing model under the assumption that the available information with respect to the demand distribution are historical data. The traditional approach first estimates the demand distribution among a predefined family of distributions based on data fitting of historical demand observations, and then optimizes the inventory using the estimation, which often leads to suboptimal solutions. In this work we propose a minimax robust model that integrates data fitting and inventory optimization. We also prove that the optimal inventory control policy of the robust model share the same structure as the traditional stochastic dynamic programming counterpart.

Stochastic lot-sizing problems with random lead time

KAI HUANG
University of Arizona

coauthor: Simge Küçükyavuz
keywords: lead time, lot sizing, polynomial algorithms, stochastic integer programming

In this research, we study stochastic lot-sizing problems with random lead time from the view of stochastic programming. First, we present two multistage stochastic integer programming formulations, corresponding to the linear cost case and the fixed charge case. Then we study the problem structure, and derive the so called Semi-Wagner-Whitin property. Using this property, we develop polynomial algorithms based on dynamic programming. Finally, we present several useful cutting planes.

Lot-sizing with minimum order quantity

DIEGO KLABJAN
University of Illinois at Urbana-Champaign

keywords: algorithm, lot sizing

We study the deterministic lot-sizing problem under the assumption that in each time period either no order is placed or at least a certain given amount is ordered. We present two polynomially solvable cases and we develop a fully polynomial time approximation scheme.

MO2-R21 DYNAMIC PROGRAMMING
Approximate dynamic programming
organizer/chair: Daniela Pucci de Farias

Relaxations of weakly coupled stochastic dynamic programs

ADAM MERSEREAU
University of Chicago GSB

coauthor: Dan Adelman
keywords: approximate dynamic programming

We consider a broad class of stochastic dynamic programming problems that are amenable to relaxation via decomposition. These problems comprise multiple subproblems that are independent of each other except for a collection of coupling constraints on the action space. We fit an additively separable value function approximation using two techniques, namely Lagrangian relaxation and the linear programming (LP) approach to approximate dynamic programming. We prove various results comparing the relaxations to each other and to the optimal problem value. We also provide a column generation algorithm for solving the LP-based relaxation to any desired optimality tolerance, and we report on numerical experiments on bandit-like problems. Our results provide insight into the complexity versus quality tradeoff when choosing which of these relaxations to implement.

An optimal approximate dynamic programming algorithm for concave single asset management

JULIANA NASCIMENTO
Princeton University

coauthor: Warren Powell
keywords: approximate dynamic programming, distribution free, Monte Carlo simulation, stochastic algorithms

Purchasing forward contracts to satisfy demands in the future, defining the level of cash held by a mutual fund and determining the amount of an asset that should be sold/bought in an inventory system are examples of single asset management problems with uncertainties. The forward prices, demands, the selling/purchasing prices are all random variables with unknown distributions. Even though the optimal value functions can not be explicitly computed, they are concave in the asset dimension.

We use this structural property to propose an approximate dynamic programming algorithm that uses pure exploitation and is distribution free (nonparametric). We prove almost sure convergence to an optimal policy. Numerical work showed that our approach outperforms other standard approximate algorithms such as Q-learning and Adaptive Real Time Dynamic Programming. Furthermore, comparisons to a classical dynamic programming algorithm showed that our algorithm is a good alternative even when the distributions are known.

Performance bounds and state relevance selection in the LP approach to approximate DP

DANIELA PUCCI DE FARIAS
MIT

coauthors: Theophane Weber, David Jeria, Yann Le Tallec
keywords: performance bounds, value function approximation

An important question in approximate dynamic programming algorithms is how well the resulting policies perform. We consider the linear programming approach to approximate dynamic programming, where this question is intimately related to the choice of parameters known as state-relevance weights. In the case of arbitrary basis functions, we prove the existence of state-relevance weights which can be used to generate a policy with performance proportional to the trength of the approximation architecture. We characterize these weights through a fixed-point equation. In the special case of features defined on a partition of the state space, we give a simpler method to find the solution, as well as a stronger performance bound. Finally, we introduce a technique based on homotopy methods to find adequate state-relevance weights in an efficient and flexible manner.

MO3-R1 COMBINATORIAL OPTIMIZATION

Trees and TSP

organizer: Luis Gouveia
chair: Thomas Magnanti

Network design with reload costs

IOANNIS GAMVROS
University of Maryland, College Park

coauthors: Luis Gouveia, S. Raghavan
keywords: network design

We present several different network design problems that incorporate reload costs. These costs are associated with the usage of two consecutive edges (as opposed to just one) and are common in practice in the transportation industry's intermodal business model and in the telecommunication industry, when different technologies (e.g., fiber, copper, satellite) are in use in the same network. We developed various formulations for these problems and discuss their strengths and weaknesses. Computational results on a variety of problems will be presented.

On time-dependent formulations for routing problems

THOMAS MAGNANTI
MIT

coauthors: Teresa Godinho, Luis Gouveia, Pierre Pesneau, Jose Pires
keywords: combinatorial optimization, time-dependent formulations, travelling salesman problem

We discuss the use of time-dependent formulations for routing problems. In particular: i) we present a computational study between the LP relaxation of multicommodity and time-dependent formulations for the TSP with and without flow costs; ii) we present results taken from a cutting plane approach for the cumulative TSP enhanced with time-dependent valid inequalities iii) we produce some inequalities which result from projecting the LP feasible set of the time-dependent formulation in the space of flow and design variables and in the space of designa variables.

New formulations for the max-leaf spanning tree problem

ABILIO LUCENA
UFRJ

keywords: formulations, linear programming, spanning trees

Given a connected undirected graph $G = (V,E)$ with a set V of vertices and a set E of edges, the Maximum-Leaf Spanning Tree Problem (MLSTP) is to find a spanning tree (ST) of G with as many leaves as possible. The problem is *MAX-SNP*-hard and, so far, has received relatively little attention in the literature. In this presentation, a MLSTP formulation from the literature is investigated and gives rise to a stronger reformulation of the problem. Additionally, a new formulation is introduced after viewing MLSTP solutions as a combination of *local access* edges, i.e. ST leaves, and *backbone trees*, i.e. STs where leaves are eliminated. This new formulation easily extends to a problem involving *backbone cycles* instead of backbone trees. Likewise, it also accommodates some other telecommunication network design problems. Computational results are presented for each corresponding linear programming relaxation bound.

MO3-R2 COMBINATORIAL OPTIMIZATION

Combinat. Opt. in VLSI design II: trees and timing

organizer/chair: Jens Vygen

Repeater trees in VLSI design

DIETER RAUTENBACH
Research Institute for Discrete Mathematics

coauthors: Christoph Bartoschek, Stephan Held, Jens Vygen
keywords: Kraft's inequality, Steiner tree, VLSI design

One of the most fundamental tasks in VLSI design is to propagate an electrical signal from one point on a chip (the root) to many destinations (the sinks) subject to timing restrictions. This task can often not be fulfilled by pure metal connections of the involved terminals because of signal and delay degradation. In order to meet all timing requirements one has to build up a repeater tree which is a tree structure consisting of wire and signal-strengthening gates. The main optimization goals next to meeting the timing requirements are the reduction of power- and area-consumption.

We present a very fast algorithm for topology generation of repeater trees. Based on the criticality of the individual sinks, which is estimated taking their required signal arrival times and their distance from the root of the repeater tree into account, this topology connects very critical sinks in such a way as to optimize the overall timing and to minimize wiring for non-critical sinks. We establish theoretical bounds on the optimum solution and prove that our algorithm produces results that are close to optimum with respect to timing and wirelength. Experimental results on industrial designs in 130 nm and 90 nm technologies demonstrate the excellent quality of our algorithm.

Distributing signals by unbalanced trees

JENS MASSBERG
Uni-Bonn

keywords: combinatorial optimization, network design, VLSI design

A major task in VLSI design is to distribute signals by trees to several locations on a chip. These trees should be short but also have to keep individual length restrictions on their root-leaf paths. Neither minimal Steiner trees nor balanced trees meet these requirements in general.

In practice two types of instances occur: one the one hand we have to build a few large trees with up to one million terminals, on the other hand we need to construct millions of small trees. For both types we need fast and efficient heuristics.

In this talk we present new approximation algorithms for these problems.

Cycle time optimization in VLSI-design

STEPHAN HELD
Uni-Bonn

keywords: combinatorial optimization, geometric programming, VLSI design

In the last decade cycle time optimization has become one of the key problems in VLSI-design. The complexity of computer chips increased enormously. Classical optimization algorithms from combinatorial optimization or geometric programming are applied in various ways. However on large instances many of them encounter numerical problems and unpredictable runtimes (though theoretically bounded).

We introduce new algorithms for selected subproblems that outperform classical ones in practice both in terms of stability and runtime. By either computing

lower bounds or proving optimality we show an overall high quality of our algorithms.

Cycle time optimization which took several days in the past can now be solved within a few hours.

MO3-R3 COMBINATORIAL OPTIMIZATION
Hybrid metaheuristics
organizer/chair: El-Ghazali Talbi

Combining variable neighborhood search with IP for the generalized minimum spanning tree problem

GÜNTHER RAIDL
Vienna University of Technology

coauthors: Bin Hu, Markus Leitner
keywords: dynamic programming, generalized minimum spanning tree problem, integer linear programming, variable neighborhood search

We consider the generalized version of the classical Minimum Spanning Tree problem where the nodes of a graph are partitioned into clusters and exactly one node from each cluster must be connected. We present a general Variable Neighborhood Search (VNS) approach which uses three different neighborhood types. Two of them work in complementary ways in order to maximize the effectivity. Both are large in the sense that they contain exponentially many candidate solutions, but efficient polynomial-time algorithms are used to identify best neighbors. The third neighborhood type uses Integer Linear Programming to solve parts of the problem to provable optimality. Tests on Euclidean and random instances with up to 1280 nodes indicate especially on instances with many nodes per cluster significant advantages over previously published metaheuristic approaches.

Adaptive memory with GRASP for the for the scheduling workover rigs for onshore oil production

TIAGO NEVES
Universidade Federal Fluminense - UFF

coauthor: Luiz Satoru Ochi
keywords: adaptive memory, GRASP, metaheuristics, scheduling

The term memory, in the metaheuristic literature, was used explicitly for Tabu Search algorithm, but some other as Genetic Algorithm, Scatter Seacrh and Ant Colony System use mechanisms that can be considered as memories. In this paper we propose an adaptive memory programming method using concepts of GRASP for solving a Workover Rigs Routing and Scheduling Problem. GRASP is originally a multistart method, it means that the iterations are independent and no information of previous iterations are used to improve the search. Experimental results illustrate the effectiveness of adaptive GRASP over pure GRASP.

Towards a classification of hybrid metaheuristics

TALBI EL-GHAZALI
INRIA - Lille

keywords: hybrid algorithms, metaheuristics, optimization

Over the last years, interest in hybrid metaheuristics has risen considerably among researchers in combinatorial optimization and data mining. The best results found for many practical or academic optimization and data mining problems are obtained by hybrid algorithms. Combinations of algorithms such simulated annealing, tabu search, and evolutionary algorithms have provided very powerful search algorithms.

In this talk, a taxonomy of hybrid algorithms is presented in an attempt to provide a common terminology and classification mechanisms. The goal of the general taxonomy given here is to provide a mechanism to allow comparison of hybrid algorithms in a qualitative way. In addition, it is hoped the categories and their relationships to each other have been chosen carefully enough to indicate areas in need of future work as well as to help classify future work. Among existing taxonomies in other domains, one can find examples of flat and hierarchical classifications schemes. The taxonomy proposed here is a combination of these two schemes - hierarchical as long as possible in order to reduce the total number of classes, and flat when the descriptors of the algorithms may be chosen in an arbitrary order.

We extend the basic classification by defining the space of hybrid metaheuristics as a grammar, where each sentence is a method that describes a combination of metaheuristics.

MO3-R4 COMBINATORIAL OPTIMIZATION
Polyhedral combinatorics I
organizer/chair: Francisco Barahona

Polyhedral characterizations of the Clar and Fries problems on plane bipartite graphs

HERNAN ABELEDO
George Washington University

coauthor: Hua Ni
keywords: network flows, planar graphs, polyhedral combinatorics, unimodularity

The Clar and Fries indices are two optimization problems in chemical graph theory defined over the set of perfect matchings (or Kekulé structures) of a benzenoid graph. We study the generalization of these two problems to plane bipartite graphs. Abeledo and Atkinson proved that the natural IP formulation of these two problems has the integrality property, implied by equality constraints with a unimodular coefficient matrix. However, these constraint matrices are not totally unimodular in general. We derive new formulations with totally unimodular matrices and which require additional variables. Alternative proofs of the unimodularity of the natural formulations are established by projecting onto the subspace of the original variables. Using a network flow model, Abeledo and Atkinson established a combinatorial dual for the Clar problem. We use similar arguments to obtain a combinatorial dual for the Fries problem.

Odd cycle inequalities and the p-median polytope of Y-free graphs

FRANCISCO BARAHONA
IBM Research

coauthor: Mourad Baiou
keywords: facility location, p-median problem

We study the effect of odd cycle inequalities in the p-median problem. We give an algorithm for their separation, and we show that when added to the classical LP-relaxation, they are sufficient to describe the polytope of a special class of graphs, namely Y-free graphs.

The p-median polytope of restricted y-graphs

MOURAD BAIOU
Laboratoire LIMOS, Université Clermont II

coauthor: Francisco Barahona
keywords: odd cycle inequalities, p-median problem, uncapacitated facility location problem

We further study the effect of odd cycle inequalities in the description of the polytopes associated with the *p*-median and uncapacitated facility location problems. We show that the obvious integer linear programming formulation together with the odd cycle inequalities completely describe these polytopes for the class of *restricted Y-graphs*. This extends our results for the class of *Y-free graphs*. As a consequence, we obtain a necessary and sufficient conditions under which the obvious linear relaxation suffices to characterize the *p*-median polytope, for oriented and bidirected graphs.

MO3-R5 INTEGER AND MIXED INTEGER PROGRAMMING
Advances in integer programming I
organizer/chair: Andrea Lodi

On the strength of Gomory mixed-integer cuts as group cuts

DASH SANJEEB
IBM Research

coauthor: Oktay Gunluk
keywords: cutting planes, cyclic group polyhedron, Gomory mixed integer cut, mixed-integer rounding

Gomory mixed-integer (GMI) cuts generated from optimal simplex tableaus are known to be useful in solving mixed-integer programs. Further, it is well-known that GMI cuts can be derived from facets of Gomory's master cyclic group polyhedron and its mixed-integer extension studied by Gomory and Johnson. In this paper we examine why cutting planes derived from other facets of master cyclic group polyhedra (group cuts) do not seem to be as useful when used in conjunction with GMI cuts. For many practical problem instances, we numerically show that once GMI cuts from different rows of the optimal simplex tableau are added to the formulation, all other group cuts from the same tableau rows are satisfied.

Using superadditive functions with GUBs and VUBs to improve Gomory fractional and MIR cuts

ZONGHAO GU
ILOG Inc.

keywords: cutting planes, Gomory fractional cuts, mixed integer programming

It is well-known that MIR cuts or Gomory fractional cuts can be obtained by applying superadditive functions to a constraint or to a row in the optimal tableau for LP relaxation. We will show how to strengthen MIR and Gomory fractional cuts by using supperadditive functions with GUBs and VUBs and we will also discuss the computational experiences within CPLEX MIP Solver.

Branch-and-cut for piecewise linear optimization

ISMAEL DE FARIAS
State University of New York at Buffalo

coauthors: Ming Zhao, Hongxia Zhao
keywords: branch-and-cut, piecewise linear optimization, polyhedral combinatorics, special ordered sets

Piecewise linear (PL) optimization can be used to approximate a nonlinear function to any degree of accuracy. A standard model to it is the so called special ordered set of type 2 (SOS2). However, SOS2 requires the PL functions to be continuous. We extend SOS2 to include the case of noncontinuous PL functions. We then give three families of cutting planes to solve PL optimization, both continuous and discontinuous, through branch-and-cut. Finally, we give computational results on our approach.

MO3-R6 OPTIMIZATION IN NATURAL RESOURCES
Gas models
chair: Ronald Farina

Energy, ethanol & ethics: evaluating economic and environmental arguments regarding the pros and cons of biomass ethanol as a sustainable fuel technology

RONALD FARINA
Daniels College of Business, University of Denver

keywords: ethanol, ethics, network, sustainable

Generalized network optimization methodology is applied to evaluate ethical tradeoffs among alternative fuel scenarios reflecting different mixes of resource availability, political action and technology. Soaring energy costs, increased global demand, supply restrictions and disruptions, infrastructure limitations, and natural disasters have forced governments to rethink national energy strategies. No "one-size-fits-all" panacea exists. Among the pieces of the puzzle are alternative fuels technologies and resources, innovative automotive technologies, and infrastructure impacts. Political issues include selective protective import duties, subsidies and the consequences of nationalizations of energy resources. Economic questions regarding ethanol and oil include actual ethanol/oil efficiency yields, the impact of subsidies, consumption rates, and conventional fuels resource development. Related ethical issues encompass environmental threats including rainforest destruction, greenhouse gases, pollution levels, land use/food/fuel tradeoffs and others.

Optimal expansion of the world liquefied natural gas market

YRIS OLAYA
Universidad Nacional de Colombia

coauthors: Alexandra Newman, Carol Dahl
keywords: liquefied natural gas, market model, optimal expansion

International natural gas trade is increasing because gas demand is growing while domestic reserves are declining in many countries. Much of the expansion in the world natural gas market will entail liquefied natural gas (LNG), leading both suppliers and consumers to determine when to expand their LNG facilities. To model future LNG trade, we build an optimization model for a competitive market that incorporates the addition of facility capacity.

MO3-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.
Spanning trees in networks
chair: Andréa Cynthia

Algorithms for updating minimum spanning trees in dynamic graphs

RODRIGO FRANCO TOSO
Universidade Federal Fluminense

coauthor: Celso Ribeiro
keywords: dynamic graph algorithms, local search heuristics, metaheuristics, minimum spanning tree

This work highlights the on-line fully-dynamic minimum spanning tree problem (DMSTP), whose objective consists in maintaining a minimum spanning tree of a dynamically changing graph, where the changes are modifications on edge weights.

Algorithms for such problems can be particularly helpful in the implementation of metaheuristics and local search heuristics for solving broadcast optimization and design problems in communication networks, similar to recent algorithms involving a dynamic shortest path problem arising from weigth setting in OSPF/IS-IS routing.

We propose a simple algorithm for the DMSTP, together with an easy-to-implement supporting data structure for dynamic trees representation. We experimentally investigated both the proposed algorithm and the associated data-structure against a comprehensive set of graph instances from the 2006 DIMACS Implementation Challenge, showing that our algorithm outperform other implementations in real-life problems.

A GRASP with adaptive memory for the generalized minimum spanning tree problem

CRISTIANE MARIA SANTOS FERREIRA
Universidade Federal Fluminense

coauthors: Luiz Satoru Ochi, Elder Macambira
keywords: adaptive memory programming, graph optimization, metaheuristics

The Generalized Minimum Spanning Tree Problem consists of given a graph G whose vertices are divided into clusters, finding a tree T spanning exactly one vertex from each cluster of G, in such a way that minimizes the total cost of the edges. Another version of the problem consists of finding at least one vertex from each cluster. Applications of this problem can be found in telecommunications networks, power distribution networks and in agricultural irrigation systems. We present versions of GRASP heuristics with Adaptive Memory for this problem using different construction and local search procedures in addition to a path relinking mecanism. We have considered the instances found in literature and new larger instances to test the proposed algorithms. Experimental results illustrate the effectiveness of the proposed methods.

Heuristics for the diameter constrained minimum spanning tree problem

ANDRÉA CYNTHIA SANTOS
PUC-RIO

coauthors: Celso Ribeiro, Abilio Lucena
keywords: Lagrangian heuristics, metaheuristics and hybrid heuristics, minimum spanning tree, NP-hard problems

In this work, Lagrangean heuristics and a hybrid heuristic are proposed for the Diameter Constrained Minimum Spanning Tree Problem. This problem typically models network design applications where all vertices must communicate with each other at a minimum cost, while meeting a given quality requirement. Adaptations are made in the constructive heuristics proposed by Deo and Abdalla, and by Raidl and Julstrom. The resulting heuristics are then embedded into a Lagrangean relaxation framework, associated to a multicommodity network flow formulation of the problem. In doing that, Lagrangian heuristics are obtained. The hybrid heuristic is based on the GRASP and ILS metaheuristics. The local search used in the hybrid algorithm is similar to a VND scheme. Upper bounds within 2% of the optimal solution values were obtained for two classes of instances from the literature. For another class of instances, consisting of 30 OR-Library instances, stronger upper bounds than those available in the literature were obtained for 11 instances.

MO3-R8 GAME THEORY
Search, assignment and matching games
organizer/chair: Flip Klijn

Tracking a moving fugitive: a game-theoretic representation of search

GUILLERMO OWEN
Naval Postgraduate School

coauthor: Gordon McCormick
keywords: game theory, search games, stochastic games

We develop and analyze a "man-hunting" game involving a mobile hider, who wishes to maximize his time to capture, and a mobile searcher, who wishes to minimize this same time. The game takes place within a variegated environment that offers better and worse locations to evade capture. The hider is able to move from one hide site to another at will. In choosing a hide site, he must consider the risk of discovery, the risk that he will be betrayed, and the risk that he will be captured while moving from one site to another. The searcher can select any cell to search within the fugitive's feasible hiding set. We examine the strategic behavior of both players and provide examples.

A simple procedure to obtain the extreme core allocations of an assignment market

CARLES RAFELS
University of Barcelona

coauthors: Josep M. Izquierdo, Marina Nunez
keywords: assignment game, core, extreme core points

Given an assignment market, we introduce a set of vectors, one for each possible ordering on the player set, which we name the max-payoff vectors. Each one of these vectors is obtained recursively only making use of the assignment matrix. Those max-payoff vectors that are efficient turn up to give the extreme core allocations of the market. When the assignment market has large core (that is to say, the assignment matrix is dominant diagonal and doubly dominant diagonal) all the max-payoff vectors are extreme core allocations.

Fairness in a student placement mechanism with restrictions on the revelation of preferences

FLIP KLIJN
Institute for Economic Analysis

coauthor: Guillaume Haeringer
keywords: acyclic priority structure, fairness, student-optimal stable mechanism, two-sided matching

We study situations of assigning students to schools based on exogenously fixed priorities (e.g., entrance exams). It is known that Gale-Shapley's (1962) student-optimal Deferred Acceptance algorithm yields a widely used fair mechanism that is (i) Pareto superior to any other fair mechanism (Balinski and

Sonmez, 1999), and (ii) Pareto-efficient when priorities are acyclic (Ergin, 2002). When students can submit any preference list it is in their best interest to act truthfully (Dubins and Freedman, 1981; Roth, 1982). If the school assignment procedure, however, impedes students to submit a preference list that contains all their acceptable schools, then simply submitting a preference list that consists of the first schools may not be a weakly dominant strategy for a student. Thus, the student-optimal mechanism induces a non-trivial preference revelation game where students can only declare up to a fixed number (quota) of schools to be acceptable. We show that, except for the extreme quotas, even strong Nash equilibria in undominated "truncation" strategies may yield unfair assignments. Our main result identifies acyclicity as a necessary and sufficient condition on the priorities to guarantee fair Nash equilibrium outcomes. In particular, as a policy implication, our result suggests that fairness in the restrictive procedure is recovered through strategic interaction if the assignment of students is based on a centralized entrance exam.

MO3-R9 GLOBAL OPTIMIZATION

Applications of global optimization

chair: Leo Liberti

The discretizable molecular distance geometry problem

LEO LIBERTI
LIX, Ecole Polytechnique

coauthors: Carlile Lavor, Nelson Maculan

keywords: branch-and-prune, graph drawing, molecular distance geometry problem, protein conformation

The problem of finding the 3D structure of a molecule is very important as it is strongly related to its chemical properties. If a subset of interatomic distances is known via NMR techniques, the problem can be formalized as a 3D graph drawing problem, and is usually solved using continuous optimization techniques. Proteins are an important class of molecules with a particular structure, i.e. a main backbone chain with some side-chain dangling residues. The backbone chain is a linear atom ordering such that distances between all triplets of successive atoms are known. Under the additional (realistic) assumption that at NMR can at least find all distances between pairs of atoms of the form $(i, i+3)$, we are able to show that the problem of finding the conformation of the protein backbone can be discretized yielding a very fast branch-and-prune algorithm, which can potentially find all possible molecular conformations.

Partitioning numerical data sets by particle swarm optimization

JAVIER TREJOS
Universidad de Costa Rica

coauthors: Mario Villalobos, Eduardo Piza, Alex Murillo

keywords: classification, clustering, metaheuristics

We deal with the problem of clustering a set of data described by numerical variables by means of partitining it in K disjoint clusters and minimizing the within–variance criterion. We apply particle swarm optimization (PSO), in which agents are the K cluster kernels, which move in $\mathbb{R}^p$ acoording to PSO principles ; each kernel is associated to its cluster by the membership allocation of objects to the closest kernel. Hence, the algorithm consists in moving K kernels or particles in $\mathbb{R}^p$ in the direction of the velocity resulting from a consensus between the best neighbor, the past of the particle, and the last particle's velocity. Results are compared to those obtained with some other metaheuristics applied by the authors in partitioning, such as simulated annealing, genetic algorithm, tabu search, and ant colonies, as well as to some classical algorithms (k–means and Ward hierarchical clustering).

MO3-R10 MULTICRITERIA OPTIMIZATION

Theory of vector optimization

chair: Lee Gue Myung

Epsilon-optimality conditions for convex infinite vector optimization problem

GUE MYUNG LEE
Division of Mathematical Sciences, Pukyong National University

keywords: convex infinite optimization problems, optimality conditions, vector optimization

A convex infinite vector optimization probelm (CIVP), which consists of more than two convex objective functions and infinitely many convex constraint functions, is considered. We introduce two kinds of epsilon efficient solutions for (CIVP), and to get epsilon-optimality theorems for such solutions, we define a constraint qualification expressed with epigraphs of conjugate functions. Under such a constraint qualification, we prove necessary and sufficient epsilon-optimality theorems for (CIVP).

This talk is based upon joint works with G. S. Kim and N. Dinh.

On regularity conditions to multiobjective optimization

GRACIELA SOTTOSANTO
Universidad Nacional del Comahue

coauthors: María Cristina Maciel, Sandra Santos

keywords: constraint qualifications, nonlinear multiobjective optimization, Pareto points, regularity conditons

This work is concerned with the differentiable constrained multiobjective optimization problem. A characterization based on positive linear dependence of gradient sets is introduced for this class of problems. Moreover, this characterization is extended in order to obtain adequate regularity properties. The main contribution of this work is to develop a new regularity condition for the inequality constrained multiobjective optimization problem, which is sufficient for regularity without any convexity hypothesis.

On vector matrix game and vector dual problems

MOON HEE KIM
Department of Multimedia Engineering, Tongmyong University

coauthors: Lee Gue Myung, Hong Jeong Min

keywords: fractional dual problems, vector matrix game, Wolfe type symmetric dual problems

Vector matrix game, which is a vector version of the usual matrix game, consists of more that two skew symmetric matrices and vector orderings. In this talk, we formulate a Wolfe type dual prolem for a vector optimization problem, and establish equivalent relations between the dual problem and the vector matrix game. Furthermore, we formulate a Wolfe type symmetric dual problem, second-order Wolfe type symmetric

dual problem, symmetric fractional dual problem for a vector optimization problem and establish equivalent relations between the dual problem and the vector matrix game.

MO3-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Computational challenges for large scale SDP

organizer/chair: Makoto Yamashita

A conic interior point decomposition approach for semidefinite programming

KARTIK KRISHNAN SIVARAMAKRISHNAN
North Carolina State University

keywords: decomposition and nonsmooth optimization, semidefinite programming

We present a conic interior point decomposition approach for solving large scale and structured semidefinite programs. The basic idea is to solve such an SDP in an iterative fashion between a master problem (a mixed conic problem over linear and smaller dimensional semidefinite cones) , and decomposed and distributed subproblems (smaller SDPs) in a high performance computing environment. In this talk we motivate and develop the decomposition approach, highlight some of the issues involved in an efficient implementation, and finally present our computational experiences with the algorithm.

Computational techniques of interior-point methods for ill-conditioned semidefinite programs

KAZUHIDE NAKATA
Tokyo Institute of Technology

coauthor: Keiichiro Urayama
keywords: ill-conditioned, interior-point methods, multiple precision arithmetic, semidefinite programming

Semidefinite programs has been intensively investigated from theoretical and practical aspects. The solution of semidefinite programs has been found using primal-dual path-following interior-point methods and many software packages have been developed. However, we face troubles of numerical instability especially for solving ill-conditioned semidefinite programs. The ill-conditioned problems are frequently observed in the applications of many fields. To overcome this difficulty, we propose the computational methods in order to correct the primal feasibility of the iterative points and inexact inverse matrix of dual variables, etc. As a result, we can obtain higher accuracy solutions. We also implement interior-point methods with multiple precision arithmetic instead of double precision arithmetic. To decrease computing time, we attempt to restrict multiple precision arithmetic. We will talk these computational techniques of interior-point methods and report some numerical results.

Large-scale semidefinite programming from quantum chemistry

MAKOTO YAMASHITA
Kanagawa University

coauthors: Mituhiro Fukuda, Katsuki Fujisawa, Masakazu Kojima, Kazuhide Nakata, Maho Nakata
keywords: parallel computing, quantum chemistry, semidefinite programming

In quantum chemistry, computing the ground state energy for atoms and molecules is a fundamental problem. The historical breakthrough brought by M.Nakata et al is that the problem can be reduced into SemiDefinite Programming (SDP) and can be solved with standard SDP software. Even though the approach provides enough accuracy, the size of the reduced SDPs are often extremely large. To solve such extremely large SDPs, we apply parallel SDP solver on PC-clusters.

In this presentation, we show how we reduce the computation for the ground state energy into SDP briefly and report their numerical results on parallel computing envrionment.

MO3-R12 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Extensions of SDP

chair: Amir Beck

Quadratic matrix programming

AMIR BECK
Technion - Israel Institute of Technology

keywords: nonconvex quadratic optimization, semidefinite relaxations, strong duality

We introduce and study a special class of nonconvex quadratic problems in which the objective and constraint functions have the form $f(X) = Tr(X^TAX) + 2Tr(B^TX) + c, X \in R^{n\times r}$ The latter formulation is termed *quadratic matrix programming* (QMP) of order r. We construct a specially devised semidefinite relaxation (SDR) and dual for the QMP problem and show that under some mild conditions strong duality holds for QMP problems with at most r constraints. Using a result on the equivalence of two characterizations of the nonnegativity property of quadratic functions of the above form, we are able to compare the constructed SDR and dual problems to other known SDR and dual formulations of the problem. An application to robust least squares problems is discussed.

Penalized complementarity functions on symmetric cones

SANGHO KUM
Chungbuk National University

coauthor: Yongdo Lim
keywords: complementarity functions, complementarity problem, merit functions, symmetric cones

We show that penalized functions of the Fischer-Burmeister and the natural residual functions defined on symmetric cones are complementarity functions. Boundedness of the solution set of a symmetric cone complementarity problem, based on the penalized natural residual function, is proved under monotonicity and strict feasibility. The proof relies on a trace inequality on Euclidean Jordan algebras.

Filter methods for nonlinear semidefinite programming

HECTOR RAMIREZ C.
DIM-CMM, Universidad de Chile

coauthor: Walter Gomez
keywords: filter methods, global convergence, nonlinear semidefinite programming

In this talk we propose a filter method for solving nonlinear semidefinite programming problems. Our method extends to this setting the filter SQP (sequential quadratic programming) algorithm, recently introduced for solving nonlinear programming problems, obtaining their respective global convergence results.

MO3-R13 NONLINEAR PROGRAMMING

MINLP

organizer/chair: Jeff Linderoth

Fully polynomial time approximation schemes for mixed-integer polynomial optimization in fixed dimension

MATTHIAS KOEPPE
University of Magdeburg

coauthors: Jesús A. de Loera, Raymond Hemmecke, Robert Weismantel
keywords: complexity in fixed dimension, FPTAS, integer polynomial optimization

Integer linear optimization, that is the problem of optimizing a linear functional over the integer points of a polyhedron, is NP-hard. However, when we fix the number of variables, it can be solved in polynomial time using the algorithm of Lenstra (1983). More strongly, Khachiyan and Porkolab (2000) showed that convex polynomial functions can be minimized over the integer points of convex semialgebraic sets in polynomial time, when the number of variables is fixed.

The situation is different when we consider arbitrary (not necessarily convex) objective functions over the integer points of a polytope. Even when the dimension is fixed ≥ 2 and the degree is bounded ≤ 4, the optimization problem is still NP-hard.

We prove the existence of a fully polynomial-time approximation scheme (FPTAS) for the maximization problem where the objective function is non-negative on the feasible region, when the dimension is fixed. This is the strongest possible result, unless P = NP. Our result makes use of Barvinok's short rational generating functions for the integer points in polytopes.

We then extend the FPTAS to the case of mixed-integer polynomial optimization, where some of the variables are integers and some are reals.

Furthermore, using a different notion of approximation, we also prove the existence of a fully polynomial-time approximation scheme for arbitrary minimization and maximization problems, without a restriction on non-negativity.

FilMINT: A new MINLP solver

SVEN LEYFFER
Argonne National Laboratory

coauthors: Jeff Linderoth, Kumar Abhishek
keywords: branch-and-cut, mixed-integer nonlinear programming, sequential quadratic programming

We describe a new solver for mixed integer nonlinear programming (MINLP) that is based on a hybrid outer approximation and branch-and-cut framework. Our solver combines filterSQP to solve NLP subproblems and MINTO to handle the branch-and-cut framework. We show the effect of advanced MIP features such as cutting planes, branching and node selection rules, and cut management on the solution process. Time permitting we will also present some new ideas on primal heuristics for MINLPs.

Approximation of non-linear functions in mixed integer linear programming

ALEXANDER MARTIN
TU Darmstadt

coauthors: Susanne Moritz, Markus Möller
keywords: gas optimization, mixed-integer programming, SOS constraints

The common approach to incorporate non-linear functions into mixed integer linear programs is by piece-wise linear functions. There are two ways to model piece-wise linear function, via binary variables or via SOS constraints. We discuss both approaches and extend ideas known for the one-dimensional case to higher dimensions. We provide a complete polyhedral analysis of the SOS approach and computationally compare all approaches on some real-world problems arising in the optimization of gas networks.

MO3-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Robust optimization under data uncertainty

organizer: Javier Pena
chair: Luis Zuluaga

Network design and routing with demand and travel time uncertainty

FERNANDO ORDONEZ
University of Southern California
keywords: network design, robust optimization, vehicle routing problem

Many network applications are naturally faced with significant uncertainty which can make a carefully planned optimal solution inefficient in practice. Robust optimization models provide a promising alternative as they are typically just as difficult to solve as the deterministic counterpart and the robust solution tends to be efficient and insensitive to the uncertainty considered, thus has the potential to be efficient in practice. We use a robust optimization approach on two integer problems: the capacity expansion and vehicle routing problems on networks with uncertainty in demand and travel time. We present tractable robust optimization models for these problems and investigate how efficient is the robust solution in practice. Our results show that the robust solution is attractive for the capacity expansion and routing problems as it can reduce the worst case cost while incurring in minor sub-optimality for a given data instance.

Robust optimization in supply chain management: application cases

JORGE VERA
Universidad Catolica de Chile

coauthors: Carlos Bohle, Alfonso Perez
keywords: optimization in supply chain management, robust optimization, robust optimization applications

Robust Optimization is becoming an important approach to deal with variability and uncertainty in different problems. Applications to specific areas are emerging and in this talk we show the development of robust models for two supply chain management problems in the areas of agriculture and forestry. In both cases, the nominal models correspond to hard mixed integer linear programs. We have applied the robust approach developed by Bertsimas and Sim, including the necessary reformulations in order to have a suitable robust problems, with variation both in constraints parameters and in right hand side. We show different robust formulations and evaluate their fitness as an actual decision support tools. Results are analyzed in terms of changes in objective function within the uncertainty sets and also in terms of changes in solution structure. The results are promising showing that the methodology has an strong potential for supporting management decisions in this areas.

Robust formulations for the

CVaR portfolio allocation, and the newsvendor problem

LUIS ZULUAGA
University of New Brunswick

coauthors: Javier Pena, Donglei Du, Juan Vera

keywords: portfolio allocation, robust optimization, semi-parametric bounds

We present new robust formulations for the CVaR portfolio allocation problem, and the newsvendor problem. To obtain robust formulations for these problems, we use a distribution free or semiparametric approach to deal with the problems' inherent uncertainties. In particular, we present a novel linear programming portfolio allocation model in which worst-case Conditional Value-at-Risk (CVaR) is used as the risk measure. The worst-case CVaR is computed by considering underlying asset price probability distributions that replicate the observed prices of vanilla options. Also, we extend previous results on the distribution free newsvendor problem.

MO3-R15 INFINITE DIMENSIONAL PROGRAMMING AND OPTIMAL CONTROL

Efficient Numerical Methods

chair: Frank Strauss

High performance computing for eigenvalue constrained shape optimization

FRANK STRAUSS
University of Karlsruhe

coauthor: Vincent Heuveline

keywords: eigenvalue constraints, high performance computing, optimal control, shape optimization

We focus on problems of optimal control and stability appearing in structural mechanics and computational fluid dynamics. In that context we consider shape optimization problems subject to eigenvalue constraints. The eigenvalue state equation is derived from a system of partial differential equations. Analytical issues focusing on existence results as well as numerical aspects are addressed. Our study encompasses not only the analysis of a priori estimates but also the development of adequate numerical schemes. The complexity of the underlying problems leads to large highly nonlinear problems which are solved by means of techniques relying on high performance computing. The numerical methods developed in that framework are presented and applied to the design optimization of a racing yacht for the America's Cup.

Application of parallel computing to nonlinear optimal control problems

LUIZ OLIVEIRA
CEPEL- Centro de Pesquisas de Energia Elétrica

coauthor: João Lauro Dornelles Facó

keywords: generalized reduced gradient, linear systems, nonlinear optimal control, parallel computing

Nonlinear dynamic systems are considered in a unified approach as discrete-time nonlinear optimal control problems with time delays and inequality constraints on the state and the control variables. These problems are large-scale and Nonlinear Programming (NLP) methods are able to solve them efficiently.

A generalized reduced gradient algorithm (GRG) specialized to solve optimal control problems is proposed exploiting the staircase structure of the jacobian matrix of the dynamic equations by using priority principles to choose the basic variables at each basic matrix reinversion. Thus the basic matrix can be built as low-triangular with diagonal blocks. Parallel computing techniques are used to solve the linear systems of equations by LU decomposition, exploring the block structure in the tasks distribution of the reduced dimension blocks to each processor, diminishing the message passing effort, and improving the efficiency of the method parallel version.

MO3-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Advances in monotone variational inequalities

organizer: Paulo Jose da Silva e Silva
chair: Jonathan Eckstein

General projective splitting for monotone operators

JONATHAN ECKSTEIN
Rutgers University

coauthor: B. F. Svaiter

keywords: decomposition, monotone operators

For the problem $T_1(x) + T_2(x) + \cdots + T_n(x) \ni 0$, where the T_i are maximal monotone operators on a Hilbert space, we describe a general *splitting algorithm* — an iterative scheme that uses only the resolvents of the individual T_i. Most schemes of this type are reducible to the case $n = 2$ via a product space formulation, but ours is more general, and also has a unprecedentedly wide choice of parameters. The order of operator evaluation can vary from iteration to iteration, and one may evaluate resolvents approximately using a relative error criterion. The analysis is based on decomposably constructing separators for a certain extended solution set, and generalizes our prior work for $n = 2$.

On general variational inequalities

SUSANA SCHEIMBERG
UFRJ

coauthor: Paulo Santos

keywords: finite-dimensional approximation method, general complementarity problem, general variational inequality, variational inequalities

In this work, we analyse the General Variational Inequality problem, GVI, with nonmonotone operator, in a Hilbert space . The classical Variational Inequality and the Generalized Complementarity Problem, GCP, are particular cases of that problem. We present an existence theorem under weaker conditions that those used by Noor for GVI and by Isac for GCP. We further derive a numerical method for solving General Variational Inequalities by considering finite-dimensional approximations. The method we propose combines a Galerkin scheme and Mosco convergence of the approximation sets. Under a like-pseudomonotone condition in the Brézis sense requiered on the approximations of the involved operators, we obtain convergence results of the sequence generated by the method.

Exact penalties for KKT systems

PAULO DA SILVA E SILVA
Univeristy of São Paulo

coauthor: Thiago Afonso de André

keywords: exact penalties, KKT systems, reformulations

In this talk, we present an extension of the concept of a differentiable exact penalty for Nonlinear Programming to the context of general KKT systems.

We arrive at a new semismooth reformulation of KKT systems, closely related to the max function, that incorporates implicitly dual information. Even though

the gradient of a traditional differentiable exact penalty depends on the Hessians of the primal data, our reformulation does not use any curvature information, being easily implemented. Moreover, as the multipliers are estimated from the primal values, we show that a general KKT system may be reformulated by a n-dimensional semismooth equation if the penalization parameter is large enough.

We also specialize our reformulation to solve nonlinear (monotone) complementarity problems. We use this reformulation to compute the direction for a semismooth Newton method globalized by a variation of the Fischer-Burmeister NCP function and show some encouraging computational results.

MO3-R17 SEMI-INFINITE PROGRAMMING
Extensions of SIP
organizer/chair: Juan Alfredo Gomez

Necessary conditions and duality for inexact nonlinear semi-infinite programming problems

JUAN ALFREDO GOMEZ
Universidad de La Frontera

coauthor: Paul Bosch
keywords: duality, Dubovitskii-Milyutin approach, semi-infinite nonlinear programming

First order necessary conditions and duality results for general inexact nonlinear semi-infinite programming problems, formulated in non-reflexive spaces, are obtained. The Dubovitskii-Milyutin approach is the main tool used. Regularization of multipliers and reduction to finite dimensional dual problems are discussed. Particular cases of the general result for linear and convex programs are also given and comparisons with existing results in the literature are commented.

Stability of the feasible set mapping of linear inequality

PAUL BOSCH
Universidad Diego Portales

coauthors: Miguel A. Goberna, Jorge Amaya
keywords: feasible set mapping, linear semi-infinite programming, stability analysis

This work deals with the stability of the feasible set mapping of linear inequality systems of an arbitrary number (possibly infinite) of constraints such that the variable x ranges on a certain fixed constraint set $X \subset \mathbb{R}^n$ (X could represent the solution set of a certain constraint system, e.g., the positive cone in $\mathbb{R}^n$ in the case of sign constraints).

More in detail, the work provides necessary as well as sufficiet conditions for the lower and upper semicontinuity (in Berge sense), and the closedness, of the set-valued mapping which associates, with any admissible perturbation of the given (nominal) system its feasible set. The parameter space is formed by all the systems having the same structure (i.e., the same number of variables and constraints) as the nominal one, and the perturbations are measured by means of the pseudometric of the uniform convergence.

Cutting plane algorithms for robust conic convex optimization problems

WALTER BOFILL
Universidad de La Frontera

coauthor: Juan Alfredo Gómez Fernández
keywords: conic programming, cutting planes, semi-infinite linear programming

Some well-known cases of nonlinear programming problems are studied, presenting them as instances of inexact or semi-infinite linear programming. The class of problems considered contains, in particular, semidefinite programming, second order cone programming and special cases of inexact semidefinite programming. Strong duality results for the nonlinear problems studied are obtained via the Lagrangian duality. Based on these results a dual algorithms for the studied classes is proposed. The algorithm can be interpreted as cutting plane or discretization algorithms. Finally some comments on the convergence of the proposed algorithms and on numerical tests are given.

MO3-R18 GRAPHS AND MATROIDS
Graph algorithms
organizer/chair: Celia Mello

On graph sandwich problems

SIMONE DANTAS
COPPE/UFRJ
keywords: graph sandwich problems

Given two graphs G1=(V,E1) and G2=(V,E2), such that E1 is a subset of E2, the Graph Sandwich Problem for property Pi asks, if there exists a graph G= (V,E) such that E1 is a subset of E, and E is a subset E2.

Graph sandwich problems were introduced by Golumbic, Kaplan and Shamir, 1985. They have considered sandwich problems with respect to several subclasses of perfect graphs.

The graph sandwich problems have attracted much attention lately arising from many applications and as a natural generalization of recognition problems. In this talk, we'll discuss the computational complexity of the graph sandwich problems for many properties Pi.

Optimal transmission tower spotting using a shortest-path algorithm with preference relationships between nodes

JOÃO NEIVA DE FIGUEIREDO
UFSC

coauthor: Clovis Gonzaga
keywords: graph theory, sequential optimization, shortest paths, transmission tower spotting

Efficient tower spotting is the highest impact way to reduce total transmission line costs once tower structure types have been selected and the transmission line route has been determined. To date there has been no procedure that guarantees transmission tower spotting optimality since all prior attempts to solve this problem have been based on sliding window approaches. This presentation describes a conceptual formulation, analytical model, and algorithmic solution that guarantee spotting transmission line towers at minimum cost. Electromechanical and topographical constraints to obtaining the minimum cost are described, a model using graph theory is introduced, the nodes, arcs, costs, and paths are defined, and the optimization algorithm is presented. This algorithm uses time-tested shortest-path search methods together with the novel concept of preference relationships between nodes.

An O(VE) algorithm for ear decompositions of matching covered graphs

MARCELO CARVALHO
UFMS - Brazil

coauthor: Joseph Cheriyan
keywords: ear decomposition, matching covered graph

Our main result is an $O(nm)$-time (deterministic) algorithm for constructing an ear decomposition of a matching-covered graph, where n and m denote the number of nodes and edges. The improvement in the running time comes from new structural results that give a sharpened version of Lovász and Plummer's Two-ear Theorem. Our algorithm is based on $O(nm)$-time algorithms for two other fundamental problems in matching theory, namely, finding all the allowed edges of a graph, and finding the canonical partition of an elementary graph. To the best of our knowledge, no faster deterministic algorithms are known for these two fundamental problems.

MO3-R19 GRAPHS AND MATROIDS

Optimization in graphs and digraphs

organizer/chair: András Sebo

Reliable network design

ZOLTAN SZIGETI
Equipe Combinatoire et Opt., University Paris 6

keywords: augmentation, edge connectivity

Given a bipartite graph $G = (V,E)$ and a local edge-connectivity requirement $r(u,v)$ for each pair of vertices $u,v \in V$, find a minimum cardinality edge set F so that $G+F$ is bipartite and the local edge-connectivity $\lambda_{G+F}(u,v)$ is at least $r(u,v)$ for all $u,v \in V$.

In this talk we give a $3/2$-approximation algorithm for this problem. This result is a joint work with L. Végh. The special case, when $r(u,v) = k$ for all $u,v \in V$, is polinomially solvable; see in J. Bang-Jensen, H. Gabow, T. Jordán, Z. Szigeti, Edge-connectivity augmentation with partition constraints, *SIAM Journal on Disc. Math.* Vol. 12 No. 2 (1999) 160-207.

Fractional packing in ideal clutters

YUJI MATSUOKA
The University of Tokyo

keywords: ideal clutters, packing

We present a polyhedral framework for fractional packing problems in ideal clutters. Consider an ideal clutter with nonnegative capacities on its vertices. It follows from idealness that for any nonnegative capacity the total multiplicity of an optimal fractional packing is equal to the capacity of a minimum edge in its blocker. The framework finds an optimal packing of at most n edges with positive multiplicities, performing at most n times minimizations for a clutter and at most n^2 times minimizations for its blocker, where n denotes the cardinality of the vertex set. Applying to the clutter of dijoins (directed cut covers), our framework provides a combinatorial polynomial-time algorithm for fractional packing of dijoins.

Minimum cost partition into cliques with submodular costs

VINCENT JOST
Leibniz-IMAG

keywords: chromatic batch scheduling, cooperative game theory, P4-free graphs, submodular functions and (box-)TDI systems

We present a common generalization for min-max relations involving submodular functions and perfect graphs. These min-max formulas are relevant in scheduling as well as in cooperative game theory with restricted cooperation.

Given a graph $G = (V,E)$ and a cost function c defined for every clique of G (NOT necessarily maximal for inclusion), we want to compute a partition into cliques $\{Q_1, Q_2, \ldots, Q_k\}$ of minimum total cost. In other words, we want to minimize: $c(Q_1) + c(Q_1) + \ldots c(Q_k)$ where $\{Q_1, Q_2, \ldots Q_k\}$ is an arbitrary partition into cliques.

The following system yields various min-max formulas:

$x(Q) \leq c(Q)$ for every clique Q of G.

For instance, it is TDI if - G is perfect and c =1 - G is (co-comparability) and c is the rank of a uniform matroid - G is the line of a bipartite multigraph and c is submodular - G is P4-free and c is a "max-function"

MO3-R20 APPROXIMATION ALGORITHMS

Approximation algorithms for scheduling problems

organizer: Claire Kenyon
chair: Baruch Schieber

Fair Scheduling in Operating Systems

CLIFF STEIN
Columbia University

coauthors: Jason Nieh, Bogdan Caprita
keywords: approximation algorithms, computer systems, scheduling

Proportional share resource management provides a flexible and useful abstraction for multiplexing time-shared resources. We present Group Ratio Round-Robin (GR^3), a proportional share scheduler that combines proportional fairness scheduling behavior that is close to optimal with $O(1)$ scheduling overhead on both uniprocessor and multiprocessor systems. GR^3 uses a novel client grouping strategy to organize clients into groups of similar processor allocations which can be more easily scheduled. Using this grouping strategy, GR^3 combines the benefits of low overhead round-robin execution with a novel ratio-based scheduling algorithm. GR^3 can provide fairness within a constant factor of the ideal generalized processor sharing model and preserves its fairness properties on multiprocessor systems. We have implemented GR^3 in Linux and measured its performance against other schedulers commonly used in research and practice, including the standard Linux scheduler, Weighted Fair Queueing, Virtual-Time Round-Robin, and Smoothed Round-Robin. Our experimental results demonstrate that GR^3 can provide much lower scheduling overhead and much better scheduling accuracy in practice than these other approaches.

Scheduling with resource dependent processing times

MARC UETZ
Maastricht University

coauthors: Alexander Grigoriev, Maxim Sviridenko
keywords: approximations, LP rounding, resource constraints, unrelated machine scheduling

We consider the classical unrelated parallel machine problem with the objective to minimize the makespan. In addition, we assume a time-resource tradeoff: Processing times of jobs can be expedited by using a scarce renewable resource, eg personnel. We formulate that problem as an integer program, but relax the resource constraint to a total budget constraint. To

obtain a close to optimum integral solution, we propose a derandomized version of a recent LP rounding procedure by Kumar et al., generalizing a previous LP rounding approach by Shmoys and Tardos. We show how it can be used to derive our main result, a deterministic 3.75-approximation algorithm for the scheduling problem. This considerably improves upon previous results. The improvement over previous results is due to a better LP rounding and a new scheduling algorithm that can be viewed as a restricted version of the harmonic algorithm for bin packing.

Sequential vector packing

ALEXANDER HALL
ETH Zurich

coauthors: Riko Jakob, Marc Nunkesser
keywords: approximation algorithms, multidimensional bin packing, resource constrained scheduling

We introduce a novel variant of the well known d-dimensional bin (or vector) packing problem. Given a sequence of non-negative d-dimensional vectors, the goal is to pack these into as few bins as possible. In the classical problem the bin size vector is given and the sequence can be partitioned arbitrarily. We study a variation where the vectors have to be packed in the order in which they arrive. The bin size vector can be chosen once in the beginning, under the constraint that the coordinate-wise bounds sum up to at most a given total bin size. This setting arises from a special resource constrained scheduling problem. We prove that the problem is NP-hard and we propose LP based approximation algorithms. Furthermore, we investigate properties of natural greedy algorithms, and present an easy to implement heuristic which is fast and performs well in practice. Experiments with the heuristic and an ILP formulation yield very promising results on real world data.

MO3-R21 DYNAMIC PROGRAMMING

Stochastic dynamic programming

organizer/chair: Eugene Feinberg

Scalable approximate dynamic programming algorithms for stochastic resource allocation

WARREN POWELL
Princeton University

coauthors: Belgacem Bouzaiene-Ayari, Hugo Simao, Abraham George
keywords: approximate dynamic programming, resource allocation, stochastic programming

Resource allocation problems arise in a broad variety of settings including portfolio management, transportation fleet management, and the management of blood inventories, all of which exhibit significant forms of uncertainty. Formulated as dynamic programs, they exhibit state variables that range from under 100 dimensions, to over 100,000. We present a class of approximate dynamic programming strategies that merge machine learning with math programming to provide practical solutions to these problems. The current status of provably convergent results will be reviewed.

Non-randomized control of constrained Markov decision processes

RICHARD CHEN
NRL

coauthor: Eugene Feinberg
keywords: Markov decision processes

This talk concerns the optimal control of constrained Markov decision processes with expected-cost criteria using non-randomized policies. A dynamic programming approach for constructing optimal policies will be presented. The convergence of the finite horizon value function to the infinite horizon value function will also be shown. Examples and applications will be discussed.

Multiple objective nonatomic discounted dynamic programming

EUGENE FEINBERG
Stony Brook University

coauthor: Aleksey Piunovskiy
keywords: dynamic, nonatomic stochastic dynamical programming, program, stochastic algorithms

A stochastic dynamic programming problem is called nonatomic if the initial distribution and transition probabilities are nonatomic. We discuss the existence of nonrandomized stationary and Markov optimal policies in nonatomic discounted dynamic problems with multiple criteria and constraints. We also discuss the link between the results on nonatomic dynamic programming problems and the work of Dvoretzky, Wald, and Wolfowitz on nonrandomized statistical decisions.

TU1-R1 COMBINATORIAL OPTIMIZATION

Matrices and optimization

chair: Davaatseren Baatar

Matrix decomposition problem with application in cancer radiation treatment planning

DAVAATSEREN BAATAR
Research Fellow

coauthors: Horst Hamacher, Natashia Boland, Robert Johnston
keywords: consecutive ones property, decomposition of integer matrices, multileaf collimator sequencing

In this paper, we consider the problem of decomposing a positive integer matrix into a positive integer linear combination of binary matrices, which have so-called consecutive ones (C1) property. This problem is motivated by an application in cancer radiation treatment planning, namely the sequencing of multileaf collimators to realize a given intensity matrix. We consider the problem of minimizing the number of the binary matrices used in the decomposition, which has been shown to be strongly NP-hard by Baatar et al (2005). New models and heuristic algorithms will be presented in comparison with other existing algorithms.

On symmetric combinatorial IP models and inequalities eliminating symmetries

PABLO REY
UNIVERSIDAD DE CHILE, ACADEMICO

keywords: integer programming, symmtries elimination

We study some integer programming models for problems in combinatorial and coding theory. The instances considered are computationally difficult symmetric set covering instances. The symmetries involved arise from the authomorphisms of the underlying structures. We present computational experiments analizing the effect of adding inequalities which eliminate symmetries to the standard set covering models.

The traveling salesman problem on permuted Monge matrices

GEORGE STEINER
McMaster University

coauthors: Vladimir Deineko, Dvir Shabtay, Zhihui Xue
keywords: permuted Monge matrix, scheduling, travelling salesman problem

A large variety of scheduling problems has recently been identified as special cases of the Traveling Salesman Problem (TSP) on permuted Monge matrices. Although the TSP on permuted Monge matrices is known to be strongly NP-hard, we show that polynomial-time solutions exist for many of the special cases generated by the scheduling problems. We also show that a simple subtour-patching heuristic is asymptotically optimal for the TSP on permuted Monge matrices under some mild technical conditions.

TU1-R2 COMBINATORIAL OPTIMIZATION

Integrated methods for optimization

organizer/chair: John Hooker

A new hybrid heuristic for the quadratic assignment problem

PAULO BOAVENTURA NETO
PEP/COPPE/UFRJ

coauthors: André de São Thiago Moreira, Valdir Agustinho de Melo
keywords: matrix structures, metaheuristics, quadratic assignment problem

A new hybrid heuristic is proposed for the quadratic assignment problem, through the use of a matrix defined by Picard and Queyranne in the 70's. This matrix has the advantage of guaranteeing the feasibility of a solution through the structural arrangement of the corresponding entries. It is of order n^2, where n is the instance order and because of that it has to be worked on virtually. Its use integrates the concept of pseudo-feasible solution defined by Rangel. The proposed heuristic is a modified GRASP using a taboo search, with the possibilities of guiding the search through equal-valued solutions for instances with significative number of equal-valued flow and/or distance matrix entries and, on the other hand, of accepting worse solutions in order to explore regions adjacent to new local optima.

Disco-Novo-GoGo: integrating local search and complete search with restarts

MEINOLF SELLMANN
Brown University

keywords: heuristics, local search, restarts

A hybrid algorithm is devised to boost the performance of complete search on under-constrained problems. We suggest to use random variable selection in combination with restarts, augmented by a coarse-grained local search algorithm that learns favorable value heuristics over the course of several restarts. Numerical results show that this method can speed-up complete search by orders of magnitude.

Continuous relaxation of combinatorial constraints

JOHN HOOKER
Carnegie Mellon University

keywords: global constraints, relaxation

We present continuous relaxations of several combinatorial constraints that appear as global constraints in constraint programming systems, including the all-different, circuit, disjunctive scheduling, and cumulative scheduling constraints. The relaxations are formulated in the original variables, without the use of 0-1 or other auxilliary variables.

TU1-R3 COMBINATORIAL OPTIMIZATION

Metaheuristics and applications I

organizer: Toshihide Ibaraki
chair: Ana Viana

iMDF: intelligent metaheuristics development framework

HOONG LAU
The Logistics Institute Asia Pacific

coauthor: Wee Chong Wan
keywords: adaptive algorithm, frameworks, metaheuristics

The community has seen proposals on several meta-heuristics software frameworks (Hotframe, EasyLocal, OpenTS etc). Typically, these frameworks aim at providing a platform for prototyping search algorithms thereby the effort in coding, but often rely entirely on the developer's knowledge in designing search strategies. For instance, they lack the intelligent capability that allows users to implement adaptive algorithms that apply different strategies to different instances of the same problem. In this work, we propose a novel meta-heuristics framework that adopts the pheromone concept of Ant Colony Optimization (ACO) that automatically applies "the right strategy at the right time". Essentially, an intelligence controller within the framework

will monitor the relative performance of applying different strategies (pheromone density), and consequently converges itself on strategies that perform well for a given instance. This adaptive capability allows the developers to offload the decision on when to apply a certain strategy, and relieving them to focus on design and experimentation. We illustrate this framework, which we called intelligent Meta-heuristics Development Framework (iMDF), in an experiment that solves the Multi-dimensional Knapsack Problem (MDKSP).

DNA sequence design by dynamic neighborhood searches

HIROTAKA ONO
Kyushu University

coauthors: Suguru Kawashimo, Kunihiko Sadakane, Masafumi Yamashita
keywords: local search, sequence design

We propose a local-search based algorithm to design biological sequence sets that satisfy constraints about hamming-distance criteria. Our method considers the overlapping measure, which is more combinatorial than other constraints. To deal with the combinatorial constraints in the local search, we adopt a dynamic neighborhood search framework, called the Variable Neighborhood Search (VNS) and the Variable Depth Search (VDS). In spite that our algorithm can be easily adapted to other constraints due to the flexibility of the local search, the computational experiments show that generated sequence sets are as good as the ones generated by exiting methods, or better.

Hydrothermal coordination: an integrated approach with metaheuristics

ANA VIANA
ISEP/INESC Porto

coauthors: Jorge Pinho de Sousa, Manuel Matos
keywords: constraint oriented neighbourhoods, hydro-thermal coordination, metaheuristics

In a hydrothermal system a proper coordination between the hydro and the thermal systems is required to minimize the system total production costs. This is generally achieved by decomposing the base problem in two subproblems, one handling the hydro system and the other handling the thermal one. Usually, the hydro scheduling subproblem is solved first and then, for the remaining demand (the total load demand minus the hydro production) the thermal subproblem is solved. The process is repeated until the thermal marginal costs or hydro generation converge.

Metaheuristics approaches dealing with the Hydrothermal Coordination problem (HTC) do also follow this reasoning: the metaheuristic tackles the combinatorial thermal problem, while other techniques are used to solve the hydro subproblem. Hierarchical approaches may however lead to suboptimal results, due to lack of convergence of the iterative approach and, in spite of that, an integrated approach where both systems are tackled simultaneously is desirable.

This paper proposes an integrated approach for solving the HTC with metaheuristics. This is achieved by discretizing the production levels of the hydro units and defining appropriate neighborhood movements that allow changes to be made in the thermal and in the hydro units simultaneously. Different neighbourhood movements are designed to be applied during the search process, according to the type of constraints that are violated in each iteration.

TU1-R4 COMBINATORIAL OPTIMIZATION

Cutting planes for MIPs and polynomial programs

organizer: Michael Juenger
chair: Frauke Liers

A linear bound on the diameter of the transportation polytope

LEEN STOUGIE
TU Eindhoven and CWI Amsterdam

coauthors: Jan van den Heuvel, Graham Brightwell
keywords: Hirsch Conjecture, polyhedral combinatorics, transportation polytope

We prove that the combinatorial diameter of the skeleton of the polytope of feasible solutions of any $m \times n$ transportation problem is at most $8\,(m+n-2)$.

Efficient reduction of logic optimization problems to max-cut

CHRISTOPH BUCHHEIM
Universität zu Köln

coauthors: Giovanni Felici, Giovanni Rinaldi
keywords: logic optimization, max cut, polynomial 0-1 optimization

We present a novel ILP approach to reduce polynomial 0-1 optimization problems to the quadratic case via separation. In the unconstrained case, this yields a reduction to the maximum cut problem. The polytope corresponding to our new model is then a face of a cut polytope of slightly higher dimension, such that the well-known cutting plane techniques for max-cut can be used to solve the original polynomial problem in a branch-and-cut framework. Applying further extensions, this approach leads to new exact algorithms for various logic optimization problems.

Polynomial binary optimization over 'easy' polytopes

FRAUKE LIERS
Institut fuer Informatik, Universitaet zu Koeln, Germany

coauthors: Christoph Buchheim, Marcus Oswald
keywords: polynomial optimization

The task of optimizing a polynomial function over binary variables that additionally satisfy a set of linear constraints has many applications. Usually, these problems are much harder to solve than binary linear programs. In this talk, we focus on solving problems that would be polynomially solvable if we had chosen a linear instead of a polynomial objective function. Additionally, the degree of the polynomial should be 'small'. Examples for this are the quadratic assignment or the quadratic matching problem.

We apply a linearization to the product variables and design a branch-and-cut algorithm in which we exploit the polynomial solvability of the corresponding linear optimization problem. For fixed k, we present an exact polynomial-time algorithm for separating all valid inequalities whose support contains linear variables and product variables operating on at most k linear ones. Furthermore, we show a practically effective heuristic separation routine based on projection cuts. Being applied to the lp relaxations during separation, our approach can also help

solving arbitrary polynomial binary programs of small degree. We show computational results for several problems arising in practice.

TU1-R5 INTEGER AND MIXED INTEGER PROGRAMMING

Graph partitioning problems

organizer/chair: Alexander Martin

Mixed-integer programming for topology optimization in sheet metal design

ARMIN FÜGENSCHUH
TU Darmstadt

coauthor: Alexander Martin
keywords: mechanical engineering, mixed-integer programming, topology optimization

Topology optimization lies at the heart of many design tasks in mechanical engineering. For those sheet metal products that consist of a bundle of seperate channels (such as conduits) we formulate the design task as a linear mixed-integer optimization problem. The design goal is to find a topology where each channel has a given cross section area, using a minimum amount of sheet metal. In addition to a light-weight design, stiffness should also be taken into account. The entire approach is demonstrated in the design of a conduit with five separate channels.

Polyhedral and semidefinite relaxations for graph bisection problems

MARZENA FÜGENSCHUH
TU Darmstadt

coauthors: Michael Armbruster, Christoph Helmberg, Alexander Martin
keywords: cut polytope, graph partitioning, graph bisection, semidefinite programming

Semidefinite relaxations are known to deliver good approximations for combinatorial optimization problems like graph bisection. Using methods like the spectral bundle method it is possible to exploit structural properties of the underlying problem and to apply, even in large scale instances, cutting plane methods, probably the most successful technique in linear programming. The approach requires a profound understanding of the relevant polyhedral structure and hinges on good separation routines. We present several classes of valid inequalities for the cut polytope associated with the graph bisection problem, incorporate the corresponding separation algorithms in a branch-and-cut framework and discuss their interaction with linear and semidefinite relaxations.

Bisection knapsack path inequalities for graph bisection problems

CHRISTOPH HELMBERG
TU Chemnitz

coauthors: Michael Armbruster, Marzena Fügenschuh, Alexander Martin
keywords: cut polytope, graph partitioning, polyhedra

In graph bisection problems a knapsack type constraint on the node weights is used to limit the size of the clusters while the decision variables are typically edge variables describing the cut. We present bisection knapsack path inequalities that transfer the size constraint to the edge variables by judging the linkage of the nodes to some selected root node via "shortest´´ paths between nodes and root node. The cluster weight polytope is introduced in order to strengthen these inequalities by lower bounding the minimum size requirements of the subgraph consisting of those nodes that are not represented in the knapsack path inequality, because, e.g., no path to the root node exists. The cluster weight polytope is the convex hull of the cut vectors of the subgraph with one additional coordinate giving once the weight of the smaller and once the weight of the larger cluster. We discuss a class of basic facets and present a complete description of the unconstrained cluster weight polytope for stars.

TU1-R6 OPTIMIZATION IN NATURAL RESOURCES

Mathematical models in forestry 1

organizer: Andres Weintraub
chair: Marc MacDill

Using column generation to solve spatially explicit forest management planning problems

MARC MCDILL
Penn State School of Forest Resources

coauthor: Babu Rajasekaran
keywords: column generation, forestry, integer programming, spatially-explicit forest planning

Spatially-explicit forest harvest scheduling models can result in very large integer programming problems that can be very difficult to solve. Column generation is a promising approach for obtaining near-optimal solutions for these problems because most forests can be divided naturally into smaller, relatively independent sub-forest areas. We tested a column generation approach with 40 hypothetical problems and two methods of generating initial solutions to the sub-problems (i.e., seeds). For each method, 25, 50 and 100 seeds were generated for each subproblem. These tests show that both the method of generating the seeds and the number of seeds significantly influence both solution time and the quality of the final solution.

Optimizing inventory collection effort for forest planning

HORACIO GILABERT
Pontificia Universidad Católica de Chile

coauthor: Marc McDill
keywords: cost-plus-loss, forestry, harvest scheduling, yield inputs

The optimum value of the objective function and the optimal solution vector of land harvests are used to propose a loss function that links the cost, quality, and amount of yield information gathered from forest inventories and growth and yield simulation models and the outcomes of a harvest scheduling model. Accounting for the impact of yield estimates uncertainty that is carried through to the planning model and the potential effects on quality of planning decisions opens the possibility to model the tradeoff between the cost of gathering information and the benefit of preventing costs from sub-optimal decisions. Different sampling intensities and simulated plot sizes, and distinct growth models express the quality and amount of yield information. The method is tested using stands of radiata pine (Pinus radiata D.Don) plantations growing in southern Chile.

A mixed integer programming model for harvest scheduling

MIGUEL CONSTANTINO
University of Lisbon

coauthors: Isabel Martins, José Borges
keywords: forest management, integer programming

Forest ecosystem management often requires spatially explicit planning as the spatial arrangement of harvests has become a critical economic and environmental concern. Recent research on exact methods has addressed both the design and the solution of forest management problems with constraints on the clearcut size, but where harvesting simultaneously two adjacent stands in the same period does not necessarily exceed the maximum opening size. Two main integer programming approaches have been proposed for this area restriction model. Yet both encompass an exponential number of variables or constraints. In this work, we present a new integer programming model with a polynomial number of variables and constraints. Branch-and-bound is used to solve it. The model was tested with both real and hypothetical forests ranging from 45 to 1363 polygons and up to 12 time periods. Results show that the proposed model's solutions were within or slightly above 1% of the optimal solution and were obtained in a short computation time.

TU1-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.

Models and methods for network design problems

organizer/chair: Anantaram Balakrishnan

Single facility network loading in hybrid telecommunication networks

RAGHAVENDRAN SIVARAMAN
Massachusetts Institute of Technology

coauthor: Thomas Magnanti
keywords: approximation algorithms, combinatorial optimization, network design, telecommunications

Most current long-distance telecommunication networks are hybrids between traditional Time Division Multiplexing (TDM) and the more recent VoIP technologies. In such hybrid networks, capacity expansion in the TDM subnetwork is usually carried out separately from the IP sub-network. We consider computing an optimal capacity expansion plan in the TDM sub-network of a hybrid network, modeled as a single facility network loading problem in a star network (SNLP). We show that SNLP is APX-Complete even for restrictive special cases. For an important special case of this problem, we provide a simple $2-$factor approximation algorithm that is asymptotically optimal for large demands. Using ideas from the knapsack problem, we devise a polynomial time $(2+\varepsilon)-$approximation scheme for the most general case of SNLP. This approximation scheme can be extended to incorporate such practical constraints as link capacities and surviving single link failures.

Models and heuristics for minimum spanning trees with node degree dependent costs

LUIS GOUVEIA
University of Lisbon - CIO

coauthors: Christophe Duhamel, Pedro Moura, Maurício Cardoso de Souza
keywords: network design, spanning trees

We consider a variant of the degree constrained minimum spanning tree problem where a concave cost function on the degree of each vertex is added to the objective function. We propose a reformulation by discretization combined with a shortest path reformulation of an embedded knapsack subproblem. Upper bounds are computed using an hybrid GRASP/VND metaheuristic. Computational results are proposed on a set of medium-sized instances.

Cutting plane approach for service network design

ANANTARAM BALAKRISHNAN
University of Texas at Austin

coauthors: Prakash Mirchandani, Bo Zhang
keywords: cutting planes, integer programming, network design

Long-term planning for transportation, telecommunications, and other service operations entails designing networks that are both cost-effective and responsive. Planners must address the trade-off between minimizing the total cost of the network configuration while ensuring that the traffic routes satisfy end-to-end service requirements such as limits on traversal time or reliability. For this purpose, we propose the following service network design problem: given the required origin-to-destination flows and costs for installing links of the network, select a minimum cost network design and route the required flows along the chosen arcs subject to service requirements, expressed as limits on the total weight of each route. This model generalizes hop-constrained network design and other difficult problems. To effectively solve the service network design problem, we focus on a polyhedral approach to strengthen its arc-flow formulation. We develop several classes of strong cuts, and report computational results that demonstrate the effectiveness of these inequalities.

TU1-R8 GAME THEORY

Games on graphs

organizer/chair: Encarnación Algaba

Revenue management of perishable products under competition

DANIEL GRANOT
Sauder School of Business, Univ of British Columbia

coauthors: Frieda Granot, Benny Mantin
keywords: duopolistic competition, dynamic pricing, revenue management, subgame perfect Nash equilibrium

We study a multi-period no-replenishment model of competition between independent retailers who sell identical goods to N myopic consumers. Any one of the consumers visits one of the retail stores in every period and purchases the good once the observed price is below his valuation. If the posted price is above his valuation, the consumer does not purchase the good. Rather, in the following period he returns to the same store with a certain probability, P, and with probability 1 - P he will visit one of the other retail stores. The probability P, which may differ from store to store, could either depend on the experience of the consumer at the store, or, alternatively, it could be affected by market structure characteristics, such as market share, size of the store, and geography. We find that prices decline exponentially as long as P is not too close to one. Thus, even a dominant retailer who faces competition with a relatively weak retailer is forced to suppress his prices significantly. We also find that consumers would maximize their surplus if they are price conscious in the sense that they ignore, e.g., store ambience, in their search for a price which is below their valuation for the good. Finally, we show that

while a change from a monopoly to a duopoly competition has a dramatic effect on prices, further intensifying the competition by introducing additional retailers has a relatively marginal effect on prices.

Cooperative games restricted by augmenting systems

ENCARNACIÓN ALGABA
University of Seville

coauthors: Jesús Mario Bilbao, Peter Borm, Marco Slikker
keywords: augmented systems, cooperative game, shapley value

Cooperative games under combinatorial restrictions are cooperative games in which the players have restricted communication possibilities, which are defined by a combinatorial structure. There have been previous models developed to confront the problem of unallowable coalitions. Games restricted by a communication graph were introduced by Myerson and Owen. In this model, the feasible coalitions are those that induce connected subgraphs. Another type of model is introduced in Gilles, Owen and van den Brink, and van den Brink. In their model, the possibilities of coalition formation are determined by the positions of the players in a so-called permission structure. We introduce a new combinatorial structure called augmenting system which is a generalization of the antimatroid structure and the system of connected subgraphs of a graph. The main result of the paper is the caracterization of the value α for augmenting structures by using component efficiency, loop-null and balanced contributions. Furthermore, we obtain a direct algorithm to compute this value by using the worths of the original game. The value α is a generalization of the Myerson value for games restricted by graphs and the Shapley value for games restricted by permission structures.

TU1-R9 GLOBAL OPTIMIZATION
Global optimization techniques I
chair: Panayiotis Lemonidis

Enterprise optimization - problems found, problems solved

GILSILEY DARU
Osvaldo Henrique Daru
keywords: cycle vendor, enterprise optimization, practical cases

Currently, few companies apply optimization broadly across their business processes. Most decision making is heuristic, combining experience with best practice knowledge. Due to unfamiliarity, and lack of practical success stories in the lay business literature, optimization techniques are underutilized. In this talk, we chronicle several experiences from real cases of development of optimization solutions in the Brazilian market. We cover a complete cycle, from presentation and sales to implementation, discussing the problems found, the approaches taken, and the results obtained.

On the divergence of line search methods

WALTER MASCARENHAS
University of Sao Paulo
keywords: Armijo condition, convergence, line search methods, Wolfe conditions

We discuss the convergence of line search methods for minimization. We present examples showing that Newton's method and the BFGS method can fail even if the restrictions of the objective function to the search lines are strictly convex, the line searches are exact and the first Wolfe condition is satisfied. These examples illustrate the use of general mathematical concepts and symbolic computation to analyze the convergence of line search methods.

TU1-R10 MULTICRITERIA OPTIMIZATION
Integer and combinatorial problems
chair: Ranga Muhandiramge

A branch and bound algorithm for solving the binary bilevel integer programming problem

JOHN KARLOF
University of North Carolina Wilmington
keywords: bilevel programming, binary integer programming

Bilevel programming is a model for two independent levels of hierarchical decision making. Each decision maker attempts to optimize its own objective function and is affected by the actions of the other planner. There is a top planner and a bottom planer. The lower planner makes its decisions after, and in view of, the decisions of the top planner. In this talk, we introduce the concept of bilevel programming and present a branch and bound algorithm to solve the binary bilevel integer programming problem.

A mathematical analysis of the political redistricting problem in Japan

KEISUKE HOTTA
Bunkyo University

coauthor: Toshio Nemoto
keywords: combinatorial optimization, electoral redistricting

The parliament of Japan is made up of two houses: the House of Representatives and the House of Councilors. The House of Representatives has 480 members. The election system consists of two voting methods. Of the 480 seats, 300 are elected according to the single-seat constituency system. In Japan, revision of single-seat electoral districts is discussed carefully every 5 years. The aim is to reduce the widening vote-value disparity through redistricting. We formulate this redistricting problem using two types of 0,1-integer programming: set partition-type and graph partition-type. We solved them and obtained the optimal 300 districts through our own methods. Consequently, we can show the quantitative index for the discussions of electoral redistricting.

Network algorithms for continuous path planning problems

RANGA MUHANDIRAMGE
University of Western Australia

coauthors: Natashia Boland, Song Wang
keywords: constrained shortest paths, global optimization

We use the network weight constrained shortest path problem (WCSPP) to solve continuous path planning problems in which we want to minimise the path integral of a risk function subject to a length constraint on the path.

We explore the importance of node placement and edge connectivity in improving solution quality. These techniques are compared to other strategies in numerical experiments.

TU1-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Non-deterministic methods for cone programming

organizer/chair: Robert Freund

Efficiency of a re-scaled perceptron algorithm for conic systems

ROBERT FREUND
MIT

coauthors: Alexandre Belloni, Santosh Vempala
keywords: complexity theory, conic optimization, perceptron, probabilistic methods

The classical perceptron algorithm is a simple and intuitive row-action/relaxation algorithm for solving a homogeneous linear inequality system $Ax \geq 0$, $x \neq 0$. Its complexity is $O(1/\rho^2)$ iterations where ρ is the Euclidean width of the cone of feasible solutions, and so is inefficient. Recently, Dunagan and Vempala have developed a re-scaling version of the perceptron algorithm with an improved complexity of $O(\ln(1/\rho))$ iterations (with high probability), which is notable in that it is theoretically efficient, i.e., polynomial-time in logarithm of the width. We explore extensions of the concepts of these perceptron methods to the general homogeneous conic system $Ax \in C$, $x \neq 0$, and the alternative system $A^T\lambda = 0$, $\lambda \in C^*$, $\lambda \neq 0$. We provide a conic extension of the re-scaling perceptron algorithm based on the notion of a "σ-deep separation oracle" of a cone, which essentially computes a certificate of strong separation for cones. In the case of linear, second-order, semidefinite cones, as well as certain other cones, we show that the resulting re-scaling algorithm is efficient. Regarding the alternative system, we present complexity results for certificates of infeasibility or near-infeasibility in the conic case. This work is joint with Alexandre Belloni and Santosh Vempala.

Logconcave functions: sampling, integration and optimization

SANTOSH VEMPALA
MIT and Georgia Tech

coauthor: Laszlo Lovasz
keywords: integration, random walk, sampling

Logconcave functions are a common generalization of Gaussians and indicator functions of convex bodies; they appear in many areas. In this talk, we survey the algorithmic and geometric ideas behind the most recent developments in sampling, integration and optimization of logconcave functions. In particular, we will discuss the analysis of the random walk called "hit-and-run", and a general method called simulated annealing which is used in the current best algorithms for both integration and optimization.

Interior-point methods for linear optimization based on the new class of barrier functions

GORAN LESAJA
Georgia Southern University

coauthors: Yanqin Bai, Kees Roos
keywords: barrier functions, complexity analysis, interior-point methods, linear optimization

In the talk we present a class of polynomial primal-dual interior-point methods based on the new calss of kernel functions. The new function is not a self regular function because its growth term is increasing at the rate that is between linear and quadratic as opposed to self-regular functions where it is increasing at least quadratically. Several new arguments had to be developed in order to complete the complexity analysis of the algorithms. A favorable complexity bounds on the number of iterations were obtained.

TU1-R12 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Game theoretic techniques with applications

organizer/chair: Zhiquan Luo

A convex Parimutuel formulation for contingent claim markets

MARK PETERS
Stanford University

coauthors: Yinyu Ye, Anthony Man-Cho So
keywords: call auctions, contingent claim markets, convex optimization

In this paper we study the problem of centrally organizing a market where the participants submit bids for contingent claims over the outcome of a future event and the market organizer must determine which bids to accept. The bidder will select a set of future states and a price at which he is willing to buy the contingent claims. By accepting a bid, the market organizer agrees to pay the bidder a fixed amount if one of the bidder's selected states is realized. In this paper, we introduce a new mathematical formulation called the Convex Parimutuel Call Auction Mechanism (CPCAM). This formulation produces many of the same advantageous properties of the earlier Lange and Economides model but can more easily be solved due to its convexity. In particular, our model yields the first fully polynomial-time approximation scheme (FPTAS) for the problem.

Optimal spectrum management for interference-limited multiuser communication systems

ZHIQUAN LUO
University of Minnesota

coauthor: Shunsuke Hayashi
keywords: multiuser comunication

Consider a multiuser communication system in a frequency selective environment whereby users share a common spectrum and can interfere with each other. Assuming Gaussian signaling and no interference cancellation, we study optimal spectrum sharing strategies for the maximization of sum-rate under separate power constraints for individual users. Since the sum-rate function is non-concave in terms of the users' power allocations, there can be multiple local maxima for the sum-rate maximization problem in general. In this paper, we show that, if the normalized crosstalk coefficients are larger than a given threshold (roughly equal to 1/2), then the optimal spectrum sharing strategy is frequency division multiple access (FDMA). In case of arbitrary positive crosstalk coefficients, if each user's power budget exceeds a given threshold, then FDMA is again sum-rate optimal, at least in a local sense. In addition, we show that the problem of finding the optimal FDMA spectrum allocation is NP-hard, implying that the general problem of maximizing sum-rate is also NP-hard, even in the case of two users. We also propose several simple distributed spectrum allocation algorithms that can approximately maximize sum-rates. Numerical results indicate that these algo-

rithms are efficient and can achieve substantially larger sum-rates than the existing Iterative Waterfilling solutions, either in an interference-rich environment or when the users' power budgets are sufficiently high.

TU1-R13 NONLINEAR PROGRAMMING

Large scale nonlinear programming

organizer/chair: Richard Waltz

Utilizing quadratic programming subproblems for nonlinear optimization

FRANK CURTIS
Northwestern University

coauthor: Jorge Nocedal
keywords: iterative methods, KKT systems, large-scale nonlinear programming, nonconvex optimization

The success of a number of algorithms for nonlinear programming depends heavily on the design and solution of quadratic programming subproblems. For some applications, computational demands of the solver are light enough to allow for extra work to be done towards various goals including inertia correction and the accountability of third order objective terms. In other situations, however, it may not even be possible to construct components of the quadratic subproblems explicitly, so optimization-specific issues must be observed carefully in the design of specialized techniques. In this talk we discuss developments concerning these issues.

Preconditioning and convergence of interior-point methods

JORGE NOCEDAL
Northwestern University

coauthors: Long Hei, Richard Waltz
keywords: complementarity constraints, interior-point methods, preconditioning

As nonlinear interior-point methods gain popularity, several issues have come to the forefront. The use of iterative methods and preconditioning is essential for some very large applications. Quasi-Newton approximations are needed in many cases. Convergence for problems that do not satisfy constraint qualifications is important. In this talk we present algorithmic and theoretical developments designed to address these issues.

Smoothing noisy black box functions for nonlinear optimization

ANDREAS WAECHTER
IBM Research

keywords: nonlinear optimization, numerical noise

A number of practical applications of nonlinear optimization methods involve models where some of the model function values and derivatives are obtained by black box procedures. As a result, the functions seen by the optimization algorithm are not smooth and are subject to numerical noise, due to the numerical algorithm used in the black box procedures. Consequently, the optimization method, which was usually derived under the assumption that all functions are sufficiently smooth, can suffer from convergence problems.

In this talk we discuss a method for smoothing noisy function values produced by black box procedures. Numerical experiments will be presented.

TU1-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Minimum covering ellipsoids and their applications

organizer/chair: E. Alper Yildirim

On the minimum volume covering ellipsoid of ellipsoids

E. ALPER YILDIRIM
Bilkent University

keywords: algorithm, core sets, covering ellipsoids, rounding of sets

Let $\mathcal{S}$ denote the convex hull of m full-dimensional ellipsoids in R^n. Given $\varepsilon > 0$ and $\delta > 0$, we study the problems of computing a $(1+\varepsilon)$-approximation to the minimum volume covering ellipsoid of $\mathcal{S}$ and a $(1+\delta)n$-rounding of $\mathcal{S}$. We extend the first-order algorithm of Kumar and Yıldırım that computes an approximation to the minimum volume covering ellipsoid of a finite set of points in R^n, which, in turn, is a modification of Khachiyan's algorithm. Our algorithm can also compute a $(1+\delta)n$-rounding of $\mathcal{S}$. For fixed $\varepsilon > 0$ and $\delta > 0$, we establish polynomial-time complexity results for the respective problems, each of which is linear in the number of ellipsoids m. In particular, our algorithm can approximate the minimum volume covering ellipsoid of $\mathcal{S}$ in asymptotically the same number of iterations as that required by the algorithm of Kumar and Yıldırım to approximate the minimum volume covering ellipsoid of a set of m points. The main ingredient in our analysis is the extension of polynomial-time complexity of certain subroutines in the algorithm from a set of points to a set of ellipsoids. As a byproduct, our algorithm returns a finite "core" set $\mathcal{X} \subseteq \mathcal{S}$ with the property that the minimum volume covering ellipsoid of $\mathcal{X}$ provides a good approximation to the the minimum volume covering ellipsoid of $\mathcal{S}$. Furthermore, the size of the core set depends only on the dimension n and the approximation parameter ε, but not on the number of ellipsoids m. We also discuss the extent to which our algorithm can be used to compute an approximate minimum volume covering ellipsoid and an approximate rounding of the convex hull of other sets in R^n. We adopt the real number model of computation in our analysis.

On minimum volume ellipsoids: from John and Kiefer-Wolfowitz to Khachiyan and Nesterov-Nemirovski

MICHAEL TODD
Cornell University

keywords: ellipsoid, semidefinite programming, volume

The problem of finding the minimum-volume ellipsoid containing a set in R^n has arisen in contexts from optimization to statistics and data analysis over the last sixty years. We describe some of these settings and algorithms old and new for solving the problem.

Clustering via minimum volume ellipsoids

ROMY SHIODA
University of Waterloo

coauthor: Levent Tuncel
keywords: clustering, covering ellipsoids, mixed-integer programming, semidefinite programming

We propose minimum volume ellipsoids (MVE) clustering as an alternative clustering technique to k-means for data clusters with ellipsoidal shapes and explore its value and practicality. MVE clustering allocates data points into clusters in a way that minimizes the geometric mean of the volumes of each cluster's covering ellipsoids. Motivations for this approach include its scale-invariance, its ability to handle asymmetric and unequal clusters,

and our ability to formulate it as a mixed-integer semi-definite programming problem that can be solved to global optimality. We present some preliminary empirical results that illustrate MVE clustering as an appropriate method for clustering data from mixtures of "ellipsoidal" distributions and compare its performance with the k-means clustering algorithm as well as the MCLUST algorithm, which is based on a maximum likelihood EM algorithm.

TU1-R15 OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS

Integration with scripting languages and constraints

organizer/chair: Leonardo Lopes

The model object: local or remote, producer and consumer

LEONARDO LOPES
University of Arizona

coauthor: Victor Foulk
keywords: modeling language

We demonstrate a Modeling Language called POAMS, which integrates the Mathematical Program, as a well-defined rich object, into a weakly typed, dynamic scripting language: Python. We illustrate several advantages of this design: agile model composition; generic meta-algorithms; enhanced modeling interfaces; simple model integration; and vendor neutrality.

CPLEX indicator constraints

MARY FENELON
ILOG, Inc.

keywords: MIP, mixed-integer programming, software

Indicator constraints are a new type of constraint introduced in the latest version of CPLEX. These constraints enforce a linear constraint when a binary variable is set at a particular value. Indicator constraints are used to model logical conditions as an alternative to constraints with big-M terms. Our motivation for and experience with these constraints will be discussed.

PROC OPTMODEL: integrating pptimization modeling with the SAS programming environment

KEARNEY TREVOR
SAS Institute Inc

keywords: modeling language, optimization, OPTMODEL, SAS

PROC OPTMODEL is a new algebraic modeling language from SAS Institute that is specifically tailored to developing and solving optimization models. It lets the user describe an optimization problem at a high level and in a manner that emphasizes the separation of the model structure from specific data instances. The main differentiating factor of OPTMODEL is its tight integration with the SAS programming environment, including the ability to call a wide range of SAS functions and the SAS macro language. In this presentation we use a few examples to illustrate how this combination provides a rich programming capability that allows easy prototyping of optimization algorithms such as: network algorithms, scheduling heuristics, implementation of iterative algorithms, and so on. Further, integration with the SAS Business Intelligence framework facilitates easy deployment of optimization models.

TU1-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Algorithms for LCP and NLCP

chair: Jose Luis Morales

Methods for the approximate and fast solution of linear complementarity problems

JOSE LUIS MORALES
ITAM. Departamento de Matematicas

coauthors: Maxim Naumov, Jorge Nocedal, Mikhail Smelyanskiy
keywords: interior-point methods, linear complementarity problems, projection methods

In this talk we explore the solution of symmetric linear complementarity problems. The focus is on the fast and approximate solution of medium to large size problems arising in the computer game industry. We study two classes of methods: a) iterative methods based on projection; b) interior point methods. In both cases we consider the use of fixed-point iterations (Gauss-Seidel and SOR) and the effect of reordering techniques.

On van Bokhoven's modulus algorithm for the linear

UWE SCHAFER
University of Karlsruhe

keywords: linear complementarity problem, p-matrix

Van Bokhoven's modulus algorithm for the linear complementarity problem does not seem to be especially popular or otherwise recommended in the literature, whereas the projected successive overrelaxation (abbreviated as the PSOR) method is well-known. Nevertheless, we will show that the modulus algorithm seems to be superior to the PSOR method with respect to convergence: Concerning three subclasses of P-matrices the modulus algorithm and the PSOR method are compared to each other with respect to convergence. It is shown that the modulus algorithm is convergent for all three subclasses whereas the convergence of the PSOR method is only guaranteed for two of them. We will present an application where this third class of matrices arises and give some further results.

A new feasible point algorithm for nonlinear complementarity problems

SANDRO MAZORCHE
UFRJ

keywords: nonlinear complementarity problems

We consider the problem of finding $x \in R^n$ such that $x \geq 0$, $F(x) \geq 0$ and $x^t F(x) = 0$, where $F : R^n \to R^n$ is smooth. The present algorithm begins in a point at the interior of $\Omega \equiv \{x \in R^n / x \geq 0 , F(x) \geq 0\}$ generates a sequence of points also at the interior. A decrease of the potential function $x^t F(x)$ is obtained at each iteration.

The search direction is a convenient linear combination of a descent direction with respect to a potential function and a direction that restores feasibility. The first direction comes from a Newton-Raphson iteration to solve the non linear system of equations $x.F(x) = 0$. The second direction is similar to restoration iterates employed in Logarithmic Barrier methods. The line search consists on determining a new feasible iterate with lower value of the adopted potential function. The present approach is supported by strong theoretical studies.

Numerical results obtained with several test problems, and also with contact problems in solid mechanics, are described. We also include some tests with

alternative techniques. All the examples were solved very efficiently with the present algorithm, employing always the same set of parameters.

TU1-R17 STOCHASTIC PROGRAMMING

Computational stochastic integer programming

organizer/chair: David Morton

Disjunctive decomposition for two-stage stochastic mixed-integer programs with random recourse

LEWIS NTAIMO
Texas A&M University

keywords: cutting planes, decomposition, set convexification, stochastic mixed integer programming

This talk presents disjunctive decomposition (D^2) with set convexification for two-stage stochastic mixed-integer programming (SMIP) problems with random recourse. D^2 allows for cutting planes based on disjunctive programming to be generated for each scenario subproblem under a temporal decomposition setting of the SMIP problem. In this talk, a scenario-cut-coefficients theorem for SMIP with random recourse is presented. Under random recourse but fixed righthand-sides and fixed tenders, the theorem allows for a cut generated for one scenario to be easily translated and rotated into a cut that is valid for another. Based on the set convexification, a D^2 algorithm for SMIP with random course is derived. Finally, some computational experience with the new algorithm is reported.

A new recourse model for solving the vehicle routing problem with stochastic demands

CLARA NOVOA
Texas State University

keywords: stochastic programming, stochastic vehicle routing problems

This work presents a stochastic extension of the set-partitioning-based model for solving the vehicle routing problem with stochastic demands (VRPSD). The model is a two-stage stochastic program with integer recourse. We compare two recourse formulations: return to the depot as soon as the vehicle is unable to satisfy a customer demand and continue after route failure completing services on the same or other routes. We also compare our solutions to the ones provided by an exact solution of the capacitated vehicle routing problem. Simulation of the routes found by the different models show that solutions from the new recourse model decrease routing costs when the number of unsatisfied customers per route is low. VRPSD's occur in practical situations such as delivery of industrial gases, collection of money from bank branches, and restocking of retail stores, pharmacies, and hospitals.

Prioritization via stochastic integer programming

DAVID MORTON
The University of Texas at Austin

keywords: stochastic integer programming

Creating priority lists is commonplace in much of industry and government. In contrast, a combinatorial optimization problem with a knapsack-type constraint takes as input a budget and binary activity costs. Such models provide a "prioritization" only in that an activity is selected or not. We argue that if the budget or activity costs are uncertain when one must select the activities that it is sensible to create a (partially-ordered) priority list. We describe a stochastic integer program to accomplish this in the context of specific motivating applications.

TU1-R18 GRAPHS AND MATROIDS

Graphs, Matrices, and Optimization

organizer/chair: Satoru Iwata

Randomized algebraic algorithms for matroid and matching problems

NICHOLAS HARVEY
MIT

keywords: algorithm, fast matrix multiplication, matroid intersection, non-bipartite matching

The task of finding a maximum matching in a graph is one of the classical problems in the theory of algorithms, inspiring the definition of the class P. Until recently, the fastest algorithm for this task took $O(n^2.5)$ steps in an n vertex (dense) graph. But an exciting development due to Mucha and Sankoswki (FOCS '04) dropped the running time to $O(n^w)$ where $w < 2.38$ is the exponent of matrix multiplication. However, their result was quite complicated, relying on certain structural decompositions of graphs and complicated data structures to maintain certain properties dynamically.

In this talk, I will present two new results: The first is a simple algorithm achieving the same result, allowing for a self contained presentation of this result. The second is an extension of this algorithm to the task of matroid intersection (for linear matroids over any field).

Disclaimer: All algorithms are randomized unless noted otherwise.

The independent even factor problem

KENJIRO TAKAZAWA
University of Tokyo

coauthor: Satoru Iwata
keywords: matching, matroid intersection, combinatorial polynomial-time algorithm

In this talk, we deal with the independent even factor problem. For odd-cycle-symmetric digraphs, where any odd dicycle has the reverse cycle, a min-max formula is established as a common generalization of the Tutte-Berge formula for matchings and the min-max formula of Edmonds (1970) for matroid intersection. We devise a combinatorial efficient algorithm to find a maximum independent even factor in an odd-cycle-symmetric digraph accompanied with general matroids, which commonly extends Pap's even factor algorithm (2005) and the matroid intersection algorithms. This algorithm gives a proof of the min-max formula, and contains a new operation on matroids, which corresponds to shrinking factor-critical components in Edmonds' matching algorithm (1965). The algorithm runs in $O(n^4Q)$ time, where n is the number of vertices and Q the time for an independence test. The algorithm also gives a common generalization of the Edmonds-Gallai decomposition for matchings and the principal partition for matroid intersection.

Solving linear programs from sign patterns

NAONORI KAKIMURA
University of Tokyo

coauthor: Satoru Iwata

keywords: combinatorial polynomial-time algorithm, linear programming, qualitative matrix theory

In this talk, we attempt to provide a connection between qualitative matrix theory and linear programming. A linear program $\max\{cx \mid Ax = b, x \geq 0\}$ is said to be *sign-solvable* if the set of sign patterns of the optimal solutions is uniquely determined by the sign patterns of A, b, and c. It turns out to be NP-complete to decide whether a given linear program is not sign-solvable. We then introduce a class of sign-solvable linear programs in terms of totally sign-nonsingular matrices, which can be recognized in polynomial time. For a linear program in this class, we devise an efficient combinatorial algorithm to obtain the sign pattern of an optimal solution from the sign patterns of A, b, and c. The algorithm runs in $O(m\gamma)$ time, where m is the number of rows of A and γ is the number of all nonzero entries in A, b, and c.

TU1-R19 GRAPHS AND MATROIDS

Approximation algorithms

organizer/chair: Eduardo Laber

Class constrained bin packing problems

FLAVIO MIYAZAWA
Unicamp

coauthor: Eduardo Xavier
keywords: approximations, bin packing

In many applications, we have to pack a set of items, each one with a size and a class, into bins with fixed capacity. Moreover, each bin must have items partitioned into compartments, each compartment with items of the same class. Some additional constraints may consider: non-null shelf divisions between compartments, compartments with maximum capacity, on-line algorithms, maximum number of compartments in each bin, etc. We present approximation algorithms (e.g. approximation schemes and FF based algorithms) for class constrained bin packing problems under some of these constraints.

An approximation algorithm for constructing error detecting prefix codes

ARTUR PESSOA
Universidade Federal Fluminense

keywords: approximation algorithms, error detection, prefix codes

A k-bit Hamming prefix code is a binary code with the following property: for any codeword x and any prefix y of another codeword, both x and y having the same length, the Hamming distance between x and y is at least k. Given an alphabet $A = [a_1, \ldots, a_n]$ with corresponding probabilities $[p_1, \ldots, p_n]$, the k-bit Hamming prefix code problem is to find a k-bit Hamming prefix code for A with minimum average codeword length $\sum_{i=1}^{n} p_i \ell_i$, where ℓ_i is the length of the codeword assigned to a_i. In this paper, we propose an approximation algorithm for the 2-bit Hamming prefix code problem. Our algorithm spends $O(n \log^3 n)$ time to calculate a 2-bit Hamming prefix code with an additive error of at most $O(\log \log \log n)$ bits with respect to the entropy $H = -\sum_{i=1}^{n} p_i \log_2 p_i$.

On the competitive ratio of monotone boolean functions

CRISTON SOUZA
PUC-Rio

coauthors: Eduardo Laber, Ferdinando Cicalese
keywords: boolean functions, competitive analysis

We investigate the complexity of evaluating monotone boolean functions in a variant of the decision tree model. We assume that reading different variables can incur different costs. Moreover we employ competitive analysis as the cost measure used to evaluate the performance of the algorithms. In particular we focus on the problem of determining the optimal extremal competitiveness achievable by an algorithm that evaluates arbitrary monotone boolean functions. We present an novel approach to the design of algorithms that solve this task, based on the solution of a linear program defined on the set of the certificates of the function given. The competitiveness of the resulting algorithm depends on the quality of the feasible solution found for the linear program. By an optimal implementation of our approach we mean one that employs the optimal solution of the linear program. We prove that, up to finitely many exceptions, an optimal implementation of our scheme produces algorithms with the best possible extremal competitive ratio. We also show that for many subclasses of the monotone boolean functions that have been thoroughly studied in the recent literature, the optimal implementation of our scheme can be guaranteed to run in polynomial time.

TU1-R20 ON-LINE OPTIMIZATION

Online optimization I

organizer: Kirk Pruhs
chair: Susanne Albers

Energy-efficient algorithms

SUSANNE ALBERS
University of Freiburg

keywords: algorithm, competitive analysis, energy efficiency, scheduling

We study scheduling problems in battery-operated computing devices, aiming at schedules with low total energy consumption. While most of the previous work has focused on finding feasible schedules in deadline-based settings, in this paper we are interested in schedules that guarantee good response times. More specifically, our goal is to schedule a sequence of jobs on a variable speed processor so as to minimize the total cost consisting of the power consumption and the total flow time of all the jobs. We first show that when the amount of work, for any job, may take an arbitrary value, then no online algorithm can achieve a constant competitive ratio. Therefore, most of the paper is concerned with unit-size jobs. We devise a deterministic constant competitive online algorithm and show that the offline problem can be solved in polynomial time.

Cake cutting really is not a piece of cake

JEFF EDMONDS
York University

coauthor: Kirk Pruhs
keywords: algorithm, cake cutting, resourse allocation

We have two results on cutting cakes. The first proves, for two settings, a lower bound of Omega(nlogn) on the time to cut a cake so that each of n player, according to his own value system, thinks he received a fair piece. The second gives, for another setting, a surprising O(n) upper bound.

Online speed scaling for weighted flow

KIRK PRUHS
University of Pittsburgh

coauthors: Nikhil Bansal, Cliff Stein
keywords: flow time, scheduling, speed scaling

Intel's SpeedStep and AMD's PowerNOW technologies allow the the Windows XP operating system to dynamically change the speed of the processor to prolong battery life. In this setting, the operating system must not only have a job selection policy to determine which job to run, but also a speed scaling policy to determine the speed to run that job at. These policies must be online since the operating system does not in general have any knowledge about any jobs that may arrive in the future. We give an O(1)-competitive algorithm for weighted flow time.

TU1-R21 DYNAMIC PROGRAMMING

Multiobjective criteria in dynamic programming

chair: Natashia Boland

Simultaneous solution of related Lagrangean dual problems with iterated preprocessing for solving the weight constrained shortest path problem

NATASHIA BOLAND
The University of Melbourne

coauthor: Ranga Muhandiramge
keywords: constrained shortest paths, Lagrangian relaxation, shortest paths

When Lagrangean relaxation is used in preprocessing for the network Weight Constrained Shortest Path Problem, corresponding bounds can be used to eliminate nodes and edges. However, further elimination can occur through the use of (different) Lagrangean dual problems, that can be formulated for each node and edge. The solutions of such problems may differ to that of the full problem. Furthermore, eliminating nodes and edges from the network may change the Lagrangean dual solutions in the remaining reduced network.

We address these issues and propose a method for solving the related Lagrangean dual problems for each edge simultaneously, while also eliminating nodes and edges, in an iterative process. We demonstrate the effectiveness of our method computationally. comparing it with several others; we show that it reduces both solve time and the number of intractable problems encountered.

An iterated invariant-set approach for linear multiobjective dynamic programming problems

RODRIGO CARDOSO
Universidade Federal de Minas Gerais

coauthor: Ricardo Takahashi
keywords: approximation algorithms, dynamic programming, multicriteria dynamic programming

Solving linear dynamic programming problems to optimality, with discrete variables, usually consists in building the "possibility tree", with an exponential complexity algorithm. This work employs, instead, a continuous relaxation that leads to approximated solutions with computational cost equivalent to solving a linear programming problem with dimension (n+pN), where (n) is the number of state variables, (p) is the number of decision variables, and (N) is the number of stages of the decision process. The idea is to iterate, through the dynamic system, a closed set with parametric structure invariant under such iteration. The optimization is performed with the state variables constrained to such set. The linearity is employed in order to allow the composition of the optimization on the state variables in just one stage with the optimization on the decision variables. The Pareto-set of multiobjective problem can be found, in this scenario, via usual scalarization techniques.

On some minimax optimal control problems

MARIA ARONNA
Universidad Nacional de Rosario

coauthors: Laura Aragone, Pablo Lotito, Gabriela Reyero
keywords: HJB equations, L-infinity control, min-max problems

We consider an optimal control problem where the optimality criterium is to minimize the maximum cost given by a scalar function. The dynamic-system trajectory depends on the chosen control and the set of admissible control policies are the essentially bounded functions into a compact set.

We analyze the finite and infinite horizon cases. In the finite horizon case we have also considered an additive final cost and used the classical technique of adding an extra dimension to transform the Bolza formulation into a Mayer one. For the infinite horizon case we added a running cost in order to obtain an ergodic behavior.

For each problem we propose a value function, a dynamical programming principle and the corresponding Hamilton-Jacobi-Bellman equations. We develop new numerical methods to compute the optimal costs, we analyze the numerical solutions and present numerical results.

TU2-R1 COMBINATORIAL OPTIMIZATION

Heuristics II

chair: Celso Ribeiro

Referee assignment in sports tournaments

ALEXANDRE DUARTE
PUC-Rio

coauthors: Celso Ribeiro, Sebástian Urrutia
keywords: heuristic search, local search, metaheuristics, sport scheduling

Optimization in sports is a field of increasing interest. Combinatorial optimization techniques have been applied e.g. to game scheduling and playoff elimination. A common problem usually found in sports management is the assignment of referees to games already scheduled. There are a number of rules and objectives that should be taken into account when referees are assigned to games. We address a simplified version of a referee assignment problem common to many amateur leagues of sports such as soccer and basketball, among others. In order to tackle real-life large instances of the referee assignment problem, we propose a three-phase heuristic approach based on a constructive procedure, a repair heuristc to make solutions feasible, and an ILS heuristic to improve feasible solutions. The problem is formulated by integer programming and numerical results on realistic instances are given.

Heuristics for the stratification problem in survey samples

FLÁVIO MONTENEGRO
Instituto Brasileiro de Geografia e Estatística

coauthors: José Brito, Nelson Maculan, Rosemary Azevedo
keywords: heuristics, metaheuristics, sampling, stratification

This work reports new methodological purposes for the stratification problem in survey samples. From a predefined population of size N, a sample of size n and a number L of strata we must to determine, which population observations are associated to which stratum in such a way to minimize the sum of the estimator variances at each stratum, considering the allocation schemes of Neyman, proportional or uniform. Aiming to obtain good quality solutions for this problem, we have implemented three heuristics based on GRASP, VNS and Microcanonical Optimization algorithms. Computational results for a real data set are presented and discussed.

An asynchronous team proposal for the capacitated p-median problem

MARCELO LISBOA ROCHA
Universidade Federal do Rio de Janeiro

coauthor: Amit Bhaya
keywords: asynchronous team, capacitated p-median problem, exact method, GRASP

An Asynchronous Team Algorithm is proposed for the Capacitated P-Median Problem which is a NP-Hard problem arising in many applications, so that the development of efficient solution techniques is important. The Asynchronous Team proposed in this paper combines a GRASP metaheuristic with a branch-and-bound method in a parallel environment, to achieve optimal solutions with good performance. Computational comparisons with other existing techniques in the literature for this problem, carried out for benchmark instances, are favorable and show that the proposed Asynchronous Team performs quite effectively, especially for large-scale instances, solving them with computation times that are acceptable.

TU2-R2 COMBINATORIAL OPTIMIZATION

Advanced methods in real world applications

organizer: Marcus Poggi de Aragão
chair: Oscar Porto

Optimization of the continuous casting phase in steel tubes production

OSCAR PORTO
PUC-Rio

coauthors: Fernanda Menezes, Lorenza Moreno, Eduardo Uchoa
keywords: steel tubes production

The problem tackled in this work is the planning of continuous casting phase in steel tubes production. It consists of deciding the steel grade, the production order and the partition of the produced steel to attend requests of steel slabs of distinct gauges, lengths and grades. The goal is to attend all requests on time, minimizing gauge mold changes and steel waste, working with groups of similar steel grades. It comprises scheduling and bin packing problems and is particularly difficult due to the large number of demands and their diversity. We use a heuristic algorithm that combines distinct mixed integer programming problems and local branching. We will present the details of the formulation and the algorithms developed together with the results obtained. The resulting software is deployed in a large international steel company in Brazil.

Planning flight schedules to offshore platforms

LORENZA MORENO
Departamento de Informatica / PUC-Rio

coauthors: Fernanda Menezes, Marcus Poggi de Aragão, Eduardo Uchoa
keywords: integer feasibility, local branching, mixed-integer programming, timetabling

The planning of schedules of helicopter flights to the platforms of the Brazilian oil company Petrobras is a crucial step in a complex logistic operation. The associated combinatorial problem aims at finding the time-table of the flights for a week. This time-table is to be used for a whole year and it must satisfy several types of constraints including frequency and area congestion. The objective function may emphasize minimizing the required fleet, quality of the transportation service, and/or security measures. We propose a MIP formulation and devise a heuristic following the ideas of Local Branching and VNS. An extensive computational experience on different sets of scenarios defined by forecasts for platform production and location and for helicopters' prices for hiring is presented. The proposed algorithm is implemented using CPLEX 10.0. The experience shows that it produces high quality solutions while CPLEX alone is unable to find feasible solutions.

Short term iron ore pellet production planning

MARCELO REIS
GAPSO Inc.

coauthors: Artur Pessoa, Alexandre Pigatti, Marcus Poggi de Aragão, Eduardo Uchoa
keywords: decomposition, lot sizing, mixed-integer programming, production planning

We study the planning the daily production of a set of plants. The corresponding problem, a multi-plant and multi-item lot-sizing, is present in the operations of the world's largest iron ore producer. In this problem, nine plants produce different types of iron ore pellets. The production aims at requests for shipments on a 90 day horizon. We present mixed integer program (MIP) models for the whole complex of plants and for the production of a single plant. The resulting algorithm first produces a good feasible solution from the global model. This solution is then decomposed into partial solutions of single plants. Those solutions are completed and refined by solving the detailed single plant models. This work compares different emphasis on this decomposition approach. We report solutions significantly better than those that could be obtained from a single model, as attested by experiments on real world instances.

TU2-R3 COMBINATORIAL OPTIMIZATION

Distance measures and metaheuristics

organizer/chair: Kenneth Sorensen

Vehicle routing – the movie

KENNETH SORENSEN
University of Antwerp + EU/ME

keywords: distance measures, path relinking, vehicle routing problem

Path relinking (PR) is a recent technique proposed for optimization problems. The principle of PR is that good solutions can often be found on a path between other good solutions. For many combinatorial optimization problems however, and especially for permutation problems such as the vehicle routing problem, it is unclear how a path between two solutions can be defined and how solutions can be found that are on such a path.

We propose a PR procedure based on a modified version of the edit distance, that transforms a VRP solution into another one, one elementary operation at a time. Each of the intermediary solutions encountered are feasible and can be shown to lie on a shortest path between the two solutions. In this way, new high-quality solutions can be encountered. The procedure is embedded in a metaheuristic optimization strategy. We report on some computational results.

Coping with unquantifiable criteria by generating structurally different solutions - Application to a large real-life location-routing problem in the automotive industry

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University Of Antwerp, Belgium

coauthor: Kenneth Sorensen
keywords: automotive industry, distinct solutions, location-routing, unquantifiable criteria

Solutions generated by optimization software are not always fully accepted by the decision maker. This is often due to the presence of criteria that are difficult to quantify. In this paper, we discuss the case of a large location–routing problem in the automotive industry. When deciding which logistic operators to subcontract for the distribution of parts, the company is faced — next to the obviously quantifiable cost criterion — with factors that are either unknown or difficult to quantify such as the quality of handling and the organization of work at the subcontractor's site.

In order to cope with such criteria, we suggest a method which produces several potentially *very good* but *structurally different* transport networks. In this way, the automotive company can simply switch to a different transportation network when they are not satisfied with the present one, without incurring a major cost increase.

A transgenetic algorithm for the capacited traveling purchaser problem

LIGIA BAGI
Universidade Federal do Rio Grande do Norte

coauthors: Marco Goldbarg, Elizabeth Goldbarg
keywords: capacited traveling purchaser problem, evolutionary algorithms, symbiotic algorithms, transgenetic algorithm

The Traveling Purchaser Problem is a variant of the Traveling Salesman Problem, where there is a set of markets and a set of products. Each product is available on a subset of markets and its unit cost depends on the market where it is available. The objective is to buy all the products, departing and returning to a domicile, at the least possible cost defined as the summation of the weights of the edges in the tour and the cost paid to acquire the products. A Transgenetic Algorithm, an evolutionary algorithm with basis on endosymbiosis, is applied to this problem. Evolution in Transgenetic Algorithms is simulated with the interaction and information sharing between populations of individuals from distinct species. The computational results show that this is a very effective approach for the TPP regarding solution quality and runtime. Eleven new best results are presented for instances of a known benchmark.

TU2-R4 COMBINATORIAL OPTIMIZATION

Cutting plane methods in combinatorial opt.

organizer: Abdel Lisser
chair: Wadie Benajam

On multiple-points separation: theory and practice

JOSE NETO
IASI

coauthor: Walid Ben-Ameur
keywords: constraint generation, linear programming

When solving convex optimization problems with constraint generation algorithms it is common to make use of an implicit description of the feasible region by a separation oracle. Basically, the latter is a procedure that given some input point either decides whether if it is feasible and if not returns an inequality violated by this point and valid for the feasible region. Here we discuss a generalization of this scheme by considering separation on several points instead of a single one. We namely show that, under some assumptions, multiple-points separation can be done in oracle-polynomial time for a feasible region that is given by a single-point sepration oracle. Also, the complexity status of some further problems related to multiple-points separation is investigated. Finally, we report some computational experiments on randomly generated linear programs and survivable network design problems illustrating potential improvements achieved with such an approach.

Subgradient tree optimization

RAFAEL ANDRADE
Universidade Federal do Ceará

coauthor: Adriano Tavares de Freitas
keywords: branch-and-bound, Lagrangian heuristics, subgradient algorithm, subgradient tree optimization

In this work we propose a new hybrid solution approach to resolve combinatorial optimization problems. We introduce the subgradient tree algorithm, which combines three classical optimization techniques: branch-and-bound (B&B), subgradient (SG), and Lagrangian-based algorithms. We show how to construct sequences of Lagrangian multipliers, one set of Lagrangian multipliers for each node of the B&B tree, which are used to improve dual and primal B&B node solutions. We can reach primal solutions while constructing the B&B tree or by using a Lagrangian-based heuristic. The goal of our algorithm is mainly to reach feasible solutions of good quality more frequently and to promote deletion (from the B&B tree) of non-interesting nodes, thus reducing computational time to obtain optimal solutions.

SDP relaxations for the quadratic assignment problem

WADIE BENAJAM
Université de Paris Sud, LRI

coauthors: Abdel Lisser, Michel Minoux
keywords: cutting planes, quadratic assignment problem, semidefinite programming

We present a SDP based cutting plane algorithm for computing lower bounds for the Quadratic Assignment Problem. This is a classical problem of combinatorial optimization in which you have to find the optimal location among n units in order to minimise a quadratic cost depending on both inter-location distances and inter-unit flows. The quadratic assignment is modelled by a integer quadratic programming problem. We propose a cutting plane algorithm: some valid inequalities inducing facets of the quadratic polytope are added to SDP relaxation within an iterative process. We show through the numerical results the interest of our algorithm.

TU2-R5 INTEGER AND MIXED INTEGER PROGRAMMING

Covering and matching problems

chair: Jean-Marie Bourjolly

Properties of the covering and the matching numbers of minimally nonideal

GABRIELA ARGIROFFO
Universidad Nacional de Rosario

coauthor: Graciela Nasini
keywords: Lehman matrix, minimally nonideal matrix, minimally nonpacking matrix, set covering problem

Cornuéjols, Guenin and Margot (2000) proved a necessary condition for a regular minimally nonideal matrix M to be minimally nonpacking, and conjectured that this condition is also sufficient. In order to make some progress on the mentioned conjecture, in this work we find a relationship between the covering number of a regular minimally nonideal matrix and the matching number of its core. With this result, we obtain that Cornuéjols, Guenin and Margot's necessary condition is also sufficient to prove that every minor of a regular minimally nonideal matrix M obtained by deletion of only one vertex packs and we extend this result to the deletion of subsets of a cover of M.

Conditional covering on a line

JEAN-MARIE BOURJOLLY
Universite du Quebec a Montreal

coauthors: Juan Antonio Mesa, Francisco A. Ortega Riejos
keywords: conditional covering, location analysis, set covering problem, shortest paths

The Set Covering Problem (SCP) is to minimize the total cost of facilities that must be established in order to cover all nodes. (A site is said to be covered if its distance to the nearest facility is less than or equal to the covering radius.) The Conditional Covering Problem (CCP) is the same as the SCP, with one additional condition: No facility can cover the site on which it is located, and must therefore be covered by another established facility. These problems are NP-complete but are polynomially-solvable on a line. We show that CCP [resp. SCP] on a line is equivalent to finding a shortest path on a graph H with 2n+2 nodes [resp. n+2 nodes]. And we derive some results for the dominating set problem.

TU2-R6 OPTIMIZATION IN NATURAL RESOURCES

Mathematical models in forestry 2

organizer/chair: Andres Weintraub

Math modeling for efficiency in forest inventory

TARA BARRETT
Pacific Northwest Research Station, Forest Service

keywords: forestry, inventory cost reduction, measurement error

Inventories of a nation's forests are used to monitor the condition and future outlook of forest-related renewable resources and ecological services. Tradeoffs between estimation accuracy and economic efficiency for field collection of forest inventory data are examined in this study. An integer programming model is applied to tree height measurement decisions for crew traveling within an 82.5 million hectare region of N. America during one field season. With the given assumptions, the model was used to identify a solution with minimal estimation bias, a 10 percent increase in average plot error, and 33 percent reduction in measurement cost.

Spatial control and numerical chance constraint estimation

MICHAEL BEVERS
USDA Forest Service

keywords: chance-constrained programming, order statistics, sample average approximation, spatial optimization

Spatial control can be critical for effective management of biophysical resources in ecological systems. At the same time, many biological resources of conservation interest are subject to random effects that pose substantial risks. Chance constraints in spatial mathematical programming models provide one useful way to integrate risks into plans for optimal management. A numerical estimation method, based on sample average approximations of order statistics, is presented. The method appears useful for heuristically solving these complex mathematical programming models. A hypothetical habitat restoration problem is presented.

Solving difficult forestry problems with spatial adjacency

ANDRES WEINTRAUB
Universidad de Chile

coauthors: Alan Murray, Dave Ryan, Marcos Goycoolea, Juan Pablo Vielma
keywords: branch-and-price, projecting clique constraints

Planning forest harvesting needs to consider spatial constraints which limit the maximum size of contiguous area that can be harvested. Harvested blocks are composed of several basic cells, and no adjacent blocks can be harvested in the same period. This is a very difficult combinatorial problem. We present a solution based on projecting clique constraints into the block space which strengthens the formulation significantly. In addition , complicated constraints linking periods are penalized and elastisized, using constraint branching in a branch and prize approach. Positive computational results are shown.

TU2-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.

Routing and facility location

organizer/chair: Philippe Mahey

Mathematical models of the delay constrained routing problem

ADAM OUOROU
France telecom Division R&D

coauthor: Walid Ben Ameur
keywords: delay, routing problems, telecommunications

Given a network with known link capacities and traffic demands, one can compute the paths to be used and the amount of traffic to be send through each path by solving a classical multi-flow problem. However, more quality of service constraints such as delay constraints, may be imposed and the routing problem becomes difficult to solve. We assume that the delay on each link depends on both its capacity and the total flow on it. We show that satisfying the delay constraints and the capacity constraints is an NP-complete problem. We give a convex relaxation of the delay constrained routing problem and present some ways to get upper and lower bounds on the problem.

Global optimization of capacity expansion and flow assignment of data networks

RICARDO POLEY M. FERREIRA
PUC-Minas Pontific Catholic University of Minas Gerais

coauthors: Philippe Mahey, Maurício Cardoso de Souza, Henrique Pacca Luna
keywords: Benders decomposition, capacity expansion, global optimization, implicit enumeration

We propose a global optimization exact procedure to solve the capacity expansion and flow assignment of a communication network. The model combines continuous multicommodity flow variables associated with nonlinear congestion costs and discrete decision variables associated with the arc expansion costs. After establishing precise correspondences between the mixed-integer model with a continuous but non convex model proposed earlier by Luna and Mahey, we derive an implicit enumeration approach where the branching rules are based on the convexification of the continuous objective functions. Numerical experiments show that the approach is efficient on medium size instances which cannot be solved by classical exact algorithms like Benders decomposition.

Capacitated facility location problem with operational constraints

CÉDRIC CHAMAYOU
France Telecom R&D

coauthors: Karima Djebali, Christelle Scala
keywords: branch-and-price, clique partitioning, location

We consider the capacitated facility location problem (CFLP) for concentrators in telecommunication networks with operational constraints. We extend the classical facility location problem requiring the demand points assigned to the same concentrator to be strongly connected. We propose two mixed integer program formulations. The first one, solved with a standard solver, is similar to the classical program for the CFLP with new constraints satisfying strong connection between demand points. Computational experiments demonstrate that this approach is effective on a set of particular problems. The second approach is formulated as a clique partitioning problem where a branch-and-price approach significantly improves the resolution and apply to a very large class of instances.

TU2-R8 GAME THEORY

Core and equilibrium

organizer: Ramesh Johari
chair: Thomas Liebling

On the core of some combinatorial games

THOMAS LIEBLING
EPFL

coauthor: Guyslain Naves
keywords: combinatorial games, core, population monotonous allocation schemes, spanning tree and matching games

Suppose a group of friends decides to use car-pooling when commuting from home to the office. Who should pay how much of the total cost in an equitable solution? What if a new member joins in? Is there a stable way to allocate costs such that the members present in the beginning will not have to pay more now than before? We shall review this and other classical cooperative games on graphs, namely spanning tree games without and with degree constraints, bipartite and non-bipartite matching games. We will discuss the existence of solutions in the core and in some cases the existence of pmas, i.e. populationmomotonous allocation schemes. Some ofthese problems can be very naturally and elegantly approached making use of classical results in combinatorial optimization, like matroid partition and the Edmonds-Gallai decomposition. While in some cases there exist very simply found stable allocation schemes, in others we report some disappointing results either on the existence of cores or concerrning associated complexity issues.

Repeated Cournot competition: Nash investment equilibrium to increase the demand

ALBERTO PINTO
Faculdade de Ciencias da Universidade do Porto

coauthors: Fernanda A. Ferreira, Flavio Ferreira, Miguel Ferreira, Bruno Oliveira
keywords: Cournot model, deterministic dynamics, R&D projects, stochastic dynamic programming

We present deterministic and stochastic dynamics on the production costs of Cournot competitions, based on Nash equilibriums of nonlinear R &D investment strategies to reduce the production costs of the firms at every period of the game. We study some behaviours of the firms in the case of similar firms and in the case of non-identical firms with different R &D programs regarding the maximum percentage of reduction of the production costs. In the deterministic case, we study the transients

and the asymptotic dynamics on the production costs of the duopoly competition and their implications on the profit and persistence of the firms in the market. In the stochastic case, we analyse the importance of the uncertainty to reverse the initial advantage of one firm with respect to the other.

Conditions for totally balanced packing games

MARIANA ESCALANTE
Universidad Nacional de Rosario. Argentina

coauthor: Valeria Leoni
keywords: combinatorial games, imperfect graphs, totally balanced game

One of the scopes in combinatorial optimization game theory is to characterize $0,1$ matrices defining totally balanced packing and covering games. Deng et al. (2000) showed that if a matrix defines a totally balanced covering game it also defines a totally balanced packing game.

Recently, van Velzen proved that the transpose of perfect matrices are the only matrices that define totally balanced covering games. It is well-known that perfect matrices are clique-node matrices of perfect graphs. We say that a matrix is packing totally balanced if its transpose defines a totally balanced packing game.

We are interested in packing totally balanced imperfect matrices. In particular, we present necessary and sufficient conditions for a imperfect graph such that its clique-node matrix is packing totally balanced.

TU2-R9 GLOBAL OPTIMIZATION
Global optimization techniques II
chair: Ricardo Takahashi

Risk measurement for managing project financing

OTILIJA SEDLAK
Faculty of economics Subotica

keywords: Economic modeling, financial modelling, project management

In the last decades problems of measuring risk have been object of analysis by numerous researchers. Financial organizations, banks, credit institutions and project financiers need forecasts of failure for firms in which they have kind of interest. The more widely used methods are based on econometric models. The complexity of several phases and very long horizon add a vague and imprecise character and the risk parameter are made more flexible under fuzziness. The aim of this paper is to introduce a method for evaluation of the project risk level and for forecasting its financing.

Constraint quadratic approximation operator for treating equality constraints with genetic algorithms

ELIZABETH WANNER
Universidade Federal de Minas Gerais

coauthors: Ricardo Takahashi, Rodney Saldanha, Frederico Guimarães
keywords: genetic algorithms, local search, quadratic approximation

This work presents a new operator for genetic algorithms that enhances their convergence in the case of nonlinear problems with nonlinear equality constraints. The proposed operator, named CQA (Constraint Quadratic Approximation), can be interpreted as both a local search engine (that employs quadratic approximations of both objective and constraint functions for guessing a solution estimate) and a kind of elitism operator that plays the role of "fixing" the best estimate of the feasible set. The proposed operator has the advantage of not requiring any additional function evaluation per algorithm iteration, solely making usa of the information that would be already obtained in the course of the usual Genetic Algorithm iterations. The test cases that were performed suggest that the new operator can enhance both the convergence speed (in terms of the number of function evaluations) and the accuracy of the final result.

Stress optimality results for a Goupillaud-type layered elastic strip

ANI VELO
University of San diego

coauthor: George Gazonas
keywords: analytical solutions, Goupillaud type layered media, structural optimization, wave propagation

The main focus of this work is to discover the role of one-dimensional Goupillaud type layered design in controlling the stress amplitude. We first obtain explicit stress formulas through the method of characteristics and the z-transform method. Then we identify analytically classes of optimal designs which provide the smallest stress amplitude in a layered elastic strip (with up to five layers), subjected to transient loading. The results provide analytical means to validate optimization numerical codes as well as practical means to improve design quality.

TU2-R10 MULTICRITERIA OPTIMIZATION
Multicriteria issues in planning and scheduling
chair: Luiz Alves

Generación de planes temporales de proyectos

CARLOS MANUEL TOLEDO
Instituto Universitario Gastón Dachary

keywords: genetic algorithms, networks models, temporal planning

Create temporal planning for projects is a dificult task. Project networks including several tasks must verify: 1) sequencialy conditions, 2) disponibility conditions, 3) minimum execution time. This work describes an alternative solution for a set of task be executed in minimal time by the use of otimization techniques. In the first part of the work we discuss the problem. In the second part some optimization methods are analized and a genetic algoritm to solve the problem is presented.

Modeling the development of regional units

TIBOR KIS
Faculty of economics Subotica

coauthor: Marija Cileg
keywords: economic models, regional economic development

This work deals with implementation of different methods of determining general process and level of development of regional units using pooled cross sectional and time series data. The case of Serbian economy will be presented. Serbia, formerly part of Yugoslavia, experienced extreme economic and social changes in recent years, being now days in process of transformation towards market economy. Its regional units are performing highly different patterns of economic growth or descend.

Adoption of sub-optimal solutions for the equipment selection model

LUIZ ALVES
IBGE

coauthor: Carlos Augusto Alcantara Gomes
keywords: just in case, just in time, optimization

GUNASEKARAN et alii (1993) proposed a non linear mathematical model to select equipments in manufacture in processes of the kind Just in Time. This model was reformulated by ALVES(1997) and ALVES et alii (2001), where three relaxations were developed, such as delays due to broken machines may occur, existence of left-overs, and existence of diferent demands. The last one could imply loss in sales when the demand is not satisfied.

In this work we present an analysis of adoption of sub-optimal solutions of the original objective function (total cost of minimum production) for the non linear model of equipment selection in Just in Time policy, considering the mentioned relaxations and an extra criterium, the total time of minimum production, and then optimzing the respective variational relative margins.

TU2-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING
On the curvature of the central path
organizer: Antoine Deza
chair: Yinyu Ye

On the total curvature of the central path for linear programming

YURIY ZINCHENKO
AdvOL, CAS, McMaster University

coauthors: Antoine Deza, Tamás Terlaky
keywords: central path, interior-point methods, linear programming, total curvature

The central path is an intrinsic analytic object that may be associated to any well-posed linear optimization problem and is of key interest from the algorithmic standpoint. To a large extent, its geometric properties determine the efficiency of the so-called path-following interior-point methods in practice. We investigate linear optimization problems with a large central path curvature. In particular, we consider redundant representations of the n-dimensional Klee-Minty cube defined by an exponential number m of inequalities. The construction provides a counterexample to the conjecture that the order of the worst-case total curvature is n. We highlight further implications of this result.

Redundant Klee-Minty Cubes

TAMÁS TERLAKY
McMaster University

coauthors: Antoine Deza, Eissa Nematollahi
keywords: central path, interior-point methods, Klee-Minty cubes, redundancy

A redundant representation of the Klee-Minty cube allowed us to wind up the central path along the edges and vertices of the KM-cube following the exponentially long simplex path. In this paper, after introducing our redundant KM representation and discussing its implications at the central path we study and demonstrate some expected and surprising behaviors of various popular interior point algorithms on these problems.

TU2-R12 COMPLEMENTARY AND VARIATIONAL INEQUALITIES
Algorithms
organizer: Andreas Fischer
chair: Stephen Wright

An accelerated Newton method for nonlinear complementarity problems

STEPHEN WRIGHT
University of Wisconsin

coauthor: Christina Oberlin
keywords: Newton methods, nonlinear complementarity problems, singular solution of nonlinear equations

We discuss local convergence of Newton's method to a singular solution x^* of the nonlinear equations $F(x) = 0$, for $F : \mathsf{R}^n \to \mathsf{R}^n$. It is shown that an existing proof of Griewank, concerning linear convergence to a singular solution x^* from a dense starlike domain around x^* for F twice Lipschitz continuously differentiable, can be modified satisfactorily for the case in which F' is only strongly semismooth at the solution. Further, under appropriate regularity assumptions, Newton's method can be accelerated to produce fast linear convergence to a singular solution by overrelaxing every second Newton step. These results are applied to a nonlinear-equations formulation of the nonlinear complimentarity problem (NCP) whose derivative is strongly semismooth when the function f arising in the NCP is sufficiently smooth. The accelerated Newton's method applied to this formulation converges at a fast linear rate when started in a dense neighborhood of a degenerate solution of the NCP. Conditions on f are derived that ensure that the appropriate regularity conditions are satisfied for the nonlinear-equations formulation of the NCP at x^*.

Comparative experiments regarding differentiable reformulations of the GSOCCP

MARGARIDA MELLO
Unicamp

coauthors: Roberto Andreani, Ana Friedlander, Sandra Santos
keywords: bound-constrained optimization, GSOCCP, numerical experiments, reformulations

The generalized second-order cone complementarity problem (GSOCCP) has atracted much interest in recent years, and several reformulations have been suggested. We describe our own smoothness-preserving reformulation, which recasts the problem as a bound-constrained minimization problem, giving the global equivalence result. This is contrasted with the reformulation by Chen and Tseng,which has very nice theoretical properties but presents challenges regarding implementation, and that of Hayashi, Yamashita and Fukushima, whose nondifferentiable merit function is optimized by a special purpose algorithm. Numerical experiments are performed on a 1) a grasp force optimization problem, 2) a set of randomly generated problems and 3) a nonlinear second-order cone complementarity problem (SOCCP). The second and third problems are from Hayashi et. al., whereas the first is adapted from Han, Trinkle and Li.

Research Report RP 07/06, IMECC, Unicamp.

TU2-R13 NONLINEAR PROGRAMMING
Large-scale optimization
organizer: Frank Curtis
chair: Jorge Nocedal

Numerical experience With preconditioners for interior-point methods

RICHARD WALTZ
Northwestern University

coauthors: Jorge Nocedal, Long Hei
keywords: interior-point methods, nonlinear programming, preconditioning

In this talk we will report numerical results using a variety of general purpose constraint preconditioners in the context of the iterative interior-point approach implemented in the KNITRO software package. We will look at diagonal preconditioners and incomplete Cholesky preconditioners for both simple bound constrained problems as well as problems with more general inequality constraints. We will also explore preconditioners for the Hessian with respect to the barrier term.

Exact penalty methods and regularization

RICHARD BYRD
University of Colorado

keywords: exact penalty method, regularization

Exact nondifferentiable penalty methods can be viewed as a way to turn constrained optimization problems into (nondifferentiable) unconstrained problems, but their principle advantage is that they provide approximating subproblems that are always feasible. This is useful in trust region methods and also provides a means for dealing with problems lacking regularity. Historically, a tricky issue in using these methods has been the choice of penalty parameter. Recently, some new guidelines have been proposed for automatic penalty parameter choice that are intuitive and lead to good performance. In this talk we show how these guidelines can be used in a successive linear-quadratic programming method and in a classic SQP method. We show that such methods are globally convergent without regularity assumptions, even for line search methods, and present examples of good performance on problems where regularity fails.

Scaling performance of interior-point method on chip multiprocessors

MIKHAIL SMELYANSKIY
Intel

coauthors: Victor Lee, Daehyun Kim, Anthony Nguyen, Pradeep Dubey
keywords: interior-point methods, parallel IPM, task level parallelism

In this talk we will describe parallelization of interior-point method (IPM) aimed at achieving performance scaling on large-scale chip-multiprocessor (CMP). IPM is an important computational technique used to solve optimization problems which arise in engineering, finance and science. While complex mathematical analysis is the driving force behind IPM, the majority of the algorithm's computation time is spent in a few sparse linear algebra kernels, most importantly sparse linear solver. While each of these kernels contains large amount of inherent data and task level parallelism, sparse irregular dataset seen in many optimization problems make this parallelism difficult to explore. As a result, most researchers have only shown a relatively low IPM performance scalability of 4x to 12x on medium to large scale parallel machines.

In this talk we will present a detailed performance analysis of IPM which identifies the key computational kernels and discusses parallelization methods and bottlenecks preventing scalability on parallel systems. Furthermore, we propose and evaluate several algorithmic and hardware features to improve IPM parallel performance on large-scale CMP. Through our cycle accurate simulator, we demonstrate how exploring multiple levels of parallelism within IPM kernels, as well as parallel reduction hardware support and low-overhead task queues enables IPM to achieve up to 53x speedup on 64-core chip multiprocessor platform on linear programming datasets from NETLIB.

TU2-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Semidefinite programming

organizer: Christoph Helmberg
chair: Samuel Burer

Handling free variables in conic optimization with application to moment relaxations

SAMUEL BURER
University of Iowa

coauthor: Miguel Anjos
keywords: convex optimization, free variables, polynomial optimization

We revisit a regularization technique of Meszaros for handling free variables within interior-point methods for conic optimization. We combine this technique with algorithms based on inexact Newton directions and derive various computational strategies, which compare favorably with other techniques for handling free variables. In particular, we demonstrate effectiveness on moment relaxations of equality-constrained polynomial optimization problems.

Globally optimal solutions for large single-row facility layout problems

MIGUEL ANJOS
University of Waterloo

coauthor: Anthony Vannelli
keywords: convex optimization, facility layout, global optimization, semidefinite programming

This research is concerned with the single-row facility layout problem (SRFLP), which asks for a linear placement of rectangular facilities with varying lengths on a straight line so as to minimize the total cost associated with the (known or projected) interactions between facilities. We propose a new formulation for this problem, and exhibit a bijection between the feasible set of the formulation, and the set of all permutations. We then consider the semidefinite programming (SDP) relaxation arising from this new formulation. On the theoretical side, we prove that a number of triangle inequalities hold automatically for the SDP relaxation. More interestingly, if we consider the tighter relaxation obtained by adding the remaining triangle inequalities, then a significant number of other facet-defining inequalities of the underlying cut polytope are automatically enforced by this tighter relaxation. On the computational side, we use the SDP relaxation to obtain globally optimal layouts for large SRFLPs with up to 30 departments, some of which have remained unsolved since 1988.

The rotational dimension of a graph

FRANK GÖRING
TU Chemnitz

coauthors: Christoph Helmberg, Markus Wappler
keywords: algebraic connectivity, minor monotone graph properties, semidefinite programming, spectral graph theory

Imagine a graph, the edges being massless cords of fixed positive lengths connecting vertices of possibly different positive masses, rotating in $2n$-space uniformly (each vertex having the same angular speed) around its barycenter. The centrifugal force tends to maximize the weighted variance of the positions of its vertices.

For such "rotational" embeddings we show some kind of "separator shadow" theorem. Furthermore, we are interested in the minimal dimension of a rotational embedding of the graph.

The "rotational dimension" of the graph is the largest such minimum dimension (maximized over all possible cord lengths and vertex weights). We assert connections of this graph property to the algebraic connectivity of a graph.

Furthermore, we show that the rotational dimension is a minor monotone graph property, and present complete lists of forbidden minors for small values.

At the end of the talk, some related open problems will be posed.

TU2-R15 OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS

Integration with other analytical tools

organizer: Leonardo Lopes
chair: Irvin Lustig

Random variables, an AMPL extension for stochastic programming

DAVID GAY
Sandia National Labs

keywords: AMPL, recourse, stochastic programming

The AMPL modeling language facilitates stating, solving, analyzing and generally manipulating mathematical programming problems. Hitherto the only way to deal with stochastic programming problems in AMPL has been to state deterministic equivalents, which is only feasible for a few, coarsely discretized random variables. The introduction to AMPL of "random variables" will permit suitable solvers to do their own sampling, adaptively deciding where and when to sample, which may permit handling some problems with more randomness than is feasible with straightforward deterministic equivalents. Random variable declarations mention "random" and are otherwise similar to declarations of deterministic variables. A distribution may be specified in a random variable's declaration, or may be assigned later by a "let" command. As a special case, "let" can assign constant values to some random variables, giving simplified problems, which may help one to find suitable formulations.

SAS retail price optimization solutions: forecasting "leads the party"

RADHIKA KULKARNI
SAS Institute Inc

keywords: dynamic programming, forecasting, heuristic techniques, non-linear optimization, SAS retail optimization

Optimization problems arise naturally in vertical and horizontal solutions, where estimating the parameters of the optimization model is as important as solving it. The ability to combine sophisticated predictive modeling tools (statistical analysis, data mining and forecasting) with advanced optimization methods is thus an important pre-requisite to building an effective solution for most business problems. Three different SAS retail price optimization solutions are used as illustrations in this presentation: Promotion, Markdown and Regular Price Optimization. In each of these solutions, significant value is derived from efficient estimation of the price elasticity models. These evaluations are then combined with a variety of business models to build an appropriate optimization problem. Each solution, by its nature, requires a different set of optimization techniques to solve the problem efficiently: search heuristics, dynamic programming, and effective use of linear and nonlinear programming solvers.

A practical tool for sensitivity analysis

IRVIN LUSTIG
ILOG

keywords: modeling, sensitivity analysis, software

Traditional sensitivity analysis methods for mathematical programs have been based on duality theory, and are based on perturbations of single values in a problem instance. These methods were developed when it was computationally expensive to solve a new instance of a problem. These methods also do not work for mixed integer programs. ILOG has created a new tool, ILOG Optimization Decision Manager (ODM) that allows users to do sensitivity analysis for any type of optimization problem that can be modeled with ILOG's modeling language OPL. These tools make it easy to do what-if analyses, comparisons of alternative solutions, and permit the end user to gain a deeper understanding as to the reasons why the underlying optimizer obtained its answer. In this talk, we'll present some of these new concepts for doing sensitivity analysis and demonstrate the ease of creating a powerful sensitivity analysis application from an OPL model.

TU2-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Equilibrium and related problems

chair: Mauro Passacantando

A MPCC-NLP approach for an electric power market problem

HELENA RODRIGUES
Escola Superior de Ciências Empresarias, Inst. Politécnico de Viana do Castelo

coauthors: M. Teresa T. Monteiro, Ismael Vaz
keywords: electricity markets, MPCC, nonlinear programming, Stackelberg game

The electric power market is changing - it has passed from a regulated market, where the government of each country had the control of prices, to a deregulated market economy. Each company competes in order to get more clients and maximize its profits. This market is represented by a Stackelberg game with two firms, leader and follower, and the leader anticipates the reaction of the follower.

The problem is formulated as a Mathematical Program with Complementarity Constraints (MPCC). It is shown that the constraint qualifications usually assumed to prove convergence of standard algorithms fail to hold for MPCC. To circumvent this, a reformulation for a nonlinear problem (NLP) is proposed. Numerical tests using the NEOS server platform are presented.

A path-based double projection method for solving the asymmetric traffic network equilibrium

MAURO PASSACANTANDO
Department of Applied Mathematics - University of Pisa

coauthors: Barbara Stefania Panicucci, Massimo Pappalardo
keywords: asymmetric traffic network, extragradient method

We propose a new iterative method for solving the asymmetric traffic equilibrium problem when formulated as a variational inequality whose variables are the path flows. The path formulation leads to a decomposable structure of the constraints set and allows us to obtain highly accurate solutions. The proposed method is a column generation scheme based on a variant of the Khobotov's extragradient method for solving variational inequalities. Computational experiments have been carried out on several networks of a medium-large scale. The results obtained are promising and show the applicability of the method for solving large-scale equilibrium problems.

TU2-R17 STOCHASTIC PROGRAMMING
Applications of stochastic programming
organizer/chair: Pavel Popela

Reduced scenario tree generation for mid-term hydrothermal scheduling

GERSON OLIVEIRA
Power Systems Research

coauthor: Joari Costa
keywords: hydrothermal scheduling, multi-stage stochastic programming, scenario generation

The optimal scheduling of hydrothermal systems requires the representation of future inflows uncertainties for basically two reasons. Firstly, to define the present day commitment of thermal plants in order to hedge against adverse low inflows, and, secondly, to specify the volume of water storage in reservoirs to avoid spillage if high inflows occur. An inflow scenario tree must be correctly dimensioned so as to provide a parsimonious - but still representative - sample of the multivariate process underlying possible future inflows. In this article we propose a methodology to generate such a tree. The idea is to use principal component analysis to reduce the effective dimensionality of the scenario specification problem so that a discretization technique can be used in a smaller dimensional space. A stochastic hydrothermal scheduling optimization model was applied to the Brazilian interconnected power system to illustrate the proposed methodology. The quality of the reduced sample was evaluated by considering not only hydrological aspects, but also the solution stability of the stochastic problem.

Stochastic programming applications in civil engineering

PETR STEPANEK
Brno University of Technology

keywords: civil engineering, deterministic reformulation, stochastic programming applications, structural design

The purpose of the paper is to introduce and discuss challenging ideas related to the promising application area of stochastic programming - civil engineering. The common problem is that the related models are naturally complex in comparison with the available computational power that is still considered quite limited. There is also an increasing and serious request from practice to reconsider traditional approaches, how the model uncertainties have been tackled. The paper identifies several important problems that practical applications generate mainly in the area of optimum and reliable structural design. The traditional "expert-based" approaches are discussed and evaluated specifically within the context of stochastic programming and their disadvantages are shown. The model reformulations and modifications derived from the stochastic programming principles are introduced and related new ideas are marked and listed. As the next step, model approximations lead to the solvable instances of considered problems and test computations end the paper.

Safe transit of a marine minefield as a stochastic shortest path

RUTH LUSCOMBE
University of Melbourne

keywords: military applications, stochastic shortest path

In this problem, a ship must find a safe path to transit a mined region. The information about the mines is uncertain and so we treat the problem as a stochastic shortest path. During the transit we have the ability to learn about the mines and take a prescripted contingency path. A simple heuristic is used to generate path plan. We present current work focussing on improving the performance of the heuristic.

TU2-R18 GRAPHS AND MATROIDS
Algebraic methods
organizer/chair: Cristina Fernandes

Algebraic connectivity on combinatorial optimization problems

CLAUDIA JUSTEL
Instituto Militar de Engenharia

coauthor: Nair Maria Maia de Abreu
keywords: algebraic connectivity, bandwidth, cut problems

The *Laplacian matrix of a graph* G, $L(G)$, is defined as $D-A$, where A is the adjacency matrix and D is the diagonal degree matrix of G. The *spectrum of* $L(G)$ is the sequence of the eigenvalues of $L(G)$, which is displayed in non-increasing order. The second smallest eigenvalue in the spectrum is called *the algebraic connectivity of a graph*, $a(G)$. The importance of this special eigenvalue of $L(G)$ is due to the fact that is a good parameter to measure graph connectivity. We show how the algebraic connectivity of a graph can be applied on combinatorial optimization problems as vertex and edge cut sets, cutwidth, bandwidth, TSP, among others.

On 3-connected binary matroids with circumference 6 or 7

MANOEL LEMOS
UFPE

coauthors: Raul Cordovil, Bráulio Maia Junior
keywords: 3-connected, binary matroids, circumference of matroids

In this talk, we describe all the 3-connected binary matroids having circumference 6 or 7 (and rank at least 9). Essentialy, we have only one large family of matroids satisfying these conditions. This family is obtained from the graphic matroid $M(K_{3,n})$ by a sequence of well described operations. This is a joint work with Raul Cordovil and Bráulio Maia Junior.

On the representability of totally unimodular matrices on bidirected graphs

LEONIDAS PITSOULIS
Aristotle University of Thessaloniki
coauthors: Gautam Appa, Konstantinos Papalamprou, Balazs Kotnyek
keywords: bidirected graphs, binet matrices, totally unimodular matrices

Seymour's decomposition theorem for regular matroids states that any matrix constructed recursively from network matrices (N) and two matrices which are the representation matrices for R_{10} matroid (B_1 and B_2) by k-sums $(k = 1,2,3)$ and taking the transposes is totally unimodular. Appa and Kotnyek showed that B_1 and B_2 are binet matrices and, thus, they can be represented on a bidirected graph. Therefore, the building blocks for totally unimodular matrices have graphical representation which is either a directed or a bidirected graph. In this paper we want to examine whether any totally unimodular matrix has a graphical representation on a bidirected graph. First we examine whether the k-sum of a binet and a network matrix as well as those of two binet and non-network matrices is a binet matrix or not. Furthermore, we go one step further and show how k-sum operations can be represented on bidirected graphs. Let B be an $m \times n$ totally unimodular matrix obtained by repeated application of k-sum operations on any number of matrices N, B_1 or B_2. We show that there exists a bidirected graph G with t nodes and m prime and n non-prime edges such that if R is the $t \times m$ node-edge incidence matrix of the prime edges and S the $t \times n$ node-edge matrix of the non-prime edges of G, $RB = S$. Although the sub-graph $G(R)$ is a k-tree graph (a tree plus k edges) B can be interpreted as the edge-walk incidence matrix derived from G in much the same way as the columns of B_1 or B_2.

TU2-R19 GRAPHS AND MATROIDS
Graph homomorphisms and constraint satisfaction
organizer/chair: Pavol Hell

Optimal local colorings

JAROSLAV NESETRIL
KAM-ITI, Charles University
keywords: coloring, homomorphism, minors, graph classes

We survey recent results of Patrice Ossona de Mendey and the author related to optimal partitions of structures (illustrated by graphs) which satisfy local conditions. This is related to separators, Ramsey graphs and various geometrically defined graphs (meshes). The key notion is bounded exoansion.

Generalized colourings of chordal graphs and cographs

PAVOL HELL
SFU
keywords: chordal graphs, cographs, graph colourings, graph matrix partition

Ordinary colourings of chordal graphs and cographs are well understood. In this talk, I will focus on more general colourings, in which certain colour classes are restricted to be independent sets, while the others must be cliques; at the same time, certain pairs of colour classes may be restricted to have all edges, or no edges, joining them. If the number of colours is fixed, we obtain matrix partition problems. For cographs, these turn out to be all polynomially solvable and characterizable by finite sets of forbidden induced subgraphs. For chordal graphs, many such problems are also solvable in polynomial time, while certain others remain NP-complete. On the other hand, if the number of colours is not fixed, a number of other interesting problems arise, typified by the problem of recognizing polar graphs. I will discuss polynomial time recognition of polar graphs amongst chordal graphs and amongst cographs. This reports on joint results with T. Ekim, T. Feder, W. Hochstaettler, S. Klein, L. T. Nogueira, F. Protti, J. Stacho, and D. de Werra, as well as results of some of these authors joint with R. de Souza Francisco, N.H.R. Mahadev, and others.

Deciding the existence of homomorphism by games

VICTOR DALMAU
Universitat Pompeu Fabra
coauthors: Albert Atserias, Andrei Bulatov
keywords: homomorphism problem

The problem of deciding, given two relational structures A and B, whether there exists an homomorphisms from A to B is a fundamental problem that has received a lot of attention of the last years. The problem is known to be NP-complete and much effort has been devoted in the identification of those subclasses of the problem that are solvable in polynomial time.

The existential k-pebble game, defined independently in several different areas, is a fundamental tool in this study. For every k>0 the existential k-pebble game is played between to playes, a Spoiler and a Duplicator, over two relational structures A and B. If A is homomorphic to B then Duplicator wins the existential k-peble game on A and B. We address the following question: under which circunstances the converse is also true?. In other words we investigate when, deciding the winner of the game, is a sound and complete algorithm for the homomorphism problem.

A solution of the problem in its full generality seems quite challenging. So far, many results deal with a restricted version of the problem, obtained by fixing the structure B. For each choice of B, the subclass of the homomorphism problem obtained in this way is generally denoted by CSP(B). This framework, although more simple, is still capable to capture and formulate a wide range of problems including, for example, H-coloring. In particular, for every graph H, the H-coloring problem is precisely CSP(H). Furthermore, it is know that deciding the winner of the existenial k-pebble game is an algorithm for CSP(H) if and only if H has an obstruction set of treewidth<k.

In this talk we will focus on the less studied restriction of the problem obtained by fixing the source structure A. It is known (Dalmau, Kolaitis, Vardi) that if A has a core wih treewidth<k then for every B, A is homomorphic ot B, provided the Duplicator wins the existenial k pebble game. In this talk we complement the above result. More precisely, we shall show that if the treewidth of the core of A is at least k then there exists an structure B such that A is not homomorphic to B but Duplicator wins the existential k-pebble game on A and B. Putting the two results toguether we obtain a complete picture of the applicability of existential pebble games for subclasses of the homomorphism problem obtained by fixing the source structure.

TU2-R20 APPROXIMATION ALGORITHMS

Bicriteria approximation algorithms

organizer: Claire Kenyon
chair: David Shmoys

Minimizing setup and beam-on times in radiation therapy

BARUCH SCHIEBER
IBM T.J. Watson Research Center

coauthors: Nikhil Bansal, Don Coppersmith
keywords: approximation algorithms, consecutive ones, radiation therapy

Radiation therapy is one of the commonly used cancer therapies. The radiation treatment poses a tuning problem: it needs to be effective enough to destroy the tumor, but it should maintain the functionality of the organs close to the tumor. Towards this goal the design of a radiation treatment has to be customized for each patient. Part of this design are intensity matrices that define the radiation intensity in a discretization of the beam head. To minimize the treatment time of a patient the beam-on time and the setup time need to be minimized. For a given row of the intensity matrix, the minimum beam-on time is equivalent to the minimum number of binary vectors with the consecutive "1"s property that sum to this row, and the minimum setup time is equivalent to the minimum number of distinct vectors in a set of binary vectors with the consecutive "1"s property that sum to this row. We give a simple linear time algorithm to compute the minimum beam-on time. We prove that the minimum setup time problem is APX-hard and give approximation algorithms for it using a duality property. For the general case, we give a 24/13 approximation algorithm. For unimodal rows, we give a 9/7 approximation algorithm. We also consider other variants for which better approximation ratios exist.

Simultaneous optimization and fairness for resource allocation problems

ASHISH GOEL
Stanford University

keywords: approximation algorithms, fairness, resource allocation

In this talk, we will sketch the theory of simultaneous optimization for concave profit functions, and point out connections to fairness. More precisely, suppose we would like to simultaneously approximate all symmetric utility functions over a convex feasiblity region. We characterize the optimum simultaneous approximation, and present polynomial time algorithms for obtaining this optimum. We prove that our solution is a logarithmic approximation simultaneously for all symmetric utility functions. Here, a utility function is assumed to be concave, zero at zero, and non-decreasing in each argument. This problem is equivalent to doing approximately fair resource allocation under all a priori reasonable measures of fairness.

We will illustrate this approach for the problem of bandwidth allocation in networks. In particular, we will show how this allocation can be obtained using a distributed primal-dual algorithm very similar in spirit to TCP with per-flow information. If time permits, we will also illustrate this approach in the context of machine scheduling.

Minimum bounded-degree spanning trees

MICHEL GOEMANS
MIT

keywords: matroid intersection, spanning trees, travelling salesman problem, uncrossing

In this talk, I will consider the minimum cost spanning tree problem under the restriction that all degrees must be at most a given value k. The main result is that one can efficiently find a spanning tree of maximum degree at most k+2 whose cost is at most the cost of the optimum spanning tree of maximum degree k. This is almost best possible.

The approach uses a sequence of simple algebraic, polyhedral and combinatorial arguments. It illustrates many techniques and ideas in combinatorial optimization as it involves polyhedral characterizations, uncrossing, matroid intersection, and graph orientations (or packing of spanning trees).

The result generalizes to the setting where every vertex has both upper and lower bounds and gives then a spanning tree which violates the bounds by at most 2 units and whose cost is at most the cost of the optimum tree. It also gives a better understanding of the subtour relaxation for both the symmetric and asymmetric traveling salesman problems.

TU2-R21 DYNAMIC PROGRAMMING

Applications in dynamic programming

chair: Nikolaos Sahinidis

An exact algorithm for the contact map overlap problem in protein structural alignment

NIKOLAOS SAHINIDIS
University of Illinois

coauthor: Wei Xie
keywords: bioinformatics, branch-and-bound, protein structural alignment

Papers on sequence alignment of proteins have received tens of thousands of citations over the past decade, suggesting that one of the most important areas of research in protein bioinformatics is that of aligning two or more proteins based on their sequence similarity. Indeed, protein alignment has found wide applications in protein similarity detection, database search, and function prediction.

Structural alignment has been emerging recently as a technique that provides even more accurate alignments than sequence-based approaches, and is now regarded as the “standard of truth” and used to assess various sequence alignment methods. The contact map overlap (CMO) maximization problem is a particular structural alignment method that aligns proteins in a way that maximizes the number of common residue contacts.

In this paper, we develop a combinatorial, reduction-based, exact algorithm for the CMO problem. Contrary to earlier exact methods, we solve CMO directly rather than after transformation to other combinatorial optimization problems. We exploit the mathematical structure of the problem in order to develop a number of efficient lower bounding, upper bounding, and reduction schemes. Computational experiments demonstrate that our algorithm runs significantly faster than existing exact algorithms and solves some hard CMO instances that were not solved in the past. In addition, the algorithm produces protein clusters that are in excellent agreement with the SCOP classification. An implementation of our algorithm is accessible as an on-line server at http://eudoxus.scs.uiuc.edu/cmos/cmos.html.

Analysis of non convex dynamical programs and its applications

RENÉ MEZIAT
Universidad de los Andes

keywords: algebraic moments, convexification, dynamical programming, maximum principle

Recently we have analyzed non-convex problems in optimal control and calculus of variations by relaxing non-convex expressions in the derivative or in the control variable. The essential feature of this approach is the use of probability measures and their projection into convex cones of algebraic moments as has been proposed in global optimization of polynomials by other authors. By using this technique we obtain a convex version of the original non-convex, nonlinear dynamic optimization model. In this talk, we will present the extension of these ideas to the context of non-linear, non-convex dynamic programs arising in different applications of operations research. We stress the fact that this approach may be even more enlightening for dynamical programs, because the necessary conditions of the maximum principle only work well under assumptions of convexity.

Network service scheduling using a dynamic program

JESUK KO
Gwangju University

coauthor: Soonhak Park

keywords: dynamic programming, resource allocation, video on demand (VOD)

Video on Demand (VOD) is one of the most promising services in Broadband Integrated Services Digital Network (B-ISDN) for the next generation. VOD can be classified into two types of services: Near VOD (NVOD) and Interactive VOD (IVOD). For either service, some video servers should be installed at some nodes in the tree structured VOD network, so that each node with a video server stores video programs and distributes stored programs to customers. Given a tree-structured VOD network and the total number of programs being served in the network, the resource allocation problem in a VOD network providing a mixture of IVOD and NVOD services is to determine where to install video servers for IVOD service and both IVOD and NVOD services. In this paper we develop an efficient dynamic programming algorithm for solving the problem. We also implement the algorithm based on a service policy assumed in this paper.

TU3-R1 COMBINATORIAL OPTIMIZATION

Polyhedral combinatorics II

chair: Michael M. Sorensen

Characterizing all fractional extreme points of circulant matrices

SILVIA BIANCHI
Universidad Nacional de Rosario

coauthor: Gabriela Argiroffo
keywords: circulant matrix, fractional extreme point, set covering polytope

In this work we completely characterize the fractional extreme points of the set covering polyhedron corresponding to circulant matrices C_n^k based on a previous work of Cornuéjols and Novick (1994). In fact, we prove that any fractional extreme point of C_n^k can be associated to a circulant minor $C_{n'}^{k'}$ obtained by contraction of a suitable set of columns where n' and k' are relative primes.

From this result we provide a classification of circulant matrices in terms of the facet defining inequalities needed for the description of their set covering polyhedra.

These polyhedral properties of the set covering polytope of circulant matrices have a remarkable symmetry with results obtained by Pêcher and Wagler(2004) for the description of the stable set polytope of webs.

Polyhedral results for the pickup and delivery travelling salesman problem

IRINA DUMITRESCU
University of New South Wales

coauthors: Jean-Francois Cordeau, Gilbert Laporte, Stefan Ropke
keywords: branch-and-cut, pickup and delivery, polyhedral analysis, travelling salesman problem

The Pickup and Delivery Travelling Salesman Problem (PDTSP) we will address in our talk is a variant of the classical Travelling Salesman Problem (TSP). In our case, the PDTSP is the TSP with extra precedence constraints imposed on vertex pairs. We will review polyhedral results existent in the literature and propose new classes of valid inequalities. We will give conditions under which some classes of inequalities are facets for the PDTSP polytope. Preliminary numerical results for a branch-and-cut algorithm will be presented.

Polyhedral computations for the simple graph partitioning problem

MICHAEL M. SORENSEN
Aarhus School of Business - ASB

keywords: branch-and-cut, clustering, facets

The simple graph partitioning problem is to partition an edge-weighted graph into node-disjoint subgraphs, each containing no more than b nodes, such that the sum of the weights of all edges in the subgraphs is maximal. We present a branch-and-cut algorithm for the problem that uses several classes of facet-defining inequalities as cutting-planes. There are b-tree, clique, cycle with ear, multistar, and S,T-inequalities. Some computational results are presented.

TU3-R2 COMBINATORIAL OPTIMIZATION

Integer programming for graph optimization problem

organizer: Cid de Sousa
chair: Cid de Souza

Lagrangian relaxation and cutting planes for the vertex separator problem

CID DE SOUZA
Instituto de Computação - UNICAMP

coauthor: Victor Cavalcante
keywords: branch-and-cut, Lagrangian relaxation, polyhedral combinatorics, vertex separator

In this paper we propose an algorithm for the vertex separator problem (VSP) based on Lagrangian Relaxation and on cutting planes derived from valid inequalities presented by Balas and de Souza ("The Vertex Separator Problem: a polyhedral investigation", Mathematical Programming, 103(3),583-608,2005). The procedure is used as a preprocessing for the branch-and-cut (B&C) algorithm implemented for VSP by these authors, aiming to generate an initial pool of cutting planes and a strong primal bound for the latter. Computational experiments show that the exact method obtained in that way outperforms the pure B&C algorithm recently implemented in de Souza and Balas ("The vertex separator problem: algorithms and computations," Mathematical Programming, 103(3), 609–631, 2005). Besides, we show that the Lagrangian phase is a very effective heuristic for the VSP, often producing optimal solutions extremely fast.

The group Steiner tree problem

CARLOS FERREIRA
University of São Paulo

coauthor: Fernando Oliveira Filho
keywords: combinatorial optimization, group Steiner tree, polyhedral combinatorics, reduction techniques

We investigate the group Steiner tree problem: given a graph $G = (V,E)$ with non negative edge costs, and terminal sets $T_1,\ldots,T_k$ find a connected subgraph of G that contains at least one terminal from each terminal set. The problem is a well studied generalization of the Steiner problem in graphs. In this talk we show some reduction techniques and some polyhedral results we obtained for the problem.

Using ILPs to tackle the crossing number problem

MARKUS CHIMANI
University Dortmund

coauthors: Christoph Buchheim, Michael Juenger, Petra Mutzel
keywords: branch-and-cut, column generation, crossing number

The crossing number problem is an old and well known problem from graph theory, where we ask for the smallest number of edge crossings which are neccessary to draw a given graph into the plane. The problem is not only NP-hard, but also difficult to tackle both from the theoretical, as well as from the practical point of view.

Recently, the first approach to compute the exact crossing number of general graphs has been proposed, which is based on an ILP formulation and uses Branch&Cut techniques. Meanwhile, this approach has been further improved by column generation schemes, leading to an algorithm that is able to solve small and medium sized real-world graphs.

Furthermore, we try to apply this algorithm to complete graphs, since their crossing number (for more than 10 vertices) can currently only be conjectured.

TU3-R3 COMBINATORIAL OPTIMIZATION

Metaheuristics for scheduling problems

organizer/chair: Debora Ronconi

Scatter search for project scheduling with resource availability cost

DENISE YAMASHITA
UFSCar

coauthors: Vinicius Armentano, Manuel Laguna
keywords: heuristics, project scheduling, resource availability cost, scatter search

This paper considers a project scheduling problem with the objective of minimizing resource availability costs, taking into account a deadline for the project and precedence relations among the activities. Exact methods have been proposed for solving this problem, but we are not aware of existing heuristic methods. Scatter search is used to tackle this problem, and our implementation incorporates advanced strategies such as dynamic updating of the reference set, the use of frequency-based memory within the diversification generator, and a combination method based on path relinking. We also analyze the merit of employing a subset of different types when combining solutions. Extensive computational experiments involving more than 2400 instances are performed. For small instances, the performance of the proposed procedure is compared to optimal solutions generated by an exact cutting plane algorithm and upper and lower bounds from the literature. For medium and larger size instances, we developed simple multi-start heuristics and comparative results are reported.

Towards grid implementations of metaheuristics for hard combinatorial

ALETÉIA ARAÚJO
PUC - Rio de Janeiro

coauthors: Celso Ribeiro, Vinod Rebello, Cristina Boeres, Sebástian Urrutia
keywords: combinatorial optimization, GRASP with ILS, grid computing, parallel metaheuristics

Parallel computation is increasingly acknowledged as a complement to problem solving strategies, particularly when applied to large-scale applications. Metaheuristics are not exception to this trend and have witnessed a strong stream of important developments. Thus, parallel implementations of metaheuristics appear quite naturally as an effective approach to speedup the search for approximate solutions, solving larger problems and finding better solutions. Computational Grids have emerged as a real alternative for executing parallel applications that require significant amounts of computing power. Grids aim to make high performance computing available to users that do not have enough computational resources locally, by moulding geographically distributed resources into a single computing environment. We implemented and compared different strategies for the parallelization on a grid environment of an existing GRASP with ILS heuristic for the mirrored traveling tournament problem. Computational results are discussed.

Heuristic approaches for total tardiness minimization in a flowshop with blocking

DEBORA RONCONI
Universidade de Sao Paulo

coauthor: Luís R.S. Henriques
keywords: blocking in-process, flowshop scheduling, GRASP, tardiness

The flowshop scheduling problem with blocking in-process is addressed in this paper. In this environment, there are no buffers between successive machines; therefore intermediate queues of jobs waiting in the system for their next operations are not allowed. Heuristic approaches are proposed to minimize the total tardiness criterion. A constructive heuristic that explores specific characteristics of the problem is presented. Moreover, a GRASP-based heuristic is proposed and coupled with a path relinking strategy to search for better outcomes. Computational tests are presented and the comparisons made with an adaptation of the NEH algorithm and with a Branch-and-Bound algorithm indicate that the new approaches are promising.

TU3-R4 COMBINATORIAL OPTIMIZATION

Combinatorial optimization I

organizer: William H. Cunningham
chair: Eric Duchene

A solitaire game played on graphs

ERIC DUCHENE
Laboratoire Leibniz

coauthors: Laurent Beaudou, Sylvain Gravier, Luerbio Faria, Paul Dorbec
keywords: combinatorial games, hamiltonicity

Solitaire Clobber is a one-player game introduced by Demaine et al. in 2004. Our variant, called *SC2*, is the following: black and white stones are placed arbitrarily on vertices of a given graph G (one per vertex). A black (respectively white) move consists in picking a black (resp. white) stone and clobbering a white (resp. black) one located on an adjacent vertex. The clobbered stone is removed from G and is replaced by the picked one. The goal is to minimize the number of remaining stones. The minimum number of stones a player can reach is called the *reducibility value*. We here consider SC2 on grids, paths, trees, and hypercubes. In the cases of paths and trees, we give algorithms to compute polynomially the reducibilty value. We then prove that we can reduce configurations on hypercubes and d-dimensional grids to one or two stones.

Complexity of clique-coloring perfect graphs

DAVID DÉFOSSEZ
laboratoire Leibniz-IMAG

keywords: clique-coloring, perfect graphs

The problem of clique-coloring consists in assigning colors to the vertices of a graph so that every maximal clique of the graph contains at least two vertices with distinct colors.

Whereas we do not know any odd-hole-free graph that is not 3-clique-colorable, the existence of a constant C such that every perfect graph is C-clique-colorable remains an open question.

Besides this, the problem of clique-coloring is not clearly in NP since it is coNP-complete to check if a given coloring of the vertices is a clique-coloring of the graph or not. Actually Marx proved that deciding if a given graph is k-clique-colorable or not is a Σ_2P-complete problem for every $k \geq 2$.

We prove that this result still hold for the special case of perfect graphs for $k = 2$.

Note that if all perfect graphs are 2-clique-colorable, then this would imply that it is Σ_2P-complete to decide if the clique-chromatic number of a given perfect graph is 2 or 3.

An implementation for randomized truth assignments in 3-sat / nae3sat

LUERBIO FARIA
UERJ

coauthors: Giliano Novais, Simone de Melo, Jandir dos Santos
keywords: 3-satisfiability, algorithm, optimization problems, randomized algorithms

An optimization 3-SATISFIABILITY (3SAT) instance $I = (U,C)$ consists of a set U of boolean variables and a collection C of disjunctive clauses over U, such that every clause c in C has exactly 3 literals, with the goal of finding a truth assignment for the variables of U which maximizes the number of clauses of C having each one at least one true literal. An optimization NOT ALL EQUAL 3-SATISFIABILITY (NAE3SAT) instance $I = (U,C)$ consists of a 3SAT instance, with the goal of finding a truth assignment for the variables of U which maximizes the number of clauses of C having each one at least one true literal and at least one false literal. A recent result establishes that once one assigns a randomized value for the variables of U, the expected number of satisfied clauses for an instance of 3SAT and NAE3SAT are, respectively, $\frac{7}{8}m$ and $\frac{3}{4}m$, where $m = |C|$. A *complete instance* $I = (U,C)$ has $8\binom{n}{3}$ distinct clauses with $|I| = n$ variables, the maximum possible number of clauses. We observe that every feasible solution for a complete instance $I = (U,C)$ of 3SAT / NAE3SAT gives exactly $\frac{7}{8}m$ / $\frac{3}{4}m$ satisfied clauses. We also observe that every instance $I = (U,C)$ of 3SAT / NAE3SAT is contained in an complete instance $I' = (U,C')$, and therefore has optimum value at least $\frac{7}{8}m$ / $\frac{3}{4}m$. In this talk we show the results of an implementation of an algorithm that given a pair of positive integers n and $m \leq 8\binom{n}{3}$ generates a random instance $I = (U,C)$ with $|U| = n$ variables and $|C| = m$ clauses and defines a random truth assignment obtaining the number of satisfied clauses. We relate this number to the number of expected satisfied clauses and to the optimum value.

TU3-R5 — INTEGER AND MIXED INTEGER PROGRAMMING
Applications of IP II
chair: Marzena Fügenschuh

An integer programming formulation for the stratification problem in survey samples with proportional allocation

JOSÉ BRITO
Instituto Brasileiro de Geografia e Estatística - IBGE

coauthors: Flávio Montenegro, Nelson Maculan, Rosemary Azevedo
keywords: allocation, integer programming, sampling, stratification

This work reports a new methodological purpose for the stratification problem in survey samples. Given a predefined population of size N , a survey sample of size n and a number L of strata we must to determine, which population observations are associated to which stratum in such a way to minimize the sum of the estimator variances at each stratum. To solve this problem we propose an integer programming formulation with binary variables. Computational results for a real data set are presented and discussed.

MIR inequalities and mixed-integer knapsack problems

RICARDO FUKASAWA
GeorgiaTech

coauthors: William Cook, Marcos Goycoolea
keywords: Fenchel cuts, mixed-integer knapsack, mixed-integer programming, mixed-integer rounding

During the last decades, much research has been conducted in deriving valid inequalities for single-row Mixed Integer Programming (MIP) problems. However, no such class of inequalities has had as much practical success as the Mixed Integer Rounding (MIR) inequalities when applied as cutting planes to general MIP problems. In this work we analyze this empirical observation by developing an exact separation routine for single row systems, extending the work of Andrew Boyd. For this we develop a simple branch and bound algorithm for solving the mixed integer knapsack problem, and apply column generation to find violated inequalities maximizing the L1 distance to the point separated.

We compare the bounds obtained using this procedure on all miplib instances to the bounds obtained using an MIR inequality separation heuristic.

TU3-R6 — OPTIMIZATION IN NATURAL RESOURCES
Mathematical models in forestry 3
chair: Gyana Parija

Strategic budgeting for wildfire management

GYANA PARIJA
IBM Research

coauthors: Steve Carty, Andy Kirsch
keywords: IP model

We will present an IP model and a solution approach for optimizing the initial response (IR) organization needed to maximize the effectiveness of various fire containment activities in the fire planning units (FPU's) across the US. The optimization model instances for the FPU's result in large-scale integer programming problems requiring innovative solution approaches. Solution to the budgeting problem includes an initial response organization that could consist of a set of hand crews, engines, bull-dozers, helicopters, and the like.

Asymptotic convergence of optimal harvesting policies for a multiple species forest

ADRIANA PIAZZA
DIM-CMM. Universidad de Chile.

coauthor: Roberto Cominetti
keywords: asymptotic convergence, discrete dynamic programming, forest management, infinite horizon

We study the asymptotic behaviour of the optimal harvesting policies for a mixed forest with multiple species having different maturity ages. We prove the existence and uniqueness of a *sustainable state* i.e., a state invariant under an optimal policy. Moreover, we establish the asymptotic convergence of any optimal trajectory towards the sustainable state whenever the maturity ages of the species present at this state are relatively prime, and convergence towards an optimal periodic cycle in the general case. We also analyze different situations under which the convergence occurs in finite time.

Integrated system of energy using beddings of ambient engineering

JOHNSON MOURA
Universidade Federal do Rio Grande do Norte

keywords: biogas energy

We study the recycle of the vegetal organic residue of fruits for economical improvement of small agricultural communities in Rio Gande do Norte, one of the low income brazilian states. We search for technological innovation through optimization of the bioprocess in order to produce energy. We hope the new alternative and low-cost energy will help the small agricultural communities.

TU3-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.
Scheduling, Steiner and ring star problems
chair: Giuliana Carello

A transmission scheduling problem in wireless networks

GIULIANA CARELLO
Politecnico di Milano, Dipartimento di Elettronica ed informazione

coauthors: Sandro Bosio, Stefano Gualandi, Federico Malucelli
keywords: column generation, constraint programming, wireless networks

We study a transmission scheduling optimization problem arising in wireless networks assuming a time division multiple access scheme and considering also a constraint on the signal-to-interference-and-noise ratio to guarantee traffic quality. A set of nodes, representing the devices of the network, and a set of traffic demands, i.e. the number of packets to be sent from one node to another, are given. A device node cannot receive and transmit simultaneously (matching-like constraint). Besides, the set of links active simultaneously, i.e. the set of pairs of nodes transmitting/receveing traffic, must satisfy the requirement on the signal-to-interference-and-noise ratio. A set of links satisfying both such constraints is a compatible set. The transmission time is divided into time slots and a compatible set can be assigned to each of them. Our goal is to provide an assignment of all the links to time slots such that all the traffic demands are satisfied through a one hop routing. All the traffic demands must be covered by a compatible set. The objective is to minimize the number of needed time slots.

We propose a problem formulation where decision variables represent compatible sets to be assigned to time slots. Since compatible set are exponentially many, we use column generation to compute a lower bound of the problem. The pricing problem is solved in two different ways: by solving its formulation with CPLEX or by applying Constraint Programming techniques. A comparison between the behaviors of the two approaches is presented. Heuristic approaches to compute feasible integer solutions are proposed, as well.

A transgenetic algorithm for the prize collecting Steiner tree problem

CRISTINE SCHMIDT
UFRN

coauthors: Marco Goldbarg, Elizabeth Goldbarg
keywords: endosymbiosis theory, evolutionary algorithms, prize collecting Steiner tree, transgenetic

A Transgenetic Algorithm is an evolutionary algorithm with basis on the evolution theory named Serial Endosymbiosis Theory. According to that theory, the major organizational event in the history of life probably involved the merging of two or more lineages through symbiosis. Transgenetic algorithms adapt the biological concept of endosymbiosis to the computational context using, basically, two populations of individuals from distinct natures (distinct species): chromosomes and transgenetic vectors. Those populations interact and share information. Basically, the transgenetic vectors modify the chromosomes and can also be modified by them. The transgenetic vectors are constituted with information that may come from outside or inside the evolutionary process. In this paper, a transgenetic algorithm is applied to solve the Prize Collecting Steiner Tree Problem. The performance of the proposed algorithm is compared to other state-of-the-art algorithms and is showed that this is a promising approach to solve the problem efficiently.

A hybrid metaheuristic for the ring star problem

MARCIA FAMPA
UFRJ

coauthors: Gilberto Sousa, Thayse Dias, Elder Macambira, Lucídio Cabral
keywords: GRASP, network design, ring star problem, variable neighborhood search

In this work, we consider the Ring Star problem: a combinatorial optimization problem that arises in telecommunications network design. The problem consists of locating a simple cycle through a subset of vertices of a given graph with the objective of minimizing the sum of two costs: a routing cost proportional to the length of the cycle, and an assignment cost from the vertices not in the cycle to their closest vertex in the cycle. We propose a hybrid metaheuristic approach to solve the problem, which uses a Variable Neighborhood Search (VNS) to improve the quality of the solution obtained with a Greedy Randomized Adaptive Search Procedure (GRASP). A set of extensive computational experiments are reported, comparing the GRASP/VNS algorithm with other algorithm found in the literature.

TU3-R8 FINANCE AND ECONOMICS
Finance and economics IV
chair: Hilary Paul Williams

Energy swing options with load penalty

ANDREA RONCORONI
ESSEC Business School

coauthor: Valerio Zuccolo
keywords: energy markets, financial derivatives, interruptible contracts, optimal exercise policy

A swing contract is a financial security granting the holder a number of transaction rights on a given asset for a fixed strike price. Each right consists of the double option to select both timing and quantity of a given security or commodity to be delivered. Examples are interruptible clauses in energy related contracts and chooser options in interest rate markets. The energy swing option exercise policy depends on standing market conditions such as commodity price and availability. Moreover, constraint are usually introduced in terms of financial penalties on the demanded load, refractions periods and other provisions. We study general swing contracts, provide a valuation algorithm based on dynamic programming and perform a case-study under constraints affecting the number of exercisable rights. In particular, we examine load penalties and their effect on the optimal exercise policy.

The allocation of shared fixed costs

HILARY PAUL WILLIAMS
London School of Economics

keywords: fair allocation, fixed costs, integer programming duality, set covering problem

We consider the problem of sharing the fixed costs of facilities among a number of users. The original problem can be formulated as a Facilities Location model which can be tranformed into a Set Covering Problem. We therefore seek an economically meaningfull 'dual' for such a model. Our dual will be based on Chvatal-Gomory cuts which involves pricing facilities in a piecewise increasing way. Once we have such a satisfacory 'dual' we can also address the issue of obtaining a 'fair' allocation using a Minimax objective.

TU3-R9 OPTIMIZATION IN ENERGY SYSTEMS

Competitive energy market modeling

organizer/chair: Jorge Valenzuela

Transmission investments in competitive markets

CHAN PARK
Auburn University

coauthor: Sevin Sozer
keywords: competitive power market, congestion cost, transmission investment

Increasing congestion charges in competitive power markets necessitates economic transmission investments. Traditionally, transmission expansion models do not explicitly consider the economic impact of congestion in making investment decisions. From a system welfare perspective, the transmission expansion planning model considers the minimization of investment and congestion costs. In this paper, a model that includes a planning horizon with multiple load profiles is described. We illustrate the adequacy of the model by numerical examples.

Oligopoly models for the market price of electricity

MAINAK MAZUMDAR
University of Pittsburgh

coauthor: Lizhi Wang
keywords: Cournot, electricity price, supply function

Several oligopoly models have been proposed for representing strategic behavior in electricity markets, which include Bertrand, Cournot, and Supply Function Equilibrium (SFE). For the most part, these models are deterministic with the exception of the SFE originally developed by Klemperer and Meyer. However, their model does not include supply side uncertainties. In this paper, we consider both load and supply side uncertainties (resulting from generator availabilities.) We obtain Nash equilibrium solutions for Cournot and SFE models where each individual firm submits its bid so that its expected profit is maximized.

Power generation expansion under cournot competition

JORGE VALENZUELA
Auburn University

coauthor: Pinar Kaymaz
keywords: Cournot competition, generation expansion

Generation expansion planning involves decisions on location and capacity of new generation, which may lead to add or relieve congestion in transmission lines and to increase or reduce competition in deregulated markets. Generation expansion may encounter congestion in the transmission network by constrained single-line flows as well as flowgate transfer capabilities. In this paper, a model to study the interaction between competition and transmission congestion on power generation expansion is described. The generation expansion problem is modeled as a Cournot competition game. Results from two power networks are presented and discussed.

TU3-R10 MULTICRITERIA OPTIMIZATION

Utility theory and games

chair: Pedro Jara

A variant of the UTA method

LUÍS ALBERTO DUNCAN RANGEL
UFF

coauthors: Sérgio Sodré da Silva, Leticia Borges Silverio, Pollyane Pizeta da Silva
keywords: decision analysis, multicriteria decision aid, UTA method

It is proposed in this talk a variant of the UTA method, which employs a new mathematical programming method and takes into consideration the decision-makers preferences with regard to the criteria set. In order to implement this variant, it is necessary to apply a method to sort the alternatives, which is based on the multiattribute Utility Theory. The decision-makers preferences with regard to the criteria ser are taken into account in this model by including restrictions on the criteria weights, the total number of implementations necessary to obtain the utility functions was reduced to only one implementation. In addition, the estimated utility functions, obtained via the proposed variant, are much closer to the decision-makers preferences than those obtained via the original UTA method.

Strategic complementarity, heterogeneity and eductive stability in a class of non-atomic games

PEDRO JARA
DIM, U. de Chile - PSE, EHESS

keywords: expectational stability, Nash equilibrium, rational expectations, rationalizable strategies

To study the connection between two different stability concepts of rational expectations equilibria: Expectational Stability and Eductive Stability (or Strong Rationality); and the effects that Strategic Complementarity and Heterogeneity have over their relationship, a general Rational Expectations model is embedded in a game-theoretic context. Following the series of papers by Evans and Guesnerie (1993, 2003, 2005), concepts are defined and adapted from the finite game theoretical world to a Non-Atomic Game with a lattice structure. It is shown that under Strategic Complementarity, Heterogeneity of expectations makes no difference on wether a unique equilibrium is Eductively Stable or not.

A Newton Method for Multicriteria

LUIS MAURICIO GRAÑA DRUMMOND
UFRJ

coauthors: Rolando Otero, B. F. Svaiter
keywords: Newton methods

We propose a Newton type method for multicriteria for a twice continuously differentiable mapping. At each iteration, using a backtracking procedure, a step

length is chosen along the Newton direction, in such a way that the objective values keep on always decreasing. Eventually, the iterates reach a "good" vecinity of an efficient point, the full steps are then always accepeted and the sequence converges quadratically to an efficient point in that neighbourhood.

TU3-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Applications of LP and cone programming III

chair: Fernanda Raupp

Support set sensitivity analysis in bi-parametric linear optimization

ALIREZA HADIGHEH
Azarbaijan Tarbiat Moallem Uinversity

coauthors: Mohammad Dehghan, Kamal Mirnia
keywords: bi-parametric optimization, optimal partition, sensitivity analysis, support set

In bi-parametric linear programming, perturbation happens in both the right-hand-side and objective function coefficient with different nonzero parameters. Here we are interested to identify a region where the support set of given optimal solution for primal and dual linear optimization problem is invariant in bi-parametric programming. In general, we will show that these regions are the rectangles on $\mathbb{R}^2$ that might be a line segment or a singleton $\{(,0)\}$. More properties are investigated and its relation to the optimal partition invariancy sensitivity analysis is studied as well.

MILP formulation for solving the cutting stock problem in the corrugated board boxes industry

MARIA RODRIGUEZ
INGAR Instituto de Desarrollo y Diseño (CONICET - UTN)

coauthor: Aldo Vecchietti
keywords: cutting stock problem, mixed-interger linear programming, optimization, trim loss

In this paper the cutting stock problem for the corrugated board boxes industry is presented. Similar problems are found in literature. However, much more complicated scenario is presented in the industry under analysis. Several paper layers are used to form the board, there is a large number of paper types and widths to choose and only orders having same characteristics can be combined. Consequently, problem complexity is very high due to the huge number of products combinations and variables to manage in the cutting process. Reaching a solution by using a MINLP formulation is difficult, because of bilinearities, high combinatory and discrete variables involved. Instead, a MILP strategy has been developed. First, feasible cutting patterns are generated. Then a MILP optimization model selects a subset of them and the length to cut to satisfy problem constraints, minimizing trim loss costs. The approach provides a robust and fast problem solution.

Analytic center of spherical shells applied to the analytic center machine

FERNANDA RAUPP
LNCC, Brazil

coauthor: B. F. Svaiter
keywords: interior-point methods, pattern recognition

The two-case pattern recognition problem aims to find the best way of linearly separate two different classes of data points with a good generalization performance.

In the context of learning machines proposed to solve the pattern recognition problem, the analytic center machine (ACM) uses the analytic center cutting plane method restricted to spherical shells.

In this talk we prove existence and uniqueness of the analytic center of a spherical surface, which guarantees the well definedness of ACM problem. We also propose and analyze new primal, dual and primal-dual formulations based on interior point methods for the analytic center machine. Further, we study a complexity bound on the number of iterations for the primal approach.

TU3-R12 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Stochastic variational inequalities

organizer/chair: Alexander Shapiro

Approximations of Nash equilibria

GUL GURKAN
Tilburg University

coauthor: Jong-Shi Pang
keywords: stochastic variational inequalities

Inspired by previous works on approximations of optimization problems and recent papers on the approximation of Walrasian and Nash equilibria and on stochastic variational inequalities, the present paper investigates the approximation of Nash equilibria and clarifies the conditions required for the convergence of the approximate equilibria via a direct approach, a variational approach, and an optimization approach. Besides directly addressing the issue of convergence of Nash equilibria via approximation, our investigation leads to a deeper understanding of various notions of functional convergence and their interconnections; more importantly, the investigation yields improved conditions for convergence of the approximate Nash equilibria via the variational approach. An illustrative application of our results to the approximation of a Nash equilibrium in a competitive capacity expansion model under uncertainty is presented.

Algorithms for stochastic Nash and Stackelberg problems

VINAYAK V. SHANBHAG
Assistant Professor, University of Illinois at Urbana-Champaign
keywords: complementarity problem, equilibrium problems, nonlinear programming, stochastic programming

Stochastic Nash and Stackelberg equilibrium problems are discussed in a two-period setting. The former may be cast as a stochastic mixed-complementarity problem while the latter is given by a stochastic mathematical program with complementarity constraints (MPCC). A scalable convergent algorithms for each problem is given along with convergence theory and some computational results.

Stochastic mathematical programs with equilibrium constraints

ALEXANDER SHAPIRO
Georgia Institute of Technology
keywords: equilibrium constraints, stochastic programming

Topic of this talk is here-and-now type two-stage stochastic programs with equilibrium constraints. We give a general

formulation of such problems and discuss their basic properties such as measurability, continuity and differentiability of the corresponding integrand functions. We also discuss consistency and rates of convergence of sample average approximations of such stochastic problems.

TU3-R13 NONLINEAR PROGRAMMING

PDE-constrained optimization and algorithms

organizer: Stefan Ulbrich
chair: Matthias Heinkenschloss

SQP algorithms with inexact linear system solvers for the solution of PDE constrained optimization problems

MATTHIAS HEINKENSCHLOSS
Rice University

coauthor: Denis Ridzal
keywords: KKT systems, nonlinear programming, PDE constrained optimization, sequential quadratic programming

Sequential quadratic programming (SQP) algorithms are the state-of-the-art for the solution of large-scale nonlinear programming problems. These methods have also been used for the solution of several PDE constrained optimization problems. However, for these problems, the rigorous application of SQP algorithms poses several challenges. One set of challenges arises from the need to solve the large-scale linear systems that arise inside SQP algorithms and which involve linearized PDEs iteratively. In this case, one has to design implementable stopping criteria that ensure convergence of the SQP method while avoiding "over-solving" of the linear systems, one has to devise new ways of rigorously handling negative curvature, and one has to design effective preconditioners for the solution of so-called KKT systems. I will describe our approach to overcome these challenges, outline our SQP algorithm with inexact linear system solvers that is backed by rigorous convergence theory, and illustrate its performance on several PDE constrained optimization problems.

Path-following primal-dual interior-point methods in PDE constrained optimization

RONALD HOPPE
Universitaet Augsburg

coauthor: Christopher Linsenmann
keywords: interior-point methods, PDE constrained optimization

We are concerned with structural optimization problems in CFD where the state variables are supposed to satisfy a linear or nonlinear Stokes system and the design variables are subject to bilateral pointwise constraints. Within a primal-dual setting, we suggest an all-at-once approach based on interior-point methods. The discretization is taken care of by Taylor-Hood elements with respect to nested hierarchies of simplicial triangulation of the computational domain. The efficient numerical solution of the discretized problem relies on multilevel path-following techniques.

As an application, we study the optimal shape design of an electrorheological shock absorber

Increasing robustness of the L-BFGS method by using extra updates

HUGO SCOLNIK
University of Buenos Aires

coauthors: Nélida Echebest, María T. Guardarucci
keywords: Limited Memory method, extra updates, global convergence

This paper presents an algorithm for solving large nonlinear unconstrained optimization problems. It consists of an L-BFGS modification such that in certain iterations some pairs of the limited memory matrix are interchanged aiming at adding information of the local curvature. This is only done when some indicators predict a poor behavior of the L-BFGS direction. We present criteria for measuring the quality of the Hessian approximations and deciding about the convenience of adding extra local information arising from the solution of the second order approximation by discrete conjugate gradients. This approach resembles ideas used by other authors, but a crucial difference is we only perform modifications when L-BFGS exhibits either a non-convergent behaviour or a very slow rate of convergence. The added information consists of selected pairs of conjugate directions and the corresponding gradient differences gathered from the inner iterations, modifying the limited memory matrices without requiring extra storage. Numerical results are given showing sensible improvements for many well-known test problems.

TU3-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Convex analysis and algorithms

organizer: Raphael Hauser
chair: Coralia Cartis

A new perspective on the complexity of interior point methods for linear programming

CORALIA CARTIS
University of Oxford

coauthor: Raphael Hauser
keywords: complexity theory, convex optimization, interior-point methods for linear programming

In a dynamical systems paradigm, many optimization algorithms are equivalent to applying forward Euler to the system of ordinary differential equations defined by the vector field of the search directions. Thus the stiffness of such vector fields will play an essential role in the complexity of these methods. We first exemplify this point with some theoretical results for general linesearch methods for unconstrained optimization, which we further employ to investigating the complexity of a primal short-step path-following interior point algorithm for linear programming. Our analysis comprises showing that the Newton vector field associated to the primal logarithmic barrier is nonstiff in a sufficiently small and shrinking neighbourhood of its minimizer. Thus, by confining the iterates to these neighbourhoods of the primal central path, our algorithm has a nonstiff vector field of search directions, and polynomial iteration complexity.

Algorithms for computing Nash equilibria of large sequential games

JAVIER PENA
Carnegie Mellon University

coauthors: Samid Hoda, Andrew Gilpin
keywords: gradient-based methods, Nash equilibrium, smoothing

Finding a Nash equilibrium of an extensive form game is a central problem in computational game theory. For a two-person, zero-sum game this problem can be formulated as a linear program, which

in principle is solvable via standard algorithms such as the simplex or interior-point methods. However, most interesting games lead to enormous linear programs that are beyond today's computational capabilities. We propose a new gradient-based algorithm that can compute Nash equilibria of large two-person, zero-sum games within arbitrary accuracy. The algorithm combines modern smoothing techniques for saddle-point problems with the combinatorial tree-structure of the game. This results in a solution approach with an extremely low computational overhead, which makes it particularly suitable for large-scale problems.

TU3-R15 OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS

Features of large-scale optimization systems

organizer/chair: Robert Fourer

Finding conflicting constraints with CPLEX

ROLAND WUNDERLING
ILOG

coauthor: Ed Rothberg
keywords: MIP infeasibility

Infeasibility is often due to mistakes in modeling. However, if suitable tools are available, infeasible models can also be analyzed in order to better understand the real problem at hand. For example, one could deliberately introduce an infeasibility by adding an objective cutoff, in order to analyze what is preventing further improvement in the objective function. One new tool in CPLEX 10.0 for analyzing infeasible models is the Conflict Refiner. The idea of conflicts extends the well known concept of IIS (irreducibly inconsistent sets) for linear programs to general MIPs. We will describe the implementation of the conflict refiner in CPLEX as a hybrid algorithm that incorporates methods from both Mathematical Programming and Constraint Programming. The benefits from this hybrid approach will be discussed through computational results.

State-of-the-optimization using Xpress-MP v2006

ALKIS VAZACOPOULOS
Dash Optimization

coauthors: Richard Laundy, Gabriel Tavares
keywords: heuristics, linear programming, mixed-integer programming, parallel computing

The state of the Xpress-MP v2006 Linear Programming (LP) and Mixed Integer Programming (MIP) solvers is analyzed in this study.

Some new features of v2006 will be described including: the addition of in-tree cuts for parallel MIP, a feasibility pump heuristic, a 64 bit version, and improved solutions and preprocessing interfaces.

The efficiency of the v2006 Xpress solvers and the impact of the new features (parallel computing, 64 bit, FP heuristic) are demonstrated in publicly available benchmarks as well as on thousands of real problems.

Exploiting programming capabilities of LINGO 10 in multi-model analyses

FLAVIO PIZZATO
PRODUTTARE Consultores Associados

keywords: multi-model analyses

We describe how the programming capabilities in LINGO 10 can be used to do various multi-model analyses such as solve a series of related models as in computing an efficient frontier, compute multi-criteria solutions, do column generation in applications such as cutting stock, do cut generation as in some routing problems, as well as do various pre and post data processing for presenting customized reports.

TU3-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Primal-dual methods for KKT systems

chair: Mikhail Solodov

A local convergence property of primal-dual methods for nonlinear programming

PAUL ARMAND
Universite de Limoges

coauthor: Joel Benoist
keywords: constrained optimization, interior-point methods, nonlinear programming, primal-dual methods

We prove a new local convergence property of primal-dual methods for nonlinear optimization. Following a standard interior point approach, the KKT complementarity conditions are perturbed by a parameter driven to zero during the iterations. The iterates are generated by linearization of the perturbed system and strict feasibility with respect to the non-negativity constraints is maintained by applying the fraction to the boundary rule. The local convergence analysis is carried out by considering a linear or a superlinear arbitrary decreasing sequence of perturbation parameters. We show that once an iterate belongs to a neighborhood of convergence of the Newton method applied to the original system, then the whole sequence of iterates converges and asymptotically follows the central trajectory in a natural way. In particular this implies that it is not necessary to enforce the realization of the perturbed optimality conditions with a precision of the same order as the barrier parameter.

On local convergence of sequential quadratically-constrained quadratic-programming type methods, with an extension to variational problems

DAMIÁN FERNÁNDEZ
IMPA

coauthor: Mikhail Solodov
keywords: Karush-Kuhk-Tucker system, quadratic convergence, quadratically-constrained quadratic-programming, variational inequalities

We consider the class of quadratically-constrained quadratic-programming methods in the framework extended from optimization to more general variational problems. Previously, in the optimization case, Anitescu (2002) showed superlinear convergence of the primal sequence under Mangasarian-Fromovitz constraint qualification and the quadratic growth condition. Quadratic convergence of the primal-dual sequence was established by Fukushima, Luo and Tseng (2003) under the convexity assumptions, the Slater constraint qualification, and a strong second-order sufficient condition. We obtain a new local convergence result, which complements the above (it is neither stronger nor weaker): we prove primal-dual quadratic convergence under the linear independence constraint qualification, strict complementarity, and a second-order sufficiency condition. Additionally, our result applies to variational problems beyond the optimization case. Finally, we provide a necessary and

sufficient condition for superlinear convergence of the primal sequence under a Dennis-Moré type condition.

TU3-R17 STOCHASTIC PROGRAMMING

Scenario generation and optimization under uncertainty

organizer: Pavel Popela
chair: Werner Roemisch

Stability-based scenario tree generation for multistage stochastic programs

WERNER ROEMISCH
University Berlin

coauthor: H. Heitsch
keywords: multi-stage stochastic programming, multivarite scenario trees

Forward and backward approaches are developed for generating scenario trees out of an initial fan of individual scenarios. Both approaches are motivated by our recent stability results for multistage stochastic programs. They are based on upper bounds for the two relevant ingredients of the stability estimate, namely, the probabilistic and the filtration distance, respectively. These bounds allow to control the process of recursive scenario reduction and branching. Numerical experience is reported for constructing multivariate scenario trees in electricity portfolio management.

The scenario reduction for incomplete recourse

PAVEL POPELA
Brno University of Technology

keywords: incomplete recourse, scenario generation, scenario reduction, stochastic programming

Scenario generation techniques are widely discussed in stochastic programming. Their importance is based on the fact that multistage scenario-based stochastic programs have been studied as suitable models for sequential decision making under uncertainty and they are also needed by many efficient algorithms. Scenario trees are obtained by various techniques that process historical data, expert-based opinions, and theoretical assumptions about included probability distributions. They can also be considered as discrete approximations of true multivariate probability distributions. The principle question is how to generate the right scenario trees. Such trees cannot be too large because they may lead to huge programs that are unsolvable because of their sizes and limited computational power. The quality of the scenario tree can also be verified by the evaluation of the obtained first-stage optimal solution with respect to the true probability distribution. Typical stochastic programming applications, especially from the area of finance, often assume relatively complete recourse and scenario generation techniques are adopted to the assumption. However, it is not valid for several engineering applications where certain combinations of first-stage decisions and realizations of random parameters may lead to critical consequences, and hence, unrecoverable infeasibilities. In addition, achieving relatively complete recourse for such case by some preprocessing techniques is not necessarily an easy task. Therefore, traditional scenario generation technique may lead to the scenario tree that induces the stochastic program solution that will be infeasible for some realistic scenarios that are not included in the generated set of scenarios. The challenge is how to avoid such situations. The purpose of the paper is to introduce and generalize some ideas derived from specific engineering applications and present a scenario generation framework for incomplete recourse problems.

TU3-R18 GRAPHS AND MATROIDS

Graphs and Matroids

organizer: TBD
chair: Samuel Varas

A strengthened flow linear formulation for the shortest path problem in digraphs with negative cycles

MAMANE SOULEY IBRAHIM
Laboratoire d'informatique de Paris 6

coauthors: Nelson Maculan, Michel Minoux
keywords: digraphs, shortest paths

We present a strengthened flow linear formulation for the shortest path problem (*spp*) in digraphs with negative cycles. It's a formulation with a constraints' number in order of n^3, where $n = \mid V \mid$ and V is the set of the digraph's vertices. We show that the linear programming relaxation of this formulation is significantly sharper than a standard *spp* linear formulation with an exponential number of constraints.

The polytope for 1-restricted simple 2-matchings in trees

DAVID HARTVIGSEN
University of Notre Dame

keywords: matching, polyhedral combinatorics, travelling salesman problem

Given an edge-weighted graph, a simple 2-matching is a subgraph whose connected components are paths and cycles. A simple 2-matching is called "1-restricted" if it contains no isolated edges. The problem of finding a maximum weight simple 2-matching in a graph is a relaxation of the travelling salesman problem and a complete description of the associated polytope (due to Edmonds) is well known. The problem of finding a maximum weight 1-restricted simple 2-matching is a tighter relaxation of the TSP. We present an IP formulation for this problem and show that, for the case of trees, it yields a complete description of the associated polytope. (It is not a complete description even for bipartite graphs.) We also completely characterize the facets of this polytope.

Determining the minimum cost path in hypergraphs

SAMUEL VARAS
Adolfo Ibáñez University

keywords: heuristics, hypergraps, minimun cost

Hypergraphs are an extension of regular graphs, because the edges could have one or more inputs and outputs nodes. However, not all problem formulations and solutions from regular graphs can be used in hypergraphs, in particular the shortest and minimum cost problem are different in the case of hypergraphs. This is because that an edge there is possible to have many parallel alternatives to carry out, and the shortest time is the maximum time among these alternatives, but the minimum cost should add all these alternatives cost. In the literature there are well known al- gorithms for the shortest hyperpath, however they are not applicable to the minimum cost problem. This paper presents the formulation and an algorithm for the problems of the minimum cost path in F-hypergrphs, including the restricted and not restricted cases. The

formulation is a nonlinear optimization problem, with local minimums. To solve this we have developed a meta-heuristic, where we have represented a solution through a vector with zeros or ones and the neighborhood switching some values. The results present gap lower than 5%.

TU3-R19 GRAPHS AND MATROIDS
Covers
organizer: Siang Song
chair: Guillermo Durán

Approximation results on rational objectives

CRISTINA FERNANDES
Universidade de São Paulo

coauthors: Jose Correa, Yoshiko Wakabayashi
keywords: approximation algorithms, covering problems, network design problems, rational objectives

We address the problem of finding approximate solutions for a class of combinatorial optimization problems with rational objectives. We show that, if there is an α-approximation for the problem of minimizing a nonnegative linear function subject to constraints satisfying a certain *increasing* property then there is an α-approximation ($1/\alpha$-approximation) for the problem of minimizing (maximizing) a nonnegative rational function subject to the same constraints. Our framework applies to covering integer programming problems and network design problems, among others. For example, we improve a result of Gubbala and Raghavachari on the problem of finding a k-edge-connected spanning subgraph of minimum average weight, deriving a 2-approximation for the problem.

The generalized covering tour problem: a computational experience with reduction rules

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coauthor: Luiz Satoru Ochi
keywords: covering tour problem, mathematical model, reduction rules

The Covering Tour Problem (CTP) is a job sequencing problem which has several actual applications and has not received much attention in the literature so far. It can be defined on an undirected graph $G = (V \cup W, E)$, where W is a set of vertices that must be covered. The problem consists of determining a minimum length Hamiltonian cycle on a subset of V such that every vertex of W is within a given distance d from at least one node in the cycle. The CTP is NP-Hard as it reduces to a Traveling Salesman Problem (TSP) when $d = 0$ and $V = W$. This work presents a mathematical programming formulation based on flow variables to the Generalized Covering Tour Problem (GCTP), a variant of the CTP that allows vertex of W belong to the route. It also presents a computational experience with reduction rules for the GCTP.

A note on the size of minimal covers

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coauthors: Eduardo Laber, Vaston Costa, Edward Haeusler
keywords: boolean functions, computational complexity, graphs, vertex cover

For the class of monotone Boolean functions $f : V \to \{0,1\}$ where all 1-certificates have size 2, we prove the tight bound $|V| \Leftarrow (\lambda+2)^2/4$ where λ is the size of the largest 0-certificate f.

This result can be translated to graph language as follows: for every graph $G = (V,E)$ the inequality $|V| \Leftarrow (\lambda+2)^2/4$ holds, where λ is the size of the largest minimal vertex cover of G. In addition, there are infinitely many graphs for which this inequality is tight.

TU3-R20 PRODUCTION AND SCHEDULING
Approximation algorithms for scheduling problems
organizer/chair: Baruch Schieber

Multiplexing packets with arbitrary deadlines in bounded buffers

YOSSI AZAR
Tel-Aviv University & Microsoft Research

coauthor: Nir Levy
keywords: buffer, competitive algorithm, deadline, packets

We study the online problem of multiplexing packets with arbitrary deadlines in bounded multi-buffer switch. In this model, a switch consists of m input buffers each with bounded capacity B and one output port. Each arriving packet is associated with a value and a deadline that specifies the time limit till the packet can be transmitted. At each time step the switch can select any non-empty buffer and transmit one packet from that buffer. In the preemptive model, stored packets may be preempted from their buffers due to lack of buffer space or discarded due to the violation of the deadline constraints. If preemption is not allowed, every packet accepted and stored in the buffer must be transmitted before its deadline has expired. The goal is to maximize the benefit of the packets transmitted by their deadlines. To date, most models for packets with deadlines assumed a single buffer. To the best of our knowledge this is the first time a bounded multi-buffer switch is used with arbitrary deadline constraints.

Our main result is a 9.82-competitive deterministic algorithm for packets with arbitrary values and deadlines. Note that the greedy algorithm is not competitive. For the non-preemptive model we present a 2-competitive deterministic algorithm for the unit value packets. For arbitrary values we present a randomized algorithm whose competitiveness is logarithmic in the ratio between the largest and the smallest value of the packets in the sequence.

LP rounding using fractional local ratio

REUVEN BAR-YEHUDA
Technion IIT, Israel

keywords: approximation algorithms, fractional local ratio, resource allocation

Given a problem formulated as an integer program, a fractional local ratio algorithm obtains an integral solution from a fractional optimal solution using local ratio weight decompositions. In this talk, I will describe the technique and present several recent applications to various geometric packing problems related to scheduling.

Algorithms for vehicle routing

SAMIR KHULLER
University of Maryland

coauthors: Julian Mestre, Azarakhsh Malekian
keywords: approximation algorithms, combinatorial optimization, travelling salesman problem, vehicle routing problem

We develop algorithms for performing deliveries taking gas prices into account. We assume that information about gas prices at different locations is available, and use this information to develop algorithms for performing deliveries with a bounded gas tank capacity vehicle.

WE1-R1 COMBINATORIAL OPTIMIZATION
Efficient IP formulations
chair: Gilberto Miranda

A 0-1 integer formulation for the tree decomposition problem

VICTOR CAMPOS
Universidade Federal do Ceará

coauthor: Ana Silva
keywords: linear ordering, polyhedral theory, tree decomposition

We consider the tree decomposition problem, which was introduced by Robertson and Seymour in their series of articles about graph minors. Along the past decade, several heuristics and approximation algorithms have been proposed for computing upper and lower bounds. However, there is still a large gap between them for the instances contained in the literature. We propose tightening this gap by searching for new lower bounds through a polyhedral approach. For this, we propose the first 0-1 integer programming formulation for this problem based on the study of chordalizations and linear orderings. Facets based on substructures of a graph are then presented. In particular, we provide necessary and sufficient conditions for facets based on holes and paths.

Fast flow formulations for sparce QAP instances

GILBERTO MIRANDA
UFMG

coauthor: Henrique Pacca Luna
keywords: flow formulations, quadratic assignment problem, reduction tests

In this work, we present an efficient flow formulation to solve instances of the Quadratic Assignment Problem (QAP) arising in locational decisions. Comparisons of computing times and bounds achieved by a Adams and Johnson linearization of QAP, by our flow formulation and by a Branch-and-Bound code implementing Gilmore-Lawler bound are carried out. The results show the importance of the linear term, representing installation profitabilities. In locational decisions, the linear term of QAP accomplishes the heterogeneities of different kinds of environments. From the computational point of view, the linear parcel is responsible for breaking down the enormous levels of symmetry of QAP. This strategy makes possible the exact solution of large heterogeneous instances, opening several new possibilities of application. Homogeneous QAP instances usually solved in days turn out to be solved in minutes, if they cope with a linear term. The magnitude of the linear part is in fact a complexity measure of a given instance.

WE1-R2 COMBINATORIAL OPTIMIZATION
Sequences, coloring, and related applications
organizer: Uwe Zimmermann
chair: Gabriele Di Stefano

Online coloring of comparability graphs: some results

BENJAMIN LEROY-BEAULIEU
EPFL

coauthor: Marc Demange
keywords: cocoloring, coloring, comparability graphs, online algorithms

In this paper, we study online partitioning of posets from a graph point of view, which is coloring and cocoloring in comparability graphs. For the coloring problem, we propose a tight analysis of First-Fit achieving a ratio of $O(\sqrt{n})$ and we devise an algorithm with a competitivity ratio of $\frac{\chi+1}{2}$, thus improving the known result for online coloring of bipartite graphs, in the case where the arcs are given with a transitive orientation. For the cocoloring problem, we point out a tight bound of $\frac{n}{2}$, and prove that this bound still holds for some very restrictive models. We then explore relaxations of the problem, to improve this result.

How to assign tracks to trains

GABRIELE DI STEFANO
Università dell'Aquila -Italy

keywords: coloring of graphs, graph algorithms, railway optimization

The shunting problem concerns the rolling stock allocation on a railway infrastructure. It occurs in practical railway optimization problems like, e.g., the storage of trains or trams in a depot outside the rush hours, and the assignment of trains to platforms in a station. We consider a station or a depot where trains might enter and leave from both sides, but the arrival and departure times and directions are fixed according to a given time table. The problem is to assign tracks to the trains such that they can enter and leave the station/depot on time without being blocked by any other train. Some variations of the problem regarding linear time tables as well as cyclic time tables will be considered and presented as a graph coloring problem on special graph classes. One of these classes are the so called circular arc containment graphs for which an optimal $O(n \log n)$ coloring algorithm will be discussed. Under certain conditions, the problem is equivalent to the coloring of a permutation graph. In this case, an interesting open problem will be presented.

The stacking problem and its connection to graph coloring

FELIX KÖNIG
Technical University Berlin

coauthors: Rolf Möhring, Marco Lübbecke, Guido Schaefer, Ines Spenke
keywords: graph coloring, mixed-integer programming, stack

Stacking is a simple and widespread way of storing especially large and heavy items like containers on storage in harbors or slabs of raw steel awaiting further processing. Also, the process of parking cargo railcars on railway sidings may be considered a horizontal stacking process.

While stacking is generally very efficient in terms of ground space needed per item, accessing stacked items in a given order, like when compiling a train of certain railcars parked on sidings or moving containers from storage onto trucks in a given order, may be very unefficient; and the heavier and larger the items stored, the more important it is to avoid moving them around from stack to stack more than absolutely necessary.

We present a work in progress in which we define a generic stacking problem: A set of different items with associated release dates and dead lines needs to be stored on a limited number of stacks of limited height. Simultaneously, a given set of target stacks, each consisting of a given sequence of items, needs to be compiled. The goal is to minimize the total number of individual transports necessary to compile all target stacks. We show the problem's NP-hardness, its relation to the minimum graph coloring problem on permutation graphs and present theoretical results as well as practical solutions to the problem obtained

using different techniques including dynamic programming and mixed integer programming.

WE1-R3 COMBINATORIAL OPTIMIZATION

New and emerging trends in metaheuristics

organizer: Stefan Voss
chair: David Woodruff

Distances between VRP solutions

DAVID WOODRUFF
University of California Davis

coauthor: Arne Løkketangen
keywords: solution similarity, vehicle routing problem, VRP

There is a need to distinguish between good solutions, based on some other concept than quality alone (i.e. objective function value). We suggest several such distinguishing measures for the class of VRP problems, basing our difference on the underlying structure of the solutions. We produce measures of difference of the type proposed in the Psychology literature by Tversky.

Heuristic mining: a new concept and related techniques for reducing the effort and expertise to solve hard combinatorial optimization problems

MARÍA BALDOQUÍN DE LA PEÑA
ALIO, Sociedad Cubana de Matemática

keywords: asymmetric travelling salesman problems, combinatorial optimization, hyperheuristics, metaheuristics

The number of new metaheuristics, different variants of a metaheuristic one, hybrids algorithms and different hyperheuristic approaches for solving difficult combinatorial optimization problems appear in the literature in more and more growing quantities, that makes difficult, even for a specialist in the topic, the selection of the most appropriate method for a problem type or a group of instances of a given problem.

In this paper we define a new meaning of the term heuristic mining. We also describe, in a summarized way, the design of one application for the Asymmetric Traveling Salesman Problem. Finally, a combinatorial optimization website application is proposed. The design and creation of a Web-Application is conceived with a well designed database scheme as well as a unified User Interface. Through consequent use of open technologies like MySQL accessibility from different types of platforms can be achieved.

Solving multi-agent resource-constrained project scheduling problems with discounted cash flows by means of a negotiation-based coordination mechanism

ANDREAS FINK
Helmut-Schmidt-University Hamburg

keywords: negotiations, project scheduling

We consider a multi-agent resource-constrained project scheduling problem with discounted cash flows. Subsets of project activities are assigned to different agents, who aim for maximizing respective discounted cash flows depending upon the project schedule. As we take into account asymmetric preference information and opportunistic behavior of the agents, classic methods of multi-criteria optimization are not applicable. We present and examine a generic negotiation-based coordination mechanism which incorporates these restrictions. The mechanism is based on iterative negotiations about the changes to be applied to some tentative project schedule. A particular mutation is carried out only in case that all involved agents agree. To prevent the search process from getting stuck we present verifiable rules which force the agents to behave cooperatively to some extent (by means of mandatory acceptance ratios). The coordination mechanism is analyzed by computational experiments which show results with only small deviations from the Pareto frontier.

WE1-R4 INTEGER AND MIXED INTEGER PROGRAMMING

Advances in integer programming II

organizer/chair: Andrea Lodi

The football pool problem

JEFF LINDEROTH
Lehigh University

coauthors: Francois Margot, Greg Thain, James Ostrowski
keywords: coding theory, grid computing, integer programming

The football pool problem, which gets its name from a lottery-type game where participants predict the outcome of soccer matches, is to determine the smallest "covering code" of radius 1 of ternary words of length v. (Or in the football pool, to determine how many lottery tickets one would have to buy to guarantee that no more than one predicted outcome of a match is incorrect.) For v=6, the optimal solution is not known. Using a combination of isomorphism-pruning, subcode enumeration, and linear-programming based-bounding, running on a computational grid consisting of thousands of processors, we are able to report improved bounds on the size of the optimal code for this open problem in coding theory.

Randomized relaxation methods for the maximum feasible subsystem problem

PIETRO BELOTTI
DEI - Politecnico di Milano

coauthors: Edoardo Amaldi, Raphael Hauser
keywords: computational biology, maximum feasible subsystem problem, parallel algorithms, relaxation method

In the Maximum Feasible Subsystem (MaxFS) problem, given an infeasible linear system $Ax \geq b$, one seeks a feasible subsystem with a maximum number of inequalities. MaxFS is a combinatorial problem that has an increasing variety of applications, including Computational Biology and Telecommunications.

We propose to tackle MaxFS with randomized variants of the relaxation method, for which we have established probabilistic finite termination guarantees.

We present some results obtained on mid-large instances of MaxFS with a sequential version of our randomized relaxation method. However, the method can exploit the advantages of parallel computers as several vector operations are performed independent of each other.

We have developed a parallel version of this method, and applied it on a set of very large instances of MaxFS (up to 30 millions of inequalities) arising in Computational Biology, obtaining provably good solutions in limited time.

Results on the graphical relaxation of the symmetric traveling salesman problem

DIRK OLIVER THEIS
University of Heidelberg

keywords: polyhedral combinatorics, symmetric traveling salesman problem

The most successful approach to solve the *Symmetric Traveling Salesman Problem* uses Integer Programming methods, based on the IP-formulation by Dantzig, Fulkerson and Johnson (1954). The so-called *Graphical Relaxation* of Naddef & Rinaldi (1992,1993) can be used, both theoretically and in practice, to obtain valid inequalities for the associated Symmetric Traveling Salesman polytope.

In this talk, we present recent theoretical results on the properties of the Graphical Relaxation, focusing on the facial structure of the respective polyhedra. We also explain consequences for the practical solution of the TSP, namely to the *Local Cuts* method proposed by Applegate, Bixby, Chvátal and Cook (1998,2001,2003).

WE1-R5 INTEGER AND MIXED INTEGER PROGRAMMING
Multiobjective integer programming
organizer/chair: Theodore Ralphs

Column generation in integer programming with applications in multicriteria optimization

JORGEN TIND
University of Copenhagen

coauthor: Matthias Ehrgott
keywords: column generation, integer programming, multicriteria optimization

This talk presents in a unified form a column generation scheme for integer programming. The scheme incorporates the two major algorithmic approaches in integer programming, branch and bound technique and cutting plane technique. With integrality conditions imposed on the variables it is of importance to limit the number of columns introduced in the integer programming problem. This is equally important in the case of multiple criteria where usually multiple alternative efficient solutions are required. The suggested scheme gives additional dual information that limits the work required to move among the alternatives to be generated.

Multiobjective mixed-integer Stackelberg games

SCOTT DENEGRE
Lehigh University

coauthor: Theodore Ralphs
keywords: game theory, mixed-integer programming, multi-objective decision making

We consider a mixed-integer, zero-sum, static Stackelberg game. Using a multi-objective version of this game, we examine resource tradeoffs for the leader. We describe methods for generating the set of Pareto solutions to a biobjective game by solving a sequence of mixed-integer bilevel programs with weighted Chebyshev objective function.

WE1-R6 LOGISTICS AND TRANSPORTATION
Vehicle routing
chair: Ana Maria Oliveira

Adaptive routing in random time-dependent networks with real-time information

DANIELE PRETOLANI
DISMI - Universita' di Modena e Reggio Emilia

keywords: graphs and networks, routing problems, stochastic programming, transportation problem

In a discrete random time dependent network (RTDN) travel times on each arc are discrete random variables whose distributions depend on the leaving time. Hall (1986) showed that an optimal route in an RTDN is not a path, but rather a "strategy", that assigns an optimal successor to each node for each leaving time. In Hall's model only "a priori" information (i.e. distributions) are considered; an optimal strategy can be found in linear time in the size of the RTDN. Later, Fu (2001) investigated a different model, where the traveler is allowed to react to "real-time" information; he provided an approximated method for a restricted (time-independent) case. Here we provide an exact solution method for the general case of Fu's model, and we show that its complexity is polynomial (linear, under mild assumptions) in the size of the RTDN. Other variants and extensions are briefly discussed.

Integer programming formulation for an extended Dantzig-Fulkerson fleet size and routing model

DANIEL LACERDA
Universidade Federal de Goiás

coauthors: Paulo Machado, Leonardo Brito
keywords: Dantzig-Fulkerson model, fleet size and routing, maritime transportation, mixed-integer programming

Today advanced logistics, guided by quantitative optimization methods, are the last frontier for better efficient and cost reduction in maritime transportation. In this paper we present an innovative fleet size and routing model based in an early Dantzig-Fulkerson formulation. The Dantzig-Fulkerson model is reviewed and compared with the extended model. The improved version of the fleet size and routing model is formulated as MILP (mixed integer linear programming) and its efficiency is discussed.

Railroad logistics for sugar exports departing from the state of São Paulo: implications on the location of intermodal warehouses

ANA MARIA OLIVEIRA
ESALQ/USP

coauthor: José Vicente Caixeta-Filho
keywords: logistics, mathematical model, railway, warehouse

In the 90's, Brazilian sugar and alcohol sector passed through deregulation, which has meant significant changes in the production, commercialization and management skills of the sector. The optimization strategy of sugar logistics appeared then as one form of improving the commodity commercialization margin, with the intermodal operation (mainly involving rail and road tracks) becoming a very interesting and economical option. The focus of the work was on the use of the railway transportation of bulk sugar produced in the state of São Paulo for exportation to then verify the best location for warehouses along that state. To model that, mixed integer programming techniques were used to recommend the optimal spatial distribution and sizes of collecting sugar warehouses in São Paulo that would make possible the use of railway transportation. Four scenarios were defined and the results pointed out the high competitiveness of the intermodal alternative nearby the cities such as Araçatuba, Araraquara, Barretos, Ribeirão Preto, Pradópolis and

Santa Adélia, confirming the potential for the increase of the railway market share in the sugar export business.

WE1-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.
Network design
organizer/chair: Lisa Zhang

Optical network design

YIHAO ZHANG
Bell Labs

coauthors: Steve Fortune, Matthew Andrews
keywords: optical approximation, optical networking, optical transparency

Optical transparency allows signal to travel within an optical network without electronic processing. This technology promises to revolutionize optical communication, but it introduces new design challenges, such as how to assign wavelengths to multi-hop demands. In this talk we define two models of optical transparency. For both models we present a number of theoretical results, including recent hardness results on variants of wavelength assignment. We also discuss practical issues arising from design tools that we are developing at Bell Labs.

Communication and power control

ALESSANDRO PANCONESI
Università di Roma

coauthors: Emilio DeSantis, Fabrizio Grandoni
keywords: power control, wireless networks

The problem of power control is that of adjusting the transmission radius of every device of an ad hoc wireless network in order to obtain global connectivity, with minimum power consumption. We describe a distributed protocol that, when N devices are spread uniformly at random, produces with high probability a connected network whose global power consumption is O(OPT), within poly-logarithmically, in N, many communication rounds. We show that this is impossible to achieve without communication. Besides achieving essentially optimal power consumption, our protocol distributes the load evenly, in the sense that the expected degree of the resulting network is constant while the maximum degree is O(log N).

Wireless networks: algorithms for scheduling and capacity-estimation

ARAVIND SRINIVASAN
University of Maryland

coauthors: Anil Kumar, Madhav Marathe, Srinivasan Parthasarathy
keywords: approximation algorithms, network capacity, scheduling, wireless networks

Wireless networks differ significantly from wired networks, due to the notion of interference. We present algorithmic approaches to packet-scheduling and capacity-estimation for wireless networks, with a focus on provably-good approximation algorithms.

WE1-R8 FINANCE AND ECONOMICS
Finance and economics I
organizer: William Ziemba
chair: John Birge

Continuum approximations of multiple-asset taxable portfolios

JOHN BIRGE
University of Chicago, GSB

coauthor: Song Yang
keywords: portfolio optimization, stochastic programming

Taxable portfolios present considerable challenges for optimization models to maintain the tax-basis state for multiple assets. To provide a tractable formulation, we have proposed a continuum approximation using a small set of factors for systematic risk and independent idiosyncratic components. The portfolio then consists of measures on current prices relative to the tax basis and avoids problems of multiple bases. This talk will describe an optimal trading policy for this portfolio and upper and lower bounding approximations using a stochastic dominance argument. The advantage of portfolios with multiple assets will be presented in comparison to an optimal portfolio holding only index assets. The relative value of idiosyncratic volatility and implications for asset prices will also be discussed.

Portfolio optimization with robust estimates of risk

VICTOR DEMIGUEL
London Business School

coauthor: Francisco Nogales
keywords: portfolio optimization

Mean-variance portfolios constructed using the sample mean and covariance matrix of asset returns perform poorly due to estimation error. Moreover, it is commonly accepted that estimation error in the sample mean is much larger than in the sample covariance matrix. For this reason, recent research has focused on the minimum-variance portfolio. But even minimum-variance portfolios have unstable weights that fluctuate substantially over time. In this paper, we propose a class of portfolio policies with nice stability properties. The policies are based on certain robust estimators of risk and can be computed by solving a single nonlinear program. We show analytically that their portfolio weights are less sensitive to changes in the distributional assumptions than those of the minimum-variance policy. Our numerical results confirm that the proposed policies are more stable and that they preserve (or slightly improve) the already relatively high out-of-sample Sharpe ratio of the minimum-variance policy.

WE1-R9 OPTIMIZATION IN ENERGY SYSTEMS
Variational inequalities in energy
organizers: Luiz A. Barroso, Alejandro Jofre, Danny Ralph
chair: Alejandro Jofre

Strategic bidding under uncertainty and Nash equilibria in electricity markets: a binary expansion approach

LUIZ A. BARROSO
COPPE-UFRJ / PSR

coauthors: Marcia Fampa, Rafael Dix, Sergio Granville, Mario Pereira
keywords: equilibrium problem with equilibrium constraints, game theory, mixed-integer programming, power systems economics

The objective of this work is to present a mixed integer linear programming solution approach for the problem of strategic bidding in electricity markets. We consider the strategic bidding under uncertainty, where the price maker agent optimizes its bidding strategy and the uncertainty lies on the bids of its "rivals",

represented by a set of scenarios. A binary expansion (BE) scheme is used to transform the products of variables in the non-convex MPEC bidding problem into a mixed-integer formulation. We then extend the BE solution approach for the problem of finding Nash equilibrium in electricity markets, where a game-theory model represents the dynamic behavior of all agents. In this case, the Nash Equilibrium EPEC is represented by a mixed-integer formulation. The BE scheme is flexible and applicable to Cournot, Bertrand or joint price/quantity bidding models. The approach is illustrated in case studies with configurations derived from the 90-GW Brazilian system.

Complementarity models and the architecture of energy markets

DANIEL RALPH
Cambridge University

coauthor: Yves Smeers
keywords: complementarity problem, electricity markets

Energy is only one, though perhaps the most important, market in electricity or natural gas. Transmission or transport and various other ancillary services are also needed for the market to function. Markets can be real time or forward, centralised or decentralised. We show how complementary models can be used to model different architectures (markets, regulation and their interactions) and assess deficiencies of market architectures.

Optimal regulation mechanisms for electricity generation markets

ALEJANDRO JOFRE
CMM & DIM. Universidad de Chile

coauthor: Nicolas Figueroa
keywords: electricity market model

We consider a wholesale electricity market model with general networks, transmission losses and strategic producers as a Nash/optimization equilibrium problem. A previous work by Escobar and Jofre (2005) shows how regulation mechanisms such as the case when prices correspond to the Lagrange multipliers of a centralized cost minimization program allows the producers to charge significantly more than marginal price (market power). In this paper we derive an optimal regulation mechanism for that type of networks, and compare its performance with the bayesian version of the "price equal to Lagrange multiplier" one.

WE1-R10 ROBUST OPTIMIZATION

Robust optimization in engineering & network optim

organizer: Mustafa Pinar
chair: Edoardo Amaldi

Minimax regret spanning arborescence under uncertain costs

ALFREDO CANDIA
Universidad de Talca

coauthor: Eduardo Conde
keywords: combinatorial optimization, Edmond´s algorithm, minimum spanning arborescence, minmax regret

This work considers a classical combinatorial optimization problem on a network whose arc costs are partially known. It is assumed that an interval estimate is given for each cost and no further information about the statistical distribution of the truth value of the arc cost is known. In this context, given a spanning arborescence in the network, its cost can take on different values according to the choice of each individual arc cost, according to the different cost scenarios. We analize the problem of finding which spanning arborescence better approaches the optimal one under each possible scenario. The minimax regret criterion is proposed in order to obtain such a robust solution to the problem. In the paper, it is shown that a greedy-type algorithm can compute an optimal solution of this problem on acyclic networks. For general networks, the problem becomes NP-Hard. In this case, the special structure of the optimization problem allows us to design a bounding process for the optimum value that will result in a proposed heuristic algorithm.

Robust optimization using computer experiments

DICK DEN HERTOG
Tilburg University

coauthor: Erwin Stinstra
keywords: computer simulation, metamodel, robust counterpart

In metamodel-based optimization three types of implicit errors are typically made. The first error is the simulation-model error, which is defined by the difference between reality and the computer model. The second error is the meta-model error, which is defined by the difference between the computer model and the metamodel. The third is the implementation error. This paper presents new ideas on how to cope with these errors during optimization, in such a way that the final solution is robust with respect to these errors. We apply the robust counterpart theory of Ben-Tal and Nemirovsky to the most frequently used metamodels: linear regression and Kriging models. The methods proposed are applied to the design of two parts of the TV tube. The simulation-model errors receive little attention in the literature, while in practice these errors may have a significant impact due to propagation of such errors.

Network design with more traffic matrices

LAURA SANITÀ
Tor Vergata

coauthor: Gianpaolo Oriolo
keywords: network design, non-simultaneous flow, single source

A crucial assumption in many network design problems is that of knowing the traffic demand in advance. Unfortunately, in several applications, communication patterns change over time, and therefore we are not given a single static traffic matrix demand, but a set X of non-simultaneous traffic demands. Still, we would like to design a min-cost network that is able to support any traffic demand that is from X. In this talk, we discuss strategies for approaching this problem when X is explicitly given by a list of traffic matrices. We focus in particular on the single-source case, which happens to be a generalization of the minimum cost Steiner tree problem.

WE1-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Semidefinite programming: methods and models

organizer/chair: Michael Todd

Large scale semidefinite programming via a saddle point mirror-prox algorithm

RENATO MONTEIRO
Georgia Tech

coauthors: Zhaosong Lu, Arkadi Nemirovski
keywords: first-order methods, saddle point problems, semidefinite programming

We first demonstrate that positive semidefiniteness of a large well-structured sparse symmetric matrix can be represented via positive semidefiniteness of a bunch of smaller matrices linked, in a linear fashion, to the matrix. We derive also the "dual counterpart" of the outlined representation, which expresses the possibility of positive semidefinite completion of a well-structured partially defined symmetric matrix in terms of positive semidefiniteness of a specific bunch of fully defined submatrices of the matrix. Using the representations, we then reformulate well-structured large-scale semidefinite problems into smooth convex-concave saddle point problems, which can be solved by a Prox-method developed by Nemirovski (2004) with efficiency $O(\varepsilon^{-1})$. Implementations and some numerical results for large-scale Lovász capacity and MAXCUT problems are finally presented.

A semidefinite programming approach to tensegrity theory and realizability of graphs

MAN-CHO SO
Stanford University

coauthor: Yinyu Ye
keywords: graph realizability, semidefinite programming, tensegrity theory

Recently, Connelly and Sloughter have introduced the notion of *d–realizability* of graphs and have, among other things, given a complete characterization of the class of 3–realizable graphs. However, their work has left open the question of finding an algorithm for realizing those graphs. In this paper, we resolve that question by showing that the semidefinite programming (SDP) approach of [Biswas and Ye '04, So and Ye '05] can be used for realizing 3–realizable graphs. Specifically, we use SDP duality theory to show that given a graph G and a set of lengths on its edges, the optimal dual multipliers of a certain SDP give rise to a *proper equilibrium stress* for some realization of G. Using this result and the techniques in [Connelly and Sloughter '04, Sloughter '04], we then obtain a polynomial time algorithm for (approximately) realizing 3–realizable graphs. Our results also establish a little–explored connection between SDP and tensegrity theories and allow us to derive some interesting properties of tensegrity frameworks.

Semidefinite programming in machine learning: sparse and large-scale learning with heterogenous data

GERT LANCKRIET
U.C. San Diego

keywords: applied statistics, bioinformatics, machine learning, semidefinite programming

An important challenge for the field of machine learning is to deal with the increasing amount of data that is available for learning and to leverage the (also increasing) diversity of information sources, describing these data. Beyond classical vectorial data formats, data in the format of graphs, trees, strings and beyond have become widely available for data mining, e.g., the linked structure of communication networks, amino acid sequences describing proteins, etc. Moreover, for interpretability and economical reasons, decision rules that rely on a small subset of the information sources and/or a small subset of the features describing the data are highly desired: sparse learning algorithms are a must. This talk will outline on a high level some recent approaches and results that address sparse, large-scale learning with heterogeneous data.

WE1-R12 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Geometric aspects of convex programming

organizer/chair: Leonid Faybusovich

Sparse SOS and SDP relaxations for polynomial optimization problems over symmetric cones

MASAKAZU MURAMATSU
University of Electro-Communications

coauthor: Masakazu Kojima
keywords: polynomial optimization, semidefinite programming, sparsity in polynomials, sum of squares

We extend the sparse SOS (Sum Of Squares) and SDP (SemiDefinite Programming) relaxations proposed by Waki, Kim, Kojima and Muramatsu for normal POPs (Polynomial Optimization Problems) to POPs over symmetric cones, and establish its theoretical convergence based on the recent convergence result by Lasserre on the sparse SOS and SDP relaxations for normal POPs. Preliminary numerical examples are given to exhibit its high potentials.

Bilinear complementary conditions for the cone of positive polynomials

FARID ALIZADEH
Rutgers University, New Jersey, USA

coauthors: Gabor Rudolf, Nilay Noyan
keywords: complementary conditions, convex optimization, positive polynomials, semidefinite programming

For a closed, convex and full-dimensional cone $\mathcal{K} \subset \mathbb{R}^{\setminus}$ and its dual cone $\mathcal{K}^*$ the complementary slackness condition $\langle x,s\rangle = 0$ defines an n-dimensional manifold $\mathcal{C}(\mathcal{K})$ in the space $\{(x,s)|x \in \mathcal{K}, s \in \mathcal{K}^*\}$. When $\mathcal{K}$ is a symmetric cone this manifold can be described by a set of n bilinear equalities. This fact proves to be very useful when optimizing over such cones, therefore it is natural to look for similar optimality constraints for non-symmetric cones. In this talk we examine the cone of positive polynomials, $\mathcal{P}$, and its dual, the moment cone $\mathcal{M}$. We show that it is impossible to express the complementary conditions for positive polynomials and its dual with only bilinear relations. We will also outline similar results for a number of well-known non-symmetric cones.

Symmetric relaxations of nonconvex optimization problems

LEONID FAYBUSOVICH
University of Notre Dame

keywords: convex relaxations, Jordan algebras, symmetric cones

We consider exact and nonexact relaxations of certain types of optimization problems by problems involving symmetric cones. Several examples (including an abstract version of S-Lemma and problems with nonconvex quadratic constraints) are considered. The relaxations involving specifically the quaternionic and second-order cones are emphasized.

WE1-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Proximal methods and convex separable optimization

organizer/chair: Felipe Alvarez

Primal/dual convergence results for hybrid proximal-projection methods coupled with penalty methods in convex programming

FELIPE ALVAREZ
Universidad de Chile

keywords: convergence, penalty functions, proximal methods

We investigate various sets of conditions ensuring the global convergence of a generic hybrid proximal-projection algorithm with fixed relative error criterion, when it is combined with different classes of parametric approximating functions. These include some viscosity-type regularization techniques as well as several smoothing and penalty/barrier methods in convex programming. Under neither primal nor dual uniqueness hypotheses, in particular without assuming any strong second order sufficient condition, we prove some convergence results for the iterates generated by the algorithm. Part of the analysis is valid for nonsmooth data in infinite-dimensional Hilbert spaces. In the specific convex programming case, we identify multiplier sequences depending explicitly on the primal iterates, and we find conditions for their convergence toward dual optimal solutions.

Variable metric extensions of the HIPPM and HPDM schemes

LISANDRO PARENTE
CONICET

coauthors: Pablo Lotito, Mikhail Solodov
keywords: decomposition methods, varitional inclusions

The general decomposition scheme known as Hybrid Proximal Decomposition Method (HPDM) proposed by Solodov proved to be very useful in the analysis of many decomposition methods.

The decomposition method proposed by He et al. is very near to this methodology. We show that it can be put in the HPDM framework extended to allow symmetric positive definite matrices as coefficients.

This extension applies naturally to the general HIPPM scheme in the same way.

Static arbitrage bounds for basket options via linear programming

JUAN VERA
Georgia Tech

coauthors: Javier Pena, Luis Zuluaga
keywords: basket options, linear programming

We show that the problem of finding the best possible bounds on a basket option given the prices of other basket options can be cast as a linear program. We subsequently show that for special cases, e.g., when only calls on individual assets are given, the linear programming formulation can be simplified substantially and has a closed-form solution.

WE1-R15 OPTIMIZATION SOFTWARE AND MODELLING SYSTEMS

Software services and distribution

organizer/chair: Robert Fourer

Mathematical programming based approach to the multiprocessor scheduling problem with communication delays

TATJANA DAVIDOVIC
Mathematical Institute, Serbian Academy of Sciences and Arts

coauthors: Leo Liberti, Nelson Maculan, Nenad Mladenovic, Pedro Teixeira
keywords: communication delay, heuristics, mixed-integer linear programming, multiprocessor scheduling

We consider the Multiprocessor Scheduling Problem with Communication Delays, where the delay is proportional to both the amount of exchanged data between pairs of dependent tasks and the distance between processors in the multiprocessor architecture. Although scheduling problems are usually solved by means of heuristics due to their large sizes, we propose methods to identify optimal solutions of small and medium-scale instances. A set of instances (although not the large scale ones) with known optima provides a useful benchmarking tool for new heuristic algorithms. We propose two new Mixed-Integer Bilinear Programming formulations, we linearize them in two different ways, and test them with CPLEX 8.1. We then discuss a combinatorial branch-and-bound algorithm which uses the well performing VNS metaheuristic for the uper bounds.

Optimization via the internet: NEOS 5 and beyond

ROBERT FOURER
Northwestern University

coauthors: Jorge Moré, Todd Munson, Jason Sarich
keywords: server

The NEOS Server provides free net access to nearly 50 "solvers" of optimization problems via a variety of interfaces and languages. It handles 3000-6000 requests a week and features a distributed design that scales readily. This survey emphasizes ideas behind the latest, completely rewritten version, which has an application programming interface that makes it callable from other programs. The presentation also offers a look at upcoming developments: automated problem analysis, XML-based standards for optimization problem instances, and an Optimization Services framework based on new web-service standards.

COIN-OR triennial update

BRADEN HUNSAKER
University of Pittsburgh

keywords: open-source

The Computational Infrastructure for Operations Research (COIN-OR) initiative was launched six years ago at ISMP 2000 to facilitate and encourage the development of open software, standards, and data for computational OR. Since that time there has been considerable growth and development of the project, which is now managed by an independent non-profit educational foundation. This talk will give an update on the initiative, including opportunities to make use of the initiative's projects and ways to become a part of the COIN-OR community.

WE1-R17 STOCHASTIC PROGRAMMING

Simulation methods for SP problems

chair: Ozge Ozdemir

Quasi-Monte Carlo methods in stochastic optimization

TITO HOMEM-DE-MELLO
Northwestern University

coauthor: Shane Drew
keywords: quasi Monte Carlo, stochastic programming

We discuss the use of Quasi-Monte Carlo (QMC) methods when solving stochastic programming models by means of sample average approximations. It is known that pointwise convergence of approximating solutions and values in ensured under mild assumptions; here, we focus on rates of convergence. We show that, for some classes of functions, QMC methods can be much more efficient than standard Monte Carlo. We also discuss some techniques to pick the important components of the underlying random vector so that QMC can be used only on those components. We present numerical results illustrating the discussed ideas.

Optimal threshold levels in stochastic fluid models via simulation-based optimization

OZGE OZDEMIR
Tilburg University

coauthors: Gul Gurkan, Fikri Karaesmen
keywords: sample path optimization, semi-Markov processes, service-level constraints, stochastic programming

A number of important problems in production and inventory control involve optimization of multiple threshold levels or hedging points. We address the problem of finding such levels in a stochastic system whose dynamics can be modelled using generalized semi-Markov processes (GSMP). The GSMP framework enables us to compute several performance measures and their sensitivities from a single simulation run for a general system with several states and fairly general state transitions. We then use a simulation-based optimization method, sample-path optimization, for finding optimal hedging points. We report numerical results for systems with more than twenty hedging points and service-level type probabilistic constraints. In these numerical studies, our method performed quite well on problems which are considered very difficult by current standards. Some applications falling into this framework include designing manufacturing flow controllers, using capacity options and subcontracting strategies, and coordinating production and marketing activities under demand uncertainty.

Mixed integer stochastic decomposition

SUVRAJEET SEN
University of Arizona

keywords: stochastic decomposition, stochastic mixed integer programming

For Stochastic Linear Programming, the Stochastic Decomposition (SD) has turned out to be a very effective solution algorithm for two stage problems. This presentation extends the ideas of SD to two-stage mixed-integer programs with fixed recourse. The approach essentially combines a branch-and-cut method (known as D2-BAC) with SD.

WE1-R18 GRAPHS AND MATROIDS

Packings, domination and isomorphisms

organizer/chair: Luerbio Faria

Dominating Z_p^n and $Z_2^n \times Z_3^m$

EDUARDO PIZA
Escuela de Matemática / Universidad de Costa Rica

keywords: combinatorics, football pool problem, graph domination, simulated annealing

In this contribution we describe the problem of finding minimal domination subsets of a given graph by rook domains. Specifically, we study the graphs of the kind Z_p^n and $Z_3^n \times Z_2^m$ and introduce a simulated annealing algorithm to compute upper bounds of the cardinality of minimal dominating subsets.

We demonstrate the effectiveness of the algorithm by comparing the results with a previously studied class of graphs, including the so-called "football pool" graphs and others. We give some new upper bounds for graphs of the kind Z_p^n, with $p \geq 4$. The codes of some dominating subsets are given in an appendix.

Packing edges and triangles: hardness results and approximation algorithms

GORDANA MANIC
IME - University of São Paulo

coauthors: Yoshiko Wakabayashi, Frederic Chataigner
keywords: approximation algorithms, APX-hardness, packing edges and triangles, triangle packing

We present approximation and non-approximability results on two packing problems on a graph G. The first is the classical problem of finding a maximum number of vertex-disjoint triangles in G. The second is the problem of finding a subgraph H of G such that H is a union of vertex-disjoint edges and triangles, and such that H has the maximum possible number of edges. We present some APX-hardness results and approximation algorithms for the first problem on low degree graphs, and for the second problem on arbitrary graphs.

On isomorphic 4-regular circulant graphs

UGO PIETROPAOLI
Università di Roma "Tor Vergata"

coauthor: Sara Nicoloso
keywords: Adam conjecture, circulant graphs, isomorphism

Consider three integers n, a, b such that $n > 0$, $a \neq 0$, and $b \neq 0$. The simple undirected graph $C_n(a,b) = (V,E)$ where $V = \{v_0, v_1, \ldots, v_{n-1}\}$ and $E = \{(v_i, v_{i+a}), (v_i, v_{i-a}), (v_i, v_{i+b}), (v_i, v_{i-b}),$ for $i = 0, \ldots, n-1)\}$ (where all arithmetic is done modulo n) is called circulant graph. In this contribution we shall consider only circulant graphs which are 4-regular and connected. We define a simple combinatorial model for the graphs, and investigate on some characteristic cycles of them. We propose a necessary and sufficient condition for two graphs in this class to be isomorphic. The result shows that the Ádám conjecture is true on the studied class of 4-regular and connected circulant graphs. The condition can also be used to easily generate all the circulant graphs isomorphic to a given one.

WE1-R19 APPROXIMATION ALGORITHMS

Approximation algorithms for network problems

organizer: Claire Kenyon
chair: Cliff Stein

Unsplittable flows in line and ring networks

AMIT CHAKRABARTI
Dartmouth College

keywords: approximation schemes, demand flow, multicommodity flows, unsplittable flow

In the unsplittable flow problem (UFP) we are asked to route, through a given capacitated network, a maximum profit subset of a given set of demands. Each demand takes up a given capacity on the edges it is routed through and provides a given profit if it is routed. It has long been known that UFP is very hard to approximate on general networks, but its status on simple networks such as lines and rings (i.e., cycles) is less clear: whether or not the problem remains APX-hard on such networks is a long-standing open question.

In this talk, I shall first summarize earlier work that led to the first constant-factor approximation algorithms for UFP on line and ring networks. I shall then describe recent work that gives a deterministic quasi-polynomial time approximation scheme for the problem. The latter algorithm rules out an APX-hardness result, unless NP is in DTIME($2^{polylog(n)}$).

The first part of the talk is based on joint work with Chandra Chekuri, Anupam Gupta and Amit Kumar and the second part is based on joint work with Nikhil Bansal, Amir Epstein and Baruch Schieber.

Incremental medians via online bidding

NEAL YOUNG
University of California, Riverside

coauthors: Claire Kenyon, John Noga, Marek Chrobak
keywords: approximation algorithms, competitive analysis, incremental medians, k-median

In many applications of k-medians, the number of facilities to be used is not known in advance: as time passes facilities may be added to the current solution. Thus, one seeks a sequence of k-medians solutions, one for each k, each augmenting the previous. We will discuss approximation algorithms for this problem. (Some of the results have been obtained independently by Lin, Nagarajan, Rajaraman and Williamson.)

We will also discuss the first polynomial-time algorithm for non-metric k-medians to achieve the optimal k-median cost using O(k log n) medians.

Edge pricing of multicommodity networks for selfish users with elastic demands

STAVROS KOLLIOPOULOS
National and Kapodistrian University of Athens

coauthor: George Karakostas
keywords: elastic demands, selfish routing, traffic equilibrium

We examine how to induce selfish heterogeneous users in a multicommodity network to reach an equilibrium that minimizes the system cost. In the absence of centralized coordination, we use the classical method of imposing appropriate per-unit-of-flow taxes (tolls) on the edges of the network. We significantly generalize previous work, by showing that such taxes exist even when user demands are elastic. In this setting the demand of a user is not fixed a priori but it is a function of the routing cost experienced, a most natural assumption in traffic and data networks. For example, users requesting data from a web server may stop doing so if the server is slow or drivers may change their travel plans based on road traffic conditions.

The elasticity of the demands makes the analysis particularly challenging: the routing costs at equilibrium depend themselves on the demands. The taxes whose existence we demonstrate induce an equilibrium E that achieves the minimum total latency for the demand values realized at E.

WE1-R20 ON-LINE OPTIMIZATION
Online optimization II
organizer: Kirk Pruhs
chair: Alberto Marchetti-Spaccamela

Data aggregation in sensor networks with latency constraints

ALBERTO MARCHETTI-SPACCAMELA
U. Roma "La Sapienza"

coauthors: Luca Becchetti, Peter Korteweg, Martin Skutella, Leen Stougie, Andrea Vitaletti
keywords: approximation algorithms, online algorithms, sensor network

Sensor networks consist of sensing devices battery operated which exchange data through wireless communication. A particular feature of sensor networks is that they are highly energy constrained. Data aggregation is a possible way to save energy consumption: nodes may delay data in order to aggregate them into a single packet before forwarding them towards some central node (sink). Since transmission is highly energy consuming, aggregation can contribute to increasing network lifetime. However, many applications impose constraints on data freshness; this translates into latency constraints for data arriving at the sink.

Data aggregation, latency constraints and energy preservation give rise to a wide variety of combinatorial optimization problems that we address in this paper. Namely, we study the problem of data aggregation to minimize maximum energy consumption under latency constraints on sensed data delivery. In the problem we study, transmission energy and time depend only on the pair of nodes involved in the transmission and we assume unique transmission paths that form a tree rooted at the sink.

We prove that the off-line version of the problem we consider is strongly NP-hard and we design a 2-approximation algorithm. The latter uses a novel rounding technique which has potentially wider applicability.

Almost all real life sensor networks are managed on-line by simple distributed algorithms in the nodes. In this context we consider both the case in which sensor nodes are synchronized or not. We consider distributed on-line algorithms and we use competitive analysis to assess their performance. We also provide lower bounds for the models we consider, in some cases showing the optimality of the algorithms we propose.

Online deadline scheduling with energy concern

TAK-WAH LAM
University of Hong Kong

keywords: competitive analysis, deadline scheduling, dynamic voltage scaling, online algorithms

This talk is concerned with on-line algorithms for scheduling jobs with deadlines on a processor that can vary its speed to optimize energy usage. Extending the previous work, we consider a more general case where the maximum speed of the processor is fixed. That is, the system may be overloaded and some jobs may miss their deadlines. An optimal schedule is expected to maximize

the throughput, and furthermore, its energy usage, which is a function of the processor speed, should be minimized. This talk presents a new online algorithm whose throughput and energy usuage are respectively O(1) times of that of the optimal schedule.

Online knapsack problems

KAZUO IWAMA

Kyoto University

keywords: knapsack problem, online algorithms

In the online version of the Knapsack Problem (OKP), we have a bin of size 1.0 and receive input items u_1, u_2, and so on. For each item u_i, we have to decide whether or not we take (and put into the bin) u_i. At the same time, we can discard zero or more items currently existing in the bin. The goal is to maximize the content of the bin at the end of the input. We show tight bounds of competitive ratio for this OKP and its revocable extension (ROKP). In ROKP, we can use en extra bin for a "buffer" for online decisions, i.e., we can move items freely between the main bin and this buffer. The proof of the competitive ratio for ROKP needs complicated case analysis and we made a full use of computer programs for this purpose.

WE2-R1 COMBINATORIAL OPTIMIZATION

Knapsack problems

chair: Bala Krishnamoorthy

Clique-based facets for the precedence constrained knapsack problem

CHRISTOPHER FRICKE
University of Melbourne

coauthors: Natashia Boland, Gary Froyland, Renata Sotirov
keywords: clique inequalities, facet defining inequalities, integer programming, precedence constrained knapsack problem

We consider an integer programming formulation of a knapsack problem with precedence constraints imposed on pairs of items, known as the precedence constrained knapsack (PCK) problem. This problem has applications in management and machine scheduling, and also appears as a subproblem in decomposition techniques for network design and other related problems. We present a new approach for determining facets of the PCK polyhedron based on clique inequalities. A comparison with existing techniques that use a lifting of cover inequalities for the PCK problem is presented, along with preliminary computational results.

A knapsack cryptosystem secure against attacks using basis reduction and integer programming

BALA KRISHNAMOORTHY
Washington State University

coauthors: William Webb, Nathan Moyer
keywords: 0-1 knapsack, basis reduction, diophantine approximation, public key cryptosystems

A knapsack public key cryptosystem encodes an n-bit message (0–1 n-vector x) by computing the product $M = a^T x$, where a gives the knapsack coefficients (public). The security of the cryptosystem depends on the fact that 0–1 knapsack problem is NP-complete. The Merkle-Hellman system started with a vector s of superincreasing weights ($s_i > \sum_{j<i} s_j$) disguised by a modular multiplication ($a_i = ps_i \mod q$; p, q are private). Attacks were proposed on this cryptosystem using Diophantine approximation, basis reduction, and integer programming techniques. The superincreasing structure proved to be the key weakness.

We propose a knapsack crptosystem which does not have an underlying superincreasing sequence. Further, we add restrictions on the 0–1 variables (x_j's). With $n = rm$, we require that exactly one x_j from each of r subsets (of size m) be equal to 1 (in addition to satisfying the knapsack equation). In the integer programming formulation, these restrictions are represented as r additional constraints of the form $\sum_{j=mk+1}^{mk+m} x_j = 1$ for $k = 0, 1, \ldots, r-1$. We prove that the application of shortest vector calculations using basis reduction will not break this cryptosystem. Through a computational study, we demonstrate that standard integer programming methods fail to solve these problems as well. In fact, for appropriate parameters, the instances cannot be handled by reformulations using basis reduction.

WE2-R2 COMBINATORIAL OPTIMIZATION

Shortest path algorithms

organizer/chair: Andrew Goldberg

Reach for A^*: efficient point-to-point shortest path problem

ANDREW GOLDBERG
Microsoft Research – Silicon Valley

coauthor: Renato Werneck
keywords: driving directions, point-to-point, shortest paths

We study the point-to-point shortest path problem in a setting where preprocessing is allowed. We improve the reach-based approach of Gutman in several ways. In particular, we add shortcut arcs which reduce vertex reaches. Our modifications greatly reduce both preprocessing and query times. The resulting algorithm is as fast as the best previous method, due to Sanders and Schultes. However, our algorithm is simpler and combines in a natural way with A^* search, which yields significantly better query times. The resulting algorithms are practical for a wide range of platforms, from service to handheld devices.

Algorithmic techniques for path problems on dynamic graphs

CAMIL DEMETRESCU
University of Rome "La Sapienza"

keywords: dynamic graphs, shortest paths, transitive closure

In many applications of graph algorithms, including communication networks, VLSI design, graphics, and assembly planning, graphs are subject to discrete changes, such as insertions or deletions of vertices or edges. In the last two decades there has been a growing interest in such dynamically changing graphs, and a whole body of algorithmic techniques and data structures for dynamic graphs has been discovered.

In this lecture, I will focus on fully dynamic algorithms for path problems on general directed graphs. In particular, I will consider two fundamental problems: dynamic transitive closure and dynamic shortest paths. Although research on these problems spans over more than three decades, in the last couple of years many novel algorithmic techniques have been proposed. I will make a special effort to abstract some combinatorial and algebraic properties, and some common data-structural tools that are at the base of those techniques, presenting some of the newest results in a unifying framework so that they can be better understood and deployed also by non-specialists.

Fast shortest path computations on large networks

ROLF MÖHRING
Technical University of Berlin

coauthors: Heiko Schilling, Ekkehard Köhler, Thomas Willhalm, Dorothea Wagner, Birk Schütz, Peter Sanders, Dominik Schultes
keywords: acceleration method, Dijkstra's algorithm, road network, shortest paths

We present acceleration methods for shortest path computations. Our methods are based on Dijkstra's algorithm. We assume that for the same underlying network the shortest path problem has to be solved repeatedly for different node pairs. Thus, preprocessing of the network data is possible to support the computation of queries. We focus on two methods. The first method is a generalized goal directed approach, which is called the "arc-flag" method. On average, the arc-flag method achieves speed-up factors of more than 1,500 on parts of the German road network (1 million nodes, 2.5 million arcs). The second method is a hierarchical approach and is called the "highway hierarchy" method. A hierarchy preserving all shortest routes can be

constructed very efficiently: preprocessing the European road network (18 million nodes, 42 million arcs) takes 15 minutes. On this large network the highway hierarchy method achieves speed-up factors of up to 10,200 on average.

WE2-R3 COMBINATORIAL OPTIMIZATION

Metaheuristics for solving prac. logistics

organizer: Helena Ramalhinho
chair: Daniel Serra

A DSS for locating public and private facilities in Barcelona

DANIEL SERRA
Universitat Pompeu Fabra

keywords: decision support systems, facility location, metaheuristics

In this paper we present a DSS to help managers to decide on the location of public or private facilities such as fire stations, ATMs, or health care centers in the city of Barcelona, Spain. The DSS includes a module that uses metaheuristic algorithms to find solutions for the Maximal Covering Location Problem and the P-Median Problem. The metaheuristic combines TABU search with ant colonies.

A general multi-objective model for dial-a-ride problem solved by simulated annealing

GERALDO REGIS MAURI
National Institute for Space Research

coauthor: Luiz Antonio Lorena
keywords: dial-a-ride problem, multi-objective models, simulated annealing, vehicle routing problem

This paper describes a general multi-objective mathematical model for dial-a-ride problem and an application of Simulated Annealing to solve it. The dial-a-ride problem consists of designing economical routes that assist customers' requests without violating operational and qualitative restrictions. A request consists of specific origin-destination transportation with demand. The model deals with a static mode of problem and comprehend several distinct cases of the regular problem such as heterogeneous or homogeneous fleet of vehicles, multi or single depot and a multi-objective minimizing function that treats transportation costs and customer inconveniences over weighting against each other. The Simulated Annealing application is simple, but for the new neighbors' generation, three types of moves are randomly used through a uniform distribution, and the routes are clustered and scheduled in a separate way for other heuristic methods. Computational results are performed over publicly available data sets and the results are compared against current state-of-the-art methods.

Combining metaheuristics and integer programming on school timetabling problems

HAROLDO SANTOS
UFF - Universidade Federal Fluminense

coauthors: Luiz Satoru Ochi, Eduardo Uchoa
keywords: integer programming, metaheuristics, tabu search, timetabling

Fischetti and Lodi (2003) proposed the use of general MIP solvers to explore large neighborhoods around reference solutions. In the original article, this appeared as a branching strategy aimed at improving the practical behavior of exact methods, producing better solutions earlier. As predicted in this work, the potential of similar techniques in a heuristic context was worthy of further investigation. A number of papers on that subject, MIP based heuristics, already appeared. In particular, Hansen and others borrowed VNS concepts to improve such heuristics. In this work we explore the use of MIP search to improve a Tabu Search for a Class x Teacher Timetabling Problem. Besides exploring neighborhoods around reference solutions we consider exploring "ellipsoidal" neighborhoods, which use information from pairs of solutions from an Elite Pool. Proposals for automatic neighborhood size selection are also discussed. Computational experiments demonstrate that significant improvements can be achieved with the proposed method.

WE2-R4 INTEGER AND MIXED INTEGER PROGRAMMING

Advances in integer programming III

organizer: Andrea Lodi
chair: Sanjeeb Dash

Solution polishing and other recursive MIP heuristics

EMILIE DANNA
Ilog Inc.

keywords: heuristics, mixed-integer programming

Several heuristics for mixed integer programming are based on the idea of transforming the original model into a model that is easier to solve and whose solutions are still solutions of the original model. In this talk, we will present several examples of this class of heuristics, focusing on 'solution polishing' which is effective on a number of mixed integer problems.

Conflict analysis in mixed integer programming

TOBIAS ACHTERBERG
Zuse Institute Berlin

keywords: conflict analysis, infeasibility, mixed-integer programming, SAT

Conflict analysis for infeasible subproblems is one of the key ingredients in modern SAT solvers. In this talk, we show how this technique can be generalized to mixed integer programming. Computational experiments show that solving time can be reduced by 10% for general MIPs and by 50% for particular classes of infeasible MIPs.

Polynomial time algorithms for stochastic lot-sizing problems

ANDREW MILLER
University of Wisconsin

coauthor: Yongpei Guan
keywords: lot sizing, mixed-integer programming, polynomial time algorithm

We study the uncapacitated lot-sizing problem with stochastic demands, a generalization of the deterministic economic lot-size model model studied by Wagner and Whitin in 1958. If demand is modeled as a scenario tree that satisfies certain conditions, our model has properties analogous to those of the Wagner-Whitin model, and we use these to define a polynomial time algorithm for our problem. We investigate a couple of extensions as well.

WE2-R5 INTEGER AND MIXED INTEGER PROGRAMMING

Applications of mixed integer programming

organizer/chair: Carlos Ferreira

A constructive characterization of the split closure of a mixed integer linear program

JUAN PABLO VIELMA
Georgia Institute of Technology, School of Industrial and Systems Engineering

keywords: finite integral generating sets, mixed-integer linear programming, split closure

We present a characterization of the Split Closure of a Mixed Integer Linear Program using finite integral generating sets of lattice points in a polyhedral cone. This characterization is based on the relationship between integer lattices and split disjunctions introduced by Bertsimas and Weismantel (2005) and allows us to prove that every cut from a mixed integer Farka's Lemma introduced by Köppe and Weismantel (2004) is dominated by a related split cut. Finally, by using this characterization and a result by Andersen, Cornuejols and Li (2002) we give a constructive proof of the polyhedrality of the split closure.

A combinatorial optimization approach to challenging synthesis problems

UTZ-UWE HAUS
Institute for Mathematical Optimization, Univ. Magdeburg

coauthors: Dennis Michaels, Robert Weismantel
keywords: chemical engineering application, combinatorial optimization, mixed-integer nonlinear programming

Many optimization problems in chemical engineering give rise to non-convex nonlinear mixed-integer optimization problems. While many tools for generating locally optimal solutions are nowadays available, determining tight global bounds or a globally optimal solution still remains a challenging task. We introduce an approach to tackle such instances that mostly resorts to techniques from discrete optimization: Polyhedral relaxations of the nonlinear terms occuring in the original formulation are used to set up a hierarchy of mixed-integer linear problems that contain all solutions of the original nonlinear problem. A key step of this approach is to identify combinatorial substructures like stable sets or nonlinear flow conservation conditions that are given by the constraints of the original nonlinear model. A linear description of those substructures leads to valid inequalities that strengthen the linear relaxations. The capability of this approach is demonstrated by considering two different applications from chemical engineering.

On forests, stable sets and polyhedras associated with clique partitions

DENIS CORNAZ
France Telecom

keywords: graph coloring, maximum stable set, polytope

Let $G = (V,E)$ be a simple graph on n nodes. We show how to construct a partial subgraph D of the line graph of G satisfying the identity: $\overline{\chi}(G) + \alpha(D) = n$, where $\overline{\chi}(G)$ denotes the minimum number of cliques in a clique partition of G and $\alpha(D)$ denotes the maximum size of a stable set of D. This is based on correspondences between the cliques partitions and the clique-connecting forests of G. We use this to develop a cutting-plane algorithm for the graph coloring problem that is tested on random and DIMACS benchmark graphs.

WE2-R6 LOGISTICS AND TRANSPORTATION

Routing and location problems

chair: Roberto Galvão

Benders decomposition for a hub location problem with economies of scale

RICARDO CAMARGO
UFOP Campus João Monlevade - Nexos

coauthors: Henrique Pacca Luna, Gilberto Miranda
keywords: Benders decomposition, hub-and-spoke networks, large-scale optimization

In communication or transportation network, when there are commodity flows between several pairs of origin-destination, hubs can be used as consolidation and routing points. This way, traffic can be consolidated on inter-hub links, achieving scale economies. O'Kelly and Brian (1998) proposed a model that treats these scale economies by means of piecewise-linear concave cost functions on the inter-hub arcs. Then, Klincewicz (2002) showed how to solve this model as a classic uncapacitated facility location problem for a fixed set of hubs.

In this work we propose an algorithm for tackling the multiple allocation hub location problem with scale economies based on the Benders Decomposition method. Some computational experiences on large-sized instances are presented.

Interactive and hierarchical methods for location-routing problems

ROBERTO GALVÃO
COPPE/Federal University of Rio de Janeiro

coauthor: Leonardo Souza Ribeiro
keywords: location and routing problems, logistics

Location and routing problems, taken separately, are complex problems. The combined location and routing problem is a generalization of these two problems. Locational decisions, which result in long-term investments, are taken at the strategical level, while routing decisions are generally taken at the tactical/operational levels.

The objective of this paper is not to make an extensive review of the subject, a task already undertaken by several authors, but rather to introduce, in some detail, some of the main methods used to solve location-routing problems. Given the complexity of these problems, methods available in the literature are heuristic/meta-heuristic methods. Available heuristic methods may be divided into interactive and hierarchical methods. In the interactive methods the two problems are equally related to each other, while in the hierarchical methods one problem is strongly embedded into the other. Some suggestions are made for future research on the subject.

A GRASP with adaptive memory for a period vehicle routing problem

LUCIANA GONÇALVES
Universidade Federal Fluminense - Instituto de Computação

coauthors: Luiz Satoru Ochi, Simone de Lima Martins
keywords: exploitation of oil in onshore oil wells, GRASP, period vehicle routing problem

In this paper, we present some proposals to approximately solve a version of the period vehicle routing problem (PVRP), the Period Bump Mobile Units Routing

Problem (PBMURP). This problem differs from the well-known PVRP in several aspects. One major difference between them, responsible for increasing the complexity of the problem, is that the number of visits required by a customer during the period is not previously determined. The PBMURP models a real application found in the Northeastern part of Brazil concerning the exploitation of oil in onshore oil wells. In this work, we propose a mathematical formulation describing the PBMURP as a linear programming problem and GRASP heuristics including pure and hybrid versions. Experimental results illustrate the effectiveness of GRASP with adaptive memory over pure GRASP heuristics.

WE2-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.

Routing, design and control in data networks

organizer: David Johnson
chair: David Applegate

ACL optimization or compressing rectilinear pictures

DAVID APPLEGATE
AT&T Labs – Research

coauthors: Gruia Calinescu, David Johnson, Howard Karloff, Katrina Ligett, Jia Wang
keywords: access control list, rectangle painting

We consider a geometric model for the problem of minimizing access control lists (ACLs) in network routers. This model is a generalization of one previously studied in the context of rectilinear picture compression. It embodies an optimization problem that arises when drawing figures using common software packages such as Excel and Xfig.

Here the goal is to create a colored rectilinear pattern within an initially white square canvas, and the basic operation is to choose a subrectangle and paint it a single color, overwriting all previous colors in the rectangle. Motivated by the ACL application, we study the special case in which all rectangles must be strips that extend either the full length or the full height of the canvas. We provide several equivalent characterizations of the patterns achievable in this special case and present a polynomial-time algorithm for optimally constructing such patterns when, as in the ACL application, the only colors are black and white (permit or deny). We also bound the improvement one can obtain by using arbitrary rectangles in the construction of such patterns, and analyze heuristics for the case of general patterns.

Distributed dual ascent for Steiner problems in graphs

MARCELO SANTOS
UFJF / UFF

coauthors: Eduardo Uchoa, Lucia Drummond
keywords: distributed algorithms, primal-dual algorithms, Steiner tree problems

Multicast routing problems are often modeled as Steiner Problems in undirected or directed graphs, the latter case being particularly suitable to cases where most of the traffic has a single source. Sequential Steiner heuristics are not convenient in that context, since one can not assume that a central node has complete information about the topology and the state of a large wide area network. This work presents a distributed version of the Dual Ascent Heuristic proposed by Wong, known for its remarkable good practical results, lower and upper bounds, in both undirected and directed Steiner problems. The distributed Dual Ascent has worst case complexities of $O(|V|^2)$ time and $O(|T|.|V|^2)$ messages. A recent example of the distribution of another primal-dual algorithm is given by Grandoni, Könemann, Panconesi and Sozio. Experimental results are also presented, showing the efficiency of the proposed algorithm.

A model for caching mechanisms in DNS and P2P network

HECTOR CANCELA
Universidad de la República

coauthor: Pablo Rodríguez-Bocca
keywords: caching models, p2p networks, performance optimization

The application of caching mechanisms are widely used to improve performance of computer systems and networks. Depending on the context, different strategies and objectives apply.

One particular case are the caching mechanisms employed in Peer-to-Peer and similar content oriented networks, where the information changes continuously. In this context, information discovery mechanisms have to be used sparingly (due to their high bandwidth consumption, and also to the associated search latencies), so that the cache allows to reduce bandwidth usage and search latency, at the cost of introducing some inconsistencies (as cache information usually gets partially oudated before it is replaced).

In this work, we present a simplified mathematical programming formulation of these caching problems as they arise at the first aggregation level in both Peer-to-Peer and DNS networks, and we apply it to some case studies built from literature-available and real-life measurements from an ISP provider respectively.

WE2-R8 FINANCE AND ECONOMICS

Finance and economics II

organizer: William Ziemba
chair: Florian Herzog

Real option valuation under imperfect markets

MARKKU KALLIO
Helsinki School of Economics

keywords: arbitrage pricing theory, imperfect markets, real options, stochastic programming

A computational method for valuation of real options is presented. Common approaches for real option analysis assume complete markets and neglect market imperfections, such as transaction costs, interest rate spreads between borrowing and lending, costs for short positions, and restricted short selling. We allow complete or incomplete and perfect or imperfect markets. A real option is defined by a set of stochastic cash flow streams resulting from possible choices within a real investment project. Option value is obtained as a unique maximum price an agent considering the investment is willing to pay, given markets of competing investment opportunities, such as real and financial investments. The valuation results look like those provided by standard arbitrage pricing theory extended to imperfect markets. However, due to preference information, the results differ. The approach is illustrated with a number of examples in flexible manufacturing systems. The results demonstrate the significance of imperfections in valuations.

Stochastic model predictive control for portfolio optimizations

FLORIAN HERZOG
ETH Zurich, Inst. F. Mess / Regeltechnik
coauthors: Hans Peter Geering, Gabriel Dondi, Simon Kell
keywords: dynamic portfolio optimization, model predictive control

We propose a solution method for the discrete-time long-term dynamic portfolio optimization problem with state and asset allocation constraints. We use the ideas of Model Predictive Control (MPC) to solve the constrained stochastic control problem. MPC can solve constrained optimal control problems for deterministic control applications with a receding horizon, where a series of consecutive open-loop optimal control problems are solved. We develop an MPC approach to the problem of long-term portfolio optimization when the expected returns of the risky assets are modeled using a factor model based on stochastic Gaussian processes. We show that MPC is a suboptimal control strategy that includes a feedback to the current values of the factors. For the open-loop optimal control optimization, we derive the conditional portfolio distribution and the corresponding conditional portfolio mean and variance. The mean and variance depend on future decision about the asset allocation. For the dynamic portfolio optimization problem, we consider constraints on the asset allocation as well as probabilistic constraints on the attainable values of the portfolio wealth. The dynamic portfolio optimization problem is stated and the solution via MPC is explained in detailed.

Asset and liability management for swiss pension funds

GABRIEL DONDI
ETH Zurich, Inst. F. Mess / Regeltechnik
coauthors: Florian Herzog, Hans Peter Geering, Michael Koller
keywords: financial modelling, optimization in financial mathematics, stochastic programming

We present an asset and liability management model for Swiss pension funds. It consists of dynamic, stochastic models for both, liabilities and asset prices. With the models, an optimisation technique to allocate the funds with regard to the structure of the liabilities is formulated. The method is applied using member's data of two Swiss pension funds with a total of 5000 members and 1.6 billion Swiss Francs of wealth. In an extensive out of sample case study with historical data, the method is applied over a long time period and changing market environments superiorly to passive benchmarks. Also, we show what effects the partitioning of the pension fund into groups of old and young members has with respect to the investment strategy.

WE2-R9 OPTIMIZATION IN ENERGY SYSTEMS
Hydro/thermal scheduling
organizer/chair: Claudia Sagastizabal

A multistage Benders decomposition approach for the security-constrained hydrothermal scheduling with transmission losses for large scale systems

ANDRE DINIZ
COPPE / UFRJ - Programa de Engenharia de Sistemas
coauthors: Tiago Norbiato, Maria Elvira Maceira
keywords: Benders decomposition, economic dispatch, hydrothermal systems, transmission losses

This paper proposes a Multi-stage Benders Decomposition approach to solve the security constrained short term hydrothermal scheduling with transmission losses for large scale systems. This methodology, already applied in the literature for the long and mid term planning and usually called Dual Dynamic Programming, uses a time decomposition to obtain nested subproblems defining cost-to-go functions for every stage. However, contrary to traditional dynamic programming approaches, each cost-to-go function is approximated iteratively by applying a multistage Benders decomposition.

In order to consider the electrical network in detail, each outer Benders iteration is appended with an inner loop for every stage, where the (quadratic) DC network losses for each circuit are approximated by a piecewise linear function. Line capacities and additional network constraints are also considered. The hydro system is represented in high detail. It includes cascaded reservoirs, water delay times, multiple uses of water, hydraulic and flood control constraints and an accurate representation of hydro generation as a multi-dimensional piecewise linear function of storage, turbine and spillage. Moreover, ramp constraints for hydro and thermal generation and spinning reserve per control area are included.

To assess the approach, two case studies are considered. The first test is done by comparing the convergence properties and optimal dispatch when transmission losses are taken or not into account for an IEEE 118 bus system. Results obtained from this test serve as a basis for the second test, which is an actual 168 hours study for the multi area system centrally dispatched by the Brazilian Independent System Operator, ONS. The study configuration consists of over 110 hydro plants, 60 thermal plants, 3400 buses and 4800 lines. In the real life test, the level of detail employed in the loss model for each circuit may vary according to the circuit´s characteristic.

Management of a hydraulic valley by robust optimization

ROMAIN APPARIGLIATO
EDF R&D - Ecole Polytechnique
coauthors: Jean-Philippe Vial, Riadh Zorgati
keywords: hydroelectric scheduling, linear decision rules, robust optimization

Optimization models for short-term electricity production planning in linked hydraulic system often leads to infeasible controls due to random fluctuations of the water inflow. To immunize the solution against uncertainty, we propose a robust optimization approach. We use linear decision rules, which make recourse variables functions of observed past inflows. This formulation leads to a linear programming problem, the so-called affinely adjustable robust counterpart (AARC). We generate the weekly schedule for a small but critical hydraulic system. We use the decision rules to simulate the performance of the AARC solution on a large number of scenarios. An appropriate choice of the immunization parameters makes it possible to achieve good cost performance while keeping the constraint violation to almost nil.

Allocation of firm-energy rights among hydro agents using cooperative game theory: an Aumann-Shapley approach

EDUARDO FARIA
PUC-Rio

coauthors: Luiz A. Barroso, Rafael Kelman, Sergio Granville, Mario Pereira
keywords: cooperative game theory, cost allocation methods, firm energy rights

The objective of this work is to investigate the application of different methodologies of allocation of firm energy rights among hydro plants using a cooperative game-theoretic framework. It is shown that there is not an optimal and unique approach to make this allocation, but there are criteria to verify if a given approach presents any drawbacks. One of these criteria is the "justice", which is equivalent to the condition of the core of a cooperative game. The calculation of the total firm energy will be based on the solution of a linear programming problem. The paper investigates the advantages and disadvantages of different methods to allocate the firm energy, such as marginal allocation, average production on the critical period, incremental allocation rights, "nucleolus" and Auman-Shapley. Some methods will be applied to the Brazilian system and the results will be compared with the allocation method currently adopted in the regulations.

WE2-R10 ROBUST OPTIMIZATION

Robust optimization: dynamic models

organizer/chair: Daniel Bienstock

Computing robust basestock levels

DANIEL BIENSTOCK
Columbia University

coauthor: Nuri Ozbay
keywords: robust optimization

We present computational and theoretical results on finding optimal basestock levels under a variety of models for demand uncertainty in the robust framework. Our methods, motivated by work with an industrial partner, are loosely based on Benders decomposition, and scale well to problems with large number of periods.

Multi-period pricing of perishable products; competition, uncertainty and learning

GEORGIA PERAKIS
MIT

coauthor: Tri-Dung Nguyen
keywords: competitive multi-period pricing, quasi-variational inequalities, robust optimization

In this talk we discuss a model for dynamically pricing multiple perishable products that sellers need to sell over a finite time horizon (i.e. in this setting, each seller has a fixed inventory of several products that he/she needs to sell over a finite time horizon). We are considering an oligopolistic market and assume that sellers compete through pricing. The model we present addresses the competitive aspect of the problem but also the presence of demand uncertainty. In particular, we propose a model that uses ideas from quasi-variational inequalities (in order to address the aspect of competition) and ideas from robust optimization (in order to address uncertainty of demand). The latter allows us to propose a model that is tractable and does not assume any particular type of distribution for the uncertain parameters of demand. Furthermore, time permitting, we will discuss how we enhance the model to include a setting where sellers learn their demand and try to understand their competitors' demands as they collect more data on prices for them and their competitors as time progresses and the selling horizon unfolds. We use ideas from MPECs to model this enhanced model of joint pricing and demand learning. Finally we discuss some insights. Applications include pricing airline tickets in the face of competitor airlines, as well as selling seasonal products in the retail industry in the presence of competitors.

WE2-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Duality in LP and cone programming

chair: Andre Tits

Full symmetric duality in separated continuous linear programs

GIDEON WEISS
University of Haifa

keywords: continuous optimization, infinite dimensional programming, linear programming, simplex

I will give the formulation of a continuous linear program with linear objective and right hand side, and its symmetric reverse time dual. I will then describe the structure of the optimal solutions, in the case that measurable bounded solutions exist. Finally, I will give the full duality result, when impulse controls at time 0 are allowed.

Revisiting dual results in convex semidefinite programming

FLAVIA JACINTO
University of Amazonas

coauthor: Susana Scheimberg
keywords: duality, generalized equilibrium problem, semidefinite programming

In this work, we show that a convex semidefinite programming problem (CSDP) can be embedded in the formulation of generalized equilibrium problem (GEP), which furnishes a unified framework for a wide class of interesting problems, including, for example, the variational and quasivariational inequality problems. Furthermore, we prove that the application of the duality theory of GEP to CSDP gives the classical dual Lagrangian problem and a known zero duality gap theorem which confirm the robustness of the GEP theory.

Constraint reduction for certain degenerate linear programs

ANDRE TITS
University of Maryland

coauthors: Pierre-Antoine Absil, Dianne O'Leary
keywords: column generation, constraint reduction, linear programming, primal-dual interior-point methods

Recently a scheme was proposed to efficiently handle, within the framework of interior point methods, linear programs with many more constraints than variables when expressed in standard dual form. The idea was to significantly reduce the cost per iteration by solving linear systems involving only a small subset of the constraints, while adaptively selecting these constraints in such a way that, hopefully, the total number of iterations would not increase dramatically. Extensive numerical experimentation suggested that, in fact, down to a rather small, appropriately selected, "working set" of constraints, the total number of iterations hardly increases at all.

A key assumption in the above was that, at every iteration, the submatrix of

the A matrix consisting of only those columns that correspond to constraints in the working set should be full row rank. (Indeed, when it is not, the linear system to be solved becomes singular.) In many real-life problems, this is not the case. In this talk, we show how this assumption can be dispensed with, and the constraint-reduction scheme be extended to such problems. Global and local quadratic convergence are proved, and numerical results are reported.

WE2-R12 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Algorithms for cone programming and convex hulls

organizer/chair: John Mitchell

Conic cutting surface algorithms

JOHN MITCHELL
RPI

coauthor: Vasile Basescu
keywords: analytic center cutting plane method, cone programming, selective orthonormalization

The problem of finding a feasible point in a fully dimensional set in a finite dimensional Hilbert space is analyzed. An analytic center cutting surface algorithm is developed that adds conic cuts. The algorithm generalizes similar LP, SDP, and SOCP approaches. It is shown that the algorithm is fully polynomial, with the complexity dependent on a condition number of the cuts. The algorithm is refined by modifying the cuts, which allows the derivation of a complexity result that does not depend on this condition number.

A primal-dual interior-point method for the determination of the convex hull

ALEXANDRE CABOUSSAT
Department of Mathematics, University of Houston

coauthors: Neal Amundson, Jiwen He, John H. Seinfeld
keywords: aerosols modeling, convex hull, global optimization, interior-point methods

The determination of the convex hull of a smooth non convex function in any dimension is a subject of active research in global optimization. In the context of modeling atmospheric particles, the convex envelope is related to the thermodynamic phase equilibrium.

In this talk, we formulate the constrained minimization problem in primal and dual variables and introduce a geometrical notion of phase simplex related to the convex hull to characterize mathematically the equilibrium. A local optimization method, e.g. a primal-dual interior-point algorithm, is our basis for solving efficiently the phase equilibrium problem.

We extend the methodology to the time-variable optimization problem arising when the phase equilibrium constraints are coupled with differential equations. We solve the resulting system of differential-algebraic equations by using sequential quadratic programming techniques.

Numerical results are presented for the computation of the thermodynamic equilibrium and mass transfer of organic aerosol particles and the computational efficiency is highlighted.

An extension of the standard polynomial-time primal-dual path-following algorithm to the weighted determinant maximization problem and its applications

TAKASHI TSUCHIYA
The Institute of Statistical Mathematics

keywords: weighted determinant maximization problem

The problem of maximizing the sum of linear functional and several weighted logarithmic determinant (logdet) functions under semidefinite constraints is a generalization of the semidefinite programming (SDP) and has many applications including statistics, datamining, and other areas of informatics. In this talk, we extend the framework of standard primal-dual path-following algorithms for SDP to this problem. Employing this framework, we show that the long-step path-following algorithm analogous to the one in SDP has $O(N\log(1/\varepsilon)+N)$ iteration-complexity to reduce the duality gap by a factor of ε, where $N=\sum N_i$, where N_i is the size of the i-th positive semidefinite matrix block which is assumed to be an $N_i \times N_i$ matrix. A few applications of the problem including density estimation and estimation of Gaussian graphical models are also presented.

WE2-R13 NONLINEAR PROGRAMMING

Filter methods for NLP

chair: Elizabeth Karas

Non smooth, non convex optimization

CLAUDIA MARGARITA VILLAGRAN DE LEÓN
alumni Humboldt University/Universidad San Carlos

keywords: complementarity problem, Nash equilibrium, nonconvex optimization, nonsmooth optimization

The mathematical approach on how to solve a Mathematical Optimization Problem is to formulate a non convex, non smooth optimization model. It is important to be motivated by the shapes and forms of functions, that will possibly arise within a framework.

Parametric Optimization is a branch of mathematical programming, that may be considered between various subdisciplines of optimization: smooth & non smooth, convex & non convex.

There are three important areas in non linear optimization. 1.Dependence of an optimization problem on the data. 2.Transversality theory. 3. Optimization problems depending on parameters.

The algorithm of Nash Equilibrium Problem is based on mathematical programming with economical constraints (MPEC). We must follow different proceedures to solve a MPEC such as general equation complementarity problem and bundle techniques. If we have penalization in MPEC, we can use the non smooth Mangasarian Fromowitz constraint qualification, which leads to optimality conditions and numerical methods.

If there is a set of strategies with the property that "no player can benefit by changing his strategy while the other players keep their strategy unchanged", then the set of strategies and the corresponding profits constitute a Nash Equilibrium. It is a Mathematical Economy problem of Optimization.

Global convergence of filter methods for nonlinear programming

ADEMIR RIBEIRO
UFPR

coauthors: Clovis Gonzaga, Elizabeth Karas

keywords: filter methods, nonlinear programming, sequential quadratic programming

We present a general filter algorithm that allows a great deal of freedom in the step computation. The algorithm consists basically in computing a point which is not forbidden by the filter, from the current point. We prove its global convergence, assuming that the step must be efficient, in the sense that, near a feasible nonstationary point, the reduction of the objective function is ¨‘large”. We show that this condition is reasonable, by presenting two classical ways for performing the step, satisfying this condition. On the first one, the step is obtained by the inexact restoration method of Martínez and Pilotta and the proof of such a condition is given by Gonzaga, Karas and Vanti. Another way for computing the step is by sequential quadratic programming. We prove in this work that this approach also satisfies the efficiency condition.

Numerical comparison of merit functions and filter criteria in inexact restoration algorithms using hard-spheres problems

ELIZABETH KARAS
UFPR

coauthors: Elvio Pilotta, Ademir Ribeiro

keywords: filter methods, inexact restoration methods, merit functions, nonlinear programming

In this talk we compare merit function and filter criteria in inexact restoration methods. Each iteration of the inexact restoration methods is composed of two phases. The first one reduces a measure of infeasibility and in a second phase the objective function value is reduced in a tangential approximation of the feasible set. The point obtained from the second phase is compared with the current point by means of a merit function or a filter criterion. In order to compare these criteria in inexact restoration methods we selected a family of sphere packing problems known as (HSP) - *Hard-Spheres Problems*. A comparison using the well-known LANCELOT package is also presented.

WE2-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Nonsmooth algorithms

organizer: Claudia Sagastizabal
chair: Napsu Haarala

Spectral projected subgradient with a momentum term for the Lagrangean dual approach

MILAGROS LORETO
Universidad Central de Venezuela

coauthors: Marcos Raydan, Alejandro Crema

keywords: projected gradient, subgradient optimization

The Lagrangean dual problem, with a non differentiable convex objective function, is usually solved by using the subgradient method, whose convergence is guaranteed if the optimal value of the dual objective function is known. In practice, this optimal value is approximated by a previously computed bound. In this work we combine the subgradient method with a different choice of steplength, based on the recently developed spectral projected gradient method, that does not require either exact or approximated estimates of the optimal value. We also add a momentum term to the subgradient direction that accelerates the convergence process towards global solutions. To illustrate the behavior of our new algorithm we solve Lagrangean dual problems associated with integer programming problems. In particular, we present and discuss encouraging numerical results for set covering problems and generalized assignment problems.

Limited memory bundle method for bound constrained

NAPSU HAARALA
University of tha Witwatersrand

keywords: box constraints, large-scale optimization, nondifferentiable programming, nonsmooth optimization

Typically, practical optimization problems involve nonsmooth functions of hundreds or thousands of variables. As a rule, the variables in such problems are restricted to certain meaningful intervals. 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 pressentation, we describe an efficient adaptive limited memory bundle method for large-scale nonsmooth, possibly nonconvex, bound constrained optimization. The method combines the nonsmooth variable metric bundle method and the smooth limited memory variable metric method, while the constraint handling is based on the projected gradient method and the dual subspace minimization. The preliminary numerical experiments to be presented confirm the efficiency and the usability of the method.

WE2-R15 BIOINFORMATICS AND OPTIMIZATION

Biomolecular modeling and simulation

organizer/chair: Zhijun Wu

Progress and challenges in protein structure prediction

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University of Colorado, Boulder

coauthors: Richard Byrd, Silvia Crivelli, Robert Schnabel, Lianjun Jiang, Jinhui Ding

keywords: global optimization, protein modeling, protein structure prediction

The protein structure prediction problem is to predict the three-dimensional shape, or native state of a protein, given its sequence of amino-acids. Experimental methods for determining protein structures have become more efficient and the number of undiscovered novel protein folds is descreasing, but the importance of computational structure prediction lies in its relevance to predicting complex macromolecular structures, with the ultimate goal of understanding the structural complexity of an entire cell. Energy minimization reproduces the exploration process of protein folding to find the native, or free energy minimum state of the protein. Our global optimization approach to protein structure prediction has evolved to incorporate more information from known protein structures. To accomplish this, we developed an interactive protein modeling environment. Results from several (CASP) competitions to predict target proteins before their structures are publicly released, an improved local minimization technique, and new directions in energy function modeling will also be discussed.

A shooting method with inexact boundary conditions and parameter reduction for protein dynamics simulation

PETER VEDELL

Iowa State University, USA

coauthor: Zhijun Wu
keywords: boundary value problems, conformational transitions, molecular dynamics simulation, multiple shooting method

Conformational transitions of biomolecules play an important role in many cellular processes, most often in a positive way, but sometimes in a detrimental way, even causing diseases (e.g. 'mad-cow', Alzheimer's). Conformational transitions of peptides can be modeled as two-point molecular dynamics boundary value problems (BVP's). Both finite difference methods (e.g Olender, Elber 1996) and shooting methods (e.g. Vedell, Wu 2006) can be used to find numerical solution of these two-point BVP's. Some observations about relationships between these methods will be made. Implementation of the algorithms using optimization methods will be described. An approach for use of the shooting method with set-based boundary conditions rather than point-based boundary conditions and also an approach for parameter reduction will be introduced. Computational and modeling advantages and disadvantages of these approaches will be discussed and results from the study of alanine dipeptide using a MATLAB implementation of the AMBER99 force field will be presented.

Distance based protein modeling

ZHIJUN WU
Iowa State University

coauthors: Di Wu, Robert Jernigan
keywords: distance geometry, least-squares optimization, protein dynamics simulation, protein structure prediction

The coordinates for the atoms and hence the structure of a given protein can always be determined by solving a so-called distance geometry problem using the distances between the atoms in the protein. We describe the theory, methods, and applications of the distance based approach to protein modeling, including the mathematical basis from distance geometry, the algorithms for the solution of the distance geometry problem using singular-value decomposition, least-squares minimization, and geometric build-up, and the applications in NMR structure refinement, comparative structural modeling, distance-constrained dynamics simulation, and simulation of protein conformational transitions via distance interpolation. We discuss the issues yet to be addressed, the computational challenges, and the future development.

WE2-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES
Mathematical programs with equilibrium constraints
organizer: Jiri Outrata
chair: Joydeep Dutta

Directional regularity and directional metric regularity

ALEXEY IZMAILOV
Moscow State University

coauthors: Aram Arutyunov, Evgeniy Avakov
keywords: directional regularity, mathematical programs with equilibrium constraints, metric regularity, sensitivity analysis

For general constraint systems, we present the directional stability theorem based on the appropriate generalization of directional regularity condition. This theorem contains Robinson's stability theorem but does not reduce to it. Furthermore, we develop the related concept of directional metric regularity which is stable subject to small Lipschitzian perturbations of the constraint mapping, and which is equivalent to directional regularity for sufficiently smooth mappings. These results enable unification of some diverse ideas in optimization theory and variational analysis, and can serve as a basis for sensitivity analysis of variational and optimization problems, including MPECs. The latter are notorious for the lack of standard regularity of constraints, but can have directional regularity properties.

Bilevel programming with convex lower level problems

JOYDEEP DUTTA
Indian Institute of Technology Kanpur

coauthor: Stephan Dempe
keywords: coderivatives, optimality conditions, optimistic bilevel programming

In this article we study the optimality conditions for a bilevel programming problem with a convex lower-level problem. We take a completely different approach than the ones existing in literature. We first relate a bilevel optimization problem to a single level optimization problem and then deduce optimality conditions using this single level optimization problem. The optimality conditions are abstract in nature. Nonsmooth geometry plays a fundamental role here along with an important construction of nonsmooth analysis called the coderivative of a set-valued map.

WE2-R17 STOCHASTIC PROGRAMMING
Pension and portfolio applications of SP
organizer/chair: William Ziemba

The innovest austrian pension fund financial planning model InnoALM

WILLIAM ZIEMBA
University of British Columbia

keywords: multiperiod stochastic programming, pension planning, scenario modeling

InnoALM was developed for Austrian pension funds including the Siemens employees. The model uses a multiperiod stochastic linear programming framework with a flexible number of time periods. Uncertainty is modeled using multiperiod discrete probability scenarios. Correlations across asset classes: bonds, stocks, cash and other instruments, are state dependent multiple correlation matrices corresponding to differing market conditions. Austrian law and policies are modeled as constraints. The concave risk averse preference function maximizes the expected present value of terminal wealth net of expected discounted convex (piecewise linear) penalty costs for wealth and benchmark targets in each period. The user interface visualizes key model outputs, the effect of input changes, growing pension benefits from increased deterministic wealth target violations, stochastic benchmark targets, security reserves, policy changes, etc. The solution using the IBM OSL stochastic programming code generates virtually online decisions allowing for easy interaction of the user with the model to improve performance

Integrated risk control in fund management using multistage stochastic programming

CHANAKA EDIRISINGHE
University of Tennessee

keywords: money management, portfolio optimization, risk control, stochastic programming

A multistage stochastic programming approach is developed for stock fund management. Given the uncertainty of stock returns, a portfolio must be managed or re-balanced temporally as the market and economic conditions change. Such portfolio rebalancing at various points in time allows the fund manager to manage the riskiness of the fund from both the fund manager's and the clients' viewpoints. A multi-prong risk metric system is designed for the portfolio to achieve desired performance characteristics. The model incorporates important issues such as market impact costs in trading, fund drawdown, market neutrality, and catastrophic risk, within an integrative framework, modeled via stochastic programming. The model is applied to portfolios involving a large number of stocks and the performance is demonstrated with various strategies for portfolio rebalancing. Sharpe ratios, percent worst draw downs, recovery periods from drawdown, portfolio rate of return, etc. are used for performance comparisons.

Combining stochastic programming and optimal control theory to solve multistage financial problems

ELIO CANESTRELLI
University of Venice, Italy

coauthor: Diana Barro
keywords: financial applications, optimal control, stochastic programming

In this contribution we propose a solution method for a multistage stochastic optimization problem. The method combines tools from stochastic programming and optimal control approaches to dynamic optimization under uncertainty. In detail we apply a discrete version of Pontryagin maximum principle to obtain the necessary conditions for optimality of a multistage stochastic programming problem in arborescent formulation. This allow to obtain a time and nodal decomposition of the original problem. The convergence is obtained through a weighted fixed-point iterative scheme enhanced with an optimization step in which the weights are chosen in an optimal way at each iteration. The algorithm has been applied to solve dynamic portfolio problems.

WE2-R18 GRAPHS AND MATROIDS
Graph colorings I
organizer/chair: Kristina Vuskovic

Linear algebra approach to graph coloring and flow problems

MARTIN KOCHOL
Mathematical Institute, Slovak Academy of Sciences

keywords: cyclical connectivity, girth, graph, nowhere-zero flow

Let C be an edge cut on a graph G. We study correlations among numbers of nowhere-zero flows with prescribed values on C. They can be characterized by linear algebra. We apply this approach to obtain restrictions for the smallest counterexamples to the 5-flow conjecture of Tutte (every bridgeless graph has a nowhere-zero 5-flow). In particular, we show that this counterexample must be cyclically 6-edge connected and has girth at least 9.

Even pairs in bull-reducible graphs

CELINA FIGUEIREDO
UFRJ

coauthors: Claudia Maciel, Frederic Maffray
keywords: graph colourings, perfect graphs

A bull is a graph with five vertices a,b,c,d,e and five edges ab, bc, cd, be, ce. A graph G is bull-reducible if no vertex of G lies in two bulls. An even pair is a pair of vertices such that every chordless path joining them has even length. We prove that for every bull-reducible graph G with at least two vertices, either G or its complementary graph $\overline{G}$ has an even pair

On the colourings of powers of cycles

CHRISTIANE CAMPOS
Instituto de Computação - Unicamp

coauthor: Celia Picinin de Mello
keywords: edge colouring, powers of cycles, total-colouring, vertex coloring problem

Colouring is a classical problem in Graph Theory. A colouring of a graph G is an assignment of colours to elements of G so that each pair of adjacent or incident elements receives distinct colours. Elements can be either edges (edge-colourings), vertices (vertex-colourings) or both (total-colourings). In this talk we discuss these three classes of colourings for powers of cycles. We close the presentation with a conjecture on the total chromatic number of powers of cycles.

WE2-R19 APPROXIMATION ALGORITHMS
Approximation algorithms and SDP
organizer: Claire Kenyon
chair: Michel Goemans

Near-optimal algorithms for unique games

MOSES CHARIKAR
Princeton University

coauthors: Konstantin Makarychev, Yury Makarychev
keywords: approximation algorithms, constraint satisfaction, semidefinite programming, unique games

Unique games are constraint satisfaction problems – a generalization of Max-Cut to a larger domain size. The Unique Games Conjecture states that it is hard to distinguish between instances of unique games where almost all constraints are satisfiable and those where almost none are satisfiable. This has been the focus of a lot of recent attention because of complexity implications for several fundamental problems. Proving or refuting this conjecture is thus an important goal. Unique games are also of great algorithmic interest because they are representative of constraint satisfaction problems over larger domains for which SDP rounding techniques have met with limited success.

We present significantly improved algorithms for unique games. Our algorithms are based on rounding a natural SDP relaxation for the problem. The main algorithmic contribution is a technique to extract a probability distribution over assignments from the SDP solution. Our results stop just short of disproving the Unique Games Conjecture, i.e. any improvement (beyond low order terms) would refute the conjecture.

Approximating a class of semidefinite programs

DAVID PHILLIPS

Columbia University

coauthors: Garud Iyengar, Cliff Stein
keywords: approximation algorithms, combinatorial optimization, semidefinite programming

We describe the semidefinite analog of the vector packing problem, and show that the semidefinite programming relaxations for MAXCUT (Goemans and Williamson '95) and graph coloring (Karger, et. al. 1998) are in this class of problems. We extend a method of Bienstock and Iyengar ('04) which was based on ideas from Nesterov ('03) to design an algorithm for computing ε-approximate solutions for this class of semidefinite programs. Our algorithm is in the spirit of Klein and Lu ('96), and decreases the dependence of the run-time on ε from ε^{-2} to ε^{-1}. For sparse graphs, our method is faster than the best specialized interior point methods. A significant feature of our method is that it treats both the MAXCUT and the graph coloring problem in a unified manner.

A better approximation ratio for the vertex cover problem

GEORGE KARAKOSTAS
McMaster University

keywords: approximation algorithms, semidefinite relaxations, vertex cover

We reduce the approximation factor for Vertex Cover to $2 - \Theta(1/\log n^{1/2})$ (instead of the previous $2 - \Theta(\log\log n/\log n)$, obtained by Bar-Yehuda and Even, and by Monien and Speckenmeyer. The improvement of the vanishing factor comes as an application of the recent results of Arora, Rao, and Vazirani that improved the approximation factor of the sparsest cut and balanced cut problems. In particular, we use the existence of two big and well-separated sets of nodes in the solution of the semidefinite relaxation for balanced cut, proven in Arora et al. We observe that a solution of the semidefinite relaxation for vertex cover, when strengthened with the triangle inequalities, can be transformed into a solution of a balanced cut problem, and therefore the existence of big well-separated sets in the sense of Arora et al. translates into the existence of a big independent set.

WE2-R20 PRODUCTION AND SCHEDULING

Capacitated deterministic inventory models

organizer/chair: Retsef Levi

Existence of equilibria in a decentralized two-level economic lot-sizing model

DOLORES ROMERO MORALES
Said Business School, University of Oxford

coauthor: Dries Vermeulen
keywords: decentralization, economic lot-sizing model, equilibrium constraints, supply chain coordination

In this paper we analyze equilibria in competitive environments under constraints across players' strategies. This means that the action taken by one player limits the possible choices of the other players. In this context the classical approach to show existence of equilibrium does not work. In particular, best replies against a given strategy profile may not be feasible.

Our main motivation to study this problem of co-dependency comes from the field of supply chain planning. A set of buyers is faced with external demand over a planning horizon, and to satisfy this demand they request inputs from a set of suppliers. Both suppliers and buyers face production capacities and the planning is made in a decentralized manner. A well-known coordination scheme for this setting is the upstream approach where the planning of the buyers is used to decide the request to the suppliers. We show the existence of equilibria for two versions of this coordination model. Finally, we illustrate with an example that the centralized solution is not, in general, an equilibrium and that the equilibrium is not, in general, unique.

Integrated setup-sequencing and lot-sizing in production scheduling at an animal-feed plant

ALISTAIR CLARK
University of the West of England

coauthors: Reinaldo Morabito, Eli Toso
keywords: asymmetric travelling salesman problems, lot sizing and scheduling, sequence-dependent setup times

This presentation reports on an ongoing research project jointly funded by British and Brazilian national research agencies. It explores mathematical programming models for joint lot sizing and scheduling with sequence-dependent setup times, motivated by Brazilian animal feed plant where setup times do not obey the triangular inequality. An exact model based on multiple asymmetric travelling salesman problems (ATSP) is awkward so alternative formulations and methods based on subtour elimination and relax-and-fix are developed to solve the model more quickly or approximately. The model includes the "cleaning" function that certain intermediate products can perform if a sufficiently large lot is produced between two products that would otherwise require a cleaning setup. Initial computational test results are presented.

LP-based multi-item lot sizing

ANDREA LODI
DEIS, University of Bologna

coauthors: Retsef Levi, Maxim Sviridenko
keywords: approximation algorithms, complexity, linear programming, lot sizing

We consider the multi-item variant of the classical constant capacity lot-sizing problem. There are N items each with specified demands for T periods. Demands are known in advance but can vary from period to period. Each order incurs a time-dependent fix cost (independent of the size of the order) and can contain up to C units. Excess inventory incurs holding cost. The goal is to find a feasible policy that satisfies all the demands on time with minimum overall ordering and holding costs.

We show that the problem is strongly NP-hard, and then use novel LP-based rounding techniques to derive a constant factor approximation algorithm. The LP relaxation is based on the well-known flow cover inequalities. We construct an oracle that either finds a violated flow-cover inequality or provides a feasible (integer) solution with cost at most twice the optimal.

WE3-R1 COMBINATORIAL OPTIMIZATION
Bin packing
chair: Philippe Refalo

A constraint programming approach to variable-sized bin packing with color constraints

PHILIPPE REFALO
ILOG

coauthor: Antoine Gargani
keywords: large neighborhood search, variable-sized bin packing

We present a constraint programming model to a variable-sized bin packing problem using the logical and global constraints of ILOG Solver. On a set of instances from the CSP library, this model, together with a special-purpose search strategy, solves much larger instances than previous constraint programming approaches. Finally, a large neighborhood search method based on this model and strategy solves even the largest instances in a few seconds.

On the absolute error for solving the bin backing problems by subset sums

NEI YOSHIHIRO SOMA
CTA/ITA/IEC

coauthor: Nenina Marcia Junqueira
keywords: absolute error, bin packing, subset sum problem

A well known attempt to solve the Bin Packing Problem (BPP) is based on recursively filling the best possible a single bin, removing the items that form a solution up to the point that all items have been considered. Caprara and Pferschy (2005) proved recently that the absolute error generated by this approach is bounded by $4/3 + ln4/3$ provided that the BPP optimal solution does not possess any bin filled up to its capacity. Here we address the problem when all bins are completely filled for the BPP optimal solution. We show that the absolute error continues to be large, i.e., $1.6 + \varepsilon$, $0 < \varepsilon < 7/100$.

Two-dimensional bin-packing optimization model for two-stage guillotine-cutting problem

PARK SANG HYUCK
RIST

keywords: 2D packing, guillotine cutting

We considered a two-stage guillotine-cutting problem, where we are allowed to set the width, length of the mother plate while keeping its area fixed. In this paper, we proposed an efficient heuristic algorithm for solving this problem and summarized computational experiments.

WE3-R2 COMBINATORIAL OPTIMIZATION
Combinatorial optimization III
organizer/chair: Paolo Ventura

Orbitopes

VOLKER KAIBEL
ZIB, TU Berlin

coauthor: Marc Pfetsch
keywords: integer programming, lexicographic representatives, symmetry breaking

We introduce orbitopes as the convex hulls of 0/1-matrices that are lexicographically maximal subject to a group acting on the columns. Special cases are packing and partitioning orbitopes, which arise from restrictions to matrices with at most (resp. exactly) one 1-entry in each row. The goal of investigating these polytopes is to gain insight into ways of breaking certain symmetries in integer programs by adding constraints, e.g., for a well-known formulation of the graph coloring problem. In this talk, we will provide complete linear inequality descriptions of packing and partitioning orbitopes by facet-defining inequalities for the cases of the full symmetric group and of the cyclic group acting on the columns. For the cyclic group case, the descriptions turn out to be totally unimodular, while for the symmetric group case both the description and the proof are more involved. Nevertheless, the associated separation problems can be solved in linear time in both cases.

Mod-2 cuts generate the convex hull of bounded feasible integer sets

CLAUDIO GENTILE
IASI-CNR

coauthors: Paolo Ventura, Robert Weismantel
keywords: convex hull, mod-2 cuts

One of the fundamental results in the theory of linear integer programming states that the convex hull of all integer points in the intersection of finitely many rational halfspaces is a polyhedron. This polyhedron can be described by a system of linear inequalities that one obtains in finitely many steps by integer rounding, i.e., producing *Gomory cuts*. In 2000, Caprara, Fischetti, and Letchford revised Gomory cuts in the so-called mod-k cuts, for each positive integer number k.

In this talk it is shown that, if the given system contains lower and upper bounds for the variables, then the convex hull can be produced by iteratively generating mod-2 cuts only. This fact is surprising and might even be counterintuitive, since many integer rounding cuts exist that are not mod-2, i.e., representable as the zero- one-half combination of the given constraint system. The key, however, is that in general a larger (but finite) number of rounds of mod-2 cut generation are necessary to produce the final description compared to the traditional integer rounding procedure.

Lower bound for the Chvatal rank of polytopes: application to the stable set polytope of quasi-line graphs

GAUTIER STAUFFER
MIT

keywords: Chvatal rank, quasi-line graphs, stable set polytope

In this talk, we give simple sufficient conditions to prove lower bounds on the Chvátal-Gomory rank of very general rational polyhedra. These conditions are then applied to the fractional stable set polytope of Quasi-Line graphs. In particular, we show that Chvátal-Gomory rank of the fractional stable set polytope of a certain class of quasi-line graphs grows logarithmically with the number of nodes of the graph. On the other hand, it is easy to check that the Disjunctive-rank of such polytope is 1. At our best knowledge, this is the only case of a polyhedron, naturally arising from a combinatorial optimization problem, characterized by a fixed Disjunctive-rank and an unbounded Chvátal-Gomory rank.

WE3-R3 COMBINATORIAL OPTIMIZATION
Metaheuristics in facility location problems
organizer: Diptesh Ghosh
chair: Jens Wollenweber

Solving the bi-objective hub location problem with evolutionary algorithms

MARCOS ROBERTO SILVA
University of Sao Paulo - Dept. of Transportation Engineering

coauthor: Claudio Cunha
keywords: evolutionary algorithms, heuristics, hub location, multi-objective models

We introduce the bi-objective uncapacitated single allocation hub location problem (bi-USAHLP). The first objective is to solve the USAHLP, i.e., configuring a hub-and-spoke network: determining the number and the location of the hubs, as well as the allocation of non-hub nodes (spokes) to its hubs aiming to minimize the total transportation costs (fixed and variables costs). The second objective is to minimize the maximum distance of each spoke to its hub, similar to the p-center problem. To solve this bi-objective problem, we use Evolutionary Algorithms (EA) provided by PISA (Platform and Programming Language Independent Interface for Search Algorithms). In order to evaluate the robustness of the heuristic, we solve several problems of the CAB and AP data sets. Computational experiments show that even for large problems, up to 200 nodes, the proposed EA heuristic was able to find good solutions in reasonable short CPU times.

Solving large-scale multi-stage facility location problems by VNS

JENS WOLLENWEBER
RWTH Aachen University, Germany

keywords: facility location, metaheuristics, variable neighborhood search

In this paper we propose a variable neighborhood search (VNS) approach for solving large-scale multi-stage facility location problems with staircase costs (MSFLPSC).
The MSFLPSC is an extension of the *multi-stage facility location problem* and of the *facilty location problem with staircase costs*, respectively. In addition to the decision of locating candidate facilities, the appropriate capacity of each facility can be chosen among a set of different capacity levels within the model.

The heuristic approach we follow is based on VNS and contains two main steps, *shaking* and *local search*. The main purpose of the shaking-step is to diversify search procedure and to escape from a local minimum by generating a random neighbor solution of the current local optimum. In our algorithm this step is performed by applying several simple ADD- and DROP-moves, which provide a neighbor solution different to the current solution without destroying its entire structure. Aim of the local search step is to improve the solution obtained by the shaking step. We utilize two reduced 2-SWAP-neighborhoods combined to a variable neighborhood descent (VND) procedure. Each of the two neighborhoods can be scanned efficiently without performing LP-reoptimization, which enables the application to solve large-scale instances. Computational experience has been gathered on randomly generated instances with up to 2.500 candidate facilities. These instances were solved consistently with a deviaton of less than 5% from an optimal solution (if known) or from a lower bound. State-of-the-art MIP solvers like CPLEX were not able to provide a feasible solution for many of these instances.

Solving probabilistic multi-facility Weber problem by vector quantization

I. KUBAN ALTINEL
Bogazici University

coauthors: Kerem Can Ozkisacik, Necati Aras
keywords: probabilistic Weber problem, vector quantization

The Multi-facility Weber problem is concerned with locating m facilities having unlimited capacities in the plane and allocating them to n customers at minimum total cost. The deterministic version of the problem is a nonconvex optimization problem and difficult to solve exactly. In this work we focus on a probabilistic extension and consider the situation where the customer locations are randomly distributed, which is even more difficult and thus it is only feasible to solve it approximately. We propose new heuristics based on the principles of Vector Quantization and Self-organization. They are capable to compute high quality solutions even for very general distance functions and customer location distributions.

WE3-R4 INTEGER AND MIXED INTEGER PROGRAMMING

Computational integer programming II

organizers: Alexander Martin
chair: George Nemhauser

Planning activities with start-time dependent variable costs

JAMES LUEDTKE
Georgia Tech

coauthor: George Nemhauser
keywords: mixed-integer programming, polyhedral analysis, production planning

We present a multiple period planning model in which the variable cost of each activity over the entire horizon is determined by the technology available when the activity is begun. It is assumed that future technology will improve, leading to lower variable costs if the start time of the activity is delayed. This leads to a non-convex minimization problem. Our approach is to develop strong formulations for single activity relaxations. In a special case in which activities are restricted to be non-decreasing over time, strong formulations are obtained without increasing the problem size. We present computational results, based on the industrial application that motivated this research, which indicate that this approach can be used to effectively solve very large instances in a branch-and-cut framework.

Resource constrained shortest paths using branch-and-cut

RENAN GARCIA
Georgia Tech

coauthors: Shabbir Ahmed, George Nemhauser
keywords: branch-and-cut, integer programming, resource constrained shortest path, valid inequalities

A label-setting dynamic programming algorithm is the main approach used to solve the Resource Constrained Shortest Path Problem. Lagrangian relaxation of the weight constraints is another approach that has appeared widely in the literature. Here we take a polyhedral approach and look at the problem from a purely integer programming point of view. We introduce new classes of valid inequalities for use within a branch-and-cut algorithm. We also develop preprocessing and branching schemes. Compu-

tational experience is provided to measure the impact of the new ideas. We also discuss how these ideas can be applied to an on-demand air-taxi problem which contains several resource constrained path substructures.

Optimizing over the split closure

EGON BALAS
Carnegie Mellon University

coauthor: Anureet Saxena
keywords: combinatorial optimization, lift-and-project, parametric mixed integer (linear) programming, split disjunctive cuts

The (elementary) split closure of P, the LP relaxation of a mixed integer program (MIP), is the polyhedron defined by all the split cuts obtainable directly from P. We formulate the problem of optimizing over the split closure as a parametric mixed integer linear program with a single parameter in the objective function and the righthand side, and develop an algorithm for solving it, implemented in the COIN-OR framework using CPLEX as a general -purpose MIP-solver. We report computational experience with practically all benchmarks available. On 463 instances solved, elementary split cuts closed on the average 83.72% of the integrality gap. All our results, including the final set of cuts over which we optimized in each instance, are available from our website. Adding this final set of cuts to the formulation of a MIP instance otherwise unsolved may make it solvable, as was the case with the MIPLIB instance arki001.

WE3-R5 INTEGER AND MIXED INTEGER PROGRAMMING
Applications of IP I
chair: Andrew Felt

Redesigning the liver allocation hierarchy

NAN KONG
University of South Florida

coauthors: Andrew Schaefer, Braden Hunsaker, Mark Roberts
keywords: branch-and-price, column generation, organ allocation, set partitioning

In this work we consider the problem of maximizing the efficiency of the United States liver allocation hierarchy through region reorganization. Based on the current allocation policy, a transplantable organ is offered hierarchically, first within a designated service area around the procurement site, then in a larger geographic area (a region), and at the end nationwide. The design of regions is critical to allocation efficiency. We start with formulating the problem as a set-partitioning problem in which each decision variable corresponds to a potential region and proposing an analytic estimate of regional allocation efficiency. To solve the problem, we adapt branch and price to overcome the computational challenge in the problem that there are too many columns to handle explicitly. We develop a mixed-integer programming pricing problem and apply geographic decomposition, an optimization based heuristic, to solve the provably NP-hard problem. In addition, we attempt to develop stronger valid inequalities to tighten the pricing problem formulation. Finally we present computational studies using real clinical data to show the benefit of region reorganization and the efficacy of our branch-and-price application.

MILP model for university timetabling

ANDREW FELT
U. of Wisconsin-Stevens Point

keywords: mixed-interger linear programming, scheduling, timetabling

We examine a MILP model used for assigning the meeting days, times and places to each section to be offered by a department when the teaching assignments have been previously made. The model takes into account university scheduling rules, a variety of instructor schedule preferences, and room seating capacities. The model has been used in a small Mathematics Department with positive results.

Using mathematical programming to identify students at risk of failure

JON WARWICK
London South Bank University

keywords: math efficacy, mixed-interger linear programming, student retention

Improving student retention and reducing failure rates are key objectives of many Higher Education Institutions. One way to achieve this is to find means of targeting student support resources specifically at those students who can be identified as being at risk of failure. This paper reports the results of a pilot study designed to investigate whether the concept of "mathematical efficacy" (the extent to which students are able to structure and organise their own learning) can be used as a predictor of student performance in a large mathematics module taught at a UK university so that those students at risk of failing can be identified early on. Data across a number of factors contributing to mathematical efficacy were collected from a sample of students on enrolment for the module and mathematical programming techniques (mixed integer programming) applied to see whether the student group could be correctly partitioned using this data into different risk groups as defined by their end-of-module assessment scores. The results indicate the value of moving to a larger full study during the next academic year.

WE3-R6 LOGISTICS AND TRANSPORTATION
Maritime operations and transport
chair: Gary Froyland

Scheduling of rail mounted gantry cranes at port Botany, Sydney

GARY FROYLAND
University of New South Wales

coauthors: Thorsten Koch, Nicole Megow, Andre Costa, Emily Duane
keywords: integer programming, online algorithms, ports, scheduling

We outline a successful approach to scheduling the movements of rail mounted gantry cranes at Port Botany in Sydney. All international container traffic at the port must be carried by these five cranes. The schedule is formulated firstly as a strategic problem at an hourly level. An integer program is solved to minimise total crane load and balance the hourly load between the cranes. Secondly, the precise movements of the cranes within each hour are determined via an online algorithm.

Heuristic estimation of 3D airside capacity at airports

FÉLIX MORA-CAMINO
ENAC/DGAC

keywords: airport capacity, flows in networks, heuristics, optimization

With the sustained development of air transportation over the last decades, airport capacity has remained a permanent issue for airport planners and operators. Until recently, airport capacity was considered only at its two traditional bottlenecks: the runways system capacity and the passenger's terminals capacity. However, today, aircraft ground traffic at airports has become also a critical question with important influences on security and efficiency levels and new ground traffic management and control systems including a higher degree of automation have been introduced. Traditionally, with respect to airside airport capacity , a distinction has been done between theoretical and practical capacity, depending if level of service thresholds and operational practices are taken into account or not. In general, practical capacity, which is of main interest for airport managers, has been estimated on statistical grounds while cumbersome simulation models have been developed to perform some scenario based capacity predictions. It appears that since inbound and out-bound flights are competing to use the same airport facilities the nature of this problem is multi criteria and capacity must be defined in terms of Pareto frontiers. In this communication, a new approach based on the solution of successive optimization problems is proposed for the estimation of the practical airside capacity of an airport. For given mean in-bound and outbound flows and a current ground traffic situation, a new minimal cost flow problem is formulated. The interaction of aircraft flows at ground intersections (taxiways and aprons) is taken explicitly into consideration and this leads to a non convex optimization problem. A heuristic approach, based on a progressive loading of the network, is developed to get a solution for the minimal cost flow problem. The proposed heuristic is assessed numerically through extensive testing, showing acceptable performances and it seems that this approach could be of interest for other fields of application. However here, once a solution is obtained, a simplified aircraft traffic simulation model can be used to consider practical capacity margins. Outbound flows are increased in the optimization problem until practical capacity levels are reached, leading to a point of the practical capacity Pareto frontier. The proposed approach has been applied to the case of Toulouse airport for which some numerical results are displayed.

WE3-R7 TELECOMMUNICATIONS AND NETWORK DESIGN.

Network design II

chair: Arnaud Knippel

An overflow formulation for discrete cost network design

ARNAUD KNIPPEL
LMI/INSA Rouen

keywords: integer programming, multicommodity flows, network design

We study the overflow formulation for multi-commodity flows and show links with path formulations and metric inequalities. Numerical results are presented for discrete-cost network design problems.

A polynomial time algorithm for a fixed charged network design problem on a series-parallel graph

HIROAKI MOHRI
Waseda University, Japan

keywords: combinatorial optimization, facility location, fixed charged network design problem, graph and networks

First of all, we will define our " Fixed Charged Network Design Problem (FCNDP)", which has many applications for especially telecommunications and logistics. In general, FCNDP is a NP-hard problem on a complete graph in terms of computing complexity theory. But we can solve FCNDP in a polynomial time on some graph structures. We show a strong polynomial time algorithm for FCNDP on a kind of series-parallel graph. Also, we introduce a FCNDP combined with Facility Location Problem and show some results.

WE3-R8 FINANCE AND ECONOMICS

Finance and economics III

chair: Victor DeMiguel

Teaching financial modeling with Monte Carlo simulation SimKit case study

JOSÉ PAES
COPPE/UFRJ

coauthor: Ronaldo Santos
keywords: finance, option price, simkit, simulation

"Spreadsheet simulation" refers to the use of a spreadsheet as a platform for representing simulation models and performing the simulation experiment. This paper explains the reasons for using this platform for simulation, presents a teaching context and describes SimKit, a tool for performing Monte Carlo simulations via Excel spreadsheet models. An Asian Call Option problem is presented and solved using Monte Carlo Simulation with SimKit.

Qualitative stability analysis of microeconomic and design portfolio problem

SIRA MARIA ALLENDE ALONSO
Universidad de la Habana

keywords: mean variance models, microeconomic model, parametric programming, portfolio design

We consider the microeconomic models of the Producer and prove continuity properties of the profit and cost functions. We introduce also the concept of Supply and Conditional Factor Demand point to set mapping and prove their semicontinuity properties. Mean-Variance models for portfolio design are also discussed. We present the model of the maximization of the return (minimization of the risk) under bound conditions on the risk (expected return). The influence of estimation's errors of the covariance matrix in the feasible and optimal solutions of the problem is characterized by proving continuity properties of the feasible set mapping of both models and also of the optimal expected return (risk) value function

Sensitivity analysis of nonlinear models with fractional objective function related to solving methods

MARIJA CILEG
Faculty of Economics Subotica

coauthor: Tibor Kis
keywords: nonlinear programming, sensitivity analysis

This talk deals with sensitivity analysis of models with fractional criterion function. We present a technique that can determine the necessary changes in the denominator coefficients of the fraction as to compensate changes in the numerator coefficients so that the solution will remain optimal. The next part

shows a method for tracking simultaneously changes in the numerator and in the denominator. Sensitivity analysis is presented for two basic modes of solving techniques for linear and non linear models.

WE3-R9 OPTIMIZATION IN ENERGY SYSTEMS
Energy modeling
organizers: Alejandro Jofre
chair: Golbon Zakeri

Energy modeling in developing countries

AMARO PEREIRA
Empresa de Pesquisa Energética

keywords: energy modeling

Top-down, bottom-up and hybrid models for representing energy systems are often used in energy planning. However, in developing countries some of their assumptions do not apply: markets are not developed and not competitive; informal economies are representative; there are huge social inequalities; regulatory changes are not completed; there are constraints to capital flow; etc. All theses problems need to be well represented for energy analysis to be more consistent. In this work we propose a multisector dynamic recursive model that incorporates consumer behaviors, energy policies, technical progress and factors of production substitution. The static result feeds detailed energy models that provide updated values for the next step equilibrium. This approach is advantageous in terms of computation and in terms of the consistency between economic and energy modeling.

Long-term power expansion planning: an application of mixed-integer linear programming

CARLOS HENRIQUE SABOIA
CEPEL - Electric Power Research Center

coauthors: Luiz Guilherme Marzano, Maria Luiza Lisboa, Maria Elvira Maceira, Albert Cordeiro Geber de Melo
keywords: mixed-integer programming, power expansion planning

The generation expansion planning of power systems is a multi-stage stochastic mixed-integer programming problem. In order to deal with the high complexity of this problem, several approaches have been proposed in the literature. Such schemes usually divide the original expansion planning problem into an investment subproblem and an operation subproblem, which are modelled by integer and continuous variables, respectively. In this paper we propose a simplified model where the first subproblem is modelled as an $\{0,1\}$ knapsack problem and the second one adopts a simplified representation of the generation system. The numerical results obtained with the proposed model have shown that our simplified approach presents a reasonable solution from de practical point of view at a low computational cost.

Experiments with equilibria in the New Zealand electricity market

GOLBON ZAKERI
University of Auckland

coauthors: Andy Philpott, Geoff Pritchard, Tony Downward
keywords: electricity markets, equilibrium constraints, supply function

Many economic and investment related questions require a model of participant behaviour in electricity markets. In order to answer such questions, we have developed Cournot and supply function equilibria models for generators offering into the New Zealand electricity markets. We construct these equilibria using sequential best response and using a simulator of the NZ electricity market.

WE3-R10 ROBUST OPTIMIZATION
Industrial applications of robust optimization
organizer/chair: Ralf Werner

Towards a robust dynamic principal component analysis

PAPA MOMAR NDIAYE
Raise Partner

coauthor: Jérôme Malick
keywords: eigenvalue optimization, risk representation, robust PCA, semidefinite least squares

Principal Component Analysis (PCA) is a useful tool for Risk factors and risk-levels representation in view of monitoring of quantitative investment strategies in various situations such as Portfolio Management, Model Reduction for Hedging of books of Derivatives. However PCA is known to have some disadvantages, among those a high numerical sensitivity. We will present a constructive process to ensure some robustness of the PCA factors against meaningless dramatic changes when updating market information and also against weak data estimation. Using Eigenvalue optimization and Semidefinite Least Squares techniques we build a filtering approach for updating factors when the covariance matrix is regenerated from market information. That provides a set of time dependant dynamic robust factors and associated risk levels that defines a smooth function of the sample covariance matrices enabling then to keep the confidence in decision making based on sample covariance.

Towards a code for robust programming

MICHAL KOCVARA
Academy of Sciences, Czech Republic

coauthor: Michael Stingl
keywords: method of augmented Lagrangians, nonlinear programming, robust optimization, semidefinite programming

We introduce a code for smooth nonlinear optimization based on the generalized augmented Lagrangian method. The code can solve standard nonlinear, as well as conic quadratic and semidefinite programming problems. It can thus solve most smooth optimization problems and their robust counterparts, using the same algorithm and same programming core. The talk will be illustrated by numerical examples demonstrating the behaviour of the code.

Towards robust efficient frontiers

KATRIN SCHOETTLE
Technical University Munich

coauthor: Ralf Werner
keywords: portfolio optimization, robust optimization

In recent years new ideas for robustification of the traditional Markowitz frontier have appeared in the literature. In this talk we want to investigate the promising approach of the robust counterpart more thoroughly. After introducing the method and presenting some useful results, we want to compare this approach with the classical Markowitz optimization and the well-known resampling method of Michaud both on a qualitative

and a quantitative basis. Numerical results support the expectation that robustification leads to an added value in quantitative asset management.

WE3-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

SDP applications to sensor-network localization/Gr

organizer/chair: Yinyu Ye

A scalable sensor localization algorithm based on SDP subproblems

JIN HOLLY
Stanford University

coauthors: Michael Saunders, Michael Saunders
keywords: large-scale optimization, semidefinite programming, sensor network

Sensor localization problems may involve networks with thousands of nodes. We present a sensor localization algorithm with linear complexity. It solves a sequence of very small subproblems, using the SDP relaxation approach of Biswas and Ye for each subproblem. Where possible, the subproblem nodes are chosen to make the SDP solutions exact under no-noise conditions.

SOCP relaxation of sensor network localization

PAUL TSENG
University of Washington

keywords: coordinate gradient descent, error bound, second-order cone programming relaxation, sensor network

We study a second-order cone programming (SOCP) relaxation of the sensor network localization problem. We show that SOCP relaxation, though weaker than SDP relaxation, has nice properties that make it useful as a problem preprocessor. In particular, an error bound result shows that sensors that are uniquely positioned among interior solutions of the SOCP relaxation are accurate up to the square root of the distance error. Thus, these sensors, which can be readily identified, are accurately positioned. In numerical simulation, the interior solution found can accurately position up to 80-90% of the sensors. We also propose a smoothing coordinate gradient descent method for finding an interior solution faster than using SeDuMi. Extension to p-order cone programming relaxation will also be discussed.

Semidefinite programming for sensor network localization

YINYU YE
Stanford University

coauthor: Pratik Biswas
keywords: localization, semidefinite programming, sensor network

The talk describes a semidefinite programming (SDP) based model and method for the position estimation problem in Euclidean distance geometry such as wireless sensor network localization. The optimization problem is set up so as to minimize the error in sensor positions to fit incomplete and noisy distance measures. We develop an SDP relaxation model and use the duality theory to derive necessary and/or sufficient conditions for whether a network is "localizable" or not, when the distance measures are accurate. We also present probabilistic analyses of the SDP solution when the distance measures are noisy. In all cases, observable gauges are developed to certify the quality of the position estimation of every sensor and to detect possible erroneous sensors. Furthermore, we develop regularization and gradient-based local search methods to round and improve the SDP solution. Computations will be demonstrated to show the effectiveness of the method.

WE3-R12 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Cone programming

organizer: Andre Tits
chair: Simon Schurr

Hyperbolic polynomials, the Lax conjecture and its applications

OLENA SHEVCHENKO
University of Maryland, Baltimore County

keywords: hyperbolic polynomials, interior-point methods, Lax conjecture

Peter Lax made a conjecture in the late 1950s that any hyperbolic polynomial in three variables is a determinant of a linear combination of three symmetric matrices. This was resolved positively in 2003 by Lewis, Parillo, and Ramana. In this talk we demonstrate that Lax conjecture is a powerful, unifying tool. For instance, the proof of the non-trivial result that the hyperbolicity is a convex cone becomes a simple exercise. We demonstrate that many other difficult results, both in the theory of hyperbolic polynomials and its applications to the theory of interior point methods, are also easily resolved using Lax conjecture.

Towards nonsymmetric conic optimization

YURII NESTEROV
CORE (UCL)

keywords: affine-scaling direction, conic problems, convex optimization, interior-point methods

In this talk we discuss a new primal-dual interior-point approach, which is based on an extension of the ideas of self-scaled optimization to the general cones. We suggest using the primal correction process to find a *scaling point*. This point allows to compute a strictly feasible primal-dual pair by simple projection. Then, we define an affine-scaling direction, (which coincides with NT-direction for self-scaled barriers), and perform a (long) prediction step using the primal-dual barrier function.

Despite to its primal-dual nature, the proposed technique is very cheap: at any step we need to solve only the *primal* Newton system. This makes life easier even for symmetric cones.

Effects of inexact barrier function evaluations in interior-point methods for conic optimization

SIMON SCHURR
University of Maryland at College Park

coauthors: Dianne O'Leary, Andre Tits
keywords: conic optimization, inexact barrier function evaluations, interior-point methods

We consider convex optimization problems in conic form. That is, the feasible set is the intersection of an affine subspace and a pointed closed convex cone K having nonempty interior. Given a self-concordant barrier function F for K, one can use F to design primal-dual interior-point methods having polynomial iteration complexity. Such methods require the solution of linear systems of equations involving the gradient and Hessian of F.

We show that if the gradient and Hessian are only computed approximately,

one can still generate an ε-optimal solution in a polynomial number of iterations, provided the errors in the approximations are not too large. Not only does our primal-dual method not require exact evaluation of the barrier gradient and Hessian, but it does not require any evaluation (exact or approximate) of a *dual* barrier function or its derivatives. Two applications are given.

WE3-R13 NONLINEAR PROGRAMMING

Decomposition and quadratic programs

chair: María Cristina Maciel

On applying the Frank-Wolfe algorithm to projected nonlinear optimisation problems

LUIS CONTESSE
Pontificia Universidad Católica de Chile

keywords: Frank-Wolfe algorithm, projected nonlinear optimization problem, two-stage stochastic programming

The Frank-Wolfe (F-W) algorithm is probably one of the most popular optimisation techniques used in solving general linearly constrained differentiable problems. Its popularity certainly relies on the ingenious and simple way it integrates linear and nonlinear programming basic algorithms, besides the huge number of problems to whom it applies. This fact also makes the F-W algorithm be one of the most popular decomposition algorithm used in solving general large scale structured problems. Moreover, in the case of mixed-integer optimisation problems, this algorithm provides a very efficient way of solving good convex relaxations of these problems. However, when applying the F-W algorithm in order to solve a projected linearly constrained nonlinear problem, the differentiability of the projected cost function is generally lost, so that the application of the method may be not successful anymore. In this paper, we give some ways of managing with this differentiability drawback, when applying the F-W algorithm within the frame of Two-Stage Nonlinear Convex Stochastic Problems, with discrete random variables. More specifically, we apply the different results to a real world Stochastic Production Planning Problem with Quadratic Recourse Costs.

Prediction of optimal set of extreme points in parametric quadratic programming

MEHDI LACHIHEB
Faculté des sciences de Gabès

coauthor: Hichem Smaoui

keywords: decomposition, extreme point, parametric quadratic programming, polytope

Sacher's decomposition for solving large quadratic programs relies on the expression of solutions as convex combinations of sets of extreme points and rays. In methodologies involving sequences of quadratic problems it is useful to make use of such a decomposition when confronted with large scale problems. This is an instance among others where one is interested in studying the variation, with respect to some parameter, of the set of extreme points and rays, here called optimal set, that forms the convex combination expressing the optimal solution of a parameter dependent quadratic programming problem. In the present work a methodology for predicting an optimal set of extreme points of a parametric quadratic problem is presented for the case of simple polytopes. It is based on the study of the transformation that maps the unperturbed feasible polytope onto the perturbed one. Implementation of the proposed technique in a sequential quadratic programming algorithm coupled with Sacher's decomposition demonstrates its feasibility and computational advantage.

Newton's method for minimizing quadratic matrix functions

MARÍA CRISTINA MACIEL
Universidad Nacional del Sur

coauthor: María Gabriela Eberle

keywords: matrix equation, Ricatti equation, Sylvester equation

In this contribution the problem of minimizing a quadratic matrix function via the Newton method is considered. Five cases can be distinguished according to the structure of the quadratic function involved. The main aspect of this work consists in obtaining the Newton step which results as the solution of the Ricatti matrix equation. This equation can be solved by using a technique based on the sign of a matrix or via the Newton method. In the last case the step is obtained as the solution of a Sylvester matrix equation. Local convergence results and preliminary numerical experiments are reported.

WE3-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Convex functions, duality, and algorithms

chair: Igor Griva

Dini derivative and a characterization for Lipschitz and convex functions on Riemannian manifolds

ORIZON FERREIRA
Universidade Federal de Goiás

keywords: convex function, Dini derivative, Lipschitz function, Riemannian manifold

Dini derivative on Riemannian manifold setting is studied in this paper. In addition, a characterization for Lipschitz and convex functions defined on Riemannian manifolds and sufficient optimality conditions for constraint optimization problems in terms of the Dini derivative are given.

Generalized second order symmetric duality for nondifferentiable multiobjective programming

DO SANG KIM
Pukyong National University

coauthors: Hyo Jung Lee, Yu Jung Lee

keywords: generalized second order convex functions, nondifferentiable multiobjective programming, symmetric duality theorems

We introduce a pair of multiobjective generalized second order symmetric dual programs where the objective function contains a support function. Weak, strong and converse duality theorems for these second order problems are established under generalized second order convexity assumptions. Also, we give some special cases of our second order symmetric duality results.

Theoretical and numerical aspects of the exterior-point method

IGOR GRIVA
George Mason University

coauthor: Roman Polyak

keywords: augmented Lagrangian, exterior-point method, nonlinear rescaling, primal-dual system

This talk focuses on theoretical and numerical aspects of the exterior-point method for continuous nonlinear programming problem with both inequality and equality constraints. Asymptotic 1.5-Q-superlinear convergence is established and corroborated by numerical results. Furthermore, the analysis of global convergence is presented.

WE3-R15 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Quadratic programming and convex extensions

chair: Bo Kyung Choi

Convex extensions, inclusion certificates and disjunctive programming

MOHIT TAWARMALANI
Purdue University

keywords: disjunctive programming, multilinear programs, probabilities of finite event sets, relaxation hierarchies

We define the notion of an inclusion certificate in terms of the convex multipliers necessary to assert the inclusion of a point in the convex hull of a given set or collection of sets. The inclusion certificates are analyzed to present many insights into the hierarchies of relaxations, like lift-and-project and reformulation-linearization. Relations with bounding probabilities of finitely many events and with Lagrangian relaxations of multilinear programs are derived.

On solution set of convex quadratic optimization problems

BO KYUNG CHOI
Division of Mathematical Sciences, Pukyong National University

coauthor: Gue Myung Lee
keywords: convex quadratic optimization, positive semidefinite, recession cones

In this talk, we give a direct proof for Lagrange based characterizations and a boundedness condition of the optimal solution set of a convex quadratic optimization problem when one optimal solution is given. Moreover, we present examples illustrating our Lagrange based charcterizations for a convex quadratic optimization problem and a linear complementarity problem.

WE3-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Infinite dimensional variational inequalities

organizer/chair: Michael Hintermueller

Optimal control of obstacle problems by H^1-obstacles

KARL KUNISCH
University of Graz

keywords: optimal control, semi-smooth Newton method, variational inequalities

Optimal control of variational inequalities with the controls given by the obstacles is considered. Existence optimal solutions is proved for obstacles with H^1 regularity and first order optimality conditions are derived which, under additional assumptions are also sufficient. A numerical algorithm is proposed and its practical feasibility is investigated. This is joint work with Prof. K. Ito.

Optimal control problems with L1 control cost - theory and applications for optimal actuator location

GEORG STADLER
Centre of Mathematics, University of Coimbra

keywords: nonsmooth optimization, optimal actuator location, optimal control

We investigate elliptic optimal control problems with nonsmooth L^1 control cost. The formulation results in optimal controls that are identically zero on possibly large parts of the control domain. In applications, this can be used to decide the question *where* to place control devices. In this talk, we investigate structural properties of optimal controls with L^1 control cost and compare with those obtained using the usual smooth regularization. We present an efficient solution algorithm for the nonsmooth optimization problem and report on numerical results for an elliptic model problem. Finally, we give an application problem that is concerned with the optimal location of electrodes on a piezoelectric plate. Parts of this work are joint work with Isabel Figueiredo from the University of Coimbra, Portugal.

A levelset method in shape optimization for variational inequations

ANTOINE LAURAIN
Institut Elie Cartan Laboratoire de Mathématiques

coauthors: Piotr Fulmanski, Jean-François Scheid, Jan Sokolowski
keywords: level set method, optimal design, shape optimization, topological derivative

The new tool in shape optimization are topological derivatives of shape functionals introduced by Sokolowski and Zochowski. Such derivatives can be defined for the energy functionals of obstacle type problems, including the frictionless contact problems in solid mechanics.

We consider the problem of maximizing the energy functional associated with a Signorini problem. In order to have solutions to the shape optimization problem, the energy is penalized by the area and the perimeter of the domain

$$J(\Omega) = E(\Omega) + \lambda A(\Omega) - \mu P_c(\Omega)^2,$$

where

$$E(\Omega) = \frac{1}{2}\int_\Omega |\nabla u|^2 + \frac{1}{2}\int_\Omega u^2 - \int_\Omega fu$$

$$A(\Omega) = |\Omega|,$$

$$P_c(\Omega) = \max(0, \mathcal{H}^1(\partial\Omega) - c).$$

The levelset method is used to perform the evolution of the domain Ω to be optimized. This method allows to handle easily topological changes, but the number of holes is naturally decreasing during the iterations. In case of linear elasticity, the levelset method can be improved by forcing the creation of holes in the domain. We choose where to create holes by computing the topological derivative.

We present a few results, mainly numerical, which confirm the application of topological derivatives for shape optimization of the Signorini problem.

WE3-R18 GRAPHS AND MATROIDS

Helly property for graphs and hypergraphs

organizer: Sulamita Klein
chair: Marina Groshaus

Complexity aspects of generalized helly hypergraphs

MITRE DOURADO
UFRJ

coauthors: Jayme Szwarcfiter, Fábio Protti
keywords: computational complexity, Helly property

A hypergraph $\mathcal{H}$ is (p,q)-*intersecting* when every partial hypergraph $\mathcal{H}' \subseteq \mathcal{H}$ formed by p or less hyperedges has intersection of cardinality at least q. A hypergraph $\mathcal{H}$ satisfies the *Helly property* if every partial $(2,1)$-intersecting hypergraph of $\mathcal{H}$ has a nonempty intersection. In 1995, Voloshin proposed the following generalization of the Helly property: a hypergraph $\mathcal{H}$ is (p,q,s)-*Helly* when every partial (p,q)-intersecting hypergraph $\mathcal{H}' \subseteq \mathcal{H}$ has intersection of cardinality at least s.

In former work, we presented a characterization of (p,q,s)-Helly hypergraphs that leads to a polynomial time algorithm if p and q are fixed. Such result is a generalization of the characterization of p-Helly hypergraphs given by Berge and Duchet in 1975.

In this work, we show that deciding if a hypergraph is (p,q,s)-Helly, for p or q variable, is NP-hard.

Partial chracterizations of coordinated graphs

FRANCISCO SOULIGNAC
Universidad de Buenos Aires

coauthors: Flavia Bonomo, Guillermo Durán, Gabriel Sueiro
keywords: coordinated graphs

A graph G is *coordinated* if the minimum number of colors that can be assigned to the cliques of H in such a way that no two cliques with non-empty intersection receive the same color is equal to the maximum number of cliques of H with a common vertex, for every induced subgraph H of G. Coordinated graphs are a subclass of perfect graphs. The list of minimal forbidden induced subgraphs for the class of coordinated graphs is not known. In this paper, we present a partial result in this direction, that is, we characterize coordinated graphs by minimal forbidden induced subgraphs when the graph is either a line graph, or paw-free, or $\{W_4$, gem, bull$\}$-free, or the complement of a forest.

A matrix for the bicliques of a graph

MARINA GROSHAUS
Universidad de Buenos Aires

coauthor: Jayme Szwarcfiter
keywords: bicliques, clique matrix, cliques

Given a graph G, the *clique matrix* of G, is a $\{0,1\}$-matrix having one row for each (maximal) clique and one column for each vertex of G, and such if the j-th vertex belongs to the i-th clique then the i,j element of the matrix is 1, and otherwise it is 0. We define the *biclique matrix* of G is a $\{0,1,-1\}$ matrix having one row for each biclique and one column for each vertex of G, and such that a pair of 1,-1 entries in a same row corresponds exactly to adjacent vertices in the corresponding biclique. Clique matrices were characterized by Gilmore, in terms of the Helly property.

We describe a characterization for biclique matrices, in similar terms as those employed in the characterization of clique matrices. The special case of biclique matrices of bipartite graphs is also considered. Finally, we relate the clique matrix to the *positive biclique matrix* of G, that is the $\{0,1\}$ matrix obtained from its biclique marix, by replacing the -1's by 1's.

WE3-R19 APPROXIMATION ALGORITHMS

Approximation algs. for facility location problems

organizer: Claire Kenyon
chair: Moses Charikar

From stars to comets: improved local search for universal facility location

JENS VYGEN
University of Bonn
keywords: approximation algorithms, dynamic programming, facility location, local search

We improve the approximation ratio for the universal facility location problem to 6.702 by a simple local search algorithm with an enhanced pivot operation.

This new operation can redistribute demand along edges of an arbitrary oriented forest almost optimally in polynomial time. Our approximation algorithm applies this only to comets, i.e. trees in which one vertex is incident to all edges but one.

A general approach for incremental approximation and hierarchical clustering

DAVID WILLIAMSON
Cornell University

coauthors: Guolong Lin, Chandrashekar Nagarajan, Rajmohan Rajaraman
keywords: approximation algorithms, hierarchical clustering, k-median problem

We consider the incremental k-median problem introduced by Mettu and Plaxton and the hierarchical median problem introduced by Plaxton which are closely related to the well-known k-median problem. Given a metric space with facilities and clients, the objective of the k-median problem is to select a set of facilities to open so as to minimize the sum of distances from the clients to the nearest open facility. In the incremental k-median problem, we require an ordering of facilities so that the cost of opening the first k facilities in the ordering is close to the optimal solution with k facilities for all k. The hierarchical median problem asks for solutions for all k satisfying some "hierarchical" properties such that the cost the solution with k facilities is close to the optimal k-median solution with k facilities. The maximum ratio between the cost of the solution with k facilities and that of the optimum k-median solution over all k is called the competitive ratio.

We give a deterministic 16-competitive and randomized 4e-competitive algorithm for the incremental k-median problem improving the previously known 29.86-competitive algorithm by Mettu and Plaxton. We also give a deterministic 41.42-competitive and randomized 20.06-competitive algorithm for the hierarchical median problem improving the previously known 238.8-competitive algorithm by Plaxton. Our algorithms are based on sorting approximate solutions for the k-median problem into buckets of geometrically increasing values and "nesting" specific solutions to obtain the incremental solution. Our algorithmic ideas can be generalized to give incremental algorithms for many problems like k-MST, k-vertex cover, uncapacitated facility location problems which satisfy certain basic properties.

Notes on the analysis of the 1.52-approximation algorithm of Mahdian et al. for the metric uncapacitated facility location problem

JAROSLAW BYRKA
CWI Amsterdam

coauthor: Karen Aardal
keywords: approximation algorithms, facility location

In this note we consider the metric version of the classical Uncapacitated Facility Location Problem, and the 1.52-approximation algorithm of Mahdian et al., which is the algorithm with the best known approximation guarantee. In the paper presenting the 1.52-algorithm, the authors posed two open questions. First, whether the algorithm can be analyzed in a more straightforward way than the given analysis, which made use of three different steps, and second, whether their algorithm can close the gap with the lower bound on approximability of 1.463. The first question was answered by Mahdian et al. in a later paper, where they analyze the algorithm using a single linear program. In this note we provide a different linear program and use it to show that the gap with the lower bound on approximability is not closed, by providing a construction of instances for which the algorithm's approximation ratio is not better than 1.494.

WE3-R20 PRODUCTION AND SCHEDULING

Planning and scheduling applications

organizer: Jay Sethuraman
chair: Ahmet Keha

Integer programming approaches to block-cave mine planning

ANITA PARKINSON
UBC

coauthors: S. Thomas McCormick, Maurice Queyranne
keywords: integer programming

Block-cave mining is a recent technique where an underground mine is blasted from a "lattice of drawpoints" below the ore body in such a way that gravity does much of the work. For this to work well the sequence of drawpoints blasted over time must be contiguous, as well as satisfying other constraints. The one-dimensional version of the problem has been considered before under the name "unit commitment problem", among others.

We consider various integer programming formulations for the problem, some using only natural variables, and some extended formulations with auxiliary variables. Some formulations are provably tighter than others. We also propose various solution techniques including cutting planes and Cplex/MIP. We test these various formulations and techniques on some real data sets supplied by an industrial partner, and report our computational experiments.

A solution for the aggregate production planning problem in a multi-plant, multi-period and multi-product environment

LORENA PRADENAS
Universidad de Concepción

coauthors: Cesar Alvarez, Jacques Ferland
keywords: aggregate production planning, linear programming, sawmill planning

This paper introduces a linear mathematical model to the Aggregate Production Planning problem in the sawn wood area of a forestry company. The objective is to maximize the revenue to the company and to find the best option between production levels; subcontracting and inventory to satisfy the total amount of the families' product demand, considering a group of sawmills different types of raw materials and different production parameters. The model was solved with Cplex 8.1 and Xpress-Optimizer 16.10.02 with important results, because it is always possible to reach an optimal solution in a suitable time.

A branch-and-cut algorithm for single machine scheduling problems

AHMET KEHA
Arizona State University

keywords: branch-and-cut, scheduling

We study the polyhedral structure of the formulation with assignment and positional variables. We first improve the mixed integer formulation by using two new families of validinequalities. We next generalize the Queyranne cuts and show how we can use them in our branch-and-cut algorithm. We conclude our presentation with computational results that represent the effectiveness of our valid inequalities.

TH1-R1 COMBINATORIAL OPTIMIZATION

Polyhedral combinatorics III

chair: Lídia Lourenço

Strengthened lower bounds for the part families with precedence constraints problem

LÍDIA LOURENÇO
FCT-UNL

coauthor: Margarida Pato
keywords: mixed binary linear formulation, part families problem, precedence constraints, valid inequalities

The part families with precedence constraints problem (PFP) consists of grouping parts into families, within flexible manufacturing systems, by imposing capacity constraints, concerning both the number of parts and processing times, besides precedence constraints in the building of families.

An alternative to a natural formulation for this difficult NP-hard problem is an extended formulation. This mixed binary linear model enables one to develop different valid inequalities that dominate those previously deduced.

Results of a computational experiment, using the CPLEX software applied to the linear relaxation of the extended formulation and including the valid inequalities, confirmed the strengthening of the lower bounds for the most of the instances tested. Such bounds can be used to improve the performance of a specific branch-and-bound to be developed for the PFP.

Cycle-based facets of chromatic scheduling polytopes

JAVIER MARENCO
University of Buenos Aires

coauthor: Annegret Wagler
keywords: bandwidth allocation, polyhedral combinatorics

Chromatic scheduling polytopes arise as solution sets of the bandwidth allocation problem in point-to-multipoint radio access networks, which provide voice/data communication for customers with fixed antennas and individual demands. This bandwidth allocation problem is NP-complete. As algorithms based on cutting planes have shown to be successful for many other combinatorial optimization problems, the goal is to apply such methods to this problem. For that, knowledge on the associated polytopes is required. The present paper contributes to this issue, introducing three new classes of facet-inducing valid inequalities based on cycles of the interference graph. We explore the computational complexity of the separation problems for these classes, showing that two of them are solvable in polynomial time.

A branch and cut algorithm for the partition coloring problem

YURI FROTA
UFRJ

coauthors: Nelson Maculan, Thiago Noronha, Celso Ribeiro
keywords: branch-and-cut, partition coloring, routing and wavelength assignment, tabu search

Let $G = (V,E,Q)$ be a non-directed graph, where E is the set of edges and V is the set of nodes. Let also $Q = Q_1,Q_2,\ldots,Q_q$ be a partition of V into q subsets. We refer to $Q_1,Q_2,\ldots,Q_q$ as the components of the partition. The Partition Coloring Problem (PCP) consists in finding a subset V' of V with exactly one node from each component $Q_1,Q_2,\ldots,Q_q$ and such that the chromatic number of the graph induced in G by V' be minimum. This NP-hard problem is clearly a generalization of the graph-coloring problem. This work presents the first branch-and-cut algorithm proposed for PCP. An integer programming formulation based on a representative model is proposed. A tabu search heuristic is used to provide primal bounds and the linear relaxation of the proposed formulation is used to provide dual bounds. We propose several cutting plane heuristics to strength the dual bounds. Computational experiments are reported. First, we compare the performance of the branch-and-cut algorithm for several random graphs. Next, we consider the problem of Routing and Wavelength Assignment (RWA) in all optical WDM networks, which consists in establishing routes for a given set of connections in the network, using the minimum number of wavelengths. We show how this problem can be solved as a partition-coloring problem and present numerical results on a realistic network.

TH1-R2 COMBINATORIAL OPTIMIZATION

Probabilistic location analysis

organizer: Roberto Galvão
chair: Vladimir Marianov

Location of single-server facilities with Erlang distributed service times

THOMAS BOFFEY
Liverpool University
keywords: congestion, Erlang distribution, location

The location of m-server immobile facilities subject to congestion is discussed. To date, almost all research has focussed on facilities whose servers have exponentially distributed service times. This, however, is often unrealistic because the modelled system exhibits lower service time variance. To overcome this we generalise the service time distribution to an order r Erlang distribution - for appropriate value of r, this permits better modelling of service time and, when $r = 1$, reduces to the exponential case.

We also restrict queue lengths to a maximum of $N \geq 0$, with the pure loss case $N = 0$ permitting no queueing whatsoever. Such a restriction is particularly appropriate for emergency facilities in which case the relevant objective, to be minimised, is the total loss (per unit time).

It is shown how such a loss minimising model is equivalent to a particular deterministic capacitated location problem for the case of $m = 1$. (Multiserver queues are considered in a related paper.) Finally, some numerical results are presented with regard to possible location of single-server facilities in the municipality of Rio de Janeiro.

The use of the hypercube queuing model in the solution of probabilistic location problems

FERNANDO CHIYOSHI
COPPE/UFRJ
keywords: hypercube queuing model, probabilistic location problem

In the Maximum Availability Location Problem (MALP, ReVelle and Hogan, 1989), the objective is to locate p servers to maximize the coverage provided to demand areas. A demand area is covered if there is at least one server available within a critical distance S with (Probability $\geq a$). Simplifying assumptions define a mathematical programming model.

An extension (EMALP) is obtained when the simplifying assumptions are dropped and Larson¡'s hypercube model is used to calculate servers' workloads. A hypercube model with p servers has an associated system of 2^p linear equations; in order to handle larger problems Larson devised an approximate method in which a system of p non-linear equations in servers' workloads is solved. We illustrate the difference between MALP and EMALP by calculating the probability that at least one server is available within S using the simplifying assumptions and both exact and approximate methods to solve the hypercube model.

Linearisation of the service level constraint for location of multi-server congestible facilities

VLADIMIR MARIANOV
Pontificia Universidad Católica de Chile
coauthors: Brian Boffey, Roberto Galvão
keywords: Erlang distribution, location, multiple-server facilities, queues

Almost all published models for location of immobile congested facilities, have assumed exponentially distributed service time at the facilities. Although the resulting formulations are more tractable, they do not represent adequately the case of service distributions with small variances, as is often the case in practice. In a recent paper, the authors proposed utilising an order r Erlang distribution E_r for the service time, but limit their analysis to the case of single-server facilities operating as $M/E_r/1/N$ queues. We generalise this approach to the case of multiple-server facilities, which needs a different mathematical treatment. The constraint on service availability is cast as a linear constraint on the proportion of time the servers are busy, and the right hand side parameter of this constraint is provided for different situations. Extensive analysis is offered on the influence of the parameters of the service time and the capacity of the facilities on the performance of the system, having as an example a realistic data set relating to the municipality of Rio de Janeiro.

TH1-R3 COMBINATORIAL OPTIMIZATION
Metaheuristics and applications II
organizer: Toshihide Ibaraki
chair: Koji Nonobe

An iterated local search algorithm for the multi-resource generalized assignment problem with flexible assignment cost

KOJI NONOBE
Hosei University
coauthors: Toshihide Ibaraki, Akihiro Ishikawa, Hiroshi Nagamochi, Mutsunori Yagiura
keywords: GAP, metaheuristics

We propose an iterated local search algorithm for the multi-resource generalized assignment problem (MRGAP) with flexible assignment cost. This problem generalizes the MRGAP so that the assignment cost function defined for each agent can be in any form. While this flexibility achieves a wide applicability, the computation of the cost can be time-consuming. Our algorithm features two types of oracles to evaluate the assignment cost approximately; one evaluates the cost quickly, but it may be inaccurate to some extent, and the other obtains a more accurate evaluation by pending more computation time. We confirm hrough computational experiments that the algorithm combining two oracles performs well. We also apply the proposed algorithm to the parallel machine scheduling and the vehicle routing problems, which can be formulated as the MRGAP with flexible assignment cost.

On the queen graph coloring problem

MICHEL VASQUEZ
Ales School of Mines
keywords: graph coloring

The Queen Graph Coloring Problem consists in covering a $n \times n$ chessboard with n^2 colored queens such as 2 queens of same color do not attack each other. The minimum number of colors used to do so is the chromatic number X_n of the graph defined by the squares of the board and the queen move rule. An enumeration of the maximum stable sets reinforced by a clique filtering proves that X_{10}=11, X_{12}=12 and X_{14}=14. Then a geometric heuristic shows that $X_n = n$ when n = 15, 16, 18, 20, 21, 22, 24, 26, 28, 32. Finally linear congruence calculations prove that there is an infinity of n multiples of 2 or 3 so that $X_n = n$.

Multiobjective genetic algorithms for some relaxed versions of the set partitioning problem

TERESA GALVÃO DIAS
FEUP
coauthors: Jorge Pinho de Sousa, João Falcão e Cunha
keywords: combinatorial optimization, multi-objective genetic algorithms, scheduling

In this work we propose a multiobjective approach for some relaxed formulations of the Set Partitioning Problem, based on Genetic Algorithms. This approach uses the concept of Pareto dominance to rank the solutions. A new fitness assignment procedure has been implemented as well as several knowledge based crossover and mutation operators. The approach was applied to the Bus Driver Scheduling Problem (BDSP) which is a critical stage of the operational planning process in mass transit companies. It consists in constructing a set of legal duties that together cover all the trips planned for a group of vehicles and is often modeled as a Set Partitioning Problem for the minimization of the duties costs. However, the BDSP involves several, often conflicting objectives, involving costs, quality of service and the satisfaction of the drivers' expectations. In our multiobjective approach we provide some guidelines to consider and tackle all these objectives. The approach has been tested on a set of real problem instances from Portuguese companies and the solutions obtained have been compared with the solutions currently implemented in those companies. The GA has been able to consistently provide a set of competitive alternative solutions, with a rather short planning time. The new multiobjective approach proposed in this work has proved to be valuable and powerful in supporting decision making for short-term (daily) operations, as well as in the simulation of alternative operating scenarios in a medium-term horizon.

TH1-R4 INTEGER AND MIXED INTEGER PROGRAMMING
Computational integer programming I
organizer/chair: Jonathan Eckstein

Parallel integer programming with ALPS

THEODORE RALPHS
Lehigh University
coauthors: Yan Xu, Laszlo Ladanyi, Matthew Saltzman

keywords: branch-and-cut, integer programming, parallel algorithms

We discuss the latest generation of ALPS, a software library for implementating scalable parallel search algorithms. The library now supports the solution of generic mixed-integer programming problems by branch and cut. We discuss scalability issues arising in the implementation of such data-intensive algorithms and present computational results solving large integer programs in parallel.

Decomposition and mixed integer programs

LADANYI LASZLO
IBM Research

keywords: decomposition, integer programming, linear programming

LPs and MIPs with a constraint matrix that is mostly block diagonal with relatively few connecting constraints (resp. variables) can be solved via Dantzig-Wolfe (resp. Benders) decoposition. In this talk we present a unified view of the two decompostion methods which can be applied even if *both* connecting constraints and variables are present besides the block diagonal core.

Local cuts for mixed integer programming

DANIEL ESPINOZA
Universidad de Chile

coauthors: William Cook, Vasek Chvatal
keywords: cutting planes, mixed-integer programming

An interesting new approach to the cutting-generation procedure for the TSP was introduced by Applegate et al. (1998,2003). They introduce a procedure to generate cuts that relies on the equivalence between optimization and separation to get cuts resulting from small GTSP problems that are the result of a *mapping* of the original problem.

In this talk we show an extension of this approach to the case of general MIP problems, provide extra motivation for this approach, and a general procedure to obtain facets or high dimensional faces from general valid inequalities. We also give a precise mathematical definition of a mapping, as well as conditions under which the *mapping* step ensures that we will find a violated cutting plane for the original problem.

We finalize with a sample of some mapping function and spaces, as well with some preliminary numerical experience on the MIPLIB test set.

TH1-R5 INTEGER AND MIXED INTEGER PROGRAMMING
Mixing MIR inequalities
organizer/chair: Ismael de Farias

Separating from the MIR closure of polyhedra

OKTAY GUNLUK
IBM Research

coauthors: Sanjeeb Dash, Andrea Lodi
keywords: mixed-integer rounding, split closure

We study the problem of separating an arbitrary point from the MIR closure of a polyhedron (finding violated rank-1 MIR cuts). Motivated by the work of Fischetti and Lodi (2005), who gave an MIP model for separating from the Chvatal closure of a polyhedron, we describe an MIP model for separating from the MIR closure of a polyhedron. Our analysis yields a short proof of the result of Cook, Kannan and Schrijver (1990) that the split closure of a polyhedron is again a polyhedron. We present computational results on finding violated MIR cuts using this model.

Network dual mixed Integer programs

LAURENCE WOLSEY
CORE, Universite Catholque de Louvain

coauthors: Michele Conforti, Friedrich Eisenbrand
keywords: convex hull, dual network matrix, mixed-integer programs, mixing set

We study mixed integer sets described by dual network constraints involving both continuous and integer variables, namely sets of the form:

$$X^{ND} = \{v = (x,y) \in R^p_+ \times Z^{n-p} :$$

$$\alpha_{ij} \geq v_i - v_j \geq \beta_{ij} \; \forall \; i,j\},$$

which generalize mixing sets that have been studied recently. Our basic result is to show that the convex hull of X^{ND} has an extended formulation that is again a dual network matrix, namely: $Conv(X^{ND}) = \text{proj}_{x,y}(Q^{ND})$ where

$$Q^{ND} = \{(x,z) = (x,y,w) \in$$

$$(R^p \times R^{n-p}) \times R^m :$$

$$x = Bz, \gamma_{kl} \geq z_k - z_l \geq \delta_{kl} \; \forall \; k,l\},$$

with $\gamma_{kl}, \delta_{kl} \in Z \; \forall \; k,l$.

This extended formulation depends on a characterization of the set $\mathcal{F}$ of values, modulo 1, taken by the continuous variables in an extreme point v^* of $Conv(X^{ND})$, so that $v_i^* \mod 1 \in \mathcal{F}$ for $i = 1,\ldots,p$. If the set $\mathcal{F}$ is of size polynomial in n, then the network dual formulation Q^{ND} is of size polynomial in n, and so optimization over X^{ND} is in $\mathcal{P}$. This leads us to examine under what conditions $|\mathcal{F}|$ is polynomial.

First we show that when there is no dual network constraint involving two continuous variables, or $\alpha_{ij} = \infty$ and $\beta_{ij} = -\infty$ for all $1 \leq i < j \leq p$, then $|\mathcal{F}|$ is polynomial.

More generally the structure of the constraints involving two continuous variables can be represented by a digraph $D = (\{1,\ldots,p\},A)$ where $(i,j) \in A$ only if the constraint $v_i - v_j \geq \beta_{ij}$ is necessary in the description of X^{ND}. We show that when D is an in- or out-arborescence, $|\mathcal{F}|$ is polynomial.

Polar sets for simple MIP polyhedra

MING ZHAO
State University of New York at Buffalo

coauthor: Ismael de Farias
keywords: branch-and-cut, cutting planes, polarity, simple MIP sets

In their seminal work, Marchand & Wolsey and Gunluk & Pochet showed that it is possible to derive powerful cutting planes for MIP, such as MIR inequalities, from "simple" MIP sets. Later, others generalized their simple sets to more complicated structures to obtain even more powerful results. All these structures include exclusively totally unimodular (TU) constraint matrices. Here, we lift the TU assumption to describe sets that are considerably more general than the ones previously studied. We show that the polar of these sets gives a convenient way to analyse them. We give the computational complexity of MIP over these sets and separation algorithms for them that can be used to generate strong cuts for general MIP.

TH1-R6 LOGISTICS AND TRANSPORTATION
Public transport
chair: Ralf Borndörfer

School bus routing problem resolution with hybrid metaheuristics

CRISTIAN MARTINEZ
Universidad de Buenos Aires

keywords: hybrid algorithms, metaheuristics, vehicle routing problem

This paper solves the School Bus Routing Problem. It consists in obtaining a set of routes for the students' transfer from bus-stops towards their schools, subject to constraints (route length, allocation, priorities, etc.). We use a bi-objective function, that minimizes the trip maximum time and the used buses.

We show two proposals of resolution, based on constructive algorithms and improvement. The first one, constructs solutions through Ant Colony System's variation, improving them with 2 and 3-Opt's two generalized heuristic. The second one, constructs and improves solutions with GRASP and Ejection Chains.

This algorithms were tested with published paper's instances, reaching good results in terms of time and quality.

Line planning in public transport

RALF BORNDÖRFER
Zuse Institute Berlin (ZIB)

coauthor: Marc Pfetsch
keywords: column generation, line planning, multicommodity flows, public transport

The line planning problem is one of the fundamental problems in strategic planning of public and rail transport. It consists in finding lines and corresponding frequencies in a transport network such that a given travel demand can be satisfied. We study a multi-commodity flow model for line planning. It allows to freely route passenger paths and to generate lines dynamically. The talk discusses theoretical properties of this model and a column generation solution approach. Computational results for the city of Potsdam, Germany, are reported.

Optimal bus transit route network design in a medium sized city

ROBERTO DE LA LLATA
Centro Queretano de Recursos Naturales

keywords: bus route network design, integer programming, metaheuristics

Public transport planning includes different and interrelated activities, being route network design the most important because it has a decisive influence on the remaining steps. When applied in an urban setting, given an origin-destination demand matrix and a roads network representation, it can be modeled as an optimization problem. The resulting formulation is very similar to the general network design problem, it is a nonlinear, mixed integer problem with NP-hard complexity and with the additional need to include several objectives. This model is formulated and applied in a medium sized city in Mexico. Because of the difficulty to solve it optimally, two different approaches are considered: decomposition and approximation algorithms. In the first case, the problem is reduced in complexity by specifying a set of candidate routes and solving a set of related covering problems. In the second approach several metaheuristics are tested, among them genetic algorithms.

TH1-R7 AIRLINE OPTIMIZATION

Airline models and algorithms

chair: Ivo Nowak

Air lines planning: crew scheduling

EDUARDO SOARES
COPPE - UFRJ

coauthors: Nelson Maculan, Celso Ribeiro
keywords: crew scheduling, heuristics, variable neighborhood search

Every month airlines have to solve a crew scheduling problem to operate their regular flights. This is a time consuming task, divided in several phases: course allocation, vacations scheduling, creation of pairings and their allocation, and balancing the scheduling. This paper shows an integrated solution, where a heuristic algorithm solves the pairing problem together with the crew scheduling problem. Its objective is to attribute all the flights to crews minimizing the cost of the pairings and the difference between the number of flights allocated to the crew with more flights and to the one with less flights. To solve the problem, the VNS (variable neighborhood search) heuristic is used, along with an artifice of creating lags between flights that don't finish in their origin bases, allowing for a simplification in the model.

A column generation algorithm for the choice-based linear programming

JUAN JOSE MIRANDA BRONT
FCEyN-Universidad de Buenos Aires

coauthors: Gustavo Vulcano, Isabel Méndez-Díaz
keywords: airline optimization, column generation, Revenue Management

Capacity-based revenue management (RM) involves controlling fixed and perishable capacity of resources over a finite horizon, with the objective of maximizing revenues. Applications of RM spans service industries like airlines, hotels, railways, cruises, etc. In the last few years, there has been a trend to enrich traditional RM models to account for customer choice behavior. This extension involves both modeling and computational challenges.

One possible way of describing choice behavior is to assume that each customer belongs to a segment (i.e., a candidate set of products), and that he/she chooses a particular product according to a multinomial-logit model, widely used in the marketing literature. In this paper, we consider the choice-based linear programming (LP) model of van Ryzin and Liu (2005) and propose an efficient column generation algorithm that allows to implement the general version of their model, where customers belong to overlapping segments. The column generation algorithm consists of solving heuristically a fractional programming problem. Our results show that the approach has good potential to be applied on real size networks, and leads to high quality solutions.

A unified column generation approach to crew pairing and rostering

IVO NOWAK
Lufthansa Systems

keywords: column generation, crew scheduling

In this talk, we give an overview of the xOPT optimization suite for large-scale airline crew scheduling developed at Lufthansa Systems Berlin. Starting with an introduction into some basic column generation tools, we present solution techniques for the crew pairing problem and the crew rostering problem.

Moreover, we explain how these techniques can be used to solve integrated scheduling problems

TH1-R8 LEONID KHACHIYAN MEMORIAL

Leonid Khachiyan memorial I

organizer/chair: Farid Alizadeh

Two news on the ellipsoid method

ARKADI NEMIROVSKI
Georgia Institute of Technology

keywords: ellipsoid method, homogeneous self-dual cones, saddle point problems

In the talk, we discuss two recent developments related to the Ellipsoid method. The first is, that a method of this type can be associated not only with compact cross-sections of the Lorentz cones (the original Ellipsoid method, 1976) and nonnegative orthants ("Simplex method" of Bulatov and Shepot'ko, 1982), but with compact cross-sections of arbitrary homogeneous self-dual cones (e.g., the cones of psd matrices). The second is, that the Ellipsoid method is capable to generate on-line "accuracy certificates" - convex combinations of the linearizations of the objective taken at the search points with minima on the feasible domain (these minima are lower bounds on the true optimal value) approaching, at a linear rate, the best found so far values of the objective. We discuss applications of the latter feature in the saddle point context.

Integer rounding in graphs, cones and bin packing

ANDRÁS SEBO
CNRS, Grenoble

keywords: bin packing, min-max problems, modified integer round up, totally dual integral (TDI)

We revisit integer rounding and modified integer rounding. The former means that the integer minimum of a linear program is equal to the fractional minimum rounded up, the latter is the same but an error of 1 is allowed.

As a new example we show a general minmax theorem on the maximum union of k stable sets for any k, implying : both theorems of Bessy and Thomassé (on the maximum stable set and minimum coloring), the Green-Kleitman theorem and "strong versions" (strong = variant for strongly connected graphs, usually more difficult, but without formal implication), of conjectures of Berge and Linial on stable sets and path partitions, where the original conjectures remain open. We show the main ideas of how the corresponding algorithmic problem can be solved by Khachian's algorithm or in a combinatorial way.

We then show: whenever integer rounding occurs simultaneously with some other properties (TDI and "independence system"), it implies similar minmax theorems on unions of combinatorial objects. We finally exhibit some new cases of modified integer rounding for the bin packing problem, a recent joint result with Gennady Shmonin.

Fast algorithms for approximate semidefinite programming using the multiplicative weights update method

KALE SATYEN
Princeton University

coauthors: Sanjeev Arora, Elad Hazan
keywords: Lagrangian relaxation, semidefinite programming

Semidefinite programming (SDP) relaxations appear in many recent approximation algorithms but the only general technique for solving such SDP relaxations is via interior point methods. We use a Lagrangian-relaxation based technique (modified from the papers of Plotkin, Shmoys, and Tardos (PST), and Klein and Lu) to derive faster algorithms for approximately solving several families of SDP relaxations. The algorithms are based upon some improvements to the PST ideas –which lead to new results even for their framework– as well as improvements in approximate eigenvalue computations by using random sampling.

TH1-R9 OPTIMIZATION IN ENERGY SYSTEMS

Capacity expansion and investment planning

organizer/chair: Luiz A. Barroso

Solving multi-stage stochastic capacity-planning problems

ANDY PHILPOTT
University of Auckland

coauthors: Kavinesh Singh, Kevin Wood
keywords: capacity expansion, stochastic integer programming

We describe a general multi-stage stochastic integer-programming model for planning the discrete capacity expansion of production facilities in a situation in which a scenario tree represents uncertainty. A split-variable reformulation of the basic model leads to a strong Dantzig-Wolfe decomposition, whose efficiency we demonstrate on a capacity-expansion model for electric power distribution. When a facility can expand at most once over the planning horizon, a specialised model yields substantial computational savings.

Investment issues inrestructured electricity systems

YVES SMEERS
CORE, Université Catholique de Louvain

keywords: capacity expansion in electricity markets, investment planning in electricity markets, market powet, mathematical programming

Capacity expansion was a well understood optimization problem in the regulated electricity industry. It is much more difficult to grasp after restructuring. This is specially true if one follows the common wisdom of assuming that generators exercise market power. We discuss various investment games and explore, firstly, the wide variety of plausible economic assumptions that can be made in these models and, secondly, the sensitivity of the outcome of the models to these economic assumptions. We also elaborate on the mathematical programming difficulties raised by these models.

Expansion planning of generation and interconnections under uncertainty

MARIO PEREIRA
PSR, Brazil

coauthors: Nora Campodonico, Silvio Binato
keywords: Benders decomposition, investment planning, mixed-integer programming, multi-stage stochastic programming

This work discusses conceptual and methodological issues in the expansion planning of generation and interconnections under uncertainty. The solution approach is based on large scale Benders decomposition techniques, in which the first stage (investment) problem is

formulated as a multistage MIP problem, and the second stage (operations) problem is formulated as a multistage stochastic scheduling model, solved by stochastic dual dynamic (SDDP) techniques. These techniques detailed representation of hydrothermal scheduling, such as chronological simulation, modeling of water coupling for reservoirs in cascade, pumped storage, stochastic optimization of reservoir operation, multivariate probabilistic inflow modeling, transmission network constraints, demand uncertainty and emission limits. On the investment side, one can represent capacity reserve constraints, mutually exclusive and interdependent projects, and both integer and continuous investment decisions. Examples and case studies will be presented for the multi-regional planning for the ten-country Balkans region and the 95-GW Brazilian power system.

TH1-R10 ROBUST OPTIMIZATION

Applications of robust optimization

organizer/chair: Georgia Perakis

Dynamic pricing and inventory control; uncertainty and competition through robust optimization and quasi variational inequalities

ELODIE ADIDA
MIT

coauthor: Georgia Perakis
keywords: differential games, normalized Nash equilibrium, pricing and inventory control, robust optimization

We study a make-to-stock manufacturing system where two firms compete through dynamic pricing and inventory control. Our goal is to address competition (in particular a duopoly setting) together with the presence of demand uncertainty. We consider a dynamic setting where multiple products share production capacity. We introduce a demand-based fluid model where the demand is a linear function of the price of the supplier and of her competitor, the inventory and production costs are quadratic and all coefficients are time-dependent. A key part of the model is that no backorders are allowed and the strategy space of a supplier depends on her competitor's strategy. We first reformulate the robust problem as a fluid model of similar form to the deterministic one and show existence of a Nash equilibrium in continuous time. We discuss issues of uniqueness and address how to compute a particular Nash equilibrium, i.e. the normalized Nash Equilibrium.

Robust Wardrop equilibrium

NICOLAS STIER-MOSES
Columbia University

coauthor: Fernando Ordonez
keywords: game theory, network optimization, robust optimization, selfish routing

Network games can be used to model competitive situations in which players select routes to maximize their utility. Although traditional network models have assumed that utilities only depend on congestion, in most applications they also have an uncertain component. In this work, we extend Wardrop's network game by introducing Robust Wardrop Equilibria (RWE), in which utility maximizing players take the utility uncertainty into account by selecting routes that solve a robust optimization problem. We show that the RWE solution always exists and can be computed using efficient column generation methods. We show through a computational study that a robust Wardrop equilibrium tends to be more fair than the classic Wardrop equilibrium, which ignores the uncertainty. Hence, a robust Wardrop equilibrium is more stable than the nominal counterpart as it reduces the regret that players experience after the uncertainty is revealed.

TH1-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Computational Issues in LP and SDP I

chair: Joao Goncalves

Computing matrix exponentials for smooth semidefinite optimization

RONNY LUSS
Princeton University

coauthor: Alexandre d'Aspremont
keywords: matrix exponential, semidefinite programming, smooth optimization, sparse principal component analysis

We examine a first order method for solving semidefinite programs which arise in relaxing the hard sparsity constraint in sparse PCA. Matrix exponentiation is the most CPU intensive step in the method and, when results do not require machine precision (as is the case here), the classic Pade approximation to the exponential may not be the most competitive method. We discuss Pade and two additional approximation techniques for the matrix exponential - partial eigenvalue decompositions and Pade-Chebyshev approximations.

An efficient simplex LU factorization update

DANIELA CANTANE
Unicamp

coauthor: Aurelio Oliveira
keywords: factorization update, linear optimization, simplex, sparse matrix

In this work we develop simplex basis LU update factorization techniques, using a static reordering of the matrix columns. In the static reordering, the matrix columns are rearranged in accordance with the increasing number of nonzero entries, leading to sparse factorization of the basis without computational effort to reorder the columns. Therefore the matrix reordering is static and the columns of the basis follow this ordering. A simulation of the simplex iterations is carried through according to the base sequence obtained from MINOS. The factorization and LU update are performed considering sparsity. The objective of this work is to compare the developed reordering approach with the results from MINOS. Preliminary computational results in Matlab for problems from the Netlib collection show that this is a very promising idea, since there is no need to refactorize the matrix in the tested problems.

A computational study of new elementary algorithms for linear programming

JOAO GONCALVES
IBM Research

coauthors: Jacek Gondzio, Robert Storer
keywords: elementary algorithms, linear programming

We extend an elementary algorithm for linear programming first proposed by von Neumann. This class of algorithms is attractive due to their simplicity, but in practice can only provide an approximate solution to a linear programming problem. We describe extensions to von Neumann's algorithm that aim at improving

its practical convergence. We present computational results that show significant improvement of the new algorithms over von Neumann's algorithm. Finally, we describe an application for these algorithms.

TH1-R12 NONLINEAR PROGRAMMING

Warm starting IPMs in NLP applications

organizer/chair: Jacek Gondzio

Interior-point methods for nonlinear programming: regularization and warmstarts

HANDE BENSON
Drexel University

coauthor: David Shanno
keywords: interior-point methods, nonlinear programming, penalty methods, warm-starts

We investigate the use of an exact primal-dual penalty approach within the framework of an interior-point method for nonconvex nonlinear programming. This approach provides regularization and relaxation, which can aid in solving ill-behaved problems and in warmstarting the algorithm. We present details of our implementation within the LOQO algorithm and provide extensive numerical results on the CUTEr test set and on warmstarting in the context of nonlinear, mixed integer nonlinear, and goal programming.

Zoom: A strategy for accelerating and warm-starting interior methods

LEO TENENBLAT
Stanford / IMPA

coauthor: Michael Saunders
keywords: interior-point methods, warm-starts

Interior methods using underlying iterative solvers can require exponential amounts of computational work as higher accuracy is sought. We discuss a cheaper two-step method consisting of two cold starts to solve for an approximate solution and a zoomed-in correction. We also apply the method to warm-starting, and exhibit numerical results.

Unblocking heuristics for warmstarting interior point methods

ANDREAS GROTHEY
University of Edinburgh

coauthor: Jacek Gondzio
keywords: interior-point methods, warm-starts

Warmstarting Interior Point Methods is difficult. Unlike the situation in the simplex method, an Interior Point warmstart might not be any better than a cold-start and can even lead to worse performance. A common observation with "failed" warmstarts are blocking directions that is after a warmstart only very small steps can be made. In this talk we will present experience with a set of new unblocking heuristics resulting in better and more reliable warmstarts. We will present results on the Netlib test set as well as on a selection of large scale problems.

TH1-R13 NONLINEAR PROGRAMMING

NLP algorithms

chair: Ernesto Birgin

Positive definite sparse quasi-Newton matrices for constrained optimization

JOSE HERSKOVITS
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coauthor: Evandro Goulart
keywords: large-scale optimization, nonlinear optimization, sparse quasi-Newton matrices

We present a new quasi-Newton technique that obtains sparse positive definite matrices. This approach can be employed in Sequential Quadratic Programming algorithms or with several interior point methods for nonlinear programming, resulting in significant reductions of computations and storage area. Positive definite matrices are a requirement of algorithms including a line search procedure.

The present technique is included in FAIPA, the Feasible Arc Interior Point Algorithm. FAIPA requires at each iteration the solution of three linear systems with the same matrix. With our approach, the internal system are sparse when the constraints derivative matrix is sparse.

Some papers dealing with this problem were published by Toint et. al. and by Fletcher et. al.. Both authors obtained sparse matrices in a very efficient way, however positive definite matrices were not obtained.

We employ some ideas from these authors, but we look the quasi-Newton matrix in a set of positive definite matrices.

Numerical experiments with large problems are presented and compared with other methods. The number of iterations is similar to the traditional quasi-Newton technique.

Inexact restoration methods with inequality constraints and lagrangian tangent decrease

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coauthors: Marcia Gomes-Ruggiero, José Mario Martínez
keywords: global convergence, local convergence, nonlinear programming

Inexact Restoration (IR) methods for Nonlinear Programming were introduced by Martinez and Pilotta in 2000. An IR iteration has two phases. In Phase I, feasibility is improved using an arbitrary algorithm and in Phase II a suitable objective function is minimized on a tangent set. In 2001, Martinez defined an IR method with equality constraints and bounds in which the Lagrangian is optimized in Phase II and global convergence is obtained using a sharp-Lagrangian merit function. Local convergence was proved by Birgin and Martinez in 2005. In this communication we show how to define the IR method admitting inequality constraints and preserving Lagrangian tangent decrease, global and local convergence. Numerical results show that this implementation is much better than the one that uses slack variables. In practice, no Maratos effect is observed, so that the existence of a transition theorem may be conjectured.

Augmented Lagrangian methods with arbitrary lower-level constraints: implementation and experiments

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coauthors: Roberto Andreani, José Mario Martínez, Maria Laura Schuverdt
keywords: augmented Lagrangian methods, global convergence, nonlinear programming, numerical experiments

We describe the implementation of a safeguarded Augmented Lagrangian Method with arbitrary lower-level constraints. Different versions are given

according to the algorithm that is used for solving the subproblems (Algencan,Alspg). Experiments show that: (a) For some very large location problems in which a particular method (like SPG) solves very efficiently the subproblems, the Augmented Lagrangian algorithm outperforms every known method and is able to solve extremely large instances. (b) For large packing problems in which the Hessian of the Lagrangian is structurally dense, Algencan outperforms interior-point SQP methods. (c) When the problem has many inequality constraints, Algencan is superior to methods that use slack variables (including other Augmented Lagrangian methods like Lancelot). (d) Algencan tends to find global minimizers more often than interior-point SQP methods. (e) In massive comparisons with well-known problem libraries Algencan behaves generally better than other nonlinear programming algorithms. These methods are publicly available in the TANGO webpage http://www.ime.usp.br/ egbirgin/tango. The methods are written in Fortran 77. Interfaces with C/C++, AMPL, CUTEr, R and Python are available.

TH1-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

SDP-relaxations for polynomial problems

organizer: Jean B. Lasserre
chair: Nebojsa Gvozdenovic

Approximating the chromatic number of a graph

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CWI Amsterdam

coauthor: Monique Laurent
keywords: block diagonalization, chromatic number, semidefinite programming, Terwilliger algebra

The Lovasz theta number of a graph is a well studied graph parameter that can be computed efficiently to an arbitrary precision in polynomial time by using semidefinite programming. It is known to be "sandwiched" between two "NP-hard" parameters, i.e. the stability number of a graph and the chromatic number of a graph complement. Recently, several hierarchies of semidefinite bounds, starting either from the Lovasz theta number or one of its strengthenings were proposed in order to approximate the stability number of a graph. It turned out that some bounds in these hierarchies that can be computed efficiently give better approximations for the stability number than the Lovasz theta number for certain graph classes. We show how these hierarchies can be adapted for approximating the fractional chromatic number, and the chromatic number of a graph. We prove that our new bounds are at least as good as the best known semidefinite lower bounds on the chromatic number of a graph. In addition, we give some computational results that show that in some cases our bounds are better.

Numerical results on semidefinite programming relaxations

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coauthors: Kim Sonyoung, Masakazu Kojima, Masakazu Muramatsu
keywords: semidefinite relaxations

Semidefinite programming relaxations for polynomial optimization problems (POPs) have attracted a lot of research recently. When implementing SDP relaxation for POPs, numerical chanllenges arise from the large SDP relaxation resulted from POPs. We propose a method to reduce the size of SDP relaxation by recognizing sparse structure in POPs using correlative sparsity pattern graph. We present numerical results for various test problems to show the improved performance of the SDP relaxations.

TH1-R15 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Duality and conic theory

organizer: Claudia Sagastizabal
chair: Alfredo Iusem

A duality theory based on trianguler cylinders separating three convex sets

HIDEFUMI KAWASAKI
Kyushu University

keywords: duality theorem, partition problem, separation theorem

Separation theorems play the central role in the duality theory. Recently, we proposed a duality theorem for a three-phase partition problem. It is based on triangles separating three convex sets in R^2. The aim of this paper is to extend the duality theorem to R^n.

Antipodal pairs, critical pairs and Nash pairs in convex cones

ALFREDO IUSEM
IMPA

coauthor: Alberto Seeger
keywords: convex cones, maximal angle, polyhedral cones

An antipodal pair is a pair of unit vector in a cone which realizes the maximal angle between vectors in the cone. A critical pair is a stationary point for the associated maximization problem. A Nash pair is an intermediate concept: a pair (u, v) of unit vectors in a cone K is a Nash pair if no vector in K makes a larger angle with u than v, and the same holds when u and v are reversed. We study several properties of these three kind of pairs, and characterize them for some relevant familes of cones, e.g., polyhedral cones and elliptic ones.

TH1-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES

Algorithms for problems in strucutral mechanics

organizer/chair: Joaquim Judice

Regularized, variational, fixed-step integration of multibody systems with contacts and friction

CLAUDE LACOURSIERE
HPC2N/VRlab, University of Umea

keywords: complementarity, frictional contacts, variational mechanics

A physical regularization of the discretized variational principle of mechanics is constructed to produce a robust and stable fixed-step time stepping scheme for general constrained mechanical systems including contacts and dry friction. The regularization scheme is applicable to holonomic and non-holonomic kinematic constraints as well as to arbitrary effort constraints, including inequalities and complementarity conditions. This is used to construct a physical constraint stabilization scheme which is strictly dissipative. When applied to the Coulomb friction model, the regularization framework yields a new solvable nonlinear complementarity formulation which is isotropic and which correctly models the transition between kinetic and static friction. The overall stepping scheme is suitable for interactive real-time simulations such as virtual environment systems for heavy machinery operator training.

Computational experiments with inexact restoration for truss optimization

ANA FRIEDLANDER
UNICAMP

coauthors: Eduardo Fancello, Suzana L. C. Castro, Sandra Santos
keywords: bilevel programming, contact problems, inexat restoration, truss optimization

We present numerical experiments for truss optimization using an inexact restoration algorithm developed for bilevel programming problems. The results obtained encourage us to use this approach in topological optimization in structural optimization.

Algorithms for the eigenvalue complementarity problem

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coauthors: Isabel Ribeiro, Silvério Rosa
keywords: complementarity

The Eigenvalue Complementarity Problem (EiCP) consists of finding a scalar $\lambda > 0$ and a vector $0 \neq x \geq 0$, such that

$$(A - \lambda B)x \geq 0,\ x^T(A - \lambda B)x = 0$$

for a given matrix A and a positive definite matrix B. The EiCP has its origins on the solution of a contact problem in mechanics. If A and B are symmetric, the EiCP reduces to find a stationary point of a merit function on the simplex. In the asymmetric case, EiCP reduces to a Mathematical Programming Problem with Linear Complementarity Constraints (MPLCP). Projected–Gradient and Enumerative Tree–Search algorithms are proposed for solving the EiCP in these cases and fully exploit the formulations stated above. Computational experience is included to highlight the benefits and drawbacks of each one of the approaches mentioned before for the solution of the EiCP.

TH1-R17 STOCHASTIC PROGRAMMING
Probabilistic constraints
organizer/chair: Rene Henrion

On chance constraints with random coefficient matrix

RENE HENRION
Weierstrass Institute Berlin

keywords: chance constraints, probabilistic constraints, random coefficient matrix

Optimization problems with chance constraints induced by a random coefficient matrix play a role in many problems of engineering or finance (e.g., mixture or portfolio problems). They are typically considered to be hard to deal with. Any reasonable numerical approach requires a good understanding of structural properties. Extending previous results for the special case of a single row, we provide characterizations of compactness, nontriviality and convexity for joint chance constraints induced by a general random matrix. In particular, a recent result obtained together with C. Strugarek (ENPC, Paris) guarantees convexity in the case of independently normally distributed rows for sufficiently large probability levels. In all characterizations, the term 'for sufficiently large probability levels' can be exactly quantified from the parameters of the random distribution. Finally, we discuss the issue of stability in such problems when the underlying, usually unknown distribution is approximated.

Convexity of chance constraints with independent random variables

CYRILLE STRUGAREK
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coauthor: Rene Henrion
keywords: chance constraints, convexity, probabilistic constraints, stochastic programming

We investigate the convexity of chance constraints with independent random variables. It will be shown, how concavity properties of the mapping related to the decision vector have to be combined with a suitable property of decrease for the marginal densities in order to arrive at convexity of the feasible set for large enough probability levels. It turns out that the required decrease can be verified for most prominent density functions. The results are applied then, to derive convexity of linear chance constraints with normally distributed stochastic coefficients when assuming independence of the rows of the coefficient matrix.

TH1-R18 GRAPHS AND MATROIDS
Graph colorings II
organizer/chair: Manoel Lemos

Balanced total coloring and algorithms for interconnecting networks

ABEL LOZANO
UERJ

coauthors: Samuel Jurkiewicz, Clicia Valladares Friedmann
keywords: balanced total coloring, interconecting network, parallel algorithms, proper total coloring

A proper total coloring φ of a graph $G(V,E)$ is a mapping from $V \bigcup E$ to a set of colors C, such that no two adjacents or incidents elements have the same image. Given a proper total coloring of a graph G, we denote by $a(c)$ the number of times that color c appears in the coloring.A balanced total coloring of G is a proper total coloring satisfying: every two colors c_1 and c_2 of C, we have $|a(c_1) - a(c_2)| \leq 1$. An interconecting network is a structure composed by a set P of $n > 1$ processors so that each processor has its local memory shared among different processors and a set T of connections among processors.
In the present work we study the relationship between balanced total coloring of a graph and the implementation of paralell algorithms for interconnecting networks.

The vertex coloring problem of UEH graphs

PRISCILA PETITO
COPPE/UFRJ

coauthor: Márcia Cerioli
keywords: UEH graph, vertex coloring problem

The UEH graphs are the edge intersection graphs of paths in a tree, satisfying the Helly property. We might think of the tree as a communications network and the paths in this tree as message routes competing for use of the network. Two paths conflict if they both require the use of some same link. The UEH graphs model this notion of conflict if we consider that the family of these paths satisfies the Helly property. A coloring of the vertices of a UEH graph corresponds to a scheduling of the messages where each color represents a different time interval. We prove that the vertex coloring problem is NP-Complete for UEH graphs.

Lower bounds for the vertex coloring problem via columns and cuts generation

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Universidade Federal do Ceará

coauthors: Ricardo C. Corrêa, Manoel B. Campêlo
keywords: column generation, cutting planes, graph coloring

In this work the vertex coloring problem is approached via integer programming. A tighter version of the independent set formulation is used, where the vertex-related constraints are substituted by subgraph-related constraints. Each constraint establishes a lower bound on the number of independent sets intersecting a subgraph H. It is shown a sufficient condition for this inequality to define a facet of the associated polytope. Basically, H is required to be color critical, not included in another color critical subgraph, and to have a connected complement. It is proved this is also a necessary condition if the polytope is restricted to the optimal solutions. Also, the column generation algorithm proposed by Mehotra and Trick (INFORMS Journal in Computing, 1996) is adapted to allow the addition of cutting planes and to provide lower bounds along the process, which may abbreviate its end. Some computational experiments are reported.

TH1-R19 APPROXIMATION ALGORITHMS
Approximation algs for stochastic optimization
organizer: Claire Kenyon
chair: Jens Vygen

A fully polynomial time approximation scheme for single-item stochastic lot-sizing problem with discrete demand

DAVID SIMCHI-LEVI
MIT

coauthors: Nir Halman, Diego Klabjan, Mohamed Mostagir, James Orlin
keywords: approximations, inventory, stochastic dynamic programming

The single-item stochastic lot-sizing problem is to find an inventory replenishment policy in the presence of a stochastic demand under periodic review and finite time horizon. We prove that this problem is intractable and therefore we provide a fully polynomial time approximation scheme. In other words, for fixed epsilon, we design an algorithm polynomial in the size of the problem and in 1/epsilon, that finds a policy that is within a factor (1 + epsilon) of the value of an optimal policy.

Provably near-optimal dual-balancing policies for hard stochastic inventory control problems

RETSEF LEVI
IBM, T.J. Watson Research Center

coauthors: Martin Pal, Robin Roundy, David Shmoys
keywords: approximations, dual-balancing, stochastic inventory control

We consider classical periodic-review stochastic inventory control problem in which the goal is to coordinate a sequence of orders of a single commodity, aiming to supply stochastic demands over a discrete finite horizon with minimum expected overall ordering, holding and backlogging costs.

In this talk, we address the long-standing problem of finding computationally efficient and provably good inventory control policies for this classical model in the presence of stochastic non-stationary (time-dependent) demands that are correlated and evolve over time. This problem arises in many domains and has many practical applications in supply chain management.

We provide the first computationally efficient policies with constant worst-case performance guarantees; that is, for any instance of the problem, the expected cost of the policy is at most twice the expected cost of an optimal policy. Our approach is based on several novel ideas: we present a new marginal cost accounting techniques for stochastic inventory models; and we use cost-balancing techniques. Our results are valid for all approaches used in the literature to model correlation of demands over time and are extendable to a broad class of classical stochastic inventory control models.

Provably near-optimal sampling-based algorithms for stochastic inventory control models

DAVID SHMOYS
Cornell University

coauthors: Retsef Levi, Robin Roundy
keywords: approximation algorithms, newsvendor problem, sample average approximation, stochastic inventory control

We consider two well-studied stochastic optimization problems that arise in the context of supply-chain models, the single-period newsvendor problem and its multiperiod extension with independent demands. Instead of assuming that the probability distributions are given explicitly, we make the more realistic assumption that the probability distribution is given by a "black box" from which independent samples can be drawn. We give the first fully polynomial randomized approximation schemes (FPRAS) for these two problems in this sampling-based model. Our work provides new insights into the power of two of the most often-used approaches to solving stochastic optimization problems, the sample average approximation (SAA) and stochastic dynamic programming. For the newsvendor problem, we show that the SAA yields a FPRAS. For the multiperiod extension with independent demands, we adapt the framework of stochastic dynamic programming to yield an approximation scheme. We believe that this is an interesting first step towards the goal of providing a mechanism for deriving efficient approximate stochastic dynamic programming methods for a wide range of multistage stochastic optimization problems.

TH1-R20 ON-LINE OPTIMIZATION
Online optimization III
organizer: Kirk Pruhs
chair: Thomas Erlebach

Online capacitated interval coloring

THOMAS ERLEBACH
University of Leicester

coauthors: Leah Epstein, Asaf Levin
keywords: competitive analysis, interval coloring, scheduling

In the online version of the capacitated interval coloring problem, requests arrive over time and each request is an interval of links on a line with an associated bandwidth. Each link of the line has a certain capacity. A set of requests can be assigned the same color if their total bandwidth on each link does not exceed the capacity of that link. The goal is to color the requests as they arrive, using a minimum number of colors. We present a constant competitive algorithm for the case where the maximum request bandwidth is at most the minimum link capacity. For the general case, we give an algorithm with logarithmic competitive ratio and, using resource augmentation, a

constant competitive algorithm. We also give a lower bound showing that constant competitive ratio cannot be achieved in the general case without resource augmentation. Finally, we also present constant competitive algorithms for a variable sized version of the problem, where the (uniform) capacity of a color is determined by the algorithm when the color is first used, and the goal is to minimize the sum of the capacities of all colors used.

Knowledge states: a tool in randomized online algorithms

WOLFGANG BEIN
University of Nevada, Las Vegas
coauthors: Lawrence Larmore, Ruediger Reischuk
keywords: online algorithms, online optimization, randomized algorithms

We introduce the novel concept of knowledge states; many well-known algorithms can be viewed as knowledge state algorithms. The knowledge state approach can be used to to construct competitive randomized online algorithms and study the tradeoff between competitiveness and memory. A knowledge state simply states conditional obligations of an adversary, by fixing a work function, and gives a distribution for the algorithm. When a knowledge state algorithm receives a request, it then calculates one or more subsequent knowledge states, together with a probability of transition to each. The algorithm then uses randomization to select one of those subsequents to be the new knowledge state. We show how this method can be used to find competitive randomized algorithms for paging and the server problem.

Search and exploration of unknown graphs

RUDOLF FLEISCHER
Fudan University
coauthors: Gerhard Trippen, Elmar Langetepe, Tom Kamphans
keywords: competitive analysis, graph exploration, graph search, search ratio

We study search and exploration problems in unknown graphs. For directed graphs, we present an exploration algorithm with competivie ratio polynomial in the defeciency of the graph. For undirected graphs, we present a general framework to transform an exploration algorithm into a search algorithm with similar search ratio.

TH2-R1 COMBINATORIAL OPTIMIZATION

Applied combinatorial optimization I

chair: Alain Prodon

Dynamic planning of trajectory system for an Blimp

FÁBIO VIDAL
Military Institute of Engeneering

coauthors: Julio Cezar Silva Neves, Paulo Rosa
keywords: ant colony meta-heuristic, trajectory planning

This paper describes a global trajectory planning system for a blimp in flights over a practically constant altitude. In this system, the objective is to find an obstacle free path between the goal and an starting point, minimizing the time expense, for the blimp, to carry such passage. For this, parameters related with the blimp kinematics for the objective function calculation was used; this function returns an estimation of the needed time to cover one determined passage. The environment is modeled using the Cell Decomposition Method to calculate the trajectory planning; and, it was developed an algorithm based on the Ant Colony Meta-heuristic, of which the results are improved through optimizations which eliminates turns around the same region and unnecessary parts of the trajectory.

Chasing leakages in water distribution networks and solving prize collecting Steiner arborescence problems

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EPFL FSB IMA ROSO

coauthors: Thomas Liebling, Scott DeNegre
keywords: branch-and-cut, Steiner tree problems, water distribution network

We consider a leakage detection system of a water distribution network which consists in equipping hydrants with hydrophones that measure and analyze sound waves, and aerial transmitters that relay messages from one hydrant to the next until a fixed central computer is reached. We study the problem of choosing an optimal set of hydrants to equip with hydrophones and/or transmitters, in the sense of maximizing weighted network coverage, subject to a budget constraint. We model this as a prize collecting Steiner arborescence problem and present some computational experiments. We use traditional and new methods for choosing the connectivity constraints (cuts) to add to the current description of the problem inside a Branch and Bound and Cut algorithm, exploiting the particular form of the instances in our model. Tests were performed on data from a Swiss urban water distribution network.

One facet from the knapsack equality problem

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coauthor: Araoz Julian
keywords: additive system, facets

This work presents a routine to generate one facet of the following Knapsack Equality Problem

$$\text{minimize } cx \text{s.t. } ax = b,\ x \in N^n,$$

where $c \in R^n$, $a \in N^n$ and $b \in N$ (R is the set of the real numbers and N is the set of the positive integer numbers).

The routine to compute the facet for the Knapsack Equality Problem is presented considering given an optimal solution of the problem $min\{cx : x \in S\}$, where $S = \{x \in R^n : ax = b, x \geq 0\}$.

TH2-R2 COMBINATORIAL OPTIMIZATION

Cutting and packing problems

organizer: Claudio Meneses
chair: Horacio Yanasse

On accelerating column generation for one-dimensional cutting stock problems and extensions

MARCOS ARENALES
Universidade de Sao Paulo

coauthor: Marco Lopes
keywords: column generation, cutting stock problem, valid inequalities

Column generation technique has been successfully used to solve large cutting stock problems since the seminal works by Gilmore and Gomory in the 60's. However, it is well-known a long-tail effect as problems become larger, that is, the objective function value decreases slowly near to an optimal solution. Recently, some dual cuts, i.e., valid inequalities, were used to successfully accelerate the convergence. In this talk we review and extend those approaches.

On solving a cutting stock problem with pattern sequencing constraints

HORACIO YANASSE
INPE

coauthor: Maria Lamosa
keywords: cutting stock problem, integrated problem, Lagrangian relaxation, pattern sequencing

Consider a cutting machine that has a limited number of compartments to store the cut items. Only items of the same type can be stored in each compartment and items can be removed from a compartment only if there are not any items of that type left to be cut. We present an integer linear programming formulation for this problem and a solution procedure based on lagrangian relaxation. By relaxing some of the constraints, the original problem decomposes in two NP-hard sub-problems: a regular cutting stock problem and a pattern sequencing problem. The first problem is solved relaxing the integrality constraints and the second is solved using an implicit enumeration procedure combined with an algorithm that solves the minimization of open stacks problem. On going developments to improve the performance of this procedure are indicated.

A heuristic method to generate productive 2D-cutting patterns for the furniture industry

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coauthor: Altamir Figueriredo
keywords: 2D cutting stock, furniture industry, n-group guillotine cutting

Defining cutting patterns to cut rectangular plates to produce smaller rectangular pieces with specified sizes and demands is an every day task in the furniture industry. The majority of the small and medium size furniture companies situated at Northwest region of the state of São Paulo-Brazil solve this problem manually. Therefore the development of special purpose computer based tools might help improving the industry efficiency. Besides the usual interest in cutting patterns that minimizes waste, there is also interest in developing cutting patterns with a small number of pieces with different widths. The goal is to generate cutting patterns that attain a compromise

between these two objectives. In this talk we present a heuristic method to generate composed cutting patterns based on n-group guillotine cutting. We compare the heuristic solution with the solution given by the traditional 2-stage Gilmory-Gomory method and the industry practice.

TH2-R3 COMBINATORIAL OPTIMIZATION

Metaheuristics and applications III

organizer: Toshihide Ibaraki
chair: Jorge Pinho de Sousa

Multiobjective tabu search for a mean-rsk static stochastic knapsack problem

JORGE PINHO DE SOUSA
University of Porto

coauthor: João Claro
keywords: multi-objective tabu search, stochastic knapsack, stochastic programming

The Static Stochastic Knapsack Problem (SSKP) is considered in the literature as an interesting problem because it has several practical applications and also because many other stochastic optimization problems have similar expected value objective functions. It falls into a broader class of Stochastic Combinatorial Optimization Problems (SCOP) with stochastic objective functions. In general these problems are extremely hard to tackle due to their discrete nature and to the difficulties in evaluating, exactly or approximately, the objective function.

The SSKP has been approached with a single expected value criterion, an approach that will in general only be appropriate when the exact same decision situation occurs repeatedly, or when the decision maker is risk neutral. When these assumptions are not met, the inclusion of a risk measure, leading to a mean-risk model, will provide an improved framework for decision support.

In this work we consider both an exact and a sample approximation to a mean-variance SSKP. We have designed an approach based on a multi-objective Tabu Search that finds good quality approximations to the mean-variance efficient set, in reasonable computational times. For some small instances, the results are compared to the exact non-dominated sets, obtained by full solution enumeration. Comprehensive computational evaluation shows the approach is generic and efficient for solving both exact and sample approximations to SCOP, with the use of the tabu list adding robustness to its performance.

Graph coloring via vector assignment in the plane

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coauthors: Takao Ono, Mutsunori Yagiura, Masaya Iwaki
keywords: circular arc graph, graph coloring, semidefinite programming, vector assignment

We propose a new heuristic algorithm for the graph coloring problem. The algorithm is inspired by the semidefinite programming relaxation adopted by Karger, Motwani and Sudan, which is equivalent to a vector assignment problem. We solve the vector assignment problem not in the n-dimensional space but in the plane. Then we find a clique cover in a circular arc graph in order to convert a vector assignment to a vertex coloring. Experiments show that the performance of our algorithm is comparable (sometimes superior) to existing heuristics such as a tabu search tuned up carefully. A nice thing of our algorithm is that it is easy to implement and that, though it is simple, we can expect competitive performance of existing heuristics without troublesome parameter tuning.

A GRASP algorithm for the 0-1 quadratic knapsack problem

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coauthors: Carlos Leonardo Póvoa, Geraldo Galdino de Paula Jr.
keywords: 0-1 quadratic knapsack, GRASP

This work considers the 0-1 Quadratic Knapsack Problem (QKP), a well known NP-Hard problem, with applications in location and finance, and suggests an $O(n^2)$ GRASP algorithm to solve it. The suggested algorithm (HGQKP) was tested using randomly generated instances with up to 500 binary variables and using a branch-and-bound solver which allows comparisons between heuristic and exact values up to 200 variables. The good outcomes observed make it suitable to be utilized as a solver in huge real problems or as a supplier of bounds for exact enumerative methods.

TH2-R4 INTEGER AND MIXED INTEGER PROGRAMMING

Stable set polytopes

organizer/chair: Volker Kaibel

A Conjecture on the stable set polytope of Claw-Free graphs

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coauthor: Arnaud Pecher
keywords: claw-free graphs, stable set polytope

The question of a polyhedral description for claw-free graphs remains one of the interesting open problems in polyhedral combinatorics. Galluccio and Sassano (1997) characterized the rank facets of claw-free graphs, but regarding their non-rank facets there was even no conjecture at hand so far. For the subclass of quasi-line graphs, Eisenbrandt et al. (2005) proved that all non-trivial facets of their stable set polytopes are clique family inequalities. However, clique family inequalities do not suffice for general claw-free graphs. Cook (1980) proved for graphs G with $\alpha(G) = 2$ and Stauffer (2005) conjectured for claw-free but not quasi-line graphs G with $\alpha(G) \geq 4$ that clique neighborhood constraints are the only non-rank facets. In fact, all the known difficult facets of claw-free graphs occur if $\alpha(G) = 3$ and so far, it was not clear how to classify them.

We show that all of them belong to only one class of inequalities, the co-spanning 1-forest constraints. It turns out that clique neighborhood constraints are special co-spanning 1-forest constraints. Combining all those results enables us to formulate our conjecture on the non-rank facets for general claw-free graphs, stating that all of them are inequalities of two types only, namely either clique family inequalities (for quasi-line graphs) or co-spanning 1-forest constraints (for all other claw-free graphs).

The stable set polytope of quasi-line graphs

PAOLO VENTURA
IASI - CNR

coauthors: Friedrich Eisenbrand, Gianpaolo Oriolo, Gautier Stauffer
keywords: circular ones matrices, convex hull, quasi-line graphs, stable set

It is a long standing open problem to find an explicit description of the stable set polytope of *claw-free graphs*. Yet more than 20 years after the discovery of a polynomial algorithm for the maximum stable set problem for claw-free graphs, there is even no conjecture at hand today.

Such a conjecture exists for the class of *quasi-line graphs*. This class of graphs is a proper superclass of line graphs and a proper subclass of claw-free graphs for which it is known that not all facets have $0/1$ normal vectors. The *Ben Rebea's conjecture* states that the stable set polytope of a quasi-line graph is completely described by *clique-family* inequalities. Chudnovsky and Seymour recently provided a decomposition result for claw-free graphs and proved that Ben Rebea's conjecture holds, if the quasi-line graph is not a *fuzzy circular interval graph*.

Here, we give a proof of Ben Rebea's conjecture by showing that it also holds for fuzzy circular interval graphs. Our result builds upon an algorithm of Bartholdi, Orlin and Ratliff which is concerned with integer programs defined by circular ones matrices.

The stable set problem on fuzzy circular interval graphs

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Universita' Tor Vergata

coauthors: Ugo Pietropaoli, Gautier Stauffer
keywords: claw-free graphs, matching algorithms, stable set

The only polynomial-time algorithm for the maximum weighted stable set problem on claw-free graphs was given by Minty in the 80's (and was recently revised by Nakamura and Tamura). Minty's algorithm deeply relies on Edmonds' matching algorithm. In 2004 Chudnovsky and Seymour proved a decomposition result for claw-free graphs, showing that a claw-free graph (with stability number greater than three) is either a fuzzy circular interval graph or the composition of strips. In this talk, we outline a new algorithm for the weighted stable set problem on fuzzy circular interval graphs. We build upon an algorithm for the same problem on circular interval graphs, which is a simple consequence of a recent result by Eisenbrand, Oriolo, Stauffer and Ventura, concering with the stable set polytope of quasi-line graphs. The new algorithm is based on a characterization of fuzzy circular interval graphs and does not use matching techniques. We also show a robust algorithm for recognizing fuzzy circular interval graphs (with stability number greater than three).

TH2-R5 — INTEGER AND MIXED INTEGER PROGRAMMING

Decomposition methods in integer programming

organizer: Matthew Galati
chair: Armin Fügenschuh

Solving the uncapacitated facility location problem by semi-Lagrangian relaxation

CÉSAR BELTRÁN-ROYO
Rey Juan Carlos University

coauthors: Jean-Philippe Vial, Antonio Alonso-Ayuso
keywords: combinatorial optimization, Lagrangian relaxation, location theory, UFL

We propose to solve the Uncapacitated Facility Location (UFL) problem by Semi-Lagrangian Relaxation (SLR). This method has been successfully used to solve large-scale instances of the p-median problem. The key point of the SLR method is that it drastically reduces the size of the UFL instance. The reduced instances are still NP-hard but they turn out to be much easier than the original problem and can be solved by a general purpose MIP solver like CPLEX. Furthermore, in some cases the reduced instance decomposes into smaller (NP-hard) combinatorial subproblems, which considerably eases the solution process. In the SLR method two main tasks have to be performed: First, solve the combinatorial subproblems and second, update the Lagrange multipliers. In this paper, we propose a new updating procedure. In our implementation, the combinatorial subproblems are efficiently solved by CPLEX. Computational results for large-scale UFL instances are reported.

Application of multiple Dantzig-Wolfe decomposition to a lot sizing problem

CARINA PIMENTEL
University of Minho

coauthors: Filipe Alvelos, José Valério de Carvalho
keywords: Dantzig-Wolfe decomposition, mixed-integer programming, production planning

The Multi-Item Capacitated Lot Sizing Problem (MICLS) belongs to the medium-term production planning decisions and aims at determining the quantity (or lots sizes) and timing of production for several products over a number of finite production periods so as to satisfy a known demand for each product in each period, while respecting a known capacity in each period and minimizing the overall costs involved. In this presentation, we apply multiple Dantzig-Wolfe decomposition to a classical mixed integer programming model for the MICLS. In this decomposition, two types of subproblems are defined, being one associated with products and the other associated with periods. The linear relaxation of this decomposition leads to better lower bounds than the ones obtained when using decomposition methods with only one type of subproblem. We combine this column generation approach with branch-and-bound to obtain optimal integer solutions. We present and discuss some computational results.

TH2-R6 — LOGISTICS AND TRANSPORTATION

Traffic and routing I

chair: Haldun Sural

A hybrid-bundle decomposition method and its application to the traffic assignment problem

PABLO LOTITO
PLADEMA - IMBL

coauthor: Claudia Sagastizabal
keywords: bundle methods, traffic equilibrium

The traffic assignment problem consists in finding an equilibrium state, over a network, defined in terms of arc travel costs that depend on the arc flows. Mathematically, it is a convex multi-flow problem of large scale. To obtain a good reduction of the objective function the Frank-Wolfe method based on arc flows can be applied. When more precision is needed other methodology must be considered like decomposition or column generation techniques based on route flows. We propose a new decomposition technique derived from coupling a hybrid projection-proximal point algorithm with a bundle method. We prove convergence of the resulting algorithm and report some preliminary numerical experience comparing our method with Frank-Wolfe, a column generation algorithm called DSD

and other algorithms based on other decomposition techniques.

Modelling and optimization of traffic

SERGEY SHISHKIN
United Technologies Corp., Research Center

coauthors: Robert LaBarre, Yiqing Lin, Troy Smith
keywords: Markov models, mixed-integer programming, traffic modelling, traffic optimization

Traffic modelling and control have many facets: vehicle and pedestrian traffic regulation and prediction; city evacuation; design and evacuation of airplanes, ships, buildings and other structures. These and other problems can be presented in the form of modelling and control of movement of discrete agents on a graph. Currently there exist several well-developed agent-based models of pedestrian movement and car traffic; however, they are able to process only a single scenario at a time, hence requiring a computationally expensive Monte-Carlo framework for simulation and optimization. In particular, agent-based models are unsuitable for on-line control and estimation.

In this work, we consider the probability distribution function (PDF) of the agents location throughout the simulation environment. A dynamic nonlinear model is developed for recurrent estimation of this PDF. On-line control and estimation algorithms of evacuation are then developed.

Coordinated inventory control and vehicle routing: Lagrangian relaxation based solution approach

HALDUN SURAL
Middle East Technical University, Ankara

coauthor: Oguz Solyali
keywords: inventory routing problem, Lagrangian relaxation, order-up-to level inventory policy

We consider a vendor managed system where a single supplier (vendor) delivers a product to multiple retailers over a finite time horizon. Supplier decides on the order size of retailers in each period and delivers them via a fleet of vehicles having limited capacity. Each retailer has dynamic deterministic demands and its inventory is controlled by order-up-to level inventory policy. The coordinated problem is to simultaneously determine the quantity of product to order to the supplier, retailers to be visited, the quantity of product to be delivered to retailers and routes of vehicles in each period so as to minimize system-wide costs. We present a mathematical model and a Lagrangian relaxation based solution procedure that provides upper and lower bounds to the problem. We implement the solution procedure on test instances and present the results. Computational study shows that fairly good feasible solutions are found in reasonable time.

TH2-R7 NETWORKS
Multi-task in networks
chair: Matthieu Chardy

Multiline addressing by network flow

ANDREAS KARRENBAUER
Max Planck Institut Informatik

coauthors: Friedrich Eisenbrand, Martin Skutella, Chihao Xu
keywords: network optimization, OLED display controllers

We consider an optimization problem arising in the design of controllers for OLED displays. Our objective is to minimize the current amplitude which has a direct impact on the lifetime of such a display. Modeling the problem in mathematical terms yields a class of network flow problems where the arcs are partitioned into groups and only the arc with the highest flow in each group is charged. We present an equivalent formulation as a covering (integer) linear program with an exponential number of constraints. We develop routines that solve the corresponding separation problem in linear time. Moreover, we identify a subset of the constraints yielding good starting solutions computable in linear time. We propose (fully) combinatorial approximation heuristics suitable for being implemented in the hardware of a control device that drives an OLED display. In practice, we find approximate solutions very close to the optimum in real-time.

Design of an optimization model of the time and cost of execution for mixed projects

JOSE GREGORIO MEDINA CEPEDA
Universidad La Salle
keywords: decision theory, mixed project, network models, project management

The network models can be used to help planning of complex projects that involve many activities. If the duration of each activity is known, it can be used the critical path method (CPM) to determine the time required to carry out the project. If the duration of each activity is not known, it can be used the technical PERT (Program Evaluation and Review Technique) to estimate the probability that the project ends in a specific date. It would be important construct a theory that integrates these two behaviors in a optimization model that allows to evaluate time and cost of "mixed projects ".

Cooperative stochastic games for multi-service networks cost allocation

MATTHIEU CHARDY
France Telecom R&D-division
keywords: cooperative game theory, cost allocation, lexicographical optimisation

The telecommunications world is presently facing two major evolutions: the multiplication of services and the convergence of networks. Moreover, for numerous reasons, services profits and networks building costs have become uncertain. This presentation tackles the problem of multi-service network cost allocation under uncertainty: the key question is to determine what part of the global uncertain cost of the multi-service network each service must be charged. This problem has been modeled through a cooperative stochastic game. A mono-criteria stochastic nucleolus has been analysed and a new bi-criteria nucleolus is proposed. Algorithms based on lexical optimisation have been developped for both solution concepts: algorithmic issues and numerical results will be presented.

TH2-R8 LEONID KHACHIYAN MEMORIAL
Leonid Khachiyan memorial II
organizer/chair: Farid Alizadeh

Generating k-connected spanning subgraphs

GABOR RUDOLF
RUTCOR - Rutgers University

coauthors: Kazuhisa Makino, Konrad Borys, Endre Boros, Khaled Elbassioni, Vladimir Gurvich
keywords: edge connectivity, enumeration, generation, vertex connectivity

Many efficient methods of network reliability calculations depend on the generation of minimal edge sets of graphs which provide some desired level of connectivity. In this talk we present an algorithm which generates minimal k-vertex connected subgraphs of a given graph in incremental polynomial time for any given k, and an analogous result for k-edge connected graphs.

Nondisjoint decompositions of monotone Boolean functions

JAN BIOCH
Erasmus University Rotterdam

keywords: decomposition of Boolean functions

We discuss nondisjoint decompositions of a monotone Boolean function f of the form $f = F(A,B,g(B,C))$, where A,B and C are disjoint sets of variables of f. If B is the empty set then the theory of decompositions, studied in game theory, reliability theory etc is well understood. However, in the general case little or nothing is known. We present some results on the lattice of components g of f for a fixed partition A,B and C. and on the properties of the so called modular (bound sets) of f.

TH2-R9 OPTIMIZATION IN ENERGY SYSTEMS

Parallel processing in stochastic energy models

organizer/chair: Luiz F. Legey

Distributed processing in multistage stochastic optimization

NORA CAMPODONICO
PSR, Brazil

coauthors: Luiz Maurício Thomé, Silvio Binato, Maria de Lujan Latorre
keywords: distributed processing, hydro scheduling, multi-stage stochastic programming, stochastic dynamic programming

Stochastic dual dynamic programming (SDDP) is an extension of multistage stochastic Benders decomposition that has been successfully applied to the scheduling of large-scale hydroelectric systems in more than thirty countries. Similar to other dynamic programming-like techniques, SDDP decomposes the multistage problem into several one-stage scheduling problems which can be solved in parallel. This paper describes the development of a parallel version of SDDP and its implementation on a distributed processing environment composed of standard PCs connected by a LAN. The computational performance is illustrated with scheduling applications of the Brazilian system, composed of 150 hydroelectric reservoirs. It is shown that speedup is almost linear with the number of the processors, up to twenty PCs. Extensions of the parallel SDDP technique are discussed, such as exploiting the asynchronous "forward" and "backward" steps of the algorithm

Aggregating energy scenarios using the SATyrus neuro-symbolic tool

EDUARDO FERREIRA DA SILVA
Centro de Analises de Sistemas Navais - CASNAV

coauthors: Priscila Lima, Ramon Diacovo, Felipe França
keywords: generation expansion planning, neuro-symbolic processing, satisfiability

The stochastic problems in electric power industry are known to be large-scale and hard to solve. In addition, they often suffer from the curse of dimensionality when it is necessary to increase the number of scenarios to improve the solution quality. For example, the Capacity Expansion Planning fits in this profile. This work presents a new approach to deal with scenario aggregation and detailing using a neuro-symbolic architecture named SATyurs. This tool is oriented to solve optimization problems via a satisfiability-based mapping of their specifications into sets of pseudo-Boolean constraints, which are then translated into a single energy function representing the state space of solutions of the target problem. Besides providing a declarative modeling language, SATyrus allows one to easily extend problem formulations in order to accommodate not only new constraints but also merge the original formulation with new subproblems. For instance, apart from including new scenarios, one can combine problems of different natures, such as medium and short term models or generation expansion and distribution ones, into a single model.

Parallel processing application to a hydrothermal stochastic optimization model

DJALMA FALCÃO
COPPE/UFRJ

keywords: hydrothermal systems, newave, parallel processing, stochastic dynamic programming

The NEWAVE model is a production grade computer program developed by the Electric Power Research Center (CEPEL) and used for long range energetic operational planning and expansion planning studies in the Brazilian electric power system. The NEWAVE model is also used to compute the water values that form the basis for determining the spot price in the electric power market. The solution methodology used is Stochastic Dual Dynamic Programming (SDDP). In several applications, the NEWAVE model requires long execution time (several hours) which introduce difficulties for interactive studies or when a decision has to be made in a short period. The SDDP implementation used in the NEWAVE model consists of forward and backward processes whose main computational burden is the solution of a large number of independent linear programming problems. This inherently parallel structure of the solution method is exploited in the application reported in this talk. The talk reports also on the preliminary results obtained in tests of the developed parallel version of the NEWAVE model in a cluster of PCs.

TH2-R10 ROBUST OPTIMIZATION

Robust opt in networks and portfolio construction

organizer: Raphael Hauser
chair: eha

Network design under polyhedral traffic uncertainty

EDOARDO AMALDI
DEI, Politecnico di Milano

coauthors: Pietro Belotti, Mustafa Pinar
keywords: branch-and-price, multicommodity network design, robust optimization

We consider the problem of designing a minimum cost network to serve a set of point-to-point traffic demands. In classical approaches the vector of traffic demands is assumed to be known a priori and capacity is installed/reserved so as to support this single traffic vector, but in practice the network must often be able to support a set of possible (non-simultaneous) traffic vectors.

In this work we consider the case where demands have to be served on a single path from source to destination, and we assume that the traffic demand vector lies in a bounded, non-empty polyhedron or a union of polyhedra described by a set of linear inequalities. This robust version of the multicommodity network design problem with a polyhedral traffic uncertainty model arises for example in telecommunications (e.g., Virtual Private Networks).

We propose a compact, mixed integer linear programming formulation to solve this problem. In order to deal with large network instances, we present a Branch-and-Price method based on a path formulation. Computational tests on a collection of real-world networks indicate that our method is effective in solving network instances with up to 300 nodes, for different realizations of the traffic uncertainty model.

Relative robust optimization

REHA TUTUNCU
Goldman Sachs Asset Management

coauthors: Raphael Hauser, Vijay Krishnamurthy
keywords: robust optimization, uncertainty

Most robust optimization approaches existing in the literature use the worst-case objective value as the comparison metric among alternative sets of decisions. For such formulations, extreme scenarios in the uncertainty set may have an undue influence on the final decisions. We consider alternative robust optimization formulations that measure robustness in a relative sense, with respect to the best possible decision in each scenario. We argue that these models may represent the modeler's risk-aversion more accurately. We show that for many important uncertainty structures for quadratic programming and other optimization problems, the resulting relative robustness formulation can be reduced to a (or a series of) single-level deterministic optimization problems that can be solved using conic optimization methods.

Robust portfolio optimization - Extreme case optimization

DENIS ZUEV
Oxford University

coauthor: Raphael Hauser
keywords: portfolio optimization, robust optimization

Financial portfolio stability (weights, portfolio mean and variance) is very sensible to inaccurate parameter estimation. Adjusting the covariance matrix subject to uncertainty in an appropriate way, we can significantly reduce the upper bounds on the portfolio sensitivity. We will optimize smallest eigenvalues in nonlinear setting and discuss further issues in optimization and modelling.

TH2-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Geometric approaches in LP and cone programming

chair: Jun-ya Gotoh

Geometrical method of representation of linear inequality system and applications to linear programming

KONSTANTIN KOBYLKIN
Mathematics and Mechanics Institute

keywords: linear inequality systems, linear programming

To a system of m linear inequalities

$$(c_j,x) \geq b_j, j = 1,\ldots,m,$$

where $c_j \in \mathbf{R}^n$ and $b_j \in \mathbf{R}\backslash\{0\}$, we put into correspondence the system $\mathcal{D}^* = \mathcal{A} \cup \mathcal{B}$ of $m+1$ points in $\mathbf{R}^n$ which is defined by the formulas $\mathcal{A} = \left\{\frac{c_j}{b_j} : b_j > 0\right\}$, $\mathcal{B} = \left\{\frac{c_j}{b_j} : b_j < 0\right\} \cup \{0\}$. A vector $x_0 \in \mathbf{R}^n$ satisfies the original system iff the hyperplane $(x_0,x) = 1$ separates the sets $\mathcal{A}$ and $\mathcal{B}$.

Semishadow of the convex hull $A = \operatorname{co}\mathcal{A}$ with respect to the convex hull $B = \operatorname{co}\mathcal{B}$ is the set $\mathcal{S}(A,B) = \bigcup\{(1-\lambda)x + \lambda A : \lambda \geq 1, x \in B\} = \operatorname{co}\mathcal{A} + \operatorname{cone}(\mathcal{A}-\mathcal{B})$.

Consider the linear program

$$L : \min (c,x) \text{ subject to } (c_j,x) \geq b_j,$$

where $c_j \in \mathbf{R}^n$, $c \in \mathbf{R}^n\backslash\{0\}$, $b_j \in \mathbf{R}\backslash\{0\}$, $j = 1,\ldots,m$. Let $\mathbf{r}$ be a ray with the origin 0 and a direction c, $\bar{\alpha}$ be the optimum of the program; cases $\bar{\alpha} = \pm\infty$ are possible. Consider another problem which is geometrically dual to L, which is

$$\widetilde{L} : \text{ find } \bar{c} \in \mathbf{r} \cap \mathcal{S}(A,B) \text{ nearest to } 0$$

$$\text{when } \bar{\alpha} > 0, \text{ and } \bar{c} \in -\mathbf{r} \cap \mathcal{S}(B,A)$$

$$\text{farthest from } 0 \text{ when } \bar{\alpha} < 0.$$

If $\bar{\alpha} = 0$ then we assume that $\bar{c} = +\infty \cdot c$ (the point "infinitely remoted in the direction c"). Also, when $\bar{c} \neq 0$, it is necessary to find hyperplane which separates the sets $\mathcal{A}$ and $\mathcal{B}$ contains the point $\bar{c}$ and does not pass through 0. The point $\bar{c} = \frac{c}{\bar{\alpha}}$ and the corresponding separating hyperplane are called a solution of the problem $\widetilde{L}$.

Theorem. *The linear program L is solvable and $\bar{x}$ is a solution of L iff the point $\bar{c} \neq 0$ and hyperplane $(\bar{x},x) = 1$ are solutions of the problem $\widetilde{L}$.*

Orthogonally normalized simplex

MARCOS LINS
Universidade Federal do Rio de Janeiro

coauthor: Angela Cristina Silva
keywords: Klee and Minty, simplex algorithm

In this work, the Orthogonally Normalized Simplex (ON-Simplex) method is proposed to be used when one primal or dual feasible solution is available. This method is based on a geometrical conception of the RHS coefficients as orthogonal distances to the constraint hyperplanes. Rather than the most negative coefficient, the farthest distance to unfeasible hyperplanes, at each iteration, can be used as a criterion to choose the next vertex, accelerating the algorithm. An impressive demonstration is provided, given that the ON-Simplex can solve the class of problems posed by Klee and Minty in only one iteration. Besides, the method emphasizes that the path followed by the classical Simplex is not scale-invariant, and succeeds in overcoming this drawback. Extended developments are expected, as the method provides a generalization of the ratio test and a symmetrical treatment for variables entering and leaving the canonical basis.

Conditional minimum volume ellipsoid and its application to multiclass classification

JUN-YA GOTOH
Graduate School of Systems & Information Engineering, University of Tsukuba

coauthor: Akiko Takeda
keywords: conditional value-at-risk, data mining, minimum volume covering ellipsoid, multiclass classification

In this study, we present a new formulation for constructing an ellipsoid which includes the minimum volume covering ellipsoid (MVCE) as a special case. The proposed ellipsoid construction is formulated as a convex optimization by applying the CVaR minimization technique of Rockafellar and Uryasev (2002), and an interior point algorithm for the solution can be developed by modifying the algorithm of Sun and Freund (2004) for the MVCE. Also, the maximization of the normal likelihood function can be characterized in the context of the minimum volume ellipsoid computation. Potential applicability of the new ellipsoid construction is discussed through multiclass classification (discrimination) problem. Numerical results are given, showing the nice computational efficiency of the interior point algorithm and the capability of the proposed generalization.

TH2-R12 NONLINEAR PROGRAMMING
Mixed integer nonlinear programming
organizer/chair: Andreas Waechter

An MINLP solution method for a water-network optimization problem

JON LEE
IBM Research

coauthors: Claudia D'Ambrosio, Cristiana Bragalli, Andrea Lodi, Paolo Toth
keywords: mixed-integer nonlinear programming

We discuss a formulation and solution method for a water-network design problem using mixed-integer nonlinear programming (MINLP). The problem is to decide on the diameters of the pipes, chosen from a discrete set of available pipes, to support demand at the network junctions. A primary source of nonnliearity is related to the Hazen-Williams friction loss equation. By paying careful attention to the modeling and using available MINLP software, we are able to find very good solutions to problem instances from the literature as well as some real-world data.

A new open-source solver for MINLP

PIERRE BONAMI
Carnegie Mellon University

keywords: branch-and-cut, mixed-integer nonlinear programming, outer approximation

We present our work related to developing Bonmin, an open-source solver for Mixed Integer NonLinear Programming. Bonmin has been developed in a joint effort by researchers both at IBM and Carnegie Mellon University. It implements three exact algorithms for solving MINLPs which exhibits a convex continuous relaxation: a branch-and-bound, an Outer-Approximation decomposition and an hybrid method.

Here, we focus on the hybrid. This algorithm is a flexible branch-and-cut where linear and nonlinear continuous relaxations are solved alternatively. The linear relaxations are obtained by considering outer approximations of the constraints of the problem. These relaxation are improved by solving NLPs. One of the goals is to try to build a good enough outer approximation (which can be solved very efficiently) while solving only a limited number of NLPs.

We present computational result comparing this algorithm to classical algorithms (as implemented both in commercial solvers and in our code).

A feasibility pump for mixed integer nonlinear programming

FRANCOIS MARGOT
Tepper School of Business, Carnegie Mellon University

coauthors: Pierre Bonami, Gerard Cornuejols, Andrea Lodi
keywords: heuristics, MINLP

We present a heuristic for solving Mixed Integer Nonlinear Programs (MINLP) related to the Feasibility Pump algorithm of Fischetti et al. for Mixed Integer Linear Programs (MILPs).

We construct two sequences of points. The points in the first sequence, obtained by solving Non Linear Programs, satisfy the constraints except the integrality conditions. The points in the second sequence, obtained by solving MILPs, satisfy the integrality conditions, but might be infeasible. If the integer variables are bounded and the continuous relaxation of the feasible set is convex, the algorithm either finds a feasible solution or proves that none exists in a finite number of iterations.

We present computational results on a large set of convex and non convex MINLPs showing the effectiveness of the method. We also report result for the integration of the Feasibility Pump within an Outer Approximation algorithm for MINLP.

TH2-R13 NONLINEAR PROGRAMMING
Nonlinear integer programming applications
chair: José Arica

Pseudo-boolean regression

TIBERIUS BONATES
RUTCOR – Rutgers University

coauthor: Peter Hammer
keywords: column generation, pseudo-boolean function, regression

In numerous problems of data analysis a set Ω of binary n-vectors is given, along with the real values of an unknown pseudo-Boolean "target" function f. The problem of finding a best linear L_1 approximation of f can be solved by linear programming. It is proved that a better approximation of f can be found as a linear combination of monomials of bounded degree – a problem solvable by an iterated integer programming technique. In the iterative process additional monomials are introduced gradually into the expression of the approximant with the aim of compensating for gaps. It is shown on a series of publicly available benchmark problems that the correlation between the values of the proposed approximant and those of f in Ω is close to 100% on each one of the analyzed datasets. We also present results of real-life applications to biomedical datasets analyzed in collaboration with medical researchers.

Jetty scheduling optimal control models

FABIO FAGUNDEZ
COPPE/PESC/UFRJ

coauthor: João Lauro Dornelles Facó
keywords: nonlinear programming, optimal control, scheduling

Crude oil and derivatives jetty scheduling problems are modeled by Optimal Control with nonlinear state equations and the use of flow rates as control variables. It is shown that the Optimal Control formulation is able to represent the same problems as traditional MIP formulations do, but with the differences of employing only continuous variables and in lesser number. It is shown that trigonometric equations can model certain scheduling decisions in substitution of binary variables. All variables are submitted to lower and upper bounds. Difficulties in the numerical solution of these models are overcome by using an efficient Nonlinear Programming method - Generalized Reduced Gradient (GRG). Test cases are discussed.

A planning model for offshore natural gas transmission

JOSÉ ARICA
Universidade Estadual do Norte Fluminense

coauthors: Edson K. Iamashita, Frederico Galaxe
keywords: genetic algorithms, natural gas, pipelines

This work aims an approach to solve complex integrated offshore gas balance planning problems, definning the best compression and transmission strategy for a system with a large number of platforms or compression units interconnected between themselves and with the delivery points through a complex gas pipeline network (the considered network can be a cycled one). The problem is formulated as a large quadratic mixed-integer problem, where nonconvexity is presented. Because the complexity of the problem, a genetic meta-heuristic techniques is proposed for solving it. Several experiments are presented at the end of this work. The results show that the performance of our approach is good, being genetic results better than the branch and bound algorithm given by LINGO (as expected). The model could be used for sizing and optimization designs of gas pipeline networks, as well as for the gas balance planning of an existing network seeking profit maximization.

TH2-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Topics in Convex Programming

organizer: Osman Guler
chair: Raphael Hauser

A new proof of the s-lemma

RAPHAEL HAUSER
Oxford University

keywords: robust optimization, s-lemma

Yakubovich's s-Lemma characterises conditions under which a quadratic inequality is a consequence of another quadratic inequality and provides an important technical tool in robust optimisation. In this talk we present a new proof based on a topological approach that can be adapted to deriving various generalisations of the s-Lemma.

Stochastic equilibrium and learning in traffic networks

ROBERTO COMINETTI
Universidad de Chile

keywords: congested networks, learning dynamics, stochastic equilibrium, variational formulation

We describe a model for stochastic traffic equilibrium in congested networks based on stochastic dynamic programming. In this framework passengers move towards their destinations by a sequential process of arc selection based on a discrete choice procedure at every intermediate node in their trip. Route selection is the outcome of this sequential process while network flows correspond to the invariant measures of the underlying Markov chains.

A variational formulation is exhibited which takes the form of a smooth strongly convex unconstrained mathematical program of low-dimension and leads to numerical procedures that can be effectively solved for real size networks by using a variant of the well known Method of Successive Averages (MSA). The latter is interpreted as a variable metric gradient scheme for which global convergence is established by adapting the analysis of Riemannian gradient flows.

We shall also discuss some preliminary work on the convergence of an adaptive learning process for traveller behavior. We show the existence of a critical value for the parameters, below which the dynamics converge to the unique symmetric Nash equilibrium. At this critical value a bifurcation occurs which turns the symmetric equilibrium into an unstable state and then convergence occurs towards an asymmetric equilibrium.

Efficient, first-order methods for convex programming

FILIZ GURTUNA
UMBC

coauthor: Osman Guler
keywords: convex programming, differential equations, first-order methods

Convex programming occupies a central place within mathematical programming due to a well-developed duality theory and its computational tractibility: it is possible to obtain global convergence rates. For large scale problems, first-order methods are especially important since the use of second-order information becomes prohibitive due to memory requirements. After some pioneering work by Nemirovski and Yudin, Nesterov discovered an especially simple algorithm in 1983 for minimizing a convex function with Lipschitz continuous gradient, optimal in the oracle model of Nemirovski-Yudin. Although this algorithm and others proposed later by Nesterov are fairly simple in appearance and have close resemblances to gradient and conjugate gradient methods, their inner workings are not well understood. A better undertanding of these algorithms is important for many reasons, intrinsic/extrinsic, for extending them to larger classes of problems, for example. We propose to analyze these algorithms by relating them to some evolution differential equations which can be considered their continuous versions.

TH2-R15 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Computational methods

chair: Adilson Elias Xavier

Solution of quantile regression problems by means of method ACCPM

HÉCTOR ANDRES OSPINA
Cundinamarca Sabana University

keywords: ACCPM, linear programming, nosmooth optimization, quantile regression

This work presents the solution of problems of quantile regression by means of Analytic Center Cutting Plane Method (ACCPM), because the problem of quantile regression is nonsmooth. In addition, the obtained results are compared with the solution of this problem by means of their folrmulación like a problem of linear programming by means of sotfware Gams and R.

New computacional results of the hyperbolic smoothing clustering method

LUIZ CARLOS DE SOUZA
Petróleo Brasileiro SA - PETROBRAS

coauthor: Adilson Elias Xavier
keywords: cluster analysis, min-sum-min problems, nondifferentiable programming, pattern recognition

The minimum sum-of-squares clustering problem is considered. The mathematical modeling of this problem leads to a min-sum-min formulation which, in addition to its intrinsic bi-level nature, has the significant characteristic of being strongly non-differentiable. In order to overcome these difficulties, the resolution method proposed adopts a smoothing strategy using a special completely differentiable class function. The final solution is obtained by solving a sequence of low dimension differentiable unconstrained optimization sub-problems which gradually approach the original problem. The use of this technique, called Hyperbolic Smoothing, allows the main difficulties presented by the original problem to be overcome. For the purpose of illustrating both the reliability and the efficiency of the method, a broad set of computational experiments was performed making use of traditional test problems described in the literature.

Variance reduction in Monte Carlo simulation by quadratic programming

RALF WERNER
Hypo Real Estate

keywords: Monte Carlo simulation, quadratic programming, variance reduction

In finance most pricing approaches rely on the concept of risk neutral valuation. For this valuation, Monte Carlo simulation is usually the method of choice. The more complex the underlying dynamics of the Monte Carlo simulation get, the harder it is to reduce simulation variance, as standard variance reduction techniques are no longer applicable. A novel idea of improving accuracy is to manipulate the probabilities of each scenario to achieve better fits to so-called martingale tests and thus to reduce variance. We will show how this manipulation can be easily done by solving a large-scale dense quadratic program. First numerical tests support the effectiveness of the approach.

TH2-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES
Merit function and penalty techniques
chair: Barbara Stefania Panicucci

An algorithm for generalized bilevel programming problems using exact pennalties

ESTEVE CODINA
Universitat Politècnica de Catalunya

coauthor: Lidia Montero
keywords: bilevel programming, gap functions, variational inequalities

The use of gap functions for variational inequalities with a uniform lower bound is a way to reformulate a generalized bilevel programming problem (GBLP) using exact penalizations. In this paper an algorithm is presented for the GBLP guaranteeing that a stationary point is found. The algorithm is based on successive approximations to an exact penalty reformulation of the GBLP using a differentiable gap function with uniform lower bound for the lower level variational inequality. The algorithm requires only to find an approximations to stationary points of an associated inexact penalty problem. The algorithm can be adapted advantageously to solve large models arising in engineering and some GBLP models used in transportation applications is presented illustrating the application of the proposed algorithm, using in some instances the partial linearization algorithm for nonlinear programming to solve some associated subproblems.

On gap functions for generalized variational inequalities

BARBARA STEFANIA PANICUCCI
Department of Applied Mathematics "U. Dini"

coauthors: Massimo Pappalardo, Mauro Passacantando
keywords: gap functions, generalized variational inequalities

Our aim is to consider generalized variational inequality (GVI) problem from both theoretical and algorithmic point of view. We also propose a class of differentiable gap functions for GVI, which is a natural extension of a well known class of gap functions for variational inequalities (VI). Moreover, we consider a descent method for solving a GVI under some monotonicity assumptions on the set valued operator.

Convergence of augmented Lagrangian methods with arbitrary lower-level

MARIA LAURA SCHUVERDT
UNICAMP

coauthors: José Mario Martínez, Roberto Andreani, Birgin Ernesto
keywords: augmented Lagrangian, nonlinear programming

We define Augmented Lagrangian Methods of Powell-Hestenes-Rockafellar type for minimizing nonlinear functions with equality and inequality constraints, with arbitrary additional constraints that are kept as restrictions of the subproblems. The Augmented Lagrangian methods are safeguarded in the sense that Lagrange multiplier approximations are forced to be bounded. Reasons for this safeguard are given that involve preservation of the global optimization properties of the classical External Penalty methods. We prove feasibility and optimality results. The feasibility results says that limit point of the algorithm are feasible or are stationary points of an infeasibility measure. The feasibility results say that feasible limit points are KKT or do not satisfy the Constant Positive Linear Dependence (CPLD) constraint qualification. Finally, under stronger conditions, we prove boundedness of the penalty parameters.

TH2-R18 GRAPHS AND MATROIDS
Colorings, factors and paths
organizer/chair: Yoshiko Wakabayashi

Some remarks about factors

MARTIN MATAMALA
Universidad de Chile

coauthor: Jose R. Correa
keywords: factors

A $(g,f)-$factor of a graph $G=(V,E)$ is an spanning subgraph of G with edge set F such that for all $v \in V$, $g(v) \leq \deg_F(v) \leq f(v)$. In 1970, Lovasz gave a necessary and sufficient condition for the existence of a $(g,f)-$factor. In this paper

we extend a result of Kano and Saito who showed that if $g(v) < \lambda \deg(v) < f(v)$ for any $\lambda \in [0,1]$, then a $(g,f)-$factor always exist, to the case of edge-weighted graphs. In addition, we use results of Anstee to provide new necessary and sufficient conditions for the existence of a $(g,f)-$factor. Finally, we give simplified direct proofs for a number of results about graph factors.

Non-separating paths in 4-connected graphs

ORLANDO LEE
IC-UNICAMP

coauthors: Ken Kawarabayashi, Xingxing Yu
keywords: graph theory

Let G be a 4-connected graph and let u and v be vertices in G. We show that either G has a path from u to v such that $G - V(P)$ is 2-connected or G is a double wheel with center $\{u,v\}$. This result is related to a conjecture by Lovasz.

Weighted coloring on graphs with bounded tree-width

CLAUDIA SALES
Fundação Cearense de Pesquisa e Cultura

coauthor: Bruce Reed
keywords: bounded tree-width, tree decomposition, weighted coloring

Let $G = (V,E)$ be a graph and w an assignment of non-negative weights to the vertices of G. The cost of a proper coloring C of G, denoted by w_C is the sum of the weights of the color classes $\{V_1,\ldots,V_r\}$ of C, where the weight of a color class V_i is $\max_{v\in V_i}\{w(v)\}$. The weighted chromatic number of G, denoted by $\sigma(G)$ is the minimum w_C among all the colorings C of G. We denote by $\chi_w(G)$ the number of colors used in an optimal weighted coloring of G. This problem was introduced by D.J. Guan and X. Zhu who proved that if G has a bounded tree width, for a fixed integer r and a fixed number q, then it can be decided in polynomial time if G has a r-coloring C such that $w_C \leq q$. In a join work with Bruce Reed, we proved that if G has a bounded tree width ω, then $\chi_w(G)$ is $O(\omega \lg n)$. In this talk, we will discuss these results.

TH2-R19 PRODUCTION AND SCHEDULING

Stochastic and online machine scheduling

organizer/chair: Marc Uetz

Approximation algorithms for deadline-constrained stochastic scheduling problems

BRIAN DEAN
Clemson University

coauthors: Michel Goemans, Jan Vondrak
keywords: approximation algorithms, stochastic scheduling

We study a broad class of stochastic scheduling problems with deadline constraints. Every job has a value, a random processing time (known in advance only as a probability distribution), and a deadline, and we only learn the true "instantiated" processing time of a job after it finishes processing on some machine. Our goal is to construct a scheduling policy that maximizes the expected value of jobs that are successfully scheduled by their deadlines. All of the problem variants we consider are at least NP-hard, and we show for each of them how to compute a policy whose expected value approximates that of an optimal policy to within a small constant factor.

Models and algorithms for stochastic online scheduling

NICOLE MEGOW
TU Berlin

coauthors: Tjark Vredeveld, Marc Uetz
keywords: online optimization, scheduling, stochastic dynamic programming, total weighted completion time

We consider a model for scheduling under uncertainty. In this model, we combine the main characteristics of online and stochastic scheduling in a simple and natural way. Job processing times are assumed to be stochastic, but in contrast to traditional stochastic scheduling models, we assume that jobs arrive online, and there is no knowledge about the jobs that will arrive in the future. The model incorporates both, stochastic scheduling and online scheduling as a special case. The particular setting we consider is non-preemptive parallel machine scheduling, with the objective to minimize the total weighted completion times of jobs. We analyze simple, combinatorial online scheduling policies for that model, and derive performance guarantees that match performance guarantees previously known for stochastic and online parallel machine scheduling, respectively. For processing times that follow NBUE distributions, we improve upon previously best known performance bounds from stochastic scheduling, even though we consider a more general setting.

Approximation results for preemptive stochastic online scheduling

TJARK VREDEVELD
Maastricht University

coauthor: Nicole Megow
keywords: approximation guarantees, online scheduling, preemptive scheduling, stochastic dynamic programming

We present first constant performance guarantees for preemptive stochastic scheduling to minimize the sum of weighted completion times. For scheduling jobs with release dates on identical parallel machines we derive policies with a guaranteed performance ratio of 2 which matches the currently best known result for the corresponding deterministic online problem.

Our policies apply to the recently introduced stochastic online scheduling model in which jobs arrive online over time. In contrast to the previously considered nonpreemptive setting, our preemptive policies extensively utilize information on processing time distributions other than the first (and second) moments. In order to derive our results we introduce a new nontrivial lower bound on the expected value of an unknown optimal policy that we derive from an optimal policy for the basic problem on a single machine without release dates. This problem is known to be solved optimally by a Gittins index priority rule. This priority index also inspires the design of our policies.

TH2-R20 PRODUCTION AND SCHEDULING

Production planning

organizer/chair: Laurence Wolsey

Single item lot-sizing with non-decreasing capacities

YVES POCHET
Université cathloque de Louvain, CORE / IAG

coauthor: Laurence Wolsey
keywords: compact reformulation, lot sizing, mixing set relaxation

We consider the single item lot-sizing problem with non-decreasing capacities over time. When the cost function is non-speculative or Wagner-Whitin (for instance, constant unit production costs and non-negative unit holding costs), and the production set-up costs are non-increasing over time, it is known that the minimum cost lot-sizing problem is polynomially solvable (polynomial time dynamic programming algorithm).

For the lot-sizing problem with constant capacities over time and Wagner-Whitin costs, a compact linear programming formulation of the problem is also known. This formulation is based on a mixing set relaxation and reformulation of the stock minimal solutions for this problem.

In this talk, we show how to extend this result to the problem with non-decreasing capacities over time. We provide an improved LP formulation for this lot-sizing problem, which is built from an appropriate mixing set relaxation of this problem. When the cost function satisfies the above conditions, we prove that this linear programming relaxation suffices to solve the lot-sizing problem to optimality.

We illustrate the use and efficiency of this improved LP formulation on some test problems, with/without Wagner-Whitin costs, with non-decreasing and arbitrary capacities over time.

Lot-sizing polyhedra with backlogging

SIMGE KÜÇÜKYAVUZ
University of Arizona

keywords: lot sizing

In this talk, we propose facets of uncapacitated lot-sizing polyhedron with backlogging that subsume all known inequalities for this polyhedron. We give an efficient combinatorial separation algorithm for an important special case. We summarize our computational results that show the effectiveness of our inequalities. Finally, we discuss how our inequalities can be generalized for fixed-charge network flow problems.

A computational comparison of lower bounds for big bucket production planning problems

KEREM AKARTUNALI
University of Wisconsin-Madison

coauthor: Andrew Miller
keywords: integer programming, lot sizing, production planning, valid inequalities

We review various methods for generating lower bounds for multi-level, multi-item capacitated lot-sizing problems in which items compete for capacity on a number of given machines. These methods include those using strong formulations (such as extended formulations and valid inequalities), decomposition approaches such as Lagrangian relaxation, and hybrids of these approaches. This research suggests that simple MIP heuristics are, for most problems, as effective as any other methods for generating strong lower bounds. It also shows where research effort in the future needs to be focused if the needed significant progress in generating stronger lower bounds for these problems is to be made.

TH3-R1 COMBINATORIAL OPTIMIZATION

Applied combinatorial optimization II

chair: Serigne Gueye

Constraints programming and linear programming for quadratic 0-1 problems

SERIGNE GUEYE
Université du Havre

coauthor: Philippe Michelon
keywords: constraint programming, mixed-integer linear programming, quadratic 0-1 programming

In order to solve more easily combinatorial optimization problems, one way is to find theoretically a set of necessary or/and sufficient conditions that the optimal solution of the problem has to verify. For instance, in linear programming, weak and strong duality conditions can be easily derived. And in convex quadratic programming, Karush-Kuhn-Tucker conditions gives necessary and sufficient conditions. Despite that in general such conditions doesn't exist for integer programming, some necessary conditions can be derived from Karush-Kuhn-Tucker conditions for the unconstrained quadratic 0-1 problem. In this paper, we present these conditions. We show how they can be used with constraints programming techniques to fix directly some variables of the problem. Hence, reducing strongly the size of the problem. For example, for low density problems of size lower than 50, those conditions combined with constraints programming may be sufficient to solve completely the problem, without branching. In general, for quadratic 0-1 problems with linear constraints, we propose a new method combining these conditions with constraints and linear programming. Some numerical results, with the instances of the OR-Library, will be presented.

Coordinated allocation and scheduling of air defense resources for a naval task group

NUR EVIN OZDEMIREL
Middle East Technical University

coauthors: Orhan Karasakal, Levent Kandiller
keywords: allocation, military operations research, scheduling, weapon-target allocation

We propose new formulations and a solution procedure for weapon-target allocation for coordinated air defense of a naval task group (TG). A TG consists of a number of ships each having different air defense capabilities such as no defense, self defense or area defense. Our missile allocation model (MAP) allocates surface-to-air missiles (SAMs) the TG has to a set of attacking anti-ship missiles (ASMs) so as to maximize the probability that none of the ASMs can reach their targets. MAP also schedules launching of SAM rounds according to shoot-look-shoot tactic considering multiple SAM systems and ASM types. MAP can be used for analysis of defense effectiveness under various military scenarios. We provide an efficient heuristic solution procedure for repetitive application of MAP in scenario analysis.

Computational experience with implementations of the Goemans-Williamson clustering algorithm

RAFAEL PEREIRA LUNA
Instituto de Matemática e Estatística - USP

keywords: approximation algorithms, generalized Steiner tree problem, primal-dual methods

Given a graph $G = (V,E)$, a cost function $c : E \to \mathbb{Q}_{\geq}$ and subsets $T_1, \ldots, T_p$ of V, the Generalized Steiner Tree Problem is the problem of finding a minimum cost forest in G that connects all vertices in T_i for $i = 1, \ldots, p$. Goemans and Williamson presented a general approximation technique for a large class of graph problems, including this one, that produces approximation algorithms that run in $O(n^2 \log n)$ time, where $n = |V|$, and come within a factor of 2 of optimal. Since then, many other papers appeared giving alternative implementations that turn this method more efficient as, for instance, the $O(n^2 + n\sqrt{m \log\log n})$ implementation of Gabow, Goemans and Williamson, the $O(n\sqrt{m}\log n)$ implementation of Klein and the $O((n+m)\log^2 n)$ implementation of Cole et al., where $m = |E|$. Since the time complexities of these implementations are quite similar, a comparative experimental study is interesting. We present computational results comparing the performance of these implementations, both on artificial and real world-instances.

TH3-R2 COMBINATORIAL OPTIMIZATION

Optimization in power systems engineering

organizer: Ana Viana
chair: Santiago Cerisola

Optimal long-term coordination of wind and hydropower in a hydrothermal electricity market

TERJE GJENGEDAL
Statkraft and NTNU

coauthor: Klaus Vogstad Vogstad
keywords: electricity markets

We analyse the benefits of combining wind and long-term hydro scheduling. The statistical (long-term) complementary characteristics of wind and hydro are utilised by including wind in water value calculations based on stochastic dynamic programming. How does wind energy influence the optimal long term hydro schedule in a hydrothermal system in terms of changes in reservoir management, price volatility, spillage and costs ?

Application of decomposition techniques for building optimal offer curves in an electricity spot market

SANTIAGO CERISOLA
Universidad Pontificia Comillas

coauthors: José M. Fernández-López, Alvaro Moreno
keywords: Benders decomposition, electricity markets, Lagrangian relaxation, stochastic bidding

We present a Mixed Integer Programming (MIP) approach to optimize the offer curves submitted by a power generation company to an electricity spot market. Our method takes an initial set of offer curves and proposes changes that increase the expected profit of the generation company while complying with a variety of constraints such as preserving the stepwise shape of the curves or accomplishing guidelines proposed by other longer time-scope models. Market uncertainty is taken into account by means of scenarios of residual demand curves. Modeling each scenario of hourly residual demand curves requires a large number of binary variables that dramatically increases the size of the problem, making it unaffordable for commercial optimizers. Two solution approaches are adopted: nested Benders decomposition

and Lagrangean Relaxation decomposition. On the one hand, the Lagrangean Relaxation relaxes a set of complicating constraints via its inclusion into the objective function and provides a valuable insight about mid term guidelines. However, the feasibility of the solution is not guaranteed. On the other hand, the nested Benders decomposition interprets the problem as a multistage mixed integer-programming problem. En extension of the linear method for problems with integer variables at any stage is applied. Finally, both solution approaches are benchmarked. A comparison between methods is illustrated with a real size numerical example in the context of the Spanish day ahead market.

A new mixed-integer linear formulation for the unit commitment problem

JOSÉ ARROYO
Universidad de Castilla - La Mancha

coauthor: Miguel Carrión
keywords: mixed-integer linear programming, thermal generating units, unit commitment

The solution to the unit commitment problem provides the schedule and production levels of power generators to meet system demand and spinning reserve requirements, while satisfying generation constraints over a specific short-term time span, so that the overall operation cost is minimized. Unit commitment constitutes a challenging problem in the operation of not only traditional centralized power systems but also current power markets. We present a new mixed-integer linear formulation for the unit commitment problem of thermal units. The formulation proposed requires fewer binary variables and constraints than previously reported models, yielding a significant computational saving. Furthermore, the modeling framework provided by the new formulation allows including a precise description of time-dependent start-up costs and intertemporal constraints such as ramping limits and minimum up and down times. Simulation results illustrate the effectiveness of the proposed mixed-integer linear programming framework.

TH3-R3 COMBINATORIAL OPTIMIZATION

Metaheuristics for logistic problems

organizer: Vinicius Armentano
chair: Arne Løkketangen

Combining routing and inventory for transportation of animals

ARNE LØKKETANGEN
Molde University College

coauthor: Johan Oppen
keywords: livestock collection problem, rich vehicle routing problem, tabu search

We present a problem that deals with collection of animals for slaughter. The problem is taken from the Norwegian meat industry, and may be viewed as a rich Vehicle Routing Problem extended with constraints regarding inventory and planned production at the slaughterhouse. We have developed a tabu search based metaheuristic for the Livestock Collection Problem, and computational results for this method will be presented.

Strategies and heuristics for the dynamic and stochastic vehicle routing problem with time windows

RODRIGO BRANCHINI
Unicamp

coauthor: Vinicius Armentano
keywords: dynamic vehicle routing, heuristics, stochastic demand, waiting and diversion strategies

The advance of communication and information technologies based on satellite and wireless networks have allowed transportation companies to benefit from real-time information for dynamic and stochastic vehicle routing with time windows. During daily operations, we consider the case where the demand and the location of a new customer are unknown in advance. The objective is to define a set of vehicle routes which are dynamically updated to accommodate new clients in order to minimize lateness costs and total distance. The solution approach makes use of the strategy of letting a vehicle wait at a suitable idle point during its tour and the strategy of diverting a vehicle away from its current destination in response to a new customer request. Such strategies are integrated within a granular tabu search algorithm and other heuristics, and the performance of the proposed approach is assessed in test problems based on real-life Brazilian transportation companies.

Successful applications of the pilot method

STEFAN VOSS
University of Hamburg

keywords: hybrid algorithms, logistics and transportation, metaheuristics, pilot method

The pilot method as a metaheuristic is a tempered greedy method aimed at obtaining improved solutions while avoiding the greedy trap by looking ahead for each possible choice. Repeatedly a master solution is modified; each time in a minimal fashion to account for best choices, where choices are judged by means of a separate heuristic result, the pilot solution. The pilot method may be seen as a meta-heuristic enhancing the quality of (any) heuristic in a system for heuristic repetition. Experiments show that the pilot method as well as similar methods can behave quite competitively in comparison with well-known and accepted meta-heuristics. In this presentation we provide some successful applications of the pilot method to some combinatorial optimization problems arising in various areas including logistics and transportation. Furthermore, we extend earlier eperiments incorporating the extension of neighborhoods into "local" search, creating tabu search and VNS hybrids.

TH3-R5 INTEGER AND MIXED INTEGER PROGRAMMING

Advances in integer programming IV

organizer/chair: Francois Margot

Cuts from multiple-term facial disjunctions

ANUREET SAXENA
Carnegie Mellon University

coauthor: Egon Balas
keywords: cutting planes, disjunctions, facility, integer programming

Given a polyhedron P in n-dimensional space and a facial disjunction D with q terms, we give a cut generation algorithm for P intersected with D. The algorithm solves a linear program in $n+1$ variables (the master problem), each of whose constraints is generated by optimizing q linear functions over the same polyhedron

P (the subproblems). A major advantage of this approach is that when a new disjunction is considered, the current basis of the master problem remains dual feasible, and the current bases of the subproblems remain primal feasible.

A polyhedral study of a mixed integer set

AGOSTINHO AGRA
University of Aveiro, Portugal

coauthor: Miguel Constantino
keywords: mixed-integer programming

We discuss the polyhedral structure of mixed integer sets of the form $X = \{(s,y) \in \mathbb{R}_+ \times \mathbb{Z}^{|N|} : s + a_j y_j \geq b_j, \forall j \in N\}$ where $a_j \in \mathbb{Z}_+$, $b_j \in \mathbb{Z}$, $j \in N$. These sets may arise as subsets of more general problems such as lotsizing problems. We provide a full polyhedral description for the case where only three variables are involved (two integer variables) and present a large family of inequalities for the case with $a_j \in \{a_1, a_2\}, \forall j \in N$ which generalize the so-called mixed integer inequalities. Some of the results obtained are also valid for the more general set where there are more than three different coefficients a_j involved.

Stability analysis of some integer programming algorithms

ALEXANDER KOLOKOLOV
Omsk Branch of Sobolev Institute of Mathematics, Russian Academy of Science

coauthor: Marina Devyaterikova
keywords: algorithm, integer programming, stability analysis

The input data of many practical optimization problems are subject to uncertainty. Therefore the stability analysis of integer programming (IP) problems and algorithms for their solving under variations of problems parameters is very important. Recently we have suggested an approach to study of the stability of IP algorithms. By stability of an algorithm we mean a condition of polynomial bounded growth of the iterations number under small enough variations of the input data. In this work a survey of results on some IP algorithms stability under variations of relaxation sets and objective functions is presented. The problem of construction of stable modifications of IP algorithms is considered.

TH3-R6 LOGISTICS AND TRANSPORTATION

Traffic and routing II

chair: João Sarubbi

Algorithms for system optimum on queueing networks

FREDERICO CRUZ
Department of Statistics - UFMG

coauthors: T. van Woensel, J. MacGregor Smith
keywords: genetic algorithms, queueing networks, system optimum, traffic assignment

The classical system optimum of the traffic assignment problem is addressed by means of a queueing network model and a differential evolution algorithm. We briefly review the queueing model to achieve a intuitive, simple, and direct way to estimate travel times, based on which we propose algorithms to find optimal traffic assignments in networks subjected to congestion. Computational results show that the approach is quite efficient.

A fast QAP based formulation for the minimum latency problem

JOÃO SARUBBI
Universidade Federal de Minas Gerais

coauthors: Gilberto Miranda, Henrique Pacca Luna
keywords: GRASP, lower bound, minimum latency problem, quadratic assignment problem

The Minimum Latency Problem, also known by Traveling Repairman Problem or the Deliveryman Problem, is a variant of the Traveling Salesman Problem in which a initial node of a tour is given and the goal is to minimize the sum of the arrival times at all the other nodes. We present a new linear formulation based on Quadratic Assignment Problem and a GRASP with 2-opt local search algorithm to give a first integer solution to CPLEX. We also present optimal results up to 30 nodes and a linear relaxation gap with 2% in average.

TH3-R7 CONSTRAINT LOGIC PROGRAMMING

Constraint logic programming

organizer: Krzysztof Apt
chair: Daniela Pavel

Using process calculi for dynamic enumeration strategies and hybrid solvers in constraint programming

ERIC MONFROY
UTFSM, Chile, and LINA, France

coauthors: Carlos Olarte, Camilo Rueda
keywords: constraint programming
Constraint programming (CP) has been extensively used to solve a great variety of problems. Its declarative flavor makes possible to state conditions over variables (i.e what we want to compute) and the solver gives a solution by applying generic and complete techniques. The process of computing a solution in CP consists mainly in two phases: propagation in which values that are not consistent w.r.t. the constraints are eliminated from the variable domains, and enumeration that chooses a variable and a value for this variable to continue the search when no further propagation is possible. Constraint based languages offer a set of static enumeration strategies to explore the search tree and find a solution. Nevertheless, problems tackled with CP techniques normally are NP hard. It means, for small instances the search tree may grow exponentially w.r.t. the number of variables. In this paper we propose to model dynamic enumeration strategies using a stochastic, non-deterministic timed concurrent constraint calculus. These strategies will be integrated to a constraint solver to make "good choices" when exploring the search tree. We also integrate in the same framework other techniques such as local search to guide the enumeration process.

A rule-based approach for constraint solving

CARLOS CASTRO
UTFSM

keywords: constraint logic programming, constraint programming, rule-based programming
We present transformation rules describing elementary operations carried out by algorithms developed to solve Constraint Satisfaction Problems. Several heuristics can be defined with strategies that establish the order of application of the rules. This approach allows to see constraint solving as an inference process. We also use this approach to deal with optimisation problems and we present the relationship with Branch and Bound techniques used by the Operations Research community.

Optimisation with fuzzy logic

DANIELA PAVEL
Universitatea Dunarea de Jos Galati

keywords: linguistic constraints

The functional relationship between the decision variables and the objective function in a given mathematical programming problem is not completely known. Our knowledge base consists of a set of fuzzy if-then rules with some linguistic values for the decision variables in the antecedent part of these rules. To find a fair solution for the problem we suggest the use of a fuzzy reasoning method.

TH3-R8 LEONID KHACHIYAN MEMORIAL

Leonid Khachiyan memorial III

organizer/chair: Farid Alizadeh

On the randomized integer convex hull

IMRE BARANY
Renyi Institute, Budapest

keywords: convex hull, integer programming, random lattices

Assume $K \subset R^d$ is a convex body. Its randomized integer convex hull, $I_L(K)$, is just the convex hull of $K \cap L$, where L is a randomly translated and rotated copy of the integer lattice Z^d. Motivated by questions in integer programming, we estimate the expected number of vertices of $I_L(K)$, and also the expected missed volume, that is, the expectation of $Vol(K \setminus I_L(K))$. The outcome is similar to, but not identical with, the case of random polytopes.

Matrix scaling dualities in convex programming

BAHMAN KALANTARI
Rutgers University

keywords: convex programming

We consider convex programming in a homogeneous format reminiscent of Karmarkar's canonical LP. Homogeneous programming refers to testing if a homogeneous convex function has a nontrivial zero in a subspace and a pointed convex cone, endowed with a normal barrier. We associate and prove new dualities called: matrix scaling dualities. Then using them we derive new potential-reduction and path-following algorithms for self-concordant homogeneous programming, as well as three dual problems: scaling problem, homogeneous scaling problem, and algebraic scaling problem. In particular we generalize Khachiyan-Kalantari LP/matrix scaling algorithm. To prove general results we define a notion of operator-cone and use it to reveal the intrinsic nature of scaling dualities in convex programming. While making use of basic properties from self-concordance theory, we offer new algorithms for linear, quadratic, semidefinite, and self-concordant programming itself. The algorithms also solve the scaling problems and even give algorithmic proof of generalizations of classical trace-determinant inequality.

A colourful feasibility problem

TAMON STEPHEN
Simon Fraser University

coauthors: Antoine Deza, Sui Huang, Tamás Terlaky
keywords: algorithm, combinatorial optimization, complexity

We study a colourful generalization of the linear programming feasibility problem, comparing the algorithms introduced by Barany and Onn with new methods. We perform benchmarking on generic and ill-conditioned problems, as well as recently introduced highly structured problems. We show that some algorithms can lead to cycling or slow convergence and provide extensive numerical experiments which show that others perform much better than predicted by complexity arguments.

TH3-R9 COMBINATORIAL OPTIMIZATION

Spanning tree problems

chair: Paul Elliott-Magwood

Constructing optimal solutions for the 2-edge-connected spanning subgraph problem

PAUL ELLIOTT-MAGWOOD
University of Ottawa

coauthor: Sylvia Boyd
keywords: cactus, connectivity problems, ear decomposition, linear programming

Given the complete graph, G, on n vertices with non-negative edge costs c, the 2-edge-connected spanning subgraph problem (henceforth called 2EC) is that of finding a minimum cost 2-edge-connected spanning multi-subgraph of G. It can be shown that there always exists an optimal solution to 2EC which is simple, edge-minimal, 2-vertex-connected, has maximum degree 3, and the removal of any two edges leaves a bridge in at least one of the resulting components. Let M be the set of all graphs which have the above properties. We will describe how to construct the graphs in M using their ear decompositions and min-cut cacti and give an algorithm which can find the min-cut cactus of a 2-edge-connected graph in $O(n^2)$ time. We also briefly discuss another work which uses the construction of graphs in M in calculating the worst-case ratio between the optimal value of 2EC and its linear programming relaxation for small values of n.

Modelling the hop-constrained minimum spanning tree problem over a layered graph

LUIDI SIMONETTI
UFRJ

coauthors: Eduardo Uchoa, Luis Gouveia
keywords: Hop-constrained minimum spanning tree problem, network design, Steiner tree problems

The Hop-constrained Minimum Spanning Tree Problem (HMST) is defined as follows: given a graph with a specified root node, edge costs, and a natural number H, we wish to find a spanning tree with minimum total cost such that the unique path from the root to any other node has no more than H edges (hops). This problem has important applications is network design, the hop constraints are often important to assure quality of service. We propose a new approach for the HMST that combines some ingredients: (i) view the whole problem in an appropriate layered directed graph, in contrast to previous approaches that consider the layered graph model for the underlying path subproblem, (ii) reduce the model in (i) to a Steiner problem and, (iii) use special purpose codes for the Steiner tree problem. Extensive computational experiments show that almost all instances from the literature can be solved without branching.

TH3-R10 ROBUST OPTIMIZATION

Robust optimization and probabilistic guarantees

organizer: Daniel Bienstock
chair: Aharon Ben-Tal

Some remedies for intractable robust optimization

AHARON BEN-TAL
Technion-Israel Institute of Technology

keywords: linear dynamic systems, probabilistic constraints, robust optimization, uncertain conic optimization

Uncertain optimization problems, other than linear programming, give rise to intractable semi-infinite convex problems, or nonconvex ones. We present three different possible remedies: approximations, probabilistic guaranties and reparametrization schemes. These are applied to conic optimization problems as well as synthesis of controllers for uncertainty affected linear dynamic systems.

Worst-case violation of randomized solutions for uncertain convex optimization problems

AKIKO TAKEDA
Tokyo Institute of Technology

coauthor: Takafumi Kanamori
keywords: Monte Carlo sampling, robust optimization, sampled convex program, worst-case violation

Robust optimization is one of typical approaches to solve convex optimization problems including uncertainty. For uncertain problems which are formulated as computationally intractable problems via the approach, an alternative randomized approach based on constraint sampling is helpful. Calafiore and Campi have shown sufficient number of randomly chosen constraints such that only small portion of original constraints are violated at the resulting randomized solution.

In this talk, we consider the degree of violation, that is, the worst-case violation as well as the probability of violation for the randomized solution. We derive an upper bound of the worst-case violation under general uncertainty set, and provide the relation between the probability of violation and the worst-case violation. By the relation, the probability of violation and the worst-case violation are guaranteed to be small value with sufficiently large number of random samples.

A robust approach to the chance-constrained knapsack problem

OLIVIER KLOPFENSTEIN
France Télécom R&D

coauthor: Dritan Nace
keywords: chance-constrained optimization, integer linear programming, knapsack problem, robust optimization

Chance-constrained programming is a relevant model for many concrete problems. However, it is known to be very hard to tackle directly. In this paper, the chance-constrained knapsack problem (CKP) is addressed. Relying on the recent advances in robust optimization, a tractable combinatorial algorithm is proposed to solve CKP. It always provides feasible solutions for CKP. Moreover, for two specific classes of uncertain knapsack problems, it is proved to solve CKP at optimality.

TH3-R11 LINEAR, CONE AND SEMIDEFINITE PROGRAMMING

Algorithms for LP and cone programming

chair: Kees Roos

Augmented Lagrangian method with lower-level linear constraints

MARINA ANDRETTA
IME - USP

coauthors: Ernesto Birgin, José Mario Martínez
keywords: linearly constrained optimization, nonlinear programming

Augmented Lagrangian methods with general lower-level constraints are useful when efficient algorithms exist for solving subproblems where the constraints are only of the lower-level type. A new method for solving linearly and bounded constrained problems is presented. This method is meant to be used to solve subproblems of an Augmented Lagrangian method with lower-level linear and bound constraints. The reliability of the method is tested by means of an exhaustive comparison against Minos, VE11 and Algencan. All the problems of the Cuter collection with at most 1000 variables and 1000 linear constraints are used in this comparison. Numerical results are presented.

Improved algorithms for convex minimization in relative scale

PETER RICHTARIK
Cornell University

keywords: convex optimization, gradient methods, linear programming, nonlinear optimization

We consider the problem of minimizing a homogeneous convex function on an affine subspace of R^n not containing the origin. We show that the subgradient and smoothing algorithms recently suggested by Nesterov can be improved by incorporating a simple bisection idea. We show that a linear program with n variables and m inequalities can be solved with relative error δ in $O[\sqrt{n\ln m}(\ln\ln n + 1/\delta)]$ gradient-type iterations. Work towards further practical and theoretical enhancements is discussed.

Full-Newton step polynomial-time methods for LO based on locally self-concordant barrier functions

KEES ROOS
TU Delft

coauthor: Hossein Mansouri
keywords: interior-point methods, kernel function, linear optimization, self-concordant barrier function

Recently several new search directions for interior-point methods were introduced, based on kernel functions. Some of these function are so-called self-regular, others not. The best known iteration bounds for methods based on kernel functions are $O(\sqrt{n}\ln(n/\varepsilon))$ and $O(\sqrt{n}(\ln n)\ln(n/\varepsilon))$ for small- and large-update methods, respectively.

We present some results of ongoing work that is motivated by the question whether or not such bounds also can be obtained by applying the more elegant theory of self-concordant functions to barrier functions based on kernel functions. In general these barrier functions are not self-concordant. However, on the central path and in its neighborhood they behave as being self-concordant; we call them *locally self-concordant*. As a consequence we expect it to be possible to answer the above question positively. In this talk we restrict ourselves to a special case of small-update methods, namely to full-Newton step methods.

TH3-R12 NONLINEAR PROGRAMMING

Linear algebra issues in nonlinear optimization

organizer/chair: Michael Saunders

From sparsity to block-sparsity: direct solution of very large KKT systems arising in IPMs

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coauthor: Andreas Grothey
keywords: block-sparsity, interior-point methods, parallel computing, very large-scale optimization

We discuss a method for solving very large structured symmetric indefinite equation systems arising in optimization with interior point methods.

Many real-life economic models involve system dynamics, spatial distribution or uncertainty and lead to large-scale optimization problems with a hidden structure: they are constructed by replication of some small generic block. The linear algebra subproblems which arise in optimization algorithms for such problems involve matrices which are not only sparse, but they additionally display a block-structure with many smaller blocks sparsely distributed in the large matrix.

We demonstrate OOPS (Object-Oriented Parallel Solver: http://www.maths.ed.ac.uk/ gondzio/ parallel/solver.html) which can efficiently handle very large problems and achieves scalability on a number of different computing platforms. We illustrate its performance on a collection of financial planning problems with sizes reaching one billion variables. We also report on the solution of a real-life distribution planning problem which defies the industry standard software of Cplex 9.1.

Implementation of a KKT-based active-set QP solver

MICHAEL SAUNDERS
Stanford University

coauthor: Hanh Huynh
keywords: active-set method, implementation, KKT systems, quadratic programming

Sparse SQP methods such as SNOPT need a QP solver that permits warm starts each major iteration and can handle many degrees of freedom. An active-set QP method with direct KKT solves seems the only option. We discuss some implementation issues such as updating the KKT factors, scaling the QP Hessian, and recovering from KKT singularity.

TH3-R13 NONLINEAR PROGRAMMING

Nonlinear programming applications

chair: Lara Urdaneta

A sizing optimization contact rod problem

ISABEL MARIA NARRA FIGUEIREDO
Department of Mathematics, University of Coimbra

coauthors: Joaquim J. Júdice, Luis M. Fernandes
keywords: anisotropy, complementarity, contact, rod problem

We consider a multilayered rod, whose layers are made of different homogeneous isotropic materials, and the cross section is divided into subsections with shapes similar to that of the whole rod cross section. We also suppose that this rod may be in contact, without friction, with a rigid obstacle. A model is introduced for finding the layer's thickness distribution, such that the contact between the rod and the obstacle is maximized. This structural model is formulated as a mathematical programming problem with complementarity constraints, containing independent and dependent variables, the latter ones implicity defined by the solution of a mixed linear complementarity problem. A projected-gradient algorithm incorporating a complementarity method is proposed to solve this optimization problem and several numerical examples are reported.

A tool based on nonlinear programming for minimizing the object dimensions in circle and sphere packing problems

FRANCISCO SOBRAL
IME - USP

coauthor: Ernesto Birgin
keywords: algorithm, models, nonlinear programming, packing of circles and spheres

Given a fixed set of identical or different-sized circular items, the problem consists on finding the smallest object within which the items can be packed. Circular, triangular, squared, rectangular and also strip objects are considered. Moreover, 2D and 3D problems are treated. Twice-differentiable models for all these problems are presented. A strategy to reduce the complexity of evaluating the models is employed and, as a consequence, problems with a large number of items are considered. Numerical experiments show the flexibility and reliability of the new unified approach.

Bayesian approach to solve inverse problems: application to exponential sum problems

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Decanato de Ciencias, UCLA

coauthor: Freddy Torrealba
keywords: Bayesian estimation, inverse problems, nonlinear optimization

We deal with bayesian estimation methods to solve inverse problems which arise from experimental physics. Specifically, we study decay curves modeled as sums of exponential functions. In a positron annihilation lifetime the data collected is a decay curve. Positrons from the source annihilate in one or more states in the sample and may be trapped in defects if present. These annihilation states give rise to different lifetimes leading to a multi-exponential decay spectrum. The decay spectrum is convoluted with the experimental resolution function. From this data we wish to extract the intensity spectrum, that is the intensities of the lifetimes present in a given decay curve. The difficulties involved with the resolution of this inverse problem are well known. In the present work we deal with exponential sums in a bayesian approach, which perform the regularization by choosing adequate likelihood and priori functions. This approach results in maximum a posteriori estimates which are nonlinear optimization problems. We focus on derivative calculations in this particular problem, in order to use gradient based optimization methods.

TH3-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Copositive programming and its applications

organizers: Mituhiro Fukuda, Masakazu Kojima
chair: Mituhiro Fukuda

Closing the duality gap in rank one relaxations by copositive programming

JANEZ POVH
University of Maribor, Faculty of Logistics

coauthor: Franz Rendl
keywords: copositive programming, rank one relaxation, semidefinite programming

One of the basic steps in lift-and-project approach to the problems from combinatorial optimization is relaxing the rank one constraint. The gap between the optimal value of the problem and the optimal value of the relaxation may be arbitrary large. We show that for some quadratic problems over the (discrete) set of nonnegative matrices with prescribed row and column sums we can close this gap by demanding that the matrices in the lifted space are completely positive. This result gives rise to new hierarchies of semidefinite approximation models for several problems like **graph partitioning problem**, **quadratic assignment problem**, **balanced vertex separator problem** etc. We show that these semidefinite models are at least as strong as other well-known semidefinite models from the literature for several optimization problems. For some problems (e. g. for quadratic assignment problem) these models are also better formulated and are more suitable for solving in practise.

Prospects on copositive programming

MITUHIRO FUKUDA
Tokyo Institute of Technology

coauthors: Masakazu Kojima, Makoto Yamashita
keywords: copositive programming, semidefinite relaxations

Coposite programs are linear conic and convex programs which includes for example the standard quadratic problem, the stability number of a graph and the quadratic assignment problem as special cases. We investigate some computational solutions of the copositive programs through SDP approximations inspired on the SDP approximation of Polynomial Optimization Problems.

TH3-R16 COMPLEMENTARY AND VARIATIONAL INEQUALITIES
Traffic
organizer: David Watling
chair: Agachai Sumalee

A generalized complementarity approach for optimal maintenance a deteriorating transportation facility under dynamic uncertainty

NAGAE TAKESHI
Kobe University

coauthor: Takamasa Iryo
keywords: complementarity and variational inequalities, singular stochastic control problems, transportation facility maintenance

This study examines the optimal maintenance problem of a deteriorating transportation facility (e.g., highway bridges, road tunnels, etc), taking into account dynamic uncertainty of the deterioration. We first formulate the optimal maintenance problem as a singular stochastic control problem. By applying the dynamic programming principle, we obtain the optimality condition of the problem as a sequence of infinite-dimensional generalized linear complementarity problems (GLCPs). In a certain discrete framework, this GLCP sequence can be rewritten as a set of finite-dimensional GLCPs, each of which can be solved independently and successively. This enables us to develop an effective algorithm for solving the optimal maintenance problem, exploiting the recent advances in the theory of complementarity and variational inequality problem. Several numerical examples will be shown.

Properties of stochastic user equilibrium model as a smoothing function and its application to network design problems

AGACHAI SUMALEE
University of Leeds

coauthors: David Watling, Richard Connors
keywords: mathematical programs with equilibrium constraints, network design problems, smoothing function of complementarity condition, stochastic user equilibrium

A traffic route choice model normally follows the Wardrop's user equilibrium (UE) which can be expressed mathematically as a mixed complementarity problem (MCP). When applying this UE condition as a constraint of the network design problem (NDP), aiming to find an optimal network configuration taking into account route choice model so as to optimise an objective function, the MCP imposes several difficulties including non-differentiability and non-degeneracy. This obstructs an application of existing nonlinear optimization algorithm to the NDP. The other principle of Stochastic User Equilibrium (SUE), which introduces random error terms to travel cost, offers an alternative. This SUE condition as explained in the paper resolves several problems with the MCP including the non-differentiability and non-degeneracy. In addition, the paper explains the relationship of the SUE as the smoothing function in the fashion of Fisher-Burmeister of the UE and its contribution to the solution algorithm of the NDP.

Congestion pricing for capacitated transit networks with loading

YOUNES HAMDOUCH
United Arab Emirates University

coauthor: Siriphong Lawphongpanich
keywords: congestion pricing, traffic equilibrium, transit networks

In this paper, we extend the toll pricing framework previously developed for vehicular traffic networks to networks of transit (e.g., bus, subway, and metro) lines where vehicle capacities are considered explicitly. To determine tolls, we construct a user equilibrium and system optimal model. In both models, we assume that users adopt strategies to travel between each origin-destination pair and on-board passengers have priority over boarding passengers when loading a vehicle. At each node representing a transit station, a strategy consists of a set of transit lines in decreasing order of preferences and the passenger boards the first available line in this set whose residual capacity is nonzero. As in the case of vehicular traffic networks, the set of valid tolls can be obtained from the solution to the system problem and the equilibrium conditions for the user problem. Then, objective functions similar to those for traffic networks can be used to determine an optimal toll vector. We provide a

numerical example to illustrate our approach.

TH3-R17 STOCHASTIC PROGRAMMING
Stochastic integer programming
organizer/chair: Shabbir Ahmed

An exact approach for solving probabilistically constrained integer problems with random technology matrix

PATRIZIA BERALDI
DEIS - University of Calabria

coauthor: Maria Elena Bruni
keywords: branch-and-bound, probabilistic constraints, probabilistic set covering problem, stochastic integer programming

We consider integer programming problems under probabilistic constraints involving discrete distributions. Such problems can be reformulated as large scale integer problems with knapsack constraints. For their solution we propose a specialized Branch and Bound approach where the feasible solutions of the knapsack constraint are used as partitioning rules of the feasible domain. The numerical experience carried out on a set covering problem with random covering matrix shows the validity of the solution approach and the efficiency of the implemented algorithm.

Totally unimodular stochastic programs

ANDREW SCHAEFER
University of Pittsburgh

coauthors: Nan Kong, Shabbir Ahmed
keywords: L-shaped method, stochastic integer programming, totally unimodular matrices

We consider totally unimodular stochastic programs, that is, stochastic programs whose extensive-form constraint matrix is totally unimodular. We generalize the notion of total unimodularity to apply to sets of matrices and provide properties of such sets. Using this notion, we give several sufficient conditions for stochastic programs to be totally unimodular, and provide necessary conditions for specific classes of problems. When solving such problems using the L-shaped method it is not clear whether the integrality restrictions should be imposed on the master problem. Such restrictions will make each master problem more difficult to solve. On the other hand, solving the linear relaxation of the master typically means sending fractional (and unlikely optimal) solutions to the subproblems, perhaps leading to more iterations. Our computational results investigate this trade-off and provide insight into which strategy is preferable under a variety of circumstances.

Polyhedral stochastic integer programming

AHMED SHABBIR
Georgia Institute of Technology

coauthors: George Nemhauser, Yongpei Guan
keywords: lot sizing, polyhedral study, stochastic integer programming

We present polyhedral results for scenario based models of some stochastic integer programs. The key idea is to combine valid inequalities from scenario subproblems to derive new inequalities for the overall problem. We illustrate the procedure by developing inequalities for the stochastic uncapacitated lot-sizing problem and some other stochastic integer programs.

TH3-R18 GRAPHS AND MATROIDS
Optimization on graphs and hypergraphs
organizer/chair: Carmen Ortiz

Maximal Independent Sets of Caterpillar Graphs

MONICA VILLANUEVA-ILUFI
Universidad de Santiago de Chile

keywords: caterpillar graph, maximal independent set

A caterpillar graph is a tree that has a chordless path called the “body” or “backbone”. Each vertex of the body can have adjacent vertices not belonging to the body, called the “hair” of the vertex, Thus, a hair is a chordless path that has a common vertex with the body. In this work, we develop an algorithm to construct the family of maximal independent sets of a caterpillar graph. We represente this family as the set of all the maximal source-sink paths of an oriented graph. Time complexity of this procedure is polynomial in the number of maximal independent sets of the given graph. For a general graph this problem is NP-complete.

Directed hypergraphs with balanced or totally unimodular incidence matrices

PEH NG
University of Minnesota, Morris

keywords: balanced matrices, directed hypergraphs, totally unimodular matrices

A *directed hypergraph*, $G = (V,H)$, is a generalization of a directed graph, where arcs have multiple (or no) tails or heads. We define a class of directed hypergraphs via a forbidden structure and show that the $0,\pm 1$ vertex-hyperarc incidence matrices of the hypergraphs in this class are balanced and/or totally unimodular. We also show the preservation of "balanced" or "totally unimodular" over a certain graphical transformation that simplifies the resulting directed hypergraph and its vertex-arc incidence matrix.

Strong-mixed searching and pathwidth

BOTING YANG
University of Regina

keywords: cop-and-robber game, graph search, pathwidth, pursuit-evasion problem

Given a finite graph G, the graph searching problem is to find the minimum number of searchers to capture all intruders which are hiding on vertices or anywhere along edges in G. Megiddo et al. (1988) proved that finding the minimum number of searchers for G is NP-hard. Kirousis and Papadimitriou (1986) introduced the node-search model and proved that $\mathrm{ns}(G)-1 \leq \mathrm{es}(G) \leq \mathrm{ns}(G)+1$, where $\mathrm{es}(G)$ denotes the edge-search number of G and $\mathrm{ns}(G)$ denotes the node-search number of G. Bienstock and Seymour (1991) introduced the mixed-search model that is a combination of the edge-search and node-search. In this paper, we propose a new search model, called strong-mixed search, which is a generalization of the mixed-search. The strong-mixed search number of G is the minimum number of searchers required to capture the intruder in G under the strong-mixed search model. We show that the strong-mixed search number of a graph equals the pathwidth of the graph. We also proved relationships between the strong-mixed search number and other search numbers.

TH3-R19 PRODUCTION AND SCHEDULING

Planning and scheduling under uncertainty

organizer/chair: Marc Uetz

Decentralization and mechanism design for online machine scheduling

RUDOLF MÜLLER
Maastricht University

coauthors: Birgit Heydenreich, Marc Uetz
keywords: decentralization, mechanism design, online algorithms, scheduling

We study the online version of the classical parallel machine scheduling problem to minimize the total weighted completion time from the perspective of algorithmic mechanism design: We assume that the data of each job, namely its release date r_j, its processing time p_j and its weight w_j is only known to the job itself. Furthermore, we assume a decentralized setting where jobs choose the machine on which they want to be processed themselves. We introduce the concept of a myopic best response equilibrium, a concept weaker than the dominant strategy equilibrium, but appropriate for online problems. We present a polynomial time, online scheduling mechanism that, assuming rational behavior of jobs, results in an equilibrium schedule that is 3.281-competitive. The mechanism deploys an online payment scheme that induces rational jobs to truthfully report their private data. We also show that no payment scheme makes truthful reports a dominant strategy equilibrium.

An average-case view on non-clairvoyant scheduling

ALEXANDER SOUZA
Freiburg University

keywords: average-case analysis, non-Clairvoyant scheduling, performance measures, stochastic scheduling

In the non-clairvoyant scheduling model, jobs have to be executed without knowledge of the individual stochastic processing times. We consider the makespan and total completion time objective in this model. Under some probabilistic assumptions, a simple list scheduling algorithm performs well in the following sense. The algorithm achieves an almost optimal solution with high probability for the makespan objective, and a constant factor approximation with high probability for the completion time objective. The analysis of the algorithm yields a technique for estimating second (and higher order) moments of the performance ratio random variable.

Approximation algorithms for stochastic optimization

CHAITANYA SWAMY
Caltech and U. Waterloo

coauthor: David Shmoys
keywords: approximation algorithms, stochastic optimization, linear programming, randomized algorithms

Stochastic optimization problems attempt to model uncertainty in the data by assuming that (part of) the input is specified by a probability distribution, rather than deterministic data given in advance. We consider the well-studied paradigm of stochastic recourse models, where the uncertainty evolves through a series of stages and one can take decisions in each stage in response to the new information learned. We obtain the first approximation algorithms for a variety of 2-stage and k-stage stochastic integer optimization problems where the costs may be arbitrary and the underlying random data is given by a "black box": that is, one can merely sample data from the distribution, but no other information about it is given.

Our results are based on two principal components. First, we give a fully polynomial approximation scheme for solving a broad class of 2-stage and k-stage linear programs, for any fixed k. This is based on reformulating the stochastic linear program, which has an exponential number of both variables and constraints, as a compact convex program, and adapting tools from convex optimization to solve this program to near optimality. Second, we give a rounding approach for stochastic integer programs that shows that an approximation algorithm for a deterministic analogue yields, with a small constant-factor loss, provably near-optimal solutions for the stochastic problem. Thus we obtain approximation algorithms for several stochastic problems, including the stochastic versions of the set cover, vertex cover, facility location, multicut (on trees) and multicommodity flow problems.

The talk will focus mainly on the 2-stage setting and if time permits, we will briefly disucss the ideas required to extend the results to the k-stage setting.

TH3-R20 PRODUCTION AND SCHEDULING

Miscellaneous

chair: Sueli Cunha

Capacity and flow assignment with additional constrains

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DCC - UFMG

coauthors: Henrique Pacca Luna, Ricardo Poley M. Ferreira
keywords: capacity and flow assignment, logical constraints, net of services, workflow

The ability to predict a regular operation of a net of services is affected by the understanding of its variability. The map of the net topology and flows can be obtained based on the analysis of the operation records. The problem is to anticipate the impact of the demand increase. The main issues are to avoid congestion, minimize the operational costs, and where to increase the capacity. This approach defines the capacity and flow assignment problem (CFA) with additional constrains. The aim is the study of the attending and leading persons context. In these contexts the decisions are made combining procedures with beliefs and desires under uncertainty. We model a new CFA problem establishing additional logical routing rules. The solution method adopted is a convex approximation scheme to solve the problem. Both the discrete capacity attribution and the routing flows with additional constraints are treated at the same time.

Market-based pricing models: a policy evaluation approach.

RODRIGO SCARPEL
ITA

keywords: pricing models, profit optimization

How pricing strategies are customized for particular brands, categories, chains, and markets has been a complex task in today's competitive environment. One approach to deal with this problem is to use econometric models for policy evaluation introducing an objective function to be optimized by choice of policies regarding the estimated model as a constraint in this optimization process.

We addressed the issue price optimization building a mathematical programming formulation for policy evaluation for a product and for a product line. We illustrated the proposed model to find the optimal price, i.e. the price that optimizes profit, for a consumer packaged good line.

Divers applications of a task model

SUELI CUNHA

Universidade Gama Filho

keywords: e-task-graph, planning, task model

A task model aims to represent a task to be realized by describing the needful *steps* to realize it as well as its *initial* and *final* states. Besides, a task model describes a task T by means of its successive decompositions in subtasks T_i which allow T to reach its goal. The level the less abstract of a task refinement describes the *operations* (actions or elementary tasks). However, in the realization time of a task, only the elementary tasks are actually realized, in sequence, describing in this way a *planning*, i.e., a sequence of actions to realize. So, in our works we've been used a task model in order to compare problem solving reasoning (with its input and output) as well as to describe a predictive planning for a product manufacturing (with its specifications). Now, we are interested to use the task model in the bus planning problem, which aims to state a global line network planning.

FR1-R1 COMBINATORIAL OPTIMIZATION

Combinatorial optimization IV

chair: Michal Stern

Valid inequalities and facets of the OLS polytope

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coauthor: Ioannis Mourtos
keywords: facets, orthogonal latin square, polyhedral combinatorics

A *Latin* square of order n is a square matrix L, where each value $1,..,n$ appears exactly once in each row and column. Two Latin squares of order n are called *orthogonal* if and only if each of the n^2 ordered pairs of values $(1,1),...,(n,n)$ appears exactly once in the two squares. This definition can be extended to $k > 2$ Latin squares, which are called *Mutually Orthogonal* (MOLS) if and only if they are pairwise orthogonal.

Let I,J,K,L be the $n-$sets indexing the rows, columns and values of the two squares, respectively. Define variable x_{ijkl} being 1, if pair (k,l) appears in cell (i,j) and 0 otherwise. The IP model for the OLS problem is derived by summing over all possible sets of any 2 out of the 4 indices i,j,k,l, the r.h.s. always being 1. This is a model defined on n^4 $0-1$ variables and 6 constraint sets, each one including n^2 equalities. The *OLS polytope* (P_I) is defined as the convex hull of all integer feasible vectors. The problem of optimizing a linear function over P_I is the *four-index planar assignment* problem $(4PAP_n)$.

The intersection graph G associated with the OLS polytope has a node for each variable and an edge for each pair of variables that cannot be set to 1 simultaneously. Valid inequalities for P_I can be extracted from certain subgraphs of G. In the current work, we identify classes of inequalities arising from *cliques* and *wheels* of G. The classes of inequalities presented are shown to be facet-defining for P_I and can be separated efficiently in polynomial time. Thus, they can be used within the context of a *Branch & Cut* scheme for solving the $4PAP_n$. We also present a class of lifted *antiweb* inequalities which prove that P_I is empty for $n = 2$.

On the optimal stars clustering tree problem

MICHAL STERN
The Academic College of Tel-Aviv-Yaffo

coauthor: Ephraim Korach
keywords: clustering spanning tree, combinatorial optimization, polynomial graph algorithm, stars

We consider the following optimal stars clustering tree problem, denoted by OS: Given a complete graph G=(V,E) with a weight on every edge and a collection S of subsets of V, the aim is to find a spanning tree T with minimum weight where each subset in S induces a star in T. Motivations to the problem come from the areas of designing communication networks, synchronous replications database systems and secure group communication key management. There are three incomparable cases of OS. Two of them we solved and presented in the past: (i) The complete stars case for which we proved a structure theorem that lead to a polynomial algorithm. (ii) The disjoint centers case that we solved by dynamic programming. Here we present a polynomial algorithm for the third case in which there is no restrictions on the stars to be complete and on the centers to be disjoint.

Free poset on permutations by scalar products

MARIA CRISTINA RANGEL
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coauthor: Nair Maria Maia de Abreu
keywords: comparability graphs, permutation, poset, scalar products comparability graphs

We introduce an ordering on the permutation set based on the scalar products of positive vectors in R^n. Thus, we obtain the free poset, which contains the well known inversion poset. Pairs of freely comparable permutations are defined by the scalar products of vectors related to these permutations. A polynomial algorithm to decide if a pair of these permutations is freely comparable is presented. A chain of comparability graphs corresponding to a chain of posets is built in order to prove the following result: *Let* ρ_1 *and* ρ_2 *be two freely comparable permutations, and for* $v,w \in R^n$, $\langle v,\rho_1(w)\rangle$ *and* $\langle v,\rho_2(w)\rangle$ *be the scalar products related to them. If the inversion number of the first permutation is less than the inversion number of the second, we prove that* $\langle v,\rho_1(w)\rangle$ *is no greater than* $\langle v,\rho_2(w)\rangle$.

FR1-R2 COMBINATORIAL OPTIMIZATION

Network design and optimization

organizer: Edwin Romeijn
chair: Thomas Sharkey

Facility location models with production planning considerations

THOMAS SHARKEY
Industrial and Systems Engineering, University of Florida

coauthor: Edwin Romeijn
keywords: facility location, production planning

We consider a class of facility location problems where each city is characterized by a vector of demands. The cost of assigning a set of cities to a particular facility is equal to the opening cost of the facility, connection costs of the cities to the facility, and the costs associated with a production planning problem where the vector of demands is equal to the sum of the demand vectors over the set of assigned cities. We study variants of this class of problems where we consider: capacitated and uncapacitated production, linear and fixed-charge production costs, seasonal and general demand patterns, and absence or presence of connection costs. For each variant, we either provide a polynomial-time algorithm to solve it, provide a constant-factor polynomial-time approximation algorithm for it, or prove that no constant-factor polynomial-time approximation algorithm can exist unless P=NP.

New approaches in UMTS radio network optimization

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Zuse Institute Berlin (ZIB)

coauthor: Andreas Eisenblätter
keywords: telecommunications, UMTS, wireless networks

Third generation (3G) mobile telecommunication technology such as UMTS can provide the end user with data rates comparable to fixed DSL lines. In order to do so, a careful planning of the radio interface and tuning of the base station antennas is needed. The optimization problems arising are particularly challenging, and over the years different models for evaluating and optimizing 3G radio networks have

been presented. In this talk, we focus on the recent expected-interference-coupling model for UMTS radio networks. The model allows very efficient evaluation of radio networks. It also gives rise to new mixed integer programming models with linear and convex objective functions that can address different aspects of radio network tuning problems. We derive new lower bounds on a network's best possible performance under a given set of antenna configuration alternatives.

Radio resource allocation problems in mobile telecommunications systems

PAOLO DETTI
Dipartimento di Ingegneria dell'Informazione - University of Siena

keywords: combinatorial algorithms, scheduling

In mobile telecommunications systems, Packet Data Units (PDUs) of different users belonging to different multimedia services (e.g., voice, video, data etc.) are sent across the air interface organized into radio frames. A radio frame is divided into a fixed number of radio resources and a resource is generally characterized by a time slot and/or a frequency. PDUs must be assigned to a radio resource to be transmitted, and they must be provided to mobile users with guaranteed Quality of Service (QoS) levels. QoS typically concerns transmission bit–rate, delay, packet loss, etc. In a such context, the problem of allocating PDUs to time slot in such a way that the throughput is maximized. In general, few milliseconds are available for allocating radio resources of a radio frame, so that fast algorithms are required for assigning radio resources. High-Multiplicity Models and polynomial algorithms for radio resource allocation and scheduling are proposed.

FR1-R3 COMBINATORIAL OPTIMIZATION

Enhancements to pure metaheuristics

organizer: Paola Festa
chair: Mauricio Resende

Global optimization by continuous GRASP

MAURICIO RESENDE
AT&T Labs Research

coauthors: Michael Hirsch, Claudio Meneses, Panos Pardalos
keywords: global optimization, GRASP, stochastic search

We introduce a novel global optimization method called Continuous GRASP (C-GRASP) which extends Feo and Resende's greedy randomized adaptive search procedure (GRASP) from the domain of discrete optimization to that of continuous global optimization. This stochastic local search method is simple to implement, is widely applicable, and does not make use of derivative information, thus making it a well-suited approach for solving global optimization problems. We illustrate the effectiveness of the procedure on a set of standard test problems as well as two hard global optimization problems.

Intelligent hybridization of meta-heuristics

WEE CHONG WAN
The Logistics Institute Asia Pacific

coauthors: Hoong Lau, Steven Halim
keywords: hybrid algorithms, intelligent, metaheuristics, optimization

Hybrids of meta-heuristics have been shown to be more effective and adaptable than their parents in solving various combinatorial optimization problems. However, hybridized schemes are more tedious to implement due to their complexity. We address this problem by proposing the Meta-heuristics Development Framework (MDF). In addition to being a framework that promotes reuse to reduce developmental effort, the key strength of MDF lies in its ability to model meta-heuristics using a "Request, Sense and Response" (RSR) schema, which decomposes algorithms into a set of well-defined modules that can be flexibly assembled through an intelligent central controller. Under this scheme, hybrid schemes become an event-based search that can adaptively trigger a desired parent's behavior in response to search events. MDF can hence be used to design and implement a wide spectrum of hybrids with various degrees of collaboration thereby offering the algorithm designer quick turnaround in designing and testing his meta-heuristics. This is illustrated in this paper through the construction of hybrid schemes using Ants Colony Optimization (ACO) and Tabu Search (TS).

FR1-R4 COMBINATORIAL OPTIMIZATION

Column generation

organizer: Eduardo Uchoa
chair: Christophe Duhamel

Branching in branch-and-price: a generic scheme

FRANCOIS VANDERBECK
University Bordeaux 1

keywords: branch-and-price, Dantzig-Wolfe reformulation, integer programming

In Branch-and-Price algorithms, implementing a branching scheme that performs well and is suited for the column generation procedure can be challenging. A standard branching scheme can be implemented in the space of the compact formulation to which the Dantzig-Wolfe reformulation was applied; but it may have poor performances. Specialized branching rules have been proposed for use in Branch-and-Price; but they may imply modifications to the pricing problem. This is a main concern because the specialized pricing problem solver on which the method relies might become obsolete beyond the root node. This paper presents a branching scheme for use as a default in a generic Branch-and-Price code that only relies on the pricing oracle of the root node for column generation. It proceeds by recursively partitioning the set of columns. Branching constraints are enforced in the pricing problem instead of being dualized in a Lagrangian way. The pricing problem is solved by a limited number of calls to the pricing oracle. This generic scheme builds on previously proposed approaches and unifies them. For illustration, it is applied to Bin packing and cutting stock problems (solving them to integrality without modifying the subproblem or expanding its variable space is a first).

Branch and price for the minimum cost k-splittable flow problem

CHRISTOPHE DUHAMEL
LIMOS

coauthors: Jérôme Truffot, Philippe Mahey
keywords: branch-and-price, column generation, k-splittable flow

The Minimum Cost Flow Problem with flow width constraints is a NP-hard problem. It typically appears in telecommunications when a control over the number

of routes for each commodity is required. After presenting a compact model, we propose a Dantzig-Wolfe reformulation, leading to an extended model. Symmetry breaking constraints are added to enforce the model. Then, a Branch and Price is developped to solve the problem. The column generation reduces to a variation of the Shortest Path problem and thus can be solved in polynomial time. Two branching schemes are investigated: the first one is a direct extension to the Barnhardt rule. The second one needs a Robust Branch and Price reformulation in order to keep a compatible pricing subproblem. We also consider an extension requiring disjoint paths for the routing. We show that such a problem can be solved with few modifications on the column generation procedure. Computational results are proposed to show the effectiveness of this approach.

A column generation algorithm for some networks design problems

IRENE LOISEAU
Universidad de Buenos Aires

coauthor: Nelson Maculan
keywords: column generation, cycle cover, integer programming, network design

We present an improved version of a column generation algorithm for the problem of determining a minimum cost set of cycles on a graph, that cover pairs of nodes where demands are to be satisfied. Cycles are bounded in length, number of edges and capacity. This problem was motivated by a real problem appeared in telecommunications networks design in the early 90´s. Columns are generated solving a MIP problem and with a heuristic procedure. We also adapted the column generation algorithm to the BCCP (Bounded cycle cover problem).

FR1-R5 COMBINATORIAL OPTIMIZATION
Combinatorial Optimization V
chair: Marcos José Negreiros

A Combined Exact Method for the Constrained Capacitated Clustering in Graphs

MARCOS JOSÉ NEGREIROS
State University of Ceará

coauthor: José Alexandre Dantas Filho
keywords: branch-and-bound, clustering in graphs, GRASP

The Constrained Clustering Problem in Graphs (CCPG) is stated as follows: given un undirected connected weighted graph in the nodes and links, where in each node its weight means demand, and at each link the weight means cost to connect two adjacent nodes, the problem searches for a number of connected components of the graph that does not exceed a pre-defined capacity constraint of the demanded nodes. Its objective function minimizes the variable cost related to the links used in each connected component and the fixed cost associated in openning a component. This problem is closely related to the Multi-Cut Problem, previously reported by the literature, which can be applied in VLSI design, Garbage Collection, Agregation of Similar Regions for the Bereau Census, Distribution of Disease Urban Sanitary Agent, Districting, and many others. Here we propose a composite exact method using multi-start GRASP based meta-heuristic, and a Branch & Bound approach, that explores in the branching tree the structure of groups formed to achieve the exact solution. The strategy reduces the hole branching tree characterized by other B&B approaches based on nodes. We show the parallelization of the method and the speed up related to the number of machines used versus the size of the instances, and also the results in comparison to some of the Max-Cut literature instances.

A approach for the economic activity location problem

JACQUELINE MAGALHÃES RANGEL CORTES
UENF

coauthor: Geraldo Galdino de Paula Jr
keywords: genetic algorithms, location problem, multi-objective models

The location problem of economic activities is described by a multiobjective and dynamic 0-1 model and solve by a genetic algorithm. The objectives achieved are contained in the results based on location dominante factors, qualitative and quantitative. The formulation aims to minimize investment costs, minimize access time and maximize benefits, during the planning horizon. Besides, the location process assists a group of operational restrictions, of budget, and the demand of interlinked periods of time. The effort developed results in formulation of a genetic algorithm and its adaptation to the multiobjective approach of the problem treated. Such algorithm uses correction operations, appropriate and private, and includes the penalization of the infeasible solutions through a sequential verification of the restrictions. At the end of the evolutionary process, the nondominated solutions, extracted from the group of the best solutions, are supplied to the decisor maker's evaluation.

An exact algorithm for optimal MAE stack filter design

DOMINGOS DELLAMONICA JUNIOR
USP

coauthors: Paulo da Silva e Silva, Nina S. T. Hirata, Carlos Humes Jr, Junior Barrera
keywords: filter design, network flows

We propose a new algorithm for optimal MAE stack filter design. It is based on three main ingredients. First, we show that the dual of the integer programming formulation of the filter design problem is a minimum cost network flow problem. Next, we present a decomposition principle that can be used to break this dual problem into smaller subproblems. Finally, we propose a specialization of the network Simplex algorithm based on column generation to solve these smaller subproblems.

Using our method, we were able to efficiently solve instances of the filter design problem for windows with up to 25 pixels. To the best of our knowledge, this is the largest dimension for which this problem was ever solved exactly.

FR1-R6 LOGISTICS AND TRANSPORTATION
Traffic models and robustness
chair: Siriphong Lawphongpanich

A bilevel programming formulation for the joint calibration of demand models and network parameters consistent with traffic counts information

LIDIA MONTERO
Universitat Politècnica de Catalunya

coauthor: Esteve Codina
keywords: bilevel programming, traffic assignment, urban transportation models

In the building of urban transportation planning models using Wardrop's equilibrium, the calibration of the network parameters has been considered as a previous stage to the estimation of trip tables or Origin-Destination matrices. In this scheme, the calibration of demand models for modal split is also considered as a separate task. In this scheme, the inconsistencies and errors from one stage can influence negatively the accuracy of the submodels in the following steps. As an attempt to avoid this drawback, a bilevel programming model is presented with the purpose to encompass the final tuning of network parameters and the problem of calibration of a demand model. The bilevel programming formulation permits the demand model adjusted to be consistent with the information provided by demand surveys and with traffic counts on a subset of network links. The model presented also avoids the distortion on the origin-destination matrices that some models for trip table estimation may present.

How to be in time?

SEBASTIAN STILLER
TU Berlin

keywords: combinatorial optimization, delay avoidance, railway optimization

In ordinary live people construct schedules everyday, in which they try to escape the curse of delay. The basic reasoning is simple: once you have a disturbance in a set of processes connected by precendence constraints the delay caused by this disturbance will propagate through the schedule until it is caught by some kind of buffer. But where to put these buffers, such that they have the biggest effect in exspectation for a delay-resistant schedule? Our main background for this problem is railway optimization. Yet, we give a general, structural insight to the delay phenomenon, yielding chiefly an optimality criterion and a pseudo-polynomial algorithm for acyclic graphs.

Existence of nonnegative Pareto-improving tolls

SIRIPHONG LAWPHONGPANICH
University of Florida

coauthor: Yafeng Yin
keywords: congestion pricing, Pareto optimal, traffic assignment, traffic equilibrium

When compared to the one at user equilibrium, a distribution of traffic flow is "dominating" if it ensures that no user are worse off and some are better off in terms of travel time. This paper considers nonnegative "Pareto-improving" toll vectors that induce a given dominating flow distribution and improve the social benefit without making anyone worse off. Because requiring tolls to be nonnegative may not be feasible in all cases, our focus is on establishing existence conditions when the travel demands are either fixed or elastic.

FR1-R10 ROBUST OPTIMIZATION

New directions in robust optimization

organizer/chair: Constantine Caramanis

A flexible approach to robust optimization via convex risk measures

DAVID BROWN
MIT/Duke

coauthors: Aharon Ben-Tal, Dimitris Bertsimas
keywords: convex risk measures, optimized certainty equivalent, portfolio optimization, robust optimization

In this work we investigate a flexible approach to robust optimization based on risk preferences of the decision-maker in which one specifies not only the values of the uncertain parameters for which feasibility should be ensured, but also the degree of feasibility. We show that traditional, robust optimization models are a special case of this framework. Our focus is on linear optimization and the key tool will be the theory of convex risk measures, developed by Föllmer and Schied. We consider four, primary classes of risk measures and connect them with corresponding notions of robustness. We also prove that the corresponding risk measures imply a family of probability guarantees at various degrees of feasibility, as opposed to a single bound on feasibility commonly proved in robust optimization. Finally, we illustrate the performance of these risk measures on a real-world portfolio optimization application and show promising results that our methodology can, in some cases, yield significant improvements in downside risk protection at little or no expense in expected performance over traditional portfolio approaches such as CVaR.

Constructing hierarchies of structured adaptability via data and sampling

CONSTANTINE CARAMANIS
MIT/UT Austin

coauthor: Dimitris Bertsimas
keywords: adaptable optimization, robust optimization, sampling

Sampling approaches to multi-stage Stochastic Optimization typically have a sample complexity exponential in the number of stages. Robust Optimization, on the other hand, has a very limited ability to address multi-stage optimization problems in an adaptable manner, because the inherent worst-case criterion of robustness leads to an intractable subproblem. In this talk we present a sample-based robust optimization methodology for constructing adaptability in multi-stage optimization problems, that is both tractable (in particular, not exponential in the number of stages) and also flexible, in the sense that it offers a hierarchy of adaptability. We prove polynomial upper bounds on sample complexity, and further show that our adaptability proposal, as well as our sample complexity results, extend to multi-stage problems with integer variables in the future stages. We illustrate the proposed method on several problems in Network Design, and Portfolio Optimization.

A sequential sampling procedure for stochastic programs

GUZIN BAYRAKSAN
The University of Arizona

coauthor: David Morton
keywords: Monte Carlo simulation, sequential sampling, stochastic programming

We develop a sequential sampling procedure for a class of stochastic programs. We assume that a sequence of feasible solutions with limit points that solve the stochastic program is given as input to our procedure. Such a sequence can be generated by solving a series of sampling problems with increasing sample size, or, it can be found by any other viable method. Our procedure estimates the optimality gap of a candidate solution from this sequence. If the point estimate of the optimality gap is sufficiently small according to our termination criterion, then we stop. Otherwise, we repeat with the next candidate solution from the

sequence under an increased sample size. We provide conditions under which this procedure: (i) terminates with probability one and (ii) terminates with a solution which has a small optimality gap with a pre-specified probability.

FR1-R12 NONLINEAR PROGRAMMING

Regularization methods

organizers: William Hager, Benar Svaiter
chair: William Hager

New asymptotic convergence analysis for proximal point methods

WILLIAM HAGER
University of Florida

coauthor: Hongchao Zhang
keywords: asymptotic convergence, local convergence, nonsmooth optimization, proximal point algorithm

We analyze the asymptotic convergence properties of a class of self-adaptive proximal point methods. Our analysis for the exact proximal point method only requires lower semicontinuity of the cost functional and a new local error bound property for the solution set. This latter property is expressed in terms of local function values. For the inexact proximal point method, asymptotic convergence results are obtained without smoothness provided the functional is locally convex. When the functional is twice continuously differentiable, asymptotic convergence results are established without local convexity.

Convergence of the regularized Newton trajectories

B. F. SVAITER
IMPA

coauthor: Raphael Hauser
keywords: convergence, Newton methods, regularization, trajectories

Convergence of continuous versions of iterative alogrithms shed some light on the bahavior of these methods.

For the minimization of a smooth convex function, convergence of the Cauchy trajectories where known and well understood. Convergence of Newton's trajectory depends on additional assumptions. We give conditions for the convergence of the continuous quadratic-regularized Newton method. These conditions may shed some light on the choice of regularizing parameters for the discrete algorithm.

Proximal point methods in Banach spaces without monotonicity

ROLANDO OTERO
UFRJ-IE

coauthor: Alfredo Iusem
keywords: hybrid proximal-extragradient algorithm, hypomonotone operator, proximal point algorithm

We introduce the concept of hypomonotone point-to-set operator in Banach spaces, with respect to a regularizing function. This notion coincides with the one given by Rockefellar and Wets in Hilbert spaces, when the regularizing function is the square of the norm. We study the associated proximal mapping, which leads to hybrid proximal-extragradient and proximal-projection methods for nonmonotone operators in reflexive Banach spaces. These methods allow for inexact solution of the proximal subproblems with relative error criteria. We consider then the notion of local hypomonotonicity, and propose localized versions of the algorithms, which are locally convergent.

FR1-R13 NONLINEAR PROGRAMMING

Advance and algorithms for nonlinear optimization

chair: Adilson Elias Xavier

The hyperbolic smoothing approach for solving the support vector machine problem

ADILSON ELIAS XAVIER
COPPE/UFRJ

coauthors: Alexandre Pinto Alves da Silva, Raul Fonseca Neto, Alberto de Oliveira Moreno, Patrícia Curvelo, Victor Ströeler
keywords: classification, nondifferentiable programming, pattern recognition, smoothing

This paper is intended to show a new approach for solving the linear Support Vector Machine (SVM) problem that leads to the minimization of unconstrained completely differentiable problem in a space of dimensionality equal to the number of classified points. The resolution method proposed adopts a smoothing strategy using a special completely differentiable class function. The final solution is obtained by solving a sequence of low dimension differentiable unconstrained optimization subproblems which gradually approach the original problem. The use of this technique, called Hyperbolic Smoothing, presents a new option for solving SVM problem formulations. For the purpose of illustrating both the reliability and the efficiency of the method, a set of computational experiments was performed making use of traditional test problems described in the literature.

Second-order optimality conditions for general nonlinear optimization problems

HELMUT GFRERER
Johannes Kepler University Linz

keywords: second-order optimality conditions

In this talk we present a very general and unified theory of second-order optimality conditions for general optimization problems subject to abstract constraints in Banach spaces.Our results apply both to the scalar and the multicriteria case. Our approach is based on the observation that near a local minimizer, a certain system composed of the objective and the constraints has a certain singular behaviour. We present also some variational results which show that, in a certain sense, our results are the best possible one can obtain by using second order analysis.

Generalization of the partial inverse method for closed convex cones

CHRISTIANE DE CAMPOS COSTA
UFRJ

coauthor: Maria Helena Cautiero Horta Jardim
keywords: closed convex cones

In 1983 J. E. Spingarn introduced the Partial Inverse Method in the framework of Mathematical Programming. Since his initial articles, a number of applications have been developed in several fields, such as Lagrangian Multipliers Methods, Location Theory, Convex Feasibility Problems, Analysis of Data, Economic Equilibrium Problems. The method consists of a decomposition algorithm, to which the Proximal Point Algorithm associated with operator T_A is applied, in order to solve problems whose objective is to find $x \in A$ and $y \in A^{\perp}$ such that

$y \in T(x)$. The motivation for generalizing the Partial Inverse Method on cones arises from the need to solve Optimization problems defined on cones. Such generalization, however, is not possible, due to the nonlinearity of the projection operator on cones.

FR1-R14 NONSMOOTH OPTIMIZATION AND CONVEX PROGRAMMING

Convex optimization

organizer/chair: Joerg Fliege

An efficient interior-point method for convex multicriteria optimization problems

JOERG FLIEGE
University of Birmingham

keywords: efficient point, interior-point methods, multicriteria, polynomial-time

In multicriteria optimization, several objective functions have to be minimized simultaneously. We propose a new efficient method for approximating the solution set of a multicriteria optimization problem, where the objective functions involved are arbitrary convex functions and the set of feasible points is convex. The method is based on generating warm-start points for an efficient interior-point algorithm, while the approximation computed consists of a finite set of discrete points. Polynomial-time complexity results for the method proposed are derived. In these estimates, the number of operations per point *decreases* when the number of points generated for the approximation *increases*. This reduced theoretical complexity estimate is a novel feature and is not observed in standard solution techniques for multicriteria optimization problems.

Boundedness of epsilon-approximate solution set

GWI SOO KIM
Division of Mathematical Sciences, Pukyong National University

coauthor: Gue Myung Lee
keywords: asymptotic cone, convex semidefinite optimization problems, epsilon-approximate solutions

In this talk, boundedness for the set of all the epsilon-approximate solutions for convex optimization problems are considered. We give necessary and sufficient conditions for the set of all the epsilon-approximate solutions for a convex optimization problem involving finitely many convex functions, a linear optimization problem and a convex semidefinite problems. Furthermore, we give examples illustrating our results for the boundedness.

A primal-dual interior-point method for quadratic

MARIA GONZALEZ-LIMA
Universidad Simon Bolivar

keywords: primal-dual interior-point methods, quadratic programming

In this talk we propose a primal-dual interior-point method for large, sparse, quadratic programming problems. The method is based on a reduction presented by Gonzalez-Lima, Wei, and Wolkowicz in order to solve the linear systems arising in the primal-dual methods for linear programming. The main features of this reduction is that it is well defined at the solution set and it preserves sparsity. These properties add robustness and stability to the algorithm and very accurate solutions can be obtained. We discuss the relationship of our proposals and the one used in the LOQO code.

FR1-R18 GRAPHS AND MATROIDS

Graph coloring: a classical problem in new applications

organizer/chair: Rossella Petreschi

An edge-coloring algorithm for placing data and parity to tolerate two disk failures in RAIDs

DEO NARSINGH
University of Central Florida

coauthor: Sanjeeb Nanda
keywords: edge colouring, Hamiltonian paths, perfect 1-factorization, RAID Design

Redundant Arrays of Independent Disks (RAID) systems have come into widespread use because of their enhanced I/O bandwidths, large capacities, and low cost. However, the increasing demand for larger array capacities at low cost has led to the use of arrays with larger number of disks that increases the likelihood of the concurrent occurrence of two or more random disk failures. Hence the need for RAID systems to tolerate two or more random disk failures without compromising disk utilization. In this paper, we present an algorithm based on the perfect 1-factorization of the complete graphs K_P and K_{2P-1} to obtain the placement of data and parity in two-disk fault-tolerant arrays having $(P-k)$ and $(2P-1-k)$ disks respectively, where P is a prime number and $k \geq 1$. Furthermore, we determine the fraction of space used for storing parity in such arrays and show that this fraction has the optimal value for $k = 1$. Finally, we present an overview of the contemporary state of commercial RAID implementations and how our proposed solution compares with them.

Colouring of cubic graphs and partial Steiner triple systems: a new look at old problems

MARTIN SKOVIERA
Comenius University

keywords: configuration, cubic graph, edge colouring, Steiner triple system

Vizing's edge-colouring theorem divides cubic graphs into the class of 3-edge-colourable graphs (which comprises almost all of them) and a "small" but annoying family of graphs that cannot be 3-edge-coloured. One possible approach to studying uncolourable cubic graphs consists in extending the definition of a 3-edge-colouring to include a wider class of cubic graphs. In this talk we propose a natural generalisation of the classical 3-edge-colouring based on the concept of a partial Steiner triple system. The colourings use points of the system as colours subject to the condition that any three colours meeting at a vertex form a triple. Many interesting systems occur as geometric configurations of points and lines, and the corresponding colourings seem to have a special importance.

In the talk we show that all bridgeless cubic graphs admit colourings by certain geometric configurations such as the Fano plane and the affine plane. We also discuss the relationship of our colourings to certain conjectures in graph theory. In particular, we point out that the 5-Cycle Double Cover Conjecture is equivalent to the existence of a colouring by the famous Desargues configuration 10_3, and that Fulkersons's conjecture (whose origin is in mathematical programming) is equivalent to a colouring by the Cremona configuration 15_3.

FR1-R19 APPROXIMATION ALGORITHMS

Approximation algorithms I

organizer: Claire Kenyon
chair: David Williamson

Strongly polynomial primal-dual algorithms for concave cost combinatorial optimization problems

DAN STRATILA
Operations Research Center, MIT

coauthor: Thomas Magnanti
keywords: combinatorial optimization, concave costs, fixed-charge costs, primal-dual algorithms

Primal-dual algorithms for uncapacitated fixed charge combinatorial optimization problems often possess attractive theoretical and computational properties, yet do not generalize to problems with concave costs and arbitrary demands. We consider a class of combinatorial optimization problems with concave costs. Our main result yields a primal-dual algorithm for a concave cost problem in this class whenever one exists for its fixed charge special case. As a result, we obtain new approximation algorithms for concave cost facility location and inventory problems, and new heuristics for concave cost multicommodity flows.

Approximation of octilinear Steiner trees constrained by obstacles

MATTHIAS MUELLER-HANNEMANN
TU Darmstadt

coauthor: Anna Schulze
keywords: approximation algorithms, obstacles, Steiner tree problems, VLSI design

Given a finite set of points in the plane, the octilinear Steiner tree problem is to construct a tree in the plane that interconnects the given points with minimum total length such that every line segment of the tree has one of four possible orientations: it runs vertical, horizontal, or parallel to one of the 45- and 135-degree diagonals (octilinear routing).

Octilinear routing is a novel routing paradigm in VLSI design, the so-called X-architecture. Compared to traditional and state-of-the-art rectilinear routing, such a technology promises a significant chip performance improvement and power reduction.

Recently, we proved that the octilinear Steiner tree problem is NP-hard. In this talk, we will present approximation algorithms for the octilinear Steiner tree problem with different types of obstacles. We provide reductions to the Steiner tree problem in graphs of polynomial size and thereby achieve approximation guarantees which come arbitrarily close to the best-known guarantees for the latter problem.

On the computational complexity and approximability of the minimum committee combinatorial optimization problem

MIKHAIL KHACHAY
Institute of Mathematics and Mechanics, UB of RAS

keywords: approximation algorithms, approximation threshold, APX, NP-hardness

Two special cases of the Minimum Committee Problem are studied, the Minimum Committee Problem of Finite Sets (MCFS) and the Minimum Committee Problem of a System of Linear Inequalities(MCLE). It is known that the first of these problems is *NP*-hard. In this paper we show the *NP*-hardness of two integer optimization problems connected with it. In addition, we analyze the hardness of approximation to the MCFS problem. In particular, we show that, unless $NP \subset TIME(n^{O(\log\log n)})$, for every $\varepsilon > 0$ there are no approximation algorithms for this problem with approximation ratio $(1-\varepsilon)\ln(m-1)$, where m is the number of inclusions in the MCFS problem. To prove this bound we use the SET COVER problem, for which a similar result is known. We also show that the Minimum Committee of Linear Inequalities System (MCLE) problem is *NP*-hard as well, furthermore, we show that it does not belong to the Apx class and consider an approximation algorithm for this problem

FR1-R20 PRODUCTION AND SCHEDULING

Scheduling problems

chair: Jan Pelikan

Hybrid genetic algorithm for non-determinist dynamic job shop scheduling problem

TAMIO SHIMIZU
Universidade de São Paulo

coauthor: Antonio Costa Oliveira
keywords: dynamic job shop scheduling, genetic algorithms, tabu search

In a Dynamic Job Shop Problem Scheduling (DJSP) jobs arrive to the shop at previously known fixed instants (deterministic DJSP) or, the arrival time of each job is not known in advance, and we have a problem known as non-deterministic DJSP. Non-deterministic DJSP can be considered as a sequence of classical static job shop scheduling problems (JSP) , while the time runs. This work deals with non deterministic DJSP with the objective of minimizing the total tardiness of jobs. Two versions of a hybrid algorithm, combining genetic and tabu search algorithms, are presented. Computational results of these two versions are compared with many dispatching rules used for DJSP, showing that these two heuristics, despite the use of higher runtime, presented an average of 30% better quality solutions. This result seems to encourage the use of these hybrid heuristics in more complex and realistic dynamic scheduling problem.

A batch production scheduling problem

JAN PELIKAN
University of Economics, Prague

keywords: heuristics, integer programming, scheduling

Based on case study, the following batch scheduling problem is studied. There is a set of batches of products and machine tools on which the products are being produced. Each machine has to be adjusted before producing a batch. There is only one worker for adjusting the machines, therefore the adjustment process will be considered as a serial processing of batches on one serial processor. The schedule consists in setting the order of batches being processed on machine tools, satisfying given technological requirements. Production process, during which each batch is processed on different machines, can be considered as the parallel processing of batches on parallel processors. The adjustment of a machine is the first phase of batch processing and the proper production is its second phase. The adjustment time and production time are given for each batch. The objective is to minimize the total processing time of all batches. Therefore,

delays can occur for the following reasons: (a) all machines are working so that no machine can be adjusted for another batch (a delay in the adjustment process); (b) a machine must wait for adjustment while another machine is being adjusted, since the adjustment is carried out only by one worker (a delay in the production process). The minimization of the total processing time of all batches of a given production order is carried out in such a way that the resulting schedule leads at the same time to the maximum exploitation of the machines, minimum delays, and minimum production costs. For solving the problem, the mathematical model with binary variables is proposed and the heuristics as well. Computation experiment is executed on real data, which is originated on case study. An integer programming model is proposed and solved on LINGO. Obtained results are very interesting since they lead to a significant decrease of the total processing time in comparison with the present practice.

A scheduling method for R&D projects with the minimum risk

YASUHIRO KOBAYASHI
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coauthors: Junko Ito, Osamu Kubo
keywords: optimization, R&D projects, risk, scheduling

A scheduling method has been developed for multi-task R&D Projects in which technical and market risk factors are critical issues. The R&D risk is controlled by stage-wise investment decisions and the use of real options of stage-wise development type. The project scheduling method employs the expected sum of total investment as a risk index, and minimizes the index through task ordering and task scheduling steps subjective to constraints. A risk directed ordering measure is introduced and extended to satisfy task order constraints for the first step, and the ordered tasks are scheduled by the A* search based enumeration method at the second step. The project scheduling method has been successfully applied to a medium-sized sample pharmaceutical R&D project, and the applicability of the method has been confirmed with numerical results from the two scheduling steps.

Index of Keywords

Speakers, Coauthors and Chairpersons

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