ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

16th International Symposium on Mathematical Programming

Lausanne, August 24-29, 1997

Program and Abstracts

Welcome to the
Ecole Polytechnique Fédérale de Lausanne (EPFL)

We welcome you to *ismp97*, the 16th International Symposium on Mathematical Programming, on the campus of the Swiss Federal Institute of Technology Lausanne (EPFL), celebrating the fiftieth birthday of George Dantzig's simplex algorithm.

With twenty-five featured state-of-the-art lectures, three-hundred invited and some hundred contributed sessions, totaling over twelve-hundred presentations, this is the largest *ismp* so far. All aspects of mathematical programming will be covered, from novel applications in emerging technologies, algorithms, heuristics and software, to abstract theory. This rich mixture should contain something to excite every participant and, who knows, a break-through or two.

This is a very large meeting, but it is meant to be a human one, set up for individuals, by caring people who had great fun doing it. Many persons, institutions and companies generously gave us their moral and material support, which we very gratefully acknowledge. But most important for this event's success are, of course, the participants, making available the results of thousands of years of creative work.

Whether it finally will be Lausanne's beauty and hospitality or the fertile scientific interactions that you remember from the symposium remains to be seen; we certainly hope it will be both.

We wish you a stimulating, enjoyable *ismp97*.

Dominique de Werra
Thomas M. Liebling

Lausanne, EPFL, July 1997

Contents

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Overview of Events

Registration

Sunday August 24, 15:00 - 19:00, EPFL - CO.

Welcome Reception

Sunday August 24, 17:00 - 19:30, EPFL - Esplanade, featuring the alpenhorn trio "Les Muverans". Wine offered by the City of Lausanne and the Canton de Vaud.

Opening Session

Monday August 25, 9:30 - 11:40, Métropole Concert Hall, with plenary talks by G.B. Dantzig and J. Dennis, and musical intermezzi by the Collège de Cuivres de Suisse Romande.

Prizes

During the Opening Session, the Fulkerson and Beale-Orchard-Hays Prizes will be awarded and the Tucker Prize finalists will be announced. The Tucker Prize will be awarded during the session TU4-Z-IN202, followed by presentations by the finalists.

Featured State-of-the-Art Lectures

See program on page 7.

Parallel Sessions

See program on page 10 ff.

Special Sessions

- Anthony V. Fiacco's 70th Birthday, MO3-D-CO123, MO4-D-CO123
- Philip Wolfe's 70th Birthday, WE2-A-IN1
- The Pivot Choice Challenge, with love to George, WE1-A-IN1
- Tucker Prize Award, TU4-Z-IN202
- Steven Vajda Memorial Session, TH2-A-IN1
- The Mystical Power of Twoness: in Memoriam Eugene L. Lawler, MO-pm-CO3

Simplex Birthday Party

Tuesday August 26, 19:15, Restaurant of the University of Lausanne. Master of Ceremony : Richard W. Cottle. Keynote talks by B. Bixby, H.P. Künzi, T. Magnanti and Ph. Wolfe.

Lake Cruise and Banquet

Wednesday August 27, 18:45, bus departure from EPFL campus, 19:30, departure from Ouchy Port.

Social Program

An extensive social program has been set up for accompanying persons, including sightseeing trips, museum visits, wine and cheese tasting,... See the program booklet for details.

Overview of the Program

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<tr><td>8:15 - 9:45</td><td rowspan="7"></td><td></td><td>Parallel Sessions</td><td>Parallel Sessions</td><td>Parallel Sessions</td><td>Parallel Sessions</td></tr>
<tr><td>9:45 - 10:00</td><td rowspan="4">Opening Session
Metropole Concert Hall, Downtown Lausanne
9:30 - 11:40</td><td colspan="4">Coffee Break</td></tr>
<tr><td>10:00 - 11:00</td><td>Lectures</td><td>Lectures</td><td>Lectures</td><td>Lectures</td></tr>
<tr><td>11:00 - 11:15</td><td colspan="4">Coffee Break</td></tr>
<tr><td>11:15 - 12:45</td><td>Parallel Sessions</td><td>Parallel Sessions</td><td>Parallel Sessions</td><td>Parallel Sessions</td></tr>
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<tr><td>15:30 - 15:45</td><td rowspan="3">Registration
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<tr><td>15:45 - 16:45</td><td>Lectures</td><td>Lectures</td><td>Lectures</td><td>Lectures</td><td rowspan="2">Parallel Sessions
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<tr><td>17:00 - 18:30</td><td>Welcome Reception
17:00 - 19:30</td><td>Parallel Sessions</td><td>Parallel Sessions</td><td>Parallel Sessions</td><td>Parallel Sessions</td><td rowspan="2"></td></tr>
<tr><td></td><td></td><td></td><td>Simplex Birthday Party
19:15 - 22:00</td><td>Lake Cruise & Banquet
19:30 - 22:30</td><td>Wine Tasting</td></tr>
</table>

Opening Session

Monday August 25, 9:30 - 11:40, Métropole Concert Hall, Downtown Lausanne
Chair: Th. M. Liebling

Musical intermezzi: Collège de Cuivres de Suisse Romande

Call to Order

Th. M. Liebling, Organizing Committee Chair

Welcome Addresses

A. Bidaud, President of the City Council of Lausanne
J.-C. Badoux, President of the EPFL
D. de Werra, Vice-President of the EPFL, International Advisory Committee Chair

Plenary Talk

George B. Dantzig, Stanford University

How Linear Programming First Began

Prizes

- **Beale-Orchard-Hays Prize** — for excellence in computational mathematical programming — awarded by Committee Chair Robert J. Vanderbei.
- **Fulkerson Prize** — for an outstanding paper in discrete mathematics — awarded by Committee Chair Eva Tardos.
- **Tucker Prize** — for an outstanding paper by a student — announcement and presentation of the finalists by Committee Chair Jean-Philippe Vial.

Plenary Talk

John Dennis, President of the Mathematical Programming Society, Noah Harding Professor of Computational & Applied Mathematics, Rice University

Optimization : An Essential Tool for 21st Century Commerce

Featured State-of-the-Art Lectures

Monday morning 9:30-11:40	
Opening Session	

Monday afternoon 15:45-16:45	
Andrzej Ruszczyński, *Decomposition Methods in Stochastic Programming*. Chair: P. Kall	SPO
Eva Tardos, *Routing in Networks*. Chair: A. Frank	CO1
Uwe Zimmermann, *Discrete Optimization in Public Rail Transport*. Chair: M. A. Jünger	CO2
Jan Karel Lenstra, *The Mystical Power of Twoness: in Memoriam Eugene L. Lawler*. Chair: R. H. Möhring	CO3

Tuesday morning 10:00-11:00	
Philippe Toint, *Recent progress in unconstrained nonlinear optimization without derivatives*. Chair: R. Fletcher	SPO
Michel Goemans, *Semidefinite Programming in Combinatorial Optimization*. Chair: W. H. Cunningham	CO1
Robert Gumerlock, *Financial Risk Management - A Business Between Regulation and Research*. Chair: H. J. Lüthi	CO2 CO3

Tuesday afternoon 15:45-16:45	
Jochem Zowe, *Free Material Optimization via Mathematical Programming*. Chair: A. Ben Tal	SPO
Gil Kalai, *Linear Programming, the Simplex Algorithm and Simple Polytopes*. Chair: A. Schrijver	CO1
Egon Balas, *Recent Advances in Lift-and-Project*. Chair: L. A. Wolsey	CO2 CO3

Wednesday morning 10:00-11:00	
Masakazu Kojima, *Exploiting Sparsity in Primal-Dual Interior-Point Methods for Semidefinite Programming*. Chair: M. J. Todd	SPO
Manfred Padberg, *Facets, Rank of Integer Polyhedra and Other Topics*. Chair: M. Grötschel	CO1
Pierre Hansen, *Cluster Analysis and Mathematical Programming*. Chair: D. de Werra	CO2 CO3

Wednesday afternoon 15:45-16:45	
Herbert Scarf, *Test Sets for Integer Programs*. Chair: I. Barany	SPO
Peter Hammer, *Logical Analysis of Numerical Data*. Chair: Y. Crama	CO1
Arne Drud, *Interactions between Nonlinear Programming and Modeling Systems*. Chair: D. F. Shanno	CO2 CO3

Thursday morning 10:00-11:00	
Andreas Dress, *Two Applications of the Divide and Conquer Principle in the Molecular Sciences*. Chair: G. H. Gonnet	SPO
Monique Laurent, *Cuts, Matrix Completions and Graph Rigidity*. Chair: B. Korte	CO1
Alfred Auslender, *How to deal with the unbounded in optimization: theory and algorithms*. Chair: J. Stoer	CO2 CO3

Thursday afternoon 15:45-16:45	
Juri Nesterov, *Interior-Point Methods: an Old and New Approach to Nonlinear Programming*. Chair: J.-P. Vial	SPO
Tamás Terlaky, *The Criss-Cross Method: a Fresh View on Pivot Algorithms*. Chair: V. Chvátal	CO1
Jong-Shi Pang, *Error Bounds in Mathematical Programming*. Chair: O. L. Mangasarian	CO2 CO3

Friday morning 10:00-11:00	
Alexander Barvinok, *Measure Concentration in Optimization*. Chair: G. M. Ziegler	SPO
Rainer Burkard, *Efficiently Solvable Special Cases of Hard Combinatorial Optimization Problems*. Chair: Th. M. Liebling	CO1
Matteo Fischetti, *Algorithms for Railway Crew Management*. Chair: L. E. Trotter	CO2 CO3

Sessions and Codes

Aside from the plenary Opening Session on Monday, there are two session types :

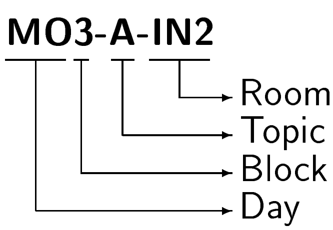
The Parallel Sessions, sets of 3 talks, denoted by a code such as **MO3-A-IN2**.

The State-of-the-Art Lectures, denoted by a code such as **WE-am-CO1**.

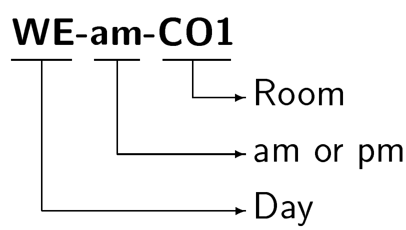
From Monday afternoon to Friday morning, every half-day is composed of one block of parallel sessions, a short break, a group of state-of-the-art lectures, a short break and another block of parallel sessions. There are no state-of-the-art lectures on Friday afternoon.

Explanation of the codes

parallel session :



state-of-the-art lecture :



The parallel session blocks are numbered from 1 to 4 :
1 : 8:15-9:45
2 : 11:15-12:45
3 : 14:00-15:30
4 : 17:00-18:30 (except Friday : 15:45-17:15)

For the state-of-the-art lectures,
am indicates the morning lectures (10:00-11:00)
pm indicates the afternoon lectures (15:45-16:45).

The rooms are located in three areas of the EPFL : **CM**, **CO** and **IN**. Within each area, the rooms are numbered. The *salle polyvalente* **SPO** is used for the state-of-the-art lectures. Please refer to the map on the inside of the back cover for a better view.

Parallel Sessions Topics & Rooms

<table>
<tr><th rowspan="2">Room</th><th colspan="2">Mo 25</th><th colspan="4">Tu 26</th><th colspan="4">We 27</th><th colspan="4">Th 28</th><th colspan="4">Fr 29</th></tr>
<tr><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>CM4</td><td rowspan="4" colspan="18">I: Combinatorial optimization, graphs and networks, matroids</td></tr>
<tr><td>CM5</td></tr>
<tr><td>CM120</td></tr>
<tr><td>CM121</td></tr>
<tr><td>CM200</td><td colspan="17"></td><td></td></tr>
<tr><td>CM201</td><td colspan="18">L: Large-scale MP and parallel computing</td></tr>
<tr><td>CM106</td><td colspan="12">K: Approximation methods, heuristics, local search,...</td><td colspan="6">V: MP in finance and economics</td></tr>
<tr><td>CO10</td><td colspan="18">B: Convex smooth and nonsmooth programming, semi-infinite programming</td></tr>
<tr><td>CO11</td><td colspan="4"></td><td colspan="12"></td><td colspan="2"></td></tr>
<tr><td>CO21</td><td colspan="18">E: Complementarity, reformulation and fixed point theory</td></tr>
<tr><td>CO2</td><td rowspan="3" colspan="18">C: Nonlinear, nonconvex, smooth and nonsmooth, global optimization</td></tr>
<tr><td>CO3</td></tr>
<tr><td>CO122</td></tr>
<tr><td>CO123</td><td colspan="15"></td><td colspan="3"></td></tr>
<tr><td>CO124</td><td colspan="18">D: Interior point and path following algorithms, semidefinite programming</td></tr>
<tr><td>CO15</td><td colspan="7">N: Algorithms and Software</td><td colspan="11">W: Interfaces with statistics, computer science and applications</td></tr>
<tr><td>CO22</td><td colspan="11">T: MP in industry, management, government, environment</td><td colspan="7">H: Game theory and multicriteria opt.</td></tr>
<tr><td>IN10</td><td colspan="18">U: MP in science, technology, transportation, telecom, energy</td></tr>
<tr><td>IN1</td><td colspan="13"></td><td colspan="5"></td></tr>
<tr><td>IN2</td><td colspan="18">A: Linear, integer, mixed-integer programming</td></tr>
<tr><td>IN11</td><td colspan="16">G: Stochastic programming and stochastic optimal control</td><td colspan="2"></td></tr>
<tr><td>IN201</td><td colspan="18">P: Scheduling and timetabling</td></tr>
<tr><td>IN203</td><td colspan="8">R: Computational geometry, VLSI-design</td><td colspan="10">F: Dynamic programming and optimal control</td></tr>
<tr><td>IN202</td><td colspan="3"></td><td>J</td><td>M</td><td>Z</td><td>O</td><td colspan="3">S</td><td colspan="8"></td></tr>
</table>

J: Computational complexity, performance guarantees, quantum computation

M: Expert, interactive and decision support systems, fuzzy logic

Z: Tucker Prize finalists

S: Computational biology

O: Simulation, optimization in discrete event simulation

Note: 'MP' stands for Mathematical Programming

Parallel sessions : Monday afternoon 14:00 - 15:30

	14:00 - 14:30	14:30 - 15:00	15:00 - 15:30
MO3-A-IN2	**Test sets in integer programming I**, Organizer: Weismantel, Chair: Weismantel		
	Schulz, *An Optimization Problem is Nine Problems*	Urbaniak, *Decomposition of Integer Programs and of Generating Sets*	Hosten, *Degrees of Groebner Bases of Integer Programs*
MO3-A-IN1	**The Criss-Cross Method I**, Organizer: Chvátal, Chair: Chvátal		
	Matsui, *On the Finiteness of the Criss-Cross Method*	Namiki, *Some Practical Behaviors of Least Index Methods for LP and LCP*	Zhang, *New Variants of Finite Criss-Cross Pivot Algorithm for Linear Programming*
MO3-B-CO11	**Infinite Programming**, Organizer: Smith, Chair: Smith		
	Garcia, *Minimal Forecast Horizons and Monotonicity of Optimal Solutions*	Lasserre, *A Theorem of the Alternative in Banach Lattices*	Schochetman, *Existence and Discovery of Average Optimal Solutions in Deterministic Infinite Horizon Optimization*
MO3-B-CO10	**Convex programming methods I**, Chair: Grant		
	Kovács, *A Quasi-Interior Path-Following Method*	Combettes, *Block-Iterative Outer Approximation Methods for Convex Programming in Banach Spaces*	Grant, *Infeasible Primal-Dual Methods for the General Cone*
MO3-C-CO2	**Generalized Convexity I**, Organizer: Martínez-Legaz, Chair: Schaible		
	Rubinov, *Convex-Along-Rays Functions and Star-Shaped Sets*	Rubinov, *Increasing Convex-Along-Rays Functions with Applications*	Andramonov, *Cutting Angle Methods for Minimizing Increasing Convex-Along-Rays Functions*
MO3-C-CO3	**Lagrangian Methods in Nonlinear Programming I**, Organizer: Di Pillo, Chair: Polak		
	Facchinei, *Convergence to Second Order Stationary Points in Inequality Constrained Optimization*	Di Pillo, *An Approach to the Solution of NLP Problems Using an Exact Augmented Lagrangian Function*	Giannessi, *Some Remarks on Lagrange Multipliers and Separation of Sets*
MO3-C-CO122	**Bundle methods and nonsmooth optimization**, Chair: Kiwiel		
	Silva, *Sufficient Conditions of Optimality for Nonsmooth Continuous Time Optimization Problems*	Gfrerer, *A Bundle Method for Nonlinear Programs with Noisy Functions*	Pola, *Image Denoising Using Interior-Point and Bundle Methods*
MO3-D-CO124	**Interior Point Methods for Nonlinear Programming**, Organizers: Roos, Terlaky, Chair: Terlaky		
	Jarre, *A Primal-Dual Interior-Point Method for Quadratically Constrained Convex Programs*	Nesterov, *Semidefinite Relaxation and Non-Convex Quadratic Optimization*	
MO3-D-CO123	**Professor Anthony V. Fiacco 70th birthday**, Organizer: Shanno, Chair: Shanno		
	Gould, *Primal-Dual Methods for Nonconvex, Linearly Constrained Minimization*	Goldfarb, *Interior Point Trajectories in Semidefinite Programming*	Sofer, *Interior Point Methods for 3-Dimensional PET Reconstructions*
MO3-E-CO21	**Simplicial algorithms**, Organizer: Talman, Chair: Talman		
	van der Laan, *On the Transition of Mixed Economies to Market Economies*	Forster, *Homotopy Algorithms and Properties of Systems of Polynomial Equations*	Anderson, *A Direct Search Algorithm for Optimization with Noisy Function Evaluations*
MO3-G-IN11	**Stochastic problems**, Chair: Morton		
	Kiseleva, *On Algorithm of Solution of the Continuous Stochastic Problem of Optimal set Partitioning with Objective Functional Restoration*	Mazalov, *Stochastic Dynamic Programming and Behavioral Ecology Problems*	Monhor, *A Probabilistic Approach to Stochastic PERT*
MO3-I-CM200	**Combinatorial Optimization I**, Organizers: Kabadi, Punnen, Chair: Kabadi		
	Orlin, *Solving inverse Spanning Tree Problems Through Network Flow Techniques*	Narayanan, *The Principal Partition and the Principal Lattice of Partitions - Connections and Analogies*	
MO3-I-CM121	**Matroids and Submodular Functions I**, Organizers: Zimmermann, McCormick, Fujishige, Chair: McCormick		
	Murota, *L-convex Functions and Their Fundamental Properties*	Vande Vate, *Finding a Maximum Vector in a 2-lattice Polyhedron*	Tardella, *Minimizing Submodular Functions on Finite Sublattices of Product Spaces*
MO3-I-CM120	**Network Design**, Organizer: Chopra, Chair: Barahona		
	Barahona, *Separation of Partition Inequalities and the k-cut problem*	Hartvigsen, *Compact Representations of Cuts*	Sastry, *A Dual Ascent Procedure with Valid inequalities for the Multi Level Concentrator Location Problem*
MO3-I-CM5	**Arc Routing**, Organizer: Gendreau, Chair: Gendreau		
	Gueguen, *Transformation of Capacitated Arc Routing Problems with Time Windows and Split Deliveries to a Node Routing Formulation. Resolution by a Column Generation Approach*	Eglese, *The General Routing Problem Polyhedron: A Unifying Framework*	Gendreau, *The Mixed Rural Postman Problem on Trees and Circles*
MO3-I-CM4	**Graph Coloring Problems**, Chair: Gravier		
	Korach, *Coloring Distance Grid Graphs*	Jansen, *Approximation Results for the Optimum Cost Chromatic Partition Problem*	
MO3-K-CM106	**Machine Learning via Mathematical Programming**, Organizer: Mangasarian, Chair: Mangasarian		
	Bennett, *A Support Vector Method for Global Induction of Decision Trees*	Solodov, *Applications of Outer Approximation Techniques to Machine Learning*	Mangasarian, *Data Mining via Concave Minimization*
MO3-L-CM201	**Applying Parallel Combinatorial Optimization**, Organizers: Savelsbergh, Eckstein, Chair: Savelsbergh		
	Gendron, *Parallel Branch-and-Bound for Multicommodity Capacitated Network Design*	Lueling, *Load Balancing Strategies for the Parallel Solution of Discrete Optimisations Problems*	Ferrez, *Parallel Implementation of Graph Diameter Algorithms*
MO3-N-CO15	**Software tools I**, Chair: Lawrence		
	Owen, *GIDEN: A Graphical Environment for Network Optimization*	Holmstroem, *TOMLAB - A General Purpose, Open MATLAB Environment for Research and Teaching in Optimization*	Makowski, *Model Analysis for Decision Support: Approach, Software and Applications*
MO3-P-IN201	**Scheduling**, Organizer: Potts, Chair: Potts		
	Chen, *Scheduling of Multiprocessor Tasks*	Trubian, *Optimal Timing of Partially Ordered Jobs for Early-Tardy Scheduling*	Mazzola, *Production Planning and Scheduling with Flexible Resources*
MO3-R-IN203	**VLSI-Design and Combinatorial Optimization I**, Organizer: Korte, Chair: Koehl		
	Korte, *VLSI-Design and Combinatorial Optimization - An Ongoing Project*	Vygen, *Efficient Algorithms for Partitioning and Placement*	Hetzel, *A Distance-Preserving Subgrid for VLSI-Routing*
MO3-T-CO22	**Novel Applications I**, Organizer: Kelley, Chair: Kelley		
	Sachs, *Optimization Methods in Food Processing*	Vicente, *Properties and Applications of the Marginal Function for a Trust-Region Problem*	Betts, *Point to Point Path Optimization*
MO3-U-IN10	**Mathematical programming approaches for production management**, Chair: Moresino		
	Quist, *A Nonlinear Assignment Problem in Nuclear Reactor Fuel Management*	Lütolf, *Short and Mid Term Energy Production Planning*	Ingold, *Flexible Lagrangean-Based Heuristics for Dynamic Multi-Level Uncapacitated and Capacitated Lot Sizing*

Parallel sessions : Monday afternoon 17:00 - 18:30

	17:00 - 17:30	17:30 - 18:00	18:00 - 18:30
MO4-A-IN2	**Test sets in integer programming II**, Organizer: Weismantel, Chair: Urbaniak		
	Thomas, *Gomory's Group Problem and Groebner Bases*	Henk, *On Hilbert Bases of Simplicial Cones*	Pasechnik, *Computing the Hilbert Basis*
MO4-A-IN1	**The Criss-Cross Method II**, Organizer: Chvátal, Chair: Matsui		
	Roos, *An Exponential Example for the Least-Index-Pivot Variant of the Criss-Cross Method*	Illés, *The Finite Criss-Cross Method for Hyperbolic Programming*	Sandblom, *External Pivoting Revisited: Finding Good Directions*
MO4-B-CO10	**Proximal Methods in Optimization I**, Organizer: Théra, Chair: Théra		
	Cominetti, *Coupling of the Proximal Point Algorithm with Approximation Methods*	Michelot, *On The Behavior of The Partial Inverse Method*	Théra, *Finding A Zero Of The Sum Of Two Maximal Monotone Operators*
MO4-B-CO11	**Piecewise Quadratic Functions in Optimization I**, Organizer: Pınar, Chair: Pınar		
	Madsen, *Use of Piecewise Quadratic Functions for Linear and Quadratic Programming*	Nielsen, *Implementation of Piecewise Quadratic Functions for Quadratic Programming*	Li, *Regularized Newton Methods for Minimization of Convex Quadratics Splines*
MO4-C-CO3	**Stability in nonlinear programming I**, Organizer: Klatte, Chair: Klatte		
	Kummer, *Regularity, Ekeland-points and uniform lower Semicontinuity of Inverse Maps*	Ralph, *Stability or Regularity of Nonsmooth Feasibility Problems*	Klatte, *Asymptotic Constraint Qualifications and Global Error Bounds for Convex Inequalities*
MO4-C-CO122	**Numerical methods for global optimization**, Chair: Sahinidis		
	Konno, *Cutting Plane/Tabu Search Algorithms for Low Rank Concave Quadratic Programming Problems*	Nowak, *Global Quadratic Optimization Using Bezier Methods*	Bulatov, *Some Special Problems of Operations Research and Numerical Methods of Global Optimization*
MO4-C-CO2	**Nonconvex Quadratic Problems**, Organizer: Yajima, Chair: Yajima		
	Thoai, *Branch and Bound Methods for the General Quadratic Programming Problem*	Yajima, *Polyhedral Approach for Solving Nonconvex Quadratic Problems with Box Constraints*	
MO4-D-CO124	**Interior Point Methods for Global Optimization and Applications**, Organizer: Trafalis, Chair: Trafalis		
	Trafalis, *Stochastic Interior Point Techniques for Global Optimization and Applications to Artificial Neural Network Training*	Resende, *A Branch and Bound Algorithm for the Quadratic Assignment Problem using Lower Bounds Based on Linear Programming*	Warners, *A Nonlinear Approach to a Class of Combinatorial Optimization Problems*
MO4-D-CO123	**Professor Anthony V. Fiacco 70th birthday**, Chair: Sofer		
	Shanno, *Interior Point Methods for Nonconvex Quadratic Programming*	Goldfarb, *A Product-form Cholesky factorization for Handling Dense Columns in Interior Point Methods for LP*	Oliveira, *A New Class of Preconditioners for Large-Scale Linear Systems from Interior Point Methods for Linear Programming*
MO4-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods I**, Organizers: Fukushima, Qi, Chair: Fukushima		
	Mangasarian, *Minimum-Support Solutions of Mathematical Programs*	Fischer, *Merit Functions and Stability*	Chen, *A Global and Local Superlinear Continuation-Smoothing Method for $P_0 + R_0$ and Monotone NCP*
MO4-G-IN11	**Stability and Estimation in Stochastic Programming**, Organizer: Römisch, Chair: Römisch		
	Pflug, *Branch and Bound Methods for Global Stochastic Optimization*	Dentcheva, *Differentiable Selections of Multifunctions and Asymptotic Behaviour of Random Sets*	Römisch, *Quantitative Stability of Stochastic Programs*
MO4-I-CM120	**Steiner Trees and Network Design Problems I**, Organizer: Smith, Chair: Smith		
	Winter, *Large Euclidean Steiner Minimum Trees in an Hour*	Provan, *Strengthening to Survivability in the Plane*	Thomas, *Rectilinear Steiner Trees with Terminals Constrained to Smooth Curves*
MO4-I-CM5	**Combinatorial Optimization for Airlines I**, Organizers: Grötschel, Zimmermann, Chair: Grötschel		
	Nemhauser, *Recent Developments and Future Directions in Airline Scheduling Problems*	Bertsimas, *Air Traffic Flow Management Problems*	Ryan, *An Optimization Model and Solution Method for Standby Crew Selection*
MO4-I-CM121	**Optimization Problems in Geometry**, Organizer: Rote, Chair: Rote		
	Fekete, *Approximation Algorithms for Lawn Mowing and Milling*	Rote, *Clustering Problems on the Line and on Trees*	Martens, *Alternate Parameter of Fractal Objects and its Use*
MO4-I-CM200	**One-Dimensional Packing**, Organizer: Martello, Chair: Martello		
	Rebetez, *On the Exact Resolution of the Bin Packing Problem*	Pisinger, *Dynamic Programming and Tight Bounds for the 0-1 Knapsack Problem*	Labbé, *The Maximum Cardinality Bin Packing Problem*
MO4-I-CM4	**Problems in graph theory**, Chair: Ferreira-Cunha		
	Khutoretsky, *Housing Market Short-Term Equilibria and the Sets of Disjoint Cycles of a Maximum Total Length*	Boratas, *Has Edge Numbering an Effect on the Performance of the Criss-Cross Method in a Directed Graph?*	Ferreira-Cunha, *Comparing E-task-Graphs by Identifying their Differences*
MO4-I-IN202	**Flows and Cuts**, Chair: Hochbaum		
	Hochbaum, *The Pseudoflow Algorithm: A New Algorithm and a New Simplex Algorithm for the Maximum Flow Problem*	Mastroeni, *Duality Relations for Variational Inequalities with Applications to Network Flows*	Fleischer, *Faster Algorithms for the Quickest Transshipment Problem*
MO4-K-CM106	**Evolutionary algorithms**, Organizer: Hertz, Chair: Maniezzo		
	Kobler, *A Taxonomy of Evolutionary Algorithms in Combinatorial Optimization*	Kuntz, *A Distributed Heuristic for Finding Clusters in Vertex Sets*	Thangiah, *A Genetic Clustering Method for Multi-Depot Vehicle Routing Problems*
MO4-L-CM201	**Parallel Interior Point Method**, Organizer: Mitra, Chair: Escudero		
	Forrest, *Progress in the Parallel Interior Point Algorithm in OSL and Successor*	Andersen, *A Parallel Interior-Point Based Linear Programming Solver for Shared-Memory Multiprocessor Computers: A Case Study Based on the APOS LP Solver*	Lustig, *Issues for Porting the CPLEX Parallel Optimizers*
MO4-N-CO15	**Software tools II**, Chair: Owen		
	Lawrence, *New Features and Experiences with the CFSQP Software Package*	Tits, *An Automatic Differentiation Interface for FFSQP*	Mäder, *Modelling and Optimization with Mathematica*
MO4-P-IN201	**Shop scheduling**, Chair: Finke		
	Brucker, *Preemptive Job-Shop Scheduling Problems with a Fixed Number of Jobs*	Schuurman, *The Two-Stage Multiprocessor Open Shop Scheduling Problem*	Grabowski, *Algorithms of Optimal Choosing a Set of Machines for Job-Shop Problem with Parallel Machines*
MO4-R-IN203	**Industrial Applications of Geometric Algorithms and OR**, Organizer: Tokuyama, Chair: Tokuyama		
	Park, *Unified Experimental Analysis of Metaheuristics for the Vehicle Routing Problem, Especially Concerning Neighborhood Search and Geometric Structure*	Okano, *Extension of Traveling Salesman Heuristics for Vehicle Routing and Experiments with a Digital Road Map*	Tajima, *Solving Airline Crew Scheduling Problem with Many Irregular Flights*
MO4-T-CO22	**Novel Applications II**, Organizer: Kelley, Chair: Sachs		
	Frank, *Optimization and Analysis via Surrogate Modeling*	Dennis, *Optimization using Surrogate Objectives*	Alexandrov, *On Using Approximations in Engineering Optimization*
MO4-U-IN10	**Telecommunications and network design**, Chair: Tomasgard		
	Wong, *SONET Ring Network Planning*	Henningsson, *A Capacitated Bus Grid Network Design Problem*	Holmberg, *Lagrangean Heuristic Based Solution Methods for Capacitated Network Design Problems with Different Characteristics.*

Parallel sessions : Tuesday morning 08:15 - 09:45

	08:15 - 08:45	08:45 - 09:15	09:15 - 09:45
TU1-A-IN1	**Linear Programming, Pivoting Algorithms**, Organizers: Terlaky, Roos, Chair: Terlaky		
	Paparrizos, *Pivoting Algorithms Generating tow Paths*	Berkelaar, *Basis- and Tripartition Identification for Quadratic Programming and Linear Complementarity Problems*	Tuniev, *Generalized Transformation of Gauss and Gram-Schmidt and Simplex Method Development*
TU1-A-IN2	**Linear and Mixed-Integer Programming**, Chair: Rangel		
	Holmberg, *Mean Value Cross Decomposition Based Branch-and-Bound for Mixed Integer Programming Problems*	Owen, *Solving Mixed-Integer Linear Programs with General Integer Variables*	Kon-Popovska, *On the Equivalence of some Classes of the Linear Programming Problems with System Matrix Parametrization*
TU1-B-CO10	**Robustness and Sensitivity in Optimization**, Organizer: Ben-Tal, Chair: Ben-Tal		
	El Ghaoui, *Robust Semidefinite Programming*	Bonnans, *Second-Order Analysis of Optimization Problems: Optimality Conditions and Sensitivity Theory*	Ben-Tal, *Robust Convex Optimization*
TU1-B-CO11	**Convex sets and functions**, Chair: Butnariu		
	Burachik, *Submonotone Enlargements and bundle methods for Maximal Monotone Operators*	Garcia-Palomares, *Relaxation Factor in Projection Methods*	
TU1-C-CO2	**Generalized Convexity II**, Organizer: Martínez-Legaz, Chair: Bilbao		
	Schaible, *Generalized Monotonicity in Equilibrium Problems I (scalar case)*	Hadjisavvas, *Generalized Monotonicity in Equilibrium Problems II (vector case)*	Morgan, *Pseudomonotonicity in Optimization Problems with Variational Inequality Constraints*
TU1-C-CO122	**Recent Advances In Global Optimization I**, Organizer: Floudas, Chair: Hansen		
	Duer, *On Global Optimization of Sums of Ratios and the Corresponding Multiple-Criteria Decision Problem*	Jones, *Engineering Optimization Using Statistical Models*	Floudas, *A Global Optimization Method aBB for General Twice-Differentiable Constrained NLPs*
TU1-C-CO3	**Nonlinear Assignment Problems**, Organizer: Pardalos, Chair: Kuipers		
	Meyer, *Large-Scale Graph Partition Assignment Problems*	Çela, *On the Asymptotic Behavior of some Hard Assignment Problems*	Pardalos, *A GRASP For The MultiTarget MultiSensor Tracking Problem*
TU1-D-CO124	**Interior Point Methods in Decomposition I**, Organizers: Gondzio, Mitchell, Chair: Mitchell		
	Goffin, *A Nonlinear Analytic Center Cutting Plane Method for a Class of Convex Programming Problems*	Kaliski, *A General Convex Cut - Based Logarithmic Barrier Decomposition Method for Hard Semi-infinite Programming*	Gupta, *An Infeasible-Interior-Point Algorithm for Convex Quadratic Programming Problems*
TU1-D-CO123	**Homotopies for Nonlinear Problems I**, Organizer: Eaves, Chair: Eaves		
	Huber, *Homotopy Methods for Effective Schubert Calculus*	Rothblum, *Polynomial Time Root Computation of Parametric Polynomials with Newton's Polygon Process*	
TU1-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods II**, Organizers: Fukushima, Qi, Chair: Facchinei		
	Huang, *Linear Complementarity Approach to Pricing American Options*	Ferris, *Inverse Problems, MPEC Models and Solution via Nonlinear Programming*	Pieper, *A New Smoothing Method for the Solution of Nonlinear Complementarity Problems based on the Fischer-Function*
TU1-G-IN11	**Stochastic Programming Computation and Applications**, Organizer: Birge, Chair: Birge		
	Ziemba, *Capital Growth with Security*	Morton, *Monte Carlo Solution Techniques for Stochastic Programs*	Frauendorfer, *On the Role of Weak Convergence in Stochastic Programming*
TU1-I-CM120	**Steiner Trees and Network Design Problems II**, Organizer: Smith, Chair: Winter		
	Marsman, *The Dynamic Predicate Stashing Copy Problem and the Steiner Problem in Graphs*	Smith, *Computing Lower Bounds for Steiner Trees in E^3 is a Hard Problem*	Luna, *Solving Extensions of the Steiner Problem in Graphs with Strong Multicommodity Flow Formulations*
TU1-I-CM121	**Matroids and Submodular Functions II**, Organizers: Fujishige, McCormick, Zimmermann, Chair: Zimmermann		
	Frank, *Covering Symmetric Supermodular Functions by Graphs*	Fleiner, *Detachment of Vertices of Graphs Preserving Edge-Connectivity*	Narayanan, *The Polymatroid Membership Problem with Matroid Expansion*
TU1-I-CM200	**Combinatorics of Polytopes I**, Organizer: Ziegler, Chair: Ziegler		
	Avis, *Large Symmetric Convex Hull Problems*	Holt, *Many Polytopes Meeting the Conjectured Hirsch Bound*	Onn, *A Polynomial Time Algorithm for Vertex Enumeration and Optimization over Shaped Partition Polytopes*
TU1-I-CM5	**Arc and node routing**, Organizer: Gendreau, Chair: Eglese		
	Hertz, *A Tabu Search Heuristic for the Capacitated Arc Routing Problem*	Gendreau, *A Tabu Search Heuristic for the Capacitated Arc Routing Problem (CARP)*	Mingozzi, *New Integer Formulations of Routing Problems Based on a Two-Commodity Network Flow Approach*
TU1-I-CM4	**Stable sets, matchings and cuts**, Chair: Sterbini		
	Tamura, *The Generalized Stable Set Problem for Bidirected Graphs and Polynomial Time Solvability for Perfect Cases*	Abeledo, *Stable Matchings and Linear Programming*	Karzanov, *Minimum Extensions of Graph Distances*
TU1-I-IN202	**The Traveling Salesman Problem II**, Chair: Pochet		
	Oguz, *An Extended Model for the Traveling Salesman Model: Some Polyhedral Results and Implications*	Gouveia, *The Assymetric Travelling Salesman Problem: Aggregating a Multicommodity Flow into a Node Oriented Formulation*	
TU1-K-CM106	**Heuristic , Simulated annealing, Tabu search, Genetic Alg., Neural Net**, Organizer: Hasan, Chair: Woodruff		
	Ochi, *A Task Allocation Problem in Machine with Time Windows and Precedence Constraints: New Upper Bound by a Hibrid Metaheuristic*	Schaal, *Scatter Search in a Hybrid Method for General Integer Problems*	
TU1-L-CM201	**Parallel routing algorithms**, Chair: Mérel		
	Bouzgarrou, *Parallel Branch and Cut for Symmetric Traveling Salesman Problem*	Larsen, *Experiments with the Auction Algorithm for the Shortest Path Problem*	
TU1-N-CO15	**Analysis Support for an Intelligent Math Programming System (IMPS): Foundations**, Organizers: Greenberg, Caron, Chinneck, Chair: Chinneck		
	Chakravarti, *Sensitivity Analysis in Discrete Optimization: a Survey*	Holder, *Sensitivity of the Central Path*	Libura, *Sensitivity Analysis for Combinatorial Optimization Problems Based on Subsets of k-Best Solutions*
TU1-P-IN201	**Scheduling**, Chair: Nott		
	Chu, *Minimizing Total Tardiness: Analysis of a Heuristic*	Möhring, *Approximation Algorithms for Scheduling Problems with Communication Delays*	Tayur, *Scheduling Orders with Release Times and Decreasing Revenues*
TU1-R-IN203	**Configurations and space partitions**, Chair: de Souza		
	Gropp, *Construction, Realization, and Drawing of Configurations*	Mueller-Hannemann, *Improved Approximations for Minimum Cardinality Quadrangulations of Finite Element Meshes*	Pocchiola, *Recent Progress on the Greedy Flip Algorithm*
TU1-T-CO22	**Applications of Mathematical Programming I**, Organizer: Rosenthal, Chair: Philpott		
	Crowder, *Mail Stream Optimization: Mathematical Programming in Direct Marketing*	Elimam, *Linear Programming Models for Disentangling a Stock Market Crash*	Dell, *Managing the Environmental Costs of Closing US Army Bases*
TU1-U-IN10	**Applications of Mathematical Programming**, Chair: Soulie		
	Rich, *A Home Health Care Scheduling Problem*	Ouveysi, *On Video Placement in a Video–On–Demand Network*	

Parallel sessions : Tuesday morning 11:15 - 12:45

	11:15 - 11:45	11:45 - 12:15	12:15 - 12:45
TU2-A-IN2	**Logic-Based Methods**, Organizers: Hooker, Dawande, Chair: Mayoraz		
	Wilson, *Solving Satisfiability Problems using a Hybrid Genetic-Algorithm/Branch-and-Bound Approach*	Dawande, *Inference-based sensitivity analysis for mixed integer/linear programming*	
TU2-A-IN1	**Average-Case Analysis of Linear Programming and Random Polyhedra**, Organizer: Borgwardt, Chair: Huhn		
	Kuefer, *On the Asymptotic Average Number of Efficient Vertices in Multiple Objective Linear Programming*	Kim, *A Method of Sensitivity Analysis for the Primal-Dual Barrier Method*	Dowling, *On the Convergence of the Affine Scaling Algotiyhm in the Presence of Degeneracy*
TU2-B-CO10	**Proximal Methods in Optimization II**, Organizer: Théra, Chair: Cominetti		
	Tseng, *Decomposition Methods Based on Alternating Projection-Proximal Steps*	Tichatschke, *On New Proximal Point Methods for Variational Inequalities with Monotone Operators*	Haubruge, *On a Splitting Method for Finding a Zero of the Sum of Two Maximal Monotone Operators*
TU2-B-CO11	**Piecewise-Quadratic Functions in Optimization II**, Organizer: Pınar, Chair: Nielsen		
	Chen, *On Newton's Method for Huber's M-Estimation Problems in Robust Linear Regression*	Edlund, *A Sparse Implementation of a Finite Continuation Algorithm for Linear Programming*	Pınar, *Continuation Methods for Chebyshev Solution of Overdetermined Linear Systems*
TU2-C-CO122	**Stochastic methods in global optimization**, Organizer: Romeijn, Chair: Romeijn		
	Zabinsky, *Enhancements to IHR: Improving Hit-and-Run*	Schoen, *Variable Threshold Methods for Global Optimization*	Reaume, *Efficient Random Algorithms for Constrained Global and Convex Optimization*
TU2-C-CO2	**SQP methods**, Chair: Schittkowski		
	Lawrence, *Computationally Efficient Feasible SQP Algorithms*	Leyffer, *Nonlinear Programming without a penalty function*	Izhutkin, *Sqp-methods based of Exact-Barrier Cost Function for Nonlinear Programming Problem*
TU2-C-CO3	**New developments in nonlinear programming**, Chair: Locatelli		
	Alder, *An Evaluation of some Methods for Solving Systems of Nonlinear Equations.*	Nicholls, *The Development of Modifications to Cobweb and Single Constraint Grid Search Procedures with the Aim of Improving their Efficiency and Robustness*	Babayev, *Piece-wise Linear Approximation of Functions of two Variables*
TU2-D-CO123	**Semidefinite Programming and Applications I**, Organizers: Wolkowicz, Overton, Chair: Overton		
	Wolkowicz, *Newton Directions in Primal-Dual Interior-Point Methods for Semidefinite Programming Optimization Problems*	Rendl, *Semidefinite Programming using Eigenvalue Optimization*	
TU2-D-CO124	**Interior Point Methods in Decomposition II**, Organizers: Gondzio, Mitchell, Chair: Gondzio		
	Portugal, *An Efficient Implementation of an Interior Point Method for Multicommodity Network Flows*	Lee, *Warmstart in an Interior Point Method within a Parallel Branch-and-Bound Framework*	Fragnière, *Hooking an Interior Point-based Decomposition with the Mathematical Programming Modeling Languages*
TU2-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods III**, Organizers: Qi, Fukushima, Chair: Potra		
	Qi, *Regular Pseudo-smooth NCP and BVIP functions and globally and quadratically convergent generalized Newton method for complementarity and variational inequality problems*	Kanzow, *A Modified Fischer-Burmeister NCP-Function.*	Dirkse, *A Comparison of MPEC Solvers Using New Interface Libraries*
TU2-G-IN11	**Stochastic and adaptive control**, Chair: Stougie		
	Nagy, *A Generalization of the Model Gravity*	Marti, *Adaptive Stochastic Path Planning for Robots*	Ferris, *Robust Path Choice and Vehicle Guidance in Networks with Failures*
TU2-I-CM200	**Polyhedral Combinatorics I**, Organizer: Reinelt, Chair: Fonlupt		
	de Vries, *Polyhedral Methods for Discrete Tomography*	Funke, *An Approach to the Feedback Vertex Set Problem with Branch and Cut*	Mutzel, *Optimization on Hierarchical Graphs*
TU2-I-CM5	**Combinatorial Optimization for Airlines II**, Organizers: Grötschel, Zimmermann, Chair: Ryan		
	Marsten, *Building an Airline Schedule: where to fly and when*	Erdmann, *Fleet Assignment with Respect to Itineraries*	Voigt, *Discrete Optimization Problems in the Airline Industry*
TU2-I-CM121	**Matroids and Submodular Functions III**, Organizers: Fujishige, McCormick, Zimmermann, Chair: Fujishige		
	Faigle, *Ordered Submodular Structures and the Greedy Algorithm*	Krüger, *Generalized Polymatroids on Partially Ordered Sets*	Hoffman, *Linear Programming over a Totally Ordered Abelian Group*
TU2-I-CM4	**Minimum Cuts Without Maximum Flows**, Organizer: Hu, Chair: Tucker		
	Stein, *Beautiful and Fast: New Minimum Cut Algorithms*	Ibaraki, *Augmenting Edge-Connectivity in O (nm) Time*	Tucker, *Minimax Programs*
TU2-I-CM120	**Packing and Tree Problems**, Organizer: Maffioli, Chair: Maffioli		
	Caprara, *Exact and Heuristic Algorithms for the 2-Dimensional Vector Packing Problem*	Pferschy, *Approximation Algorithms for Cardinality Constrained Bin Packing Problems*	Müller, *On the Dynamic Travelling Salesman and Dynamic Travelling Shortest Paths Problems*
TU2-J-IN202	**Condition Numbers and Theoretical Complexity Issues in Convex Optimization**, Organizer: Freund, Chair: Freund		
	Pena, *On the Distance to Infeasibility*	Ye, *How Partial Knowledge Helps to Solve Linear Programs*	Freund, *Condition Number Complexity of an "Elementary" Algorithm for Resolving a Conic Linear System*
TU2-K-CM106	**Local search**, Chair: Anderson		
	Odijk, *A Simple, Yet Effective, Local Search Algorithm for the Steiner Triple Set Covering Problem*	Wolfler Calvo, *A New Heuristic for the Traveling Salesman Problem with Time Windows*	Johnson, *The Asymmetric Traveling Salesman Problem: Algorithms and Applications*
TU2-L-CM201	**Parallel search and optimization algorithms**, Chair: Bouzgarrou		
	Faco, *A Nonlinear Conjugate Reduced-Gradient Method for Solving Bounded Nonlinear Optimal Control Problems on Parallel Computers*	Mérel, *Parallel Search Algorithms for Constraint Satisfaction Problems*	Akgül, *A New Simultaneous Block Projection Algorithm for the Linear Feasibility Problem*
TU2-N-CO15	**Analysis Support for an Intelligent Math Programming System (IMPS): Software I**, Organizers: Chinneck, Caron, Greenberg, Chair: Caron		
	Holder, *Overview of ANALYZE*	Chinneck, *Computer Tools for Analyzing Infeasible Mathematical Programs*	Fourer, *Analysis Support in a Modeling Language for Mathematical Programming*
TU2-P-IN201	**Dynamic/Stochastic Scheduling via Mathematical Programming**, Organizer: Nino-Mora, Chair: Nino-Mora		
	Simchi-Levi, *Supply-Chain Management: Integrating Inventory and Transportation*	Bertsimas, *Optimization of Multiclass Queueing Networks via Infinite Linear Programming and Singular Perturbation Methods*	Nino-Mora, *Dynamic and Stochastic Scheduling: A Mathematical Programming Approach*
TU2-R-IN203	**Geometric computation I**, Organizers: Fukuda, Verschelde, Chair: Verschelde		
	Enge, *Exact Volume Computation for Polytopes: A Practical Study*	Huber, *Applications of the Cayley Trick for Convex Polytopes*	Michiels, *Enumerating Mixed-Cell Configuration*
TU2-T-CO22	**Novel Applications III**, Organizer: Kelley, Chair: Dennis		
	Wright, *The Nelder-Mead Simplex Method: Recent Theory and Practice*	Torczon, *Robust Derivative-Free Methods for Linearly Constrained Minimization*	Jones, *Black-Box Global Optimization with Nonlinear Inequality Constraints and No Tuning Parameters*
TU2-U-IN10	**Facility location**, Chair: Gimadi		
	Ronnqvist, *Solving Capacitated Facility Location Problems with Single Sourcing Using a Lagrangean Heuristic, Repeated Matching and Branch-and-Bound*	Bauer, *A Capacitated Facility Location Problem with Integer Decision Variables*	Jaumard, *A Stabilized Column Generation Algorithm for the Multi Source Weber Problem*

Parallel sessions : Tuesday afternoon 14:00 - 15:30

	14:00 - 14:30	14:30 - 15:00	15:00 - 15:30
TU3-A-IN2	**Integer Programming/Cutting Planes I**, Organizers: Ceria, Wolsey, Chair: Wolsey		
	Marchand, *A Cutting Plane Procedure for Mixed 0-1 Programming Problems*	Weismantel, *The Intersection of Knapsack Polytopes*	
TU3-A-IN1	**Linear programming**, Chair: Tuniev		
	Fletcher, *Block Triangular Orderings and Factors in LP*	Matsui, *An Algorithm for Generating All the Bases of Equality Systems*	
TU3-B-CO10	**Large scale convex optimization**, Organizer: Andersen, Chair: Andersen		
	Vanderbei, *Solving Large-Scale Convex Optimization Problems with LOQO/AMPL*	Andersen, *QCOPT a Large Scale Interior-Point Code for Solving Convex Quadratically Constrained Quadratic Problems on Self-Scaled Cone Form*	Andersen, *The Homogeneous Algorithm for Convex Optimization*
TU3-C-CO2	**Primal-dual methods for nonlinear programming**, Organizers: Wright, Gill, Chair: Gill		
	Tapia, *Computational Issues Related to Interior-Point Methods for Nonlinear Programming*	Forsgren, *Inertia-Controlling Primal-Dual Interior Methods for Nonlinear Programming*	Wright, *Why Ill-Conditioning in Interior Methods Usually Doesn't Hurt*
TU3-C-CO3	**Continuous approximation**, Chair: Terpolilli		
	Bagirov, *Continuous Approximations to Subdifferential and Monotonous Methods of Nondifferentiable Minimization*	Mayergoiz, *The Algorithms for the Lower-Semi-Continuous Almost Everywhere Locally Lipschitz Minimization Problems Without Derivatives*	Czarnecki, *Smooth Representation of Epi-Lipschitzian Subsets of $\Re^n$*
TU3-C-CO122	**Optimization techniques**, Chair: Dixon		
	Byrd, *A Limited Memory Symmetric Rank-One Method*	Levin, *An Extended Parametric Decomposition of the Optimization Problems*	Bomze, *Global Escape Strategies for Standard Quadratic Programming Problems*
TU3-D-CO123	**Semidefinite Programming and Applications II**, Organizers: Wolkowicz, Overton, Chair: Wolkowicz		
	Nayakkankuppam, *Conditioning of Semidefinite Programs*	Gahinet, *Long-Step Surface-Following Interior-Point Method for Semidefinite Programming: Implementation and Numerical Results*	Pataki, *The Geometry of Convex Programs: Basic Solutions, Nondegeneracy and Strict Complementarity*
TU3-D-CO124	**Interior Point Methods**, Chair: Wright		
	Fampa, *Convergence Rate, Implementation Issues and Numerical Results of a Long-Step Path Following Algorithm for Semidefinite Programming*	El Yassini, *A Primal-Dual Polynomial Interior-Exterior Algorithm for Linear Programming*	Cominetti, *Central Trajectories for a Class of Penalty Methods in Convex Programming*
TU3-E-CO11	**Homotopy Algorithms and Applications I**, Organizer: Forster, Chair: Forster		
	Talman, *Computation of Robust Stationary Points on Polytopes*	van Maaren, *Simplicial Methods for Non Linear Integer Programming*	van Maaren, *Simplicial Algorithms for Linear Integer Programming*
TU3-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods IV**, Organizers: Qi, Fukushima, Chair: Di Pillo		
	Robinson, *Solving Maximal Monotone Operator Inclusions by Reformulation*	Gowda, *On the Connectedness of Solutions Sets of Continuous Functions*	Jiang, *Solving Nonlinear Complementarity Problems via Fischer-Burmeister Functional*
TU3-G-IN11	**Estimation problems**, Chair: Ye		
	Scales, *Automatically Estimating Data Uncertainties for Robust Optimization*	Gomez, *Regularizing the Aquifer Parameter Estimation Problem using Multi-Scale Optimization*	Schittkowski, *Numerical Solution of Parameter Estimation Problems based on One-dimensional Time-dependent PDE's*
TU3-I-CM4	**Threshold Graphs I**, Organizer: Peled, Chair: Peled		
	Mahadev, *A Characterization of Hereditary UIM Graphs*	Raschle, *Recognizing Cobithreshold Graphs in Linear Time*	Peled, *(n,e)-Graphs with Maximum Sum of Squares of Degrees*
TU3-I-CM121	**Matroids and Submodular Functions IV**, Organizers: Fujishige, McCormick, Zimmermann, Chair: Fujishige		
	Sharma, *On Submodular and Bisubmodular functions having non zero values on empty sets*	Kabadi, *Delta Matroid and Jump System*	Bouchet, *Chain-Group Representations of Multimatroids*
TU3-I-CM5	**Discrete Algorithms and Applications I**, Organizers: Recski, Wagner, Nishizeki, Chair: Nishizeki		
	Asano, *Approximation Algorithms for MAX SAT: A Framework of Hybrid Approaches*	Hirata, *Routability Checking for Planar Layouts*	Igarashi, *Reliable and Secure Communications in Distributed Systems*
TU3-I-CM200	**Combinatorial Optimization Games I**, Organizers: Granot, Granot, Chair: Kuipers		
	Solymosi, *Computing the Nucleolus of an Essential Permutation Game*	Deng, *Algorithms and Complexity Issues for Combinatorial Optimization Games*	Hamers, *On some Balanced, Totally Balanced and Submodular Delivery Games*
TU3-I-CM120	**Shortest Path Problems**, Chair: Simchi-Levi		
	Chung, *A Mathematical Model for Finding the k Most Vital Arcs in the Shortest Path Problem*	Festa, *An efficient Auction Algorithm for the Shortest Path Problem using Virtual Source Concept*	Festa, *Graph Collapsing in Auction Algorithms for the Shortest Path Problem*
TU3-K-CM106	**Metaheuristics applications**, Chair: Anderson		
	Kochetov, *Behaviour of Meta-heuristics for the Simple Plant Location Problem*	Bourjolly, *A Tabu Search Heuristic for the Capacitated Lot Sizing Problem with Setup Carry-overs*	Ribeiro, *A Grasp for a Matrix Decomposition Problem in Traffic Assignment*
TU3-L-CM201	**Computational Mixed Integer Programming I**, Organizer: Lee, Chair: Nygreen		
	Nemhauser, *Lifted Flow Cover Inequalities for Mixed 0-1 Integer Programming*	Lee, *Computational Experience with a General Purpose Mixed 0/1 Integer Solver*	Kaibel, *Computational Experiences with the QAP*
TU3-M-IN202	**Decision support systems**, Chair: Romanova		
	Romanova, *Knowledge Representation for Decision Support System of Optimization 2-D Placement Problems*	Farkas, *On the Solution Methode "Optimization With Minimal Information"*	
TU3-N-CO15	**Analysis Support for an Intelligent Math Programming System (IMPS): Software II**, Organizers: Chinneck, Caron, Greenberg, Chair: Chinneck		
	Amaldi, *Computational Complexity of Resolving LP Infeasibility by Relaxing Constraints*	Baker, *Building the MIMI Wizard*	Chinneck, *New Software: a Requirements Analysis*
TU3-P-IN201	**Scheduling for Modern Manufacturing Systems**, Organizer: Potts, Chair: Potts		
	Strusevich, *Scheduling for Parallel Dedicated Machines with a Single Server*	Pacciarelli, *Nondominated Schedules for a Job Shop with Two Competing Users*	Spieksma, *The Assembly of Printed Circuit Boards: a Case with Multiple Machines and Multiple Board Types*
TU3-R-IN203	**VLSI-Design and Combinatorial Optimization II**, Organizer: Korte, Chair: Korte		
	Koehl, *Transforming VLSI Technology into Mathematical Models*	Schietke, *Timing Analysis and Optimization based on Physical Design Information*	Albrecht, *Cycle Time Optimization for VLSI-Chips*
TU3-T-CO22	**Cutting stock problems**, Chair: Cung		
	Fábián, *On a Stochastic Cutting Stock Problem*	Konishi, *A MIP-Based Approach to the Cutting Stock Problem with Minimum Production Quantity Constraint*	Zak, *Methods for Improving Efficiency in One-Dimensional Cutting Stock Problem*
TU3-U-IN10	**Telecommunication Network Design optimization**, Organizer: Lisser, Chair: Lisser		
	Geffard, *On the Minimum Capacity Multicommodity Multiperiod Flow Network Problem*	Chardaire, *Simplex and Interior Point Specialized Algorithms For Solving Non-Oriented Multicommodity Flow Problems*	Mateus, *The Base Station Location and the Channel Allocation Problems in Cellular Systems*

Parallel sessions : Tuesday afternoon 17:00 - 18:30

	17:00 - 17:30	17:30 - 18:00	18:00 - 18:30
TU4-A-IN2	**Integer and Combinatorial Optimization**, Organizer: Porto, Chair: Lucena		
	Poggi, *The "gamma"-Connected Assignment Problem*	Lucena, *Stronger Eigenvalue Based Upper Bounds for Maximum Entropy Sampling*	Porto, *Recognizing Interval Matrices through PQR-Trees*
TU4-A-IN1	**Average-Case-Behaviour of Linear Programming Algorithms under the Rotation-Symmetry-Model**, Organizer: Borgwardt, Chair: Borgwardt		
	Huhn, *An Upper Bound for the Average Number of Iterations Required in Phase II of an Interior-Point-Method*	Borgwardt, *A Sharp Upper Bound for the Expected Number of Shadow Vertices in an LP-Quadratic in the Smaller and Sublinear in the Larger Dimension*	Huhn, *A Lower Bound on the Average Number of Pivot Steps in the Simplex Method - Valid for all Variants*
TU4-B-CO10	**Convex programming methods II**, Chair: Pappalardo		
	Kas, *Young Programming, an Analytical Approximation of Linear Programming*	Jefferson, *Duality for a Sum of Fractions*	Stefanov, *Convex Separable Minimization Problem with a Linear Inequality Constraint and Bounds on the Variables*
TU4-C-CO2	**Generalized Convexity III**, Organizer: Martínez-Legaz, Chair: Hadjisavvas		
	Bilbao, *The Shapley value on matroids*	Bilbao, *Superadditive extension of games*	
TU4-C-CO3	**Stability in nonlinear programming II**, Organizer: Klatte, Chair: Kummer		
	Lucchetti, *On Well-Posedness and Stability Analysis in Optimization*	Henrion, *Nonsmooth Constraint Mappings with Cone Increasing Behavior*	Dmitruk, *Third Order Necessary and Sufficient Conditions in the Finite-Dimensional Extremal Problem with Constraints*
TU4-C-CO122	**Global Optimization: Algorithmic and Computational Advances I**, Organizer: Sahinidis, Chair: Strekalovsky		
	Schichl, *The NOP-2 Modeling Language for Nonlinear Programming*	Neumaier, *Quadratic Programming Techniques in Branch and Bound Methods*	Sahinidis, *Computing Global Solutions of Nonconvex NLPs via Branch-and-Reduce*
TU4-D-CO123	**Primal-Dual Interior-Point Algorithms for Semidefinite Programming I**, Organizers: Kojima, Zhang, Chair: Zhang		
	Todd, *Properties of Search Directions for Semidefinite Programming*	Overton, *SDPPACK: A Package for Semidefinite Programming*	Fujisawa, *SDPA (Semidefinite Programming Algorithm)*
TU4-D-CO124	**Interior-point methods for mathematical programming**, Organizer: Monteiro, Chair: Monteiro		
	Mizuno, *Global and Polynomial-Time Convergence of an Infeasible-Interior-Point Algorithm Using Inexact Computation*	Shida, *Existence of Central Trajectory to Monotone Semidefinite Complementarity Problem and its Newton Direction*	Xue, *An Efficient Algorithm for Minimizing a Sum of Euclidean Norms with Applications*
TU4-E-CO11	**The Linear Complementarity Problem I**, Organizer: Cottle, Chair: Cottle		
	Morris, *Lemke Paths for P-matrix LCPs*	Murthy, *Some Recent Results on the Linear Complementarity Problem*	Murthy, *A Characterization of the Class P_1.*
TU4-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods V**, Organizers: Qi, Fukushima, Chair: Polak		
	Fukushima, *A New Merit function and a Descent Method for Semidefinite Complementarity Problems*	Luo, *A Globally Convergent Sequential Quadratic Programming Algorithm for Mathematical Programs with Linear Complementarity Constraints*	Qian, *A Variable Metric Proximal Point Algorithm for Monotone Operators*
TU4-G-IN11	**Approximation approaches in SP**, Organizer: Römisch, Chair: Schultz		
	Lepp, *Approximation of Stochastic Programs with Probability and Quantile Functionals*	Kankova, *A note on Exponential Rate Convergence in Stochastic Programming Problems*	Dye, *Solving Recourse Problems with Binary First Stage using Branch and Bound*
TU4-I-CM5	**Location Theory and Applications I**, Organizer: Hamacher, Chair: Nickel		
	Gimadi, *On Some Polynomial Solvable Cases of the Simple Plant Location Problem*	Klamroth, *A Discretization Result for Planar Median Problems with Barriers*	
TU4-I-CM121	**Matroids, Submodular and Supermodular Functions**, Chair: Murota		
	Nasini, *On Flexibility in Optimization Problems*	Iwata, *A Faster Cycle-Canceling Algorithm for Minimum Cost Submodular Flows*	Goldengorin, *The Data-Correcting Algorithm for Determining Global Minima if Supermodular Functions with Applications to NP-Hard Problems*
TU4-I-CM4	**Graph Theory I**, Organizer: Szwarcfiter, Chair: Szwarcfiter		
	Kratsch, *Domination algorithms*	Gutierrez, *Intersection Graphs and Clique Application*	Itai, *Improvements on Bottleneck Matching and Related Problems Using Geometry*
TU4-I-CM200	**Two-Dimensional Packing**, Organizer: Martello, Chair: Labbé		
	Terno, *New Relaxations for the Cutting Stock Problem*	Scheithauer, *A New Approach for the Multi-Container Loading Problem*	Vigo, *Exact Solution of Two-Dimensional Bin Packing Problems*
TU4-I-CM120	**Methods for Tree Network Design I**, Organizer: Gouveia, Chair: Gouveia		
	Martins, *A Sequential Approach for the Capacitated Minimum Spanning Tree Problem*	Duin, *A Repetitive Strategy for Combinatorial Optimization with Application to the Steiner Tree Problem*	Bazlamacci, *A Branch and Bound Algorithm for the Capacitated Minimal Spanning Tree Problem Using a Directed-Flow Formulation*
TU4-K-CM106	**Genetic algorithms**, Chair: Schaal		
	Gomez, *New Structures for Lennard-Jones Atomic Clusters*	Lodi, *A Genetic Algorithm for Unconstrained Binary Quadratic Optimization*	
TU4-L-CM201	**Parallel Integer Programming**, Organizer: Mitra, Chair: Dempster		
	Ashford, *The XPRESS-MP Parallel MIP System*	Lee, *A Parallel Interior-Point Based Branch-and-Bound Solver*	Onishi, *Performance Evaluation for Parallel Branch-and-Bound Method on a Cluster of Workstations*
TU4-N-CO15	**Analysis Support for an Intelligent Math Programming System (IMPS): Applications**, Organizers: Caron, Chinneck, Greenberg, Chair: Caron		
	Medova, *Application of IMPS Tools to ATM Network Planning*	Bost, *Solutions Analysis in Complex Planning Models for the Oil Industry*	Caron, *Redundacny in Nonlinear Systems*
TU4-P-IN201	**Machine scheduling**, Chair: Gordon		
	Skutella, *Showing Schedules in Slow Motion*	Abdekhodaee, *Scheduling Identical Parallel Machines including Setups and a Single Operator*	Baki, *Some Problems in One-Operator Scheduling*
TU4-R-IN203	**Optimization techniques for geometric computation**, Chair: Gropp		
	de Souza, *Minimizing the Length of Retangular Partitions: an Integer Programming Approach*	de Souza, *Integer Programming Models for Minimum-Weight Triagulations*	Witzgall, *Linear Programming Techniques for Fitting Circles and Spheres*
TU4-T-CO22	**Mathematical programming in industry**, Chair: Soumis		
	Wilhelm, *A Column Generation Approach to the Assembly System Design Problem with Tool Changes: Computational Evaluation*	Negenman, *A Linear Programming Approach to Support Production Planning*	Duman, *Precedence Constrained Traveling Salesman Problem and Automated Production of Printed Circuit Boards*
TU4-U-IN10	**Mathematical programming in telecommunications**, Chair: Chardaire		
	Oguz, *One and two Stage Dantzig-Wolfe Decomposition for the Survivability in Multi-Service Telecommunications Networks Problem*	Korach, *Dynamic Programming Approach for Saving Energy in Mobile Communication*	Ramakrishnan, *An Application of Quadratic Assignment Problem to ATM Switch Design*
TU4-Z-IN202	**Tucker Prize Award**, Chair: Vial		
	Geelen,	Karger,	Vicente,

Parallel sessions : Wednesday morning 08:15 - 09:45

	08:15 - 08:45	08:45 - 09:15	09:15 - 09:45
WE1-A-IN2	**Solving hard integer programming problems**, Organizer: Aardal, Chair: Aardal		
	Bienstock, *Experiments with a Network Design Algorithm Using Epsilon-Approximate LPs*	Cook, *A Framework for the TSP*	Aardal, *A Basis Reduction Algorithm for Solving an Integer Feasibility Problem Arising in Video Signal Processing*
WE1-A-IN1	**Special Session with Open Discussion: The Pivot Choice Challenge, With Love to George**, Organizers: Edmonds, Liebling, Fukuda, Chair: Liebling		
	Edmonds, *With Love To George, Modest Tries To Improve On 50-Year-Old Stuff Which Is Already Too Good: The Pivot-Choice Challenge.*		
WE1-B-CO10	**Eigenvalue optimization I**, Organizer: Hiriart-Urruty, Chair: Hiriart-Urruty		
	Overton, *Eigenvalue Optimization for Nonsymmetric Matrices*	Pataki, *The Provable Nonsmoothness of Spectral Functions*	Shapiro, *Second Order Analysis of Nonlinear Semidefinite Programs*
WE1-C-CO2	**Generalized Convexity IV**, Organizer: Martínez-Legaz, Chair: Flores-Bazán		
	Daniilidis, *On the Connectedness of the Efficient Set for set-valued maps*	Kassay, *Parametric Variational Inequalities with K-Pseudomonotone Operators*	Craven, *Invexity and Optimal Control*
WE1-C-CO3	**Nonconvex Optimization**, Organizer: Pardalos, Chair: Pardalos		
	Locatelli, *Conical Algorithms for Concave Optimization*	Zabinsky, *Practical Global Optimization for Engineering Design*	Huyer, *Global Optimization by Multilevel Coordinate Search*
WE1-C-CO122	**Neural Networks**, Chair: Soulie		
	Trafalis, *An Incremental Primal-Dual Technique for Nonlinear Programming and Applications to Artificial Neural Network Training*	Lang, *Neural Networks and Constrained Optimization*	
WE1-D-CO123	**Polynomial interior-point methods for convex programming**, Organizers: Todd, Nesterov, Chair: Nesterov		
	Roos, *An Exact Polynomial-Time Solution Method for the Self-Dual Linear Optimization Problem*	Ye, *Approximating Quadratic Programming with Quadratic Constraints*	Todd, *Infeasible-Interior-Point Methods for Convex Programming Problems*
WE1-D-CO124	**Interior Point Methods**, Chair: Mizuno		
	Herskovits, *Feasible Arc Interior Point Algorithms For Nonlinear Optimization*	Gilbert, *A BFGS Interior Point Algorithm for Minimizing a Convex Function Subject to Linear Constraints*	Gonzalez-Lima, *Computational Experience with Several Centrality Measures in Locating Analytic Centers*
WE1-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods VI**, Organizers: Qi, Fukushima, Chair: Qi		
	Facchinei, *Structural and Stability Properties of P_0 Nonlinear Complementarity Problems*	Rubinov, *Reformulation of Economic eEquilibria Problems*	Xu, *Non-Interior Path-Following Methods for the Linear Complementarity Problem*
WE1-E-CO11	**Computational Algorithms for complementarity, variational inequality, and related problems I**, Organizer: Tseng, Chair: Ferris		
	Ferris, *NLP2MCP: Formulating and Solving Large Scale Nonlinear Programs as Complementarity Problems*	Kanzow, *QP-free Constrained Newton-type Methods for Variational Inequalities*	More, *The NEOS Server for Complementarity Problems: PATH*
WE1-G-IN11	**Stochastic Integer Programming I**, Organizer: Van der Vlerk, Chair: Klein Haneveld		
	Caroe, *Dual Decomposition in Stochastic Integer Programming*	Schultz, *Unit Commitment Under Uncertainty via Two-Stage Stochastic Integer Programming*	Jonsbraaten, *A Class of Stochastic Programs with Decision Dependent Random Elements*
WE1-I-CM4	**Automatic Graph Drawing**, Organizer: Mutzel, Chair: Mutzel		
	Weiskircher, *2-Layer Planarization of Bipartite Graphs*	Odenthal, *A Polyhedral Approach to the Multi-Layer Crossing Number Problem*	Leipert, *Pitfalls of using PQ-Trees in the Planarization of Graphs*
WE1-I-CM5	**Discrete Algorithms and Applications II**, Organizers: Recski, Wagner, Nishizeki, Chair: Recski		
	Wagner, *Routing in Diagonal Grids*	Wagner, *On Mimicking Networks*	Brandes, *A Linear Time Algorithm for the Arc Disjoint Menger Problem in Planar Directed Graphs*
WE1-I-CM121	**Boolean and Pseudo-Boolean Functions I: Theory and Computation**, Organizer: Hammer, Chair: Hammer		
	Benzaken, *Software for Boolelan Functions*	Khachiyan, *On the Complexity of Generating all Minimal Implicants and Implicates of Monotone Boolean Functions*	Kogan, *Evaluation, Strength and Relevance of Variables of Boolean Functions*
WE1-I-CM200	**Combinatorial Optimization Games II**, Organizers: Granot, Granot, Chair: Solymosi		
	Kuipers, *A Polynomial Time Algorithm for Computing the Nucleolus of Convex Games*	Kern, *Allocation and Fractional Combinatorial Optimization*	Fekete, *Combinatorial Optimization Games*
WE1-I-CM120	**The Quadratic Assignment Problem**, Chair: Taillard		
	Bouras, *Low Rank Quadratic Assignment Problems*	Deineko, *Polynomially Solvable Cases of the Quadratic Assignment Problems for Exponential Neighbourhoods*	
WE1-K-CM106	**Heuristics for combinatorial problems**, Chair: Wolfler Calvo		
	Volgenant, *A Core Approach to the 0-1 Equality Knapsack Problem*	Romero-Morales, *A Class of Generalized Greedy Algorithms for the Generalized Assignment Problem*	Miyazawa, *Approximation Algorithms for Packing Problems with Orthogonal Rotations*
WE1-L-CM201	**Techniques for large-scale systems**, Chair: Boggs		
	Lin, *Newton's Method for Large Bound-Constrained Optimization Problems*	Marin, *Solving Convex Models with Special Structure*	Scolnik, *A Partitioning Strategy for Solving Large Nonsymmetric Systems of Equations by Row Projection Methods*
WE1-O-IN202	**Fast Simulation of Rare Events**, Organizer: L'Ecuyer, Chair: L'Ecuyer		
	Asmussen, *Rare Events Simulation for Heavy-Tailed Distributions*	McDonald, *On the Exact Asymptotics of the Fast Teller Queue*	L'Ecuyer, *Efficiency Improvement for Cell Loss Rate Estimation in a Large ATM Switch*
WE1-P-IN201	**Scheduling via mathematical programming approaches**, Chair: Möhring		
	Nott, *Sets Formulation to Schedule Mixed Batch/Continuous Process Plants with Variable Cycle Time*	Leung, *Hoist Scheduling for a Circuit Board Manufacturing Line - A Mixed Integer Programming Approach*	de Farias, *A Scheduling Problem with Special Ordered Sets: A Polyhedral Approach*
WE1-R-IN203	**Computational Geometry and Statistical Proximity**, Organizer: Imai, Chair: Imai		
	Tokuyama, *An Analysis on Learning Optimized Regions in Application to Data Mining*	Inaba, *Geometric Clustering and its Application*	Onishi, *Voronoi Diagram for the Dually Flat Space*
WE1-T-CO22	**Recent Advances in DEA**, Organizers: Tone, Banker, Cooper, Chair: Tone		
	Banker, *Testing Tradeoffs between Performance Dimensions*	Pesenti, *A DEAlike Linear Model to Distribute Resources*	Tone, *Some Mathematical Programming Aspects of DEA*
WE1-U-IN10	**Airline planning**, Organizer: Johnson, Chair: Johnson		
	Barnhart, *Airline Fleet Assignment with Time Windows*	Klabjan, *A Combined Daily/Exceptions Crew Pairing Model*	Tschoeke, *Solving Large Fleet Assignment Problems*

Parallel sessions : Wednesday morning 11:15 - 12:45

	11:15 - 11:45	11:45 - 12:15	12:15 - 12:45
WE2-A-IN2	**Integer Programming/Modeling I**, Organizers: Ceria, Wolsey, Chair: Nemhauser		
	Tebboth, *XPRESS-EMOSL: A Combined Modeller and Optimiser for Algorithm Development*	Bienstock, *Modeling and Solving ATM Network Design Problems*	Pochet, *Mixing Mixed-Integer Valid Inequalities*
WE2-A-IN1	**Philip Wolfe's 70th birthday**, Organizer: Hoffman, Chair: Hoffman		
	Cottle, *On Dodging Degeneracy in Linear Programming*	Powell, *On the Convergence of Variable Metric Algorithms for Unconstrained Optimization*	Dantzig, *Some Memories of the Golden Years at RAND*
WE2-B-CO10	**Contributions to Semi-infinite Linear Programming**, Organizer: López, Chair: López		
	Goberna, *Linear Semi-Infinite Systems and Optimization*	Sanmatías, *A Hybrid Algorithm for Solving Linear Semi-Infinite Programming Problems*	López, *An Approach to Stability in Linear Semi-Infinite Programming*
WE2-C-CO2	**Generalized Convexity V**, Organizer: Martínez-Legaz, Chair: Morgan		
	Flores-Bazán, *An Attempt to Define the Conjugate of Set-Valued Maps*	Komlosi, *On Generalized Monotonicity and Minty Variational Principle. Applications to Optimization and to Dynamical Systems*	Rubinov, *On a Multiplicative Analogue of Infimal Convolution with Application to Penalization*
WE2-C-CO3	**Lagrangian Methods in Nonlinear Programming II**, Organizer: Di Pillo, Chair: Di Pillo		
	Li, *Exact Penalty Functions for Constrained Minimization Problems and Regularized Gap Function for Variational Inequalities*	Polak, *On the Transcription of Optimization Problems with MAXMIN Constraints into Standard Nonlinear Programming Problems*	Pappalardo, *Lagrange Multipliers in Vector Optimization*
WE2-C-CO122	**Global Optimization: Algorithmic and Computational Advances II**, Organizer: Sahinidis, Chair: Sahinidis		
	Uchida, *Global Optimality Conditions for General Quadratic Optimization Problems*	Hendrix, *On the Relation between Global Optimization and Integer Programming*	Shi, *A Global Optimization Method for Minimum Maximal Flow Problem*
WE2-D-CO124	**Interior Point Methods for LP**, Organizers: Terlaky, Roos, Chair: Roos		
	Rébaï, *Perturbed Path Following Interior Point Algorithms*	Mizuno, *A Modified Layered-Step Interior-Point Algorithm for Linear Programming*	Tsuchiya, *Polynomiality of Primal-Dual Path Following Algorithms for SDP and SDLCP using the Kojima-Shindoh-Hara Search Directions*
WE2-D-CO123	**Asymptotic analysis of interior point methods**, Organizer: Gonzaga, Chair: Oliveira		
	El Afia, *Asymtotic Analysis of Barrier Trajectories without Constraint Qualifications*	Steihaug, *Deteriorating Convergence for Asynchronous Methods on Linear Least Squares Problems*	
WE2-E-CO11	**Advances in Proximal Point Methods**, Organizer: Eckstein, Chair: Eckstein		
	Teboulle, *Lagrangian Multiplier Methods for Semidefinite Programming*	Iusem, *Proximal Point Method for Convex Optimization in Banach Spaces*	Eckstein, *Smooth Methods of Multipliers for Complementarity Problems*
WE2-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods VII**, Organizers: Qi, Fukushima, Chair: Martínez		
	Potra, *Secant Methods for Semismooth Equations*	Zhang, *Globally Convergent Generalized Inexact Newton Methods for Non-Twice Differentiable Optimization Problems*	Chen, *On Homotopy-Smoothing Methods for Variational Inequalities*
WE2-G-IN11	**Stochastic programming**, Chair: Caroe		
	Swietanowski, *Solving Subproblems in Two Stage Stochastic Programming with a Penalty-Based Simplex Optimizer*	Triki, *Solving Stochastic Linear Programs with Restricted Recourse Using Interior Point Methods*	Dempster, *Sequantial Importance Sampling of Dynamic Stochastic Programmes Using EVPI Criteria*
WE2-I-CM200	**Combinatorial Optimization II**, Organizers: Punnen, Kabadi, Chair: Tamir		
	Tamir, *A Maximum b-Matching Problem Arising from Median Location Models with Applications to the Roommates Problem*	Alfakih, *Facets of an Assignment problem with a 0-1 Side Constraint*	Sharma, *A Linear Bound on Stalling in the Network Simplex Algorithm*
WE2-I-CM120	**Some problems on networks**, Chair: Telhada		
	Klinz, *Dynamic Flow Problems with Dedicated Arcs*	Chang, *Efficient Vertex-Generation for a Class of Generalized Network Polyhedra*	Telhada, *An Arc Design Formulation for the Two-Level Network Design Problem*
WE2-I-CM121	**Boolean and Pseudo-Boolean Functions II: Special Classes**, Organizer: Hammer, Chair: Benzaken		
	Bioch, *Monotonocity, Decision Trees and Pseudo-Boolean Functions*	Boros, *Maximum Renamable Horn Sub-CNFs*	Crama, *Shellable Hypergraphs, Boolean Functions and Reliability Computations*
WE2-I-CM4	**Facets and Cliques**, Chair: Penn		
	Rutten, *Patching: A Technique for Constructing Facets*	Nobili, *On Lifting Facets for Clique Reductions*	Barnes, *Bounds for the Largest Clique in a Graph*
WE2-I-CM5	**ABCC TSP**, Organizer: Liebling, Chair: Naddef		
	Applegate, *A New Paradigm for Finding Cutting Planes in the TSP*	Chvátal, *A New Paradigm for Finding Cutting Planes in the TSP*	Bixby, *A New Paradigm for Finding Cutting Planes in the TSP*
WE2-K-CM106	**Ant systems**, Organizer: Hertz, Chair: Kuntz		
	Maniezzo, *ANT-QAP: Approximate Nondeterministic Tree-search for the Quadratic Assignment Problem*	Taillard, *Ant Hybrid for the Quadratic Assignment Problem*	Colorni, *Artificial Ants to Find Bounded Length Cycle in a Network*
WE2-L-CM201	**Large-scale non-linear optimization**, Organizer: Conn, Chair: Conn		
	Gill, *MINOS and SNOPT - A Status Report*	Nocedal, *An Interior Point Method for Large Scale Nonlinear Programming*	Sachs, *A Class of Augmented Lagrangian Algorithms for Infinite Dimensional Optimization with Equality Constraints*
WE2-P-IN201	**On some specific scheduling problems**, Chair: Brucker		
	Toyama, *Schedule Revision by Graph Coloring Method*	Chelbi, *Optimal Periodic Replacement Strategy for Non Self-Announcing Failure Systems*	Ettaouil, *An Exact Algorithm for the 0-1 Nonlinear Constraint Satisfaction Problems: Application to Task Allocation in Distributed Computing System*
WE2-R-IN203	**Geometric computation II**, Organizers: Fukuda, Verschelde, Chair: Huber		
	Bremner, *Primal/Dual Methods for Convex Hulls*	Gao, *Numerical Implementations of Mixed Volume Computation*	Verschelde, *A Criterion for Points Influencing the Mixed Volume*
WE2-S-IN202	**Integer Programming in Computational Biology**, Organizer: Mutzel, Chair: Mutzel		
	Christof, *Solving Weighted Betweenness Problems in Physical Mapping by Branch-and-Cut*	Reinert, *A Polyhedral Approach for RNA Secondary Structure Alignment*	Caprara, *Sorting Permutations by Reversals through Branch-and-Price*
WE2-T-CO22	**Applications of Mathematical Programming II**, Organizer: Rosenthal, Chair: Rosenthal		
	Leachman, *An Optimization-Based Approach to Shop Floor Scheduling of Semiconductor Wafer Fabrication*	Philpott, *Hydro-Electric Unit Commitment Subject to Uncertain Demand*	Rosenthal, *Optimization Modeling for Airlift Mobility*
WE2-U-IN10	**Combinatorial issues in airline planning**, Chair: Barnhart		
	Paias, *Set Covering Problem: an Approach Based on Column Generation and State Space Relaxation*	Letrouit, *Combinatorial Issues of Air Traffic Optimization*	Jacobs, *Applications of Mathematical Programming in Airline Planning*
WE2-W-CO15	**Modeling Languages and Approaches/System Issues**, Organizers: Pollatschek, Fourer, Chair: Fourer		
	Müller, *DecisionNet: Global Access to Optimization Models and Algorithms*	Saigal, *Embedding a Modeling Language System in Specialized Application Software*	

Parallel sessions : Wednesday afternoon 14:00 - 15:30

	14:00 - 14:30	14:30 - 15:00	15:00 - 15:30
WE3-A-IN2	**Integer Programming/Computations I**, Organizers: Ceria, Wolsey, Chair: Ceria		
	Savelsbergh, *A Polyhedral Approach to the Cardinality Constrained Cycle Problem*	Ceria, *OCTANE: A New Heuristic for Pure 0-1 Programs*	Cordier, *BC-OPT, a Branch & Cut Code For Mixed Integer Programs*
WE3-A-IN1	**Hilbert bases**, Organizer: Henk, Chair: Henk		
	Bárány, *A Minimax Theorem for Test Sets in Integer Programming*	Pottier, *Computation of Hilbert bases*	Weismantel, *Generating Sets for the Knapsack Problem*
WE3-B-CO10	**Convex analysis and optimization**, Chair: Cominetti		
	Pallaschke, *Minimal Pairs of Convex Compact Sets*	Correa, *On the Stability of General Convex Programs and Variational Inequalities*	Tind, *Convex Input and Output in DEA*
WE3-C-CO3	**Math Programs with Equilibrium Constraints I**, Organizer: Ralph, Chair: Nicholls		
	Florian, *A Bilevel Programming Application in Transportation Planning*	Metzler, *Strategic Gaming Analysis for Electric Power Networks: An MPEC Approach*	Nicholls, *The Development of a Multiperiod Bilevel Model of an Aluminium Smelter Incorporating an Overriding Intertemporal Capacity Transfer Subproblem*
WE3-C-CO2	**Bilevel programming I**, Organizer: Savard, Chair: Conn		
	Morgan, *Weak Bilevel Programming Problem with Convex Data*	Dempe, *Generalized PC^1-Functions and their Application to Bilevel Programming Problems*	Savard, *Embedded Algorithms, Complexity and Linear Bilevel Programming*
WE3-C-CO122	**Convergence analysis**, Chair: Roma		
	Dai, *Further Insight Into the Convergence of the Fletcher-Reeves Method*	Mayergoiz, *The Correlation Between the Quasi-Newton-Kantovich Methods for the Multiple Solutions of the Nonlinear Operator Equations and the Quadratic Convergence of Primal-dual Interior Point Degenerate Linear Programming Algorithm*	Gourdin, *A Convergent Generalized Benders Decomposition Algorithm for Solving Bilinear and Quadratic Programming Problems*
WE3-D-CO124	**Interior Point Methods in Decomposition III**, Organizers: Gondzio, Mitchell, Chair: Goffin		
	Ye, *Bounded Error Parameter Estimation: a Sequential Analytic Center Approach*	El-Bakry, *Identifying Groups of Variables in Interior-Point Methods*	Mitchell, *A Long Step Cutting Plane Algorithm That Uses the Volumetric Barrier*
WE3-D-CO123	**Infeasible Interior Point Methods**, Organizer: Potra, Chair: Potra		
	Monteiro, *A Newton Potential Reduction Method for Constrained Equation and its Applications to Nonlinear Semidefinite Programming.*	Wright, *Infeasible-Interior-Point Methods for Nonlinear Problems*	Tseng, *Search Directions for and Convergence Analysis of Some Infeasible Path-Following Methods for the Monotone Semi-Definite LCP*
WE3-E-CO11	**The Linear Complementarity Problem II**, Organizer: Cottle, Chair: Neogy		
	Mohan, *Complementary Pivoting Methods for a Class of Non-Zero Sum Stochastic Game Problems*	Neogy, *Vertical Linear Complementarity in some Zero-Sum Stochastic Game Problems*	Sznajder, *Some Stability Aspects of the Linear Complementarity Problem and its Generalizations*
WE3-E-CO21	**Computational Contact Mechanics and Mathematical Programming I**, Organizers: Klarbring, Pang, Chair: Klarbring		
	Curnier, *Generalized Newton Method for Nonsmooth Nonsymmetric Operators*	Christensen, *Frictional Contact Algorithms Based on Semismooth Newton Methods*	Pang, *A Unified Approach to Frictional Contact Problems*
WE3-F-IN203	**Applications of optimal control**, Chair: Pickenhain		
	King, *Optimization Techniques for Stability Margins in Reduced Order Controller Design*	Dmitruk, *Quadratic Order Conditions of a Weak, Pontryagin, and Strong Minima for Singular Extremals*	Chauvier, *Optimal Control of a Deep Tow Vehicle by an Interior-Point Method*
WE3-G-IN11	**Optimization Under Uncertainty**, Organizers: Dantzig, Infanger, Chair: Dantzig		
	Infanger, *Multi-Stage Stochastic Programming for Funding Uncertain Cash-Flows of Mortgage Pools*	Birge, *Recent Results in Large-scale Stochastic Programming Implementations*	Christiansen, *Bilevel Stochastic Optimization in Truss Topology Design*
WE3-I-CM4	**Threshold Graphs II**, Organizer: Peled, Chair: Mahadev		
	Sterbini, *An $O(n^3)$ Recognition Algorithm for Threshold Dimension 2 Graphs*	Peled, *On the Structure of Universal Realization Graphs of Degree Sequences*	
WE3-I-CM3	**Combinatorial Optimization for Railway Systems**, Organizers: Grötschel, Zimmermann, Chair: Grötschel		
	Bussieck, *Design in Periodic Transportation Systems: Line planning*	Kroon, *Routing Trains through a Railway Station*	Enders, *Constructing Periodic Timetables for Local Railway Systems*
WE3-I-CM200	**Polyhedral Combinatorics II**, Organizer: Mahjoub, Chair: Mahjoub		
	Fonlupt, *Critical Extreme Points of the 2-Edge Connected Spanning Subgraph Polytope*	Penn, *On Integrality, Stability and Composition of Dicycle Packings and Covers*	Sassano, *Polyhedral and Disjunctive Cutting Planes for the p-Median Problem*
WE3-I-CM121	**Boolean and Pseudo-Boolean Functions III: Satisfiability**, Organizer: Hammer, Chair: Resende		
	Franco, *Relative Size of Certain Polynomial Time Solvable Subclasses of Satisfiability*	Kleine Büning, *On the Minimal Unsatisfiability Problem for some Subclasses of CNF*	Speckenmeyer, *What Implication Implies*
WE3-I-CM120	**Graph Connectivity Problems**, Chair: Sastry		
	Keijsper, *Packing Connectors*	Jansen, *An Optimal Greedy Algorithm for Wavelength Allocation in Directed Trees*	
WE3-K-CM106	**Applications of local search methods**, Chair: Ribeiro		
	Anderson, *Local Search for Scheduling Problems: Exploring Basins of Attraction*	Caporossi, *Variable Neighbourhood Search for Extremal Graphs*	Hurink, *Efficient Calculation of a Best Neighbor for a One Machine Batching Problem*
WE3-L-CM201	**Large-scale nonlinear optimization**, Chair: Krivonozhko		
	Franke, *Exploitation of Embedded Multistage Structure by a Large-Scale SQP Solver*	Yamashita, *A Globally and Superlinearly Convergent Primal-Dual Interior Point Method for Large Scale Nonlinear Optimization*	Boggs, *Theoretical Analysis and Applications of a Large Scale SQP Algorithm for Nonlinear Optimization*
WE3-P-IN201	**Scheduling using mathematical programming approaches**, Organizers: Hall, Potts, Chair: Spieksma		
	Chopra, *Maximum Value Job Shop Scheduling*	Valério de Carvalho, *Integer Binpacking Problems*	Hoogeveen, *Parallel Machine Scheduling by Column Generation*
WE3-S-IN202	**Reconstructing the Tree of Life**, Organizers: Dress, Vingron, Chair: Dress		
	Vingron, *Sequence Alignment and Phylogeny*	Gotoh, *Concurrent Construction of Multiple Sequence Alignment and Phylogenetic Tree*	Gonnet, *Using Paralogous/Orthologous Information for the Reconstruction of Phylogenetic Trees*
WE3-T-CO22	**Mathematical programming in real-life applications**, Chair: Escudero		
	Sadeh, *Using Low Quality Water for Irrigation*	Salo, *Forest Age Classes and Rotation Periods in Continuous Time Models for Nonindustrial Private Forest Owners in the Presence of in Situ Values*	Oyama, *A Generalized Divisor Method for the Political Apportionment Problem*
WE3-U-IN10	**Design of survivable networks**, Organizer: Stoer, Chair: Stoer		
	Bienstock, *Solving flow-survivable network design problems*	Sarkissian, *Optimal Joint Syntheses of Base and Spare Telecommunication Networks*	Wessäly, *Dimensioning the Backbone Network of E-Plus*
WE3-W-CO15	**Statistical Applications**, Organizer: Fraley, Chair: Darbellay		
	Lindstrom, *Penalized Estimation of Free Knot Splines*	Darbellay, *An Algorithm for Estimating the Degree of Dependence between Two Random Vectors*	Sardy, *New Algorithms for L_1 Penalized Regression*

Parallel sessions : Wednesday afternoon 17:00 - 18:30

	17:00 - 17:30	17:30 - 18:00	18:00 - 18:30
WE4-A-IN1	**Pivoting Algorithms for Linear Programming**, Organizers: Lüthi, Fukuda, Chair: Lüthi		
	Finschi, *Randomized Pivot Algorithms in Linear Programming*	Gärtner, *Tail Estimates for Clarkson's Randomized LP Algorithm*	Thompson, *An Integral Simplex Algorithm for Solving Combinatorial Optimization Problems– A New Paradym?*
WE4-A-IN2	**Network Design and Polyhedra**, Organizer: Barahona, Chair: Barahona		
	Chopra, *Minimum Cost Multi Level Network Design*		
WE4-B-CO10	**Quadratic programming methods**, Chair: Li		
	Santos, *Augmented Lagrangians with adaptive precision control for quadratic programming with simple bounds and equality constraints (I.Theory)*	Friedlander, *Augmented Lagrangians with Adaptive Precision Control for Quadratic Programming with Simple Bounds and Equality Constraints (II.Applications)*	Liu, *An Exterior Newton Method for Convex Quadratic Programming*
WE4-C-CO2	**Generalized Convexity VI**, Organizer: Martínez-Legaz, Chair: Daniilidis		
	Gutierrez-Diez, *A New Axiomatic Approach to Lagrangian Conditions*	Gugat, *A Prox–Regularization Method for Generalized Fractional Programming*	Penot, *Duality for Anticonvex Problems*
WE4-C-CO122	**Rigorous Global Optimization: Algorithms, Software, and Applications I**, Organizer: Kearfott, Chair: Kearfott		
	Jansson, *Exact Bounds for Linear Systems with Interval Input Data*	Csendes, *Multisection in Interval Methods for Global Optimization*	Madsen, *Simulating the Interval Optimization Method in Real Arithmetic*
WE4-C-CO3	**Trust region algorithms**, Chair: Ulbrich		
	Moore, *Copilot - Successive Linear Programming with Trust Regions for Constrained Optimization*	Yuan, *Some Properties of a Trust Region Subproblem*	
WE4-D-CO123	**Semidefinite Programming and Applications III**, Chair: Rendl		
	Jarre, *An Application of Semidefinite Programming in Combinatorial Optimization*	Helmberg, *Fixing Variables in Semidefinite Relaxations*	El Ghaoui, *Semidefinite Programming in Control*
WE4-D-CO124	**Interior Point Methods**, Chair: Herskovits		
	Sargent, *An Infeasible-Interior-Point Algorithm for Degenerate LCPs with Q-Subquadratic Convergence*	Abdessamad, *Interior Point Algorithms for Linear Programming from some New Potential Functions*	
WE4-E-CO21	**Computational Contact Mechanics and Mathematical Programming II**, Organizers: Klarbring, Pang, Chair: Pang		
	Panagiotopoulos, *New Models for Discretized Adhesive Contact Problems*	Stavroulakis, *Structured Nonconvex Modelling in Nonsmooth Mechanics*	Klarbring, *Existence of Solutions for the Steady Sliding Problem*
WE4-E-CO11	**Computational Algorithms for complementarity, variational inequality, and related problems II**, Organizer: Tseng, Chair: Fukushima		
	Yamashita, *Some Properties of the Restricted NCP-Functions for the Nonlinear Complementarity Problem*	Denault, *A Primal-Dual Infeasible Newton Analytic Center Cutting Plane Method for Variational Inequalities*	Perakis, *A Generalized Potential Approach to Averaging for Solving Variational Inequalities and Fxed Point Problems*
WE4-F-IN203	**Optimal control**, Chair: Kugelmann		
	Pickenhain, *Flows as Dual Solutions of Control Problems with Multiple Indegrals*	Felgenhauer, *Discretization Based Optimality Conditions and Solution Regularity*	
WE4-G-IN11	**Modelling Support for Stochastic Programming**, Organizer: Gassmann, Chair: Gassmann		
	Entriken, *Language Constructs for Modeling Stochastic Linear Programs*	Fourer, *Stochastic Programming Using AMPL*	Gassmann, *An Input Format and Object Library for Stochastic Programming Problems*
WE4-I-CM5	**The Traveling Salesman Problem I**, Organizers: Kabadi, Punnen, Chair: Kabadi		
	Van der Veen, *Sequencing with Job-Groups: Some Solvable Cases of the TSP*	Baki, *Pyramidal Traveling Salesman Problem*	Gruenert, *Implementing Ejection Chains for the TSP: Neighbourhoods and Evaluations*
WE4-I-CM120	**Network Design and Routing I**, Organizers: Ravi, Tayi, Chair: Ravi		
	Krumke, *Node Weighted Network Upgrading Problems*	Verbarg, *Hierarchical Euclidean Path Planning*	
WE4-I-CM200	**Combinatorics of Polytopes II**, Organizer: Ziegler, Chair: Avis		
	Richter-Gebert, *Realization Spaces of 4-Polytopes are Universal*	Santos, *Bistellar Flips in Triangulations of Point Configurations*	Schulz, *Combining a Pack of Polytopes: The Transitive Packing Polytope*
WE4-I-CM4	**Paths, Cycles, and Flows**, Organizer: Goldberg, Chair: Goldberg		
	Kolliopoulos, *Improved Approximation Algorithms for Unsplittable Flow Problems*	Goldberg, *Beyond Flow Decomposition Barrier*	Goldberg, *Negative-Cycle Detection Algorithms*
WE4-I-CM121	**On Boolean problems**, Chair: Kogan		
	Warners, *Elliptic Approximations of Satisfiability Problems*	Makino, *Bidual Horn functions*	Williams, *The Dual of a Logical Linear Programme*
WE4-K-CM106	**Tabu search**, Organizer: Gendreau, Chair: Gendreau		
	Crainic, *Parallel Tabu Search for Network Design*	Woodruff, *Combination of Tabu Search and Exact Methods for MIPs*	Gendreau, *A General Tabu Search Approach for Two-Stage Stochastic Programming with Recourse*
WE4-L-CM201	**Embedded Structures within Large Scale Linear Programming**, Organizer: Mitra, Chair: Mitra		
	Gulpinar, *Computational Solution of Large Scale Linear Programs Exploiting Embedded Network Structures*	Hsu, *Identification of Embedded Network Structure in Linear Programming Models*	Marin, *Using Restricted Simplicial Decomposition within Partial Linearization Methods*
WE4-P-IN201	**Project scheduling**, Chair: Drozdowski		
	Neumann, *New Results on Heuristic Algorithms for Resource-Constrained Project Scheduling with Minimum and Maximum Time Lags*	Mingozzi, *An heuristic procedure for the Multi-Mode Resource Constrained Project Scheduling Problem based on Benders' decomposition*	Knust, *Single-machine problems with generalized precedence constraints*
WE4-S-IN202	**Combinatorial optimization in molecular biology and chemistry**, Chair: Reinert		
	Ferreira, *A Polyhedral Approach for DNA Fragments Rearrangement*	Bollweg, *Predicting Stable and Metastable Structures of Crystalls and Molecules*	Abeledo, *Benzenoid Hydrocarbons and Integral Polyhedra*
WE4-T-CO22	**Applications of Mathematical Programming III**, Organizer: Rosenthal, Chair: Dell		
	Philpott, *Optimizing the Velocity of an America's Cup Yacht*	Raffensperger, *The Readiness Problem: Scheduling Training for Emergency Organizations*	Barros, *Decomposition Methods Applied to Integer Programming*
WE4-U-IN10	**Multicommodity networks**, Chair: Patriksson		
	Barbas, *Simplicial Secomposition with Disaggregated Representation to Solve the Capacity Multicommodity Network Problem*	Yuan, *Multicommodity Network Flow Problem with Side Constraints on Paths Solved by Column Generation*	Malashenko, *Multicommodity Flow Network Survivability Analysis*
WE4-W-CO15	**Optimization and the World Wide Web**, Organizer: Tomlin, Chair: Tomlin		
	Wright, *The NEOS Guide*	Tomlin, *Web-Based Tools for the Optimization Subroutine Library*	Kristjansson, *Optimization Modeling on the Internet using Client-Server Technologies*

Parallel sessions : Thursday morning 08:15 - 09:45

	08:15 - 08:45	08:45 - 09:15	09:15 - 09:45
TH1-A-IN2	**Software for Integer/Combinatorial Optimization I**, Organizer: Jünger, Chair: Jünger		
	Näher, *The LEDA Platform of Combinatorial and Geometric Computing*	Savelsbergh, *MINTO, A Mixed INTeger Optimizer*	Thienel, *ABACUS - A Branch-And-CUt System*
TH1-A-IN1	**On the simplex method**, Chair: Pan		
	Aráoz, *Forward Chaining is Simple(x)*	Pan, *A Basis-Deficiency-Allowing Variation of the Simplex Method for Linear Programming*	
TH1-B-CO10	**Semi-Infinite Programming and Applications I**, Organizer: Goberna, Chair: Goberna		
	Gustafson, *Computing Bounds for Functions, Defined by Power Series*	Reemtsen, *Filter Design in the Frequency Domain by Semi-Infinite Programming*	Rückmann, *One-Parameter-Families of Feasible Sets in Semi-infinite Optimization*
TH1-C-CO2	**Generalized Convexity VII**, Organizer: Martínez-Legaz, Chair: Kassay		
	Eberhard, *Towards a Rank One Convex Analysis*	Giorgi, *Nonsmooth Vector-Valued Invex Functions and Applications*	Bykadorov, *Generalized Convexity Criteria, Convex Transformability and Global Optimization*
TH1-C-CO3	**Curve fitting**, Chair: Armand		
	Petersson, *Parameter Identification Algorithms for Approximating Positive Sums of Exponentials to Empirical Data*	Merkulov, *On a New Vector Norm for Optimzation Problems*	
TH1-C-CO122	**Theory and practice of global optimization methods**, Chair: Jaumard		
	Jaumard, *Concave Minimization: Best Simplicial Bounds and a New Convergence Proof*	Khamisov, *Theory and Practice of Global Search with Concave Support Functions*	Carrizosa, *Dominators for Multiple-Objective Quasiconvex Maximization Problems*
TH1-D-CO124	**Interior Point Methods in Decomposition IV**, Organizers: Gondzio, Mitchell, Chair: Fragnière		
	Mitchell, *Solving Integer Programming Problems with an Interior Point Cutting Plane Algorithm*	Xu, *Decomposition in Large Scale Geometric Programming*	Luo, *Interior Point Column Generation Algorithms for Adaptive Filtering*
TH1-D-CO123	**Interior-Point Methods for Convex Programming**, Organizer: Güler, Chair: Güler		
	Güler, *Search Directions in Semidefinite Programming*	Nemirovskii, *On Self-Concordant Convex-Concave Functions*	Tuncel, *Desired Properties of Interior-Point Algorithms for Convex Optimization Problems*
TH1-E-CO11	**Homotopy Algorithms and Applications II**, Organizer: Forster, Chair: Isac		
	Klinz, *Extended Lemke Algorithm for All Solutions of Bimatrix Games*	Forster, *Implementation of Homotopy Algorithms*	
TH1-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods VIII**, Organizers: Qi, Fukushima, Chair: Tseng		
	Marcotte, *Reformulations of a Bicriterion Equilibrium Problem*	Li, *Minimization of Quadratic Splines and Applications*	Ralph, *Active Sets for Nonlinear Programs under a Constant Rank Assumption*
TH1-F-IN203	**Real-time optimal control I**, Organizers: Pesch, Maurer, Chair: Pesch		
	Augustin, *Stability and Sensitivity Analysis of Optimal Control Problems Subject to Pure State Constraints*	Büskens, *Sensitivity Analysis and Real-Time Control of Nonlinear Control Systems via Nonlinear Programming Methods*	Kugelmann, *Parallel Computation of Optimal Feedback Controls*
TH1-G-IN11	**Stochastic Integer Programming II**, Organizer: Van der Vlerk, Chair: Van der Vlerk		
	Stougie, *Computational Complexity of Stochastic Programming Problems*	Klein Haneveld, *Convex Simple Integer Recourse Models*	Van der Vlerk, *Convex Approximations for Simple Integer Recourse Models*
TH1-I-CM5	**Location Theory and Applications II**, Organizer: Hamacher, Chair: Hamacher		
	Carrizosa, *Location of Semi-Undesirable Facilities. A DEA Approach*	Nickel, *Sandwich Approximation for Restricted Location Problems*	Hamacher, *Combinatorial Solution Algorithms for Max Ordering Location Problems*
TH1-I-CM121	**Binary Matroids I**, Organizers: Laurent, Gerards, Chair: Gerards		
	Sebő, *Binary Metrics, Multiflows and Clutters I*	Novick, *Binary Metrics, Multiflows and Clutters II*	Conforti, *A Class of Weakly Bipartite Graphs*
TH1-I-CM200	**Neighborhood Search Methods**, Organizers: Punnen, Kabadi, Chair: Gutin		
	Gutin, *Exponential Neighbourhood Local Search for the TSP and the VRP*	Mechti, *A Tabu Search Perturbation Procedures for the Fleet Mix Problem with Time Windows*	Schilham, *A Probabilistic Cost Analysis of Simulated Annealing for TSP's*
TH1-I-CM120	**Network Flow Algorithms**, Organizer: Orlin, Chair: Orlin		
	Goldfarb, *Polynomial-Time Highest-Gain Augmenting Path Algorithms for the Generalized Circulation Problem*	Orlin, *Determining K-Route Flows Efficiently*	Orlin, *Solving Inverse Optimization Problems in Polynomial Time*
TH1-I-CM4	**Algorithms for specific combinatorial problems**, Chair: Puschmann		
	Park, *A Branch-and-Price Algorithm for the Targeting Problem*	Nemoto, *An Efficient Algorithm for the Minimum-Range Ideal Problem and Related Topics*	Burdakov, *A Greedy Algorithm for the Optimal Basis Problem*
TH1-K-CM106	**Approximation algorithms**, Chair: Romero-Morales		
	Hochbaum, *A Framework for Half Integrality and 2-Approximations*	Sviridenko, *An Approximation Algorithm for the Uncapacitated Facility Location Problem*	Neame, *An Outer Approximate Subdifferential Method for Piecewise Affine Optimization*
TH1-L-CM201	**Large-scale optimization**, Chair: Altman		
	Zakeri, *Techniques for Solving Large-scale Set Partitioning Problems*	Roma, *A New Approach to Exploiting Negative Curvature Directions in Large Scale Unconstrained Optimization*	Rohe, *Computing Minimum-Weight Perfect Matchings*
TH1-P-IN201	**Scheduling**, Organizer: Blazewicz, Chair: Blazewicz		
	Finke, *New Theoretical Results on Robotic Flowshops*	Drozdowski, *Review of Linear Programming Models for Multiprocessor Task Scheduling*	
TH1-T-CO22	**Novel Applications IV**, Organizer: Kelley, Chair: Wright		
	Lewis, *The Qualitative Nature of Hessians for Optimization Problems Governed by Partial Differential Equations*	Schnabel, *Global Optimization Methods for Protein Folding Problems*	Kelley, *Racing Vehicle Dynamics*
TH1-U-IN10	**Network Equilibrium Models and Algorithms I**, Organizers: Hearn, Florian, Chair: Florian		
	Hearn, *Congestion Toll Pricing Models and Methods*	Patriksson, *Traffic Management Through Link Tolls : New Developments*	Wynter, *Bilevel Stochastic Programming for Network Equilibrium Problems*
TH1-W-CO15	**Statistical Disclosure Control**, Organizer: Willenborg, Chair: Willenborg		
	Willenborg, *mu- and tau-ARGUS: Software for Statistical Disclosure of Control*	Salazar, *Models and Algorithms for Statistical Disclosure Control of Tabular Data*	Hurkens, *Algorithms for Set Covering Problems in Statistical Disclosure Control*

Parallel sessions : Thursday morning 11:15 - 12:45

	11:15 - 11:45	11:45 - 12:15	12:15 - 12:45
TH2-A-IN1	**The Steven Vajda Memorial Session**, Organizer: Krarup, Chair: Krarup		
	Krarup, *Steven Vajda, 1901-1995*	Jalal, *Geometrical solution to the Fermat problem with arbitrary weights*	Powell, *Kantorovich's Hidden Duality*
TH2-A-IN2	**Integer programming and cutting planes**, Chair: Holmberg		
	Oosten, *On the Strength of Inequalities*	Rangel, *A Posteriori Bounds for Variable Aggregation in Integer Programming*	Wang, *An Implementation of the Generalized Basis Reduction Algorithm for Convex Integer Programming*
TH2-B-CO10	**Nondifferentiable optimization**, Chair: Combettes		
	Sagastizábal, *$\mathcal{VU}$-Decomposition Derivatives for Convex Max-Functions. Part I*	Mifflin, *$\mathcal{VU}$-Decomposition Derivatives for Convex Max-Functions. Part II*	Kiwiel, *Ballstep Subgradient Level Methods for Convex Optimization*
TH2-C-CO3	**Lagrangian Methods in Nonlinear Programming III**, Organizer: Di Pillo, Chair: Morgan		
	Qi, *Constant Positive Linear Independence, KKT Points and Convergence of Feasible SQP Methods*	Dixon, *Reverse Differentiation and Nonlinear Programming*	Morgan, *Well Posedness and Generalized Lagrangian*
TH2-C-CO122	**Rigorous Global Optimization: Algorithms, Software, and Applications II**, Organizer: Kearfott, Chair: Kearfott		
	Ratz, *A New Global Optimization Technique Using Slopes*	Kearfott, *INTOPT_90, A Fortran 90 Package for Rigorous Global Search*	
TH2-C-CO2	**Bilevel programming II**, Organizer: Savard, Chair: Savard		
	Galé, *The Bilevel Linear/Linear Fractional Programming Problem: An enumerative algorithm for finding a global optimum*	Conn, *An ℓ_1 Penalty Function Approach to the Nonlinear Bilevel Programming Problem*	Herskovits, *A New Method for Bilevel Programming Based on a Smooth Optimization Technique*
TH2-D-CO124	**Interior Point Methods in Decomposition V**, Organizers: Gondzio, Mitchell, Chair: El-Bakry		
	Vial, *Homogeneous Analytic Center Cutting Plane Method for Variational Inequalities and Constrained Minimization*	Gondzio, *Warm Start of the Primal-dual Method in the Cutting Plane Scheme*	Lesaja, *Homogeneous Infeasible-Interior-Point Algorithm for the P*-Nonlinear Complementarity Problem*
TH2-D-CO123	**Semidefinite programming and truss topology**, Chair: Tuncel		
	Brännlund, *Semidefinite Programming Formulations and an Interior Point Method for Truss Topology Design*	Svanberg, *Optimal Truss Topology, Semidefinite Programming, and a Method Based on Conservative Approximations*	Khachiyan, *On the complexity of integer and mixed semidefinite programming*
TH2-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods IX**, Organizers: Qi, Fukushima, Chair: Solodov		
	Polak, *Structural Optimization with Reliability Constraints*	Outrata, *On a Special Class of Equilibrium Problems*	Zupke, *Trust Region Methods for Solving Nonlinear Complementarity Problems*
TH2-E-CO11	**Computational Algorithms for complementarity, variational inequality, and related problems III**, Organizer: Tseng, Chair: Marcotte		
	Iusem, *A New Search Startegy for Korpelevich s method*	Júdice, *On the Solution of the Linear MPEC*	Butnariu, *A Method of Computing almost Common Points for Relatively Nonexpansive Families of Operators with Application to Variational Inequalities*
TH2-F-IN203	**Real-time optimal control II**, Organizers: Maurer, Pesch, Chair: Maurer		
	Koslik, *Optimal Active Suspension of Vehicles Using an On-Line Dynamic Programming Method*	Pesch, *Collision Avoidance as a Differential Game: Real-Time Approximation of Optimal Strategies using Higher Derivatives of the Value Function*	von Stryk, *Optimal Guidance of Full Car Simulations in Real-Time*
TH2-G-IN11	**Progress in SP methods and software**, Organizer: Kall, Chair: Kall		
	Mayer, *Testing SLP Codes and Methods*	Prékopa, *Application of Discrete Moment Problems in Stochastic Programming*	Sen, *A Stochastic Scenario Decomposition Algorithm for Multi-stage Stochastic Linear Programming*
TH2-H-CO22	**Multi-agent optimization**, Chair: Slowinski		
	Petrov, *Parametrical Identification of Linear Models of Multifactor Estimation*	Heiskanen, *Constraint Proposals Method for Computing Pareto Solutions in n-Party Negotiations*	
TH2-I-CM4	**Perfect Graphs I**, Organizer: Preissmann, Chair: Preissmann		
	Hoang, *On Graphs with Bounded Chromatic Number*	Wagler, *On Critically and Anticritically Perfect Graphs*	Linhares-Sales, *Perfectly Contractile Graphs*
TH2-I-CM3	**Combinatorial Optimization for Public Traffic Systems**, Organizers: Grötschel, Zimmermann, Chair: Zimmermann		
	Erhard, *Applying Graph Models and Algorithms for the Train Scheduling Problem*	Löbel, *Optimal Vehicle Scheduling in Public Transit*	Borndörfer, *Set Partitioning Methods for Dial-a-Ride Systems*
TH2-I-CM121	**Frequency Assignment in Telecommunication**, Organizers: Van Hoesel, Aardal, Chair: Aardal		
	Mannino, *New Lower and Upper Bounds for the Frequency Assignment Problem*	Hurkens, *Upper and Lower Bounding Techniques for Frequency Assignment Problems*	Eisenblätter, *A Frequency Assignment Problem in Cellular Phone Networks*
TH2-I-CM200	**Polyhedral combinatorics III**, Chair: Nobili		
	de Souza, *Exact solutions for the Maximum Edge-Weighted Clique Problem*	Hadjar, *Composition Operations for the Stable Set Polytope*	Spieksma, *Polyhedral Results for the Clique Partitioning Problem*
TH2-I-CM120	**Steiner and spanning trees**, Chair: Thomas		
	Zachariasen, *Rectilinear Full Steiner Tree Generation*	Warme, *A New Exact Algorithm for Geometric Steiner Tree Problems*	Uno, *A Fast Enumerating Algorithm for all Directed Spanning Trees in a Directed Graph*
TH2-K-CM106	**Tabu search**, Chair: Crainic		
	Kobayashi, *Development and Evaluation of Improved Tabu Search*	Nonobe, *A Tabu Search Approach to the CSP (Constraint Satisfaction Problem) as a General Problem Solver*	Ribeiro, *A Framework for the Development of Local Search Based Heuristics for Combinatorial Optimization Problems*
TH2-L-CM201	**Parallel Mixed Integer Programming**, Organizers: Savelsbergh, Eckstein, Chair: Eckstein		
	Savelsbergh, *PARINO, A PARallel INteger Optimizer*	Mitra, *A Distributed Processing Algorithm for Solving Integer Programs*	
TH2-P-IN201	**Machine Scheduling and Linear Programming**, Organizer: Simchi-Levi, Chair: Simchi-Levi		
	Schulz, *Scheduling-LPs Bear Probabilities*	Simchi-Levi, *Parallel Machine Scheduling, Linear Programming and Parameter List Scheduling Heuristics*	van de Velde, *New Lower Bounds for Minimizing Total Completion In the Two-Machine Flow Shop Problem*
TH2-U-IN10	**Vehicle Routing Problems**, Organizer: Anily, Chair: Anily		
	Bixby, *The Capacitated Prize-Collecting Traveling Salesman Problem*	Vigo, *Lower and Upper Bounds for the Traveling Salesman Problem with Pickup and Delivery*	Bramel, *Approximation Algorithms for the Capacitated Traveling Salesman Problem with Pick-ups and Deliveries*
TH2-W-CO15	**Modeling Languages and Approaches/Language Issues**, Organizers: Pollatschek, Fourer, Chair: Maturana		
	Hürlimann, *Why do we need Modeling Languages?*	Maturana, *Towards a Formalism for Algebraic Modeling Languages*	

Parallel sessions : Thursday afternoon 14:00 - 15:30

	14:00 - 14:30	14:30 - 15:00	15:00 - 15:30
TH3-A-IN1	**Software for Integer/Combinatorial Optimization II**, Organizer: Jünger, Chair: Thienel		
	Ceria, *MIPO: A Mixed Integer Programming Optimizer*	Boehm, *A Parallel SAT Solver: Theoretical Analysis and Practical Performance*	
TH3-A-IN2	**Integer Programming/Modeling II**, Organizers: Ceria, Wolsey, Chair: Bienstock		
	Wolsey, *Modelling and Solving Lot-Sizing Problems by Mixed Integer Programming*	Hoffman, *A Comparison of Alternate Formulations for the Single Airport Ground Holding Problem with Banking Constraints*	van de Leensel, *Lifting Valid Inequalities for the Precedence Constrained Knapsack Problem*
TH3-B-CO10	**New Methods for Linear and Quadratic Semi-infinite Programming**, Organizers: Fang, Wu, Chair: Fang		
	Lin, *An Unconstrained Convex Programming Approach to Linear Semi-infinite Programming*	Wu, *A New Cutting Plane Method for Convex Quadratic Semi-infinite Programming*	Sheu, *A Combined Entropic Regularization and Path Following Method for Some Minimax Problems with Infinitely Many Linear Constraints*
TH3-C-CO2	**Generalized Convexity VIII**, Organizer: Martínez-Legaz, Chair: Bykadorov		
	Pini, *Optimality and Duality Results for a New Class of Generalized Convex Functions*	Cambini, *Generalized Concavity in Multiobjective Programming*	Cambini, *Nonsmooth Generalized Concave Scalar Functions*
TH3-C-CO3	**Math Programs with Equilibrium Constraints II**, Organizer: Ralph, Chair: Scholtes		
	Outrata, *Optimality Conditions for a Class of Mathematical Programs with Equilibrium Constraints*	Scholtes, *Exact Penalization of Mathematical Programs with Equilibrium Constraints*	Floudas, *Global Optimization In Batch Process Design Under Uncertainty*
TH3-C-CO122	**Theoretical developments in nonlinear programming**, Chair: Jaumard		
	Recht, *Towards a Fundamental Theorem of Calculus for Nondifferentiable Functions*	Brinkhuis, *Necessary Conditions for Extremal Problems*	Mayergoiz, *The Necessary Conditions and Algorithms for the Multiextremal Problems*
TH3-D-CO124	**Interior Point Methods for SDP and NLP**, Organizers: Roos, Terlaky, Chair: du Merle		
	de Klerk, *Primal-Dual Affine-Scaling Methods for Semidefinite Programming*	Zhang, *The Analytic Central Path and some Sensitivity Issues for sSemidefinite Programming*	Vial, *Very Deep Cuts and two Cuts in the Analytic Center Cutting Plane Method*
TH3-D-CO123	**Semi-definite programming**, Chair: Muramatsu		
	Karisch, *Solving Graph Bisection Problems with Semidefinite Programming*	Alizadeh, *Optimization over the Ice-Cream Cone*	Oustry, *A Global and Superlinear Algorithm to Minimise the Maximum Eigenvalue Function*
TH3-E-CO21	**Computational Contact Mechanics and Mathematical Programming III**, Organizers: Klarbring, Pang, Chair: Christensen		
	Stewart, *Time-Stepping for Rigid Body Dynamics and Complementarity Problems*	Glocker, *Variational Methods in Nonsmooth Dynamics*	Kocvara, *Contact and Displacement Constraints in Structural Optimization Problems*
TH3-E-CO11	**Computational Algorithms for complementarity, variational inequality, and related problems IV**, Organizer: Tseng, Chair: Tseng		
	Shindoh, *LocalConvergence Analysis of Some Interior-Point Methods for the SDP and the Monotone SDLCP*	Magnanti, *Averaging with Well Behaved Maps for Solving Fixed Point and Variational Inequality Problems*	Wright, *Local Convergence of SQP for Degenerate Problems*
TH3-F-IN203	**Infinite dimensional optimization**, Chair: Büskens		
	Ulbrich, *Superlinear Convergence of Affine-Scaling Interior-Point Newton Methods for Infinite-Dimensional Nonlinear Problems with Pointwise Bounds*	Burnside, *Modelling and Solution of Optimization Problems with Differential Equation constraints*	Arnold, *Optimal Control Application for Operational Water Management of a Canal System*
TH3-G-IN11	**Stochastic optimization**, Organizer: Robinson, Chair: Robinson		
	Ruszczyński, *A Stochastic Branch-and-Bound Method*	Shapiro, *Simulation Based Optimization, Theory and Algorithms*	Gürkan, *Sample-Path Solution of Stochastic Variational Inequalities and Equilibrium Models*
TH3-H-CO22	**Dynamic Multi-Agent Models**, Organizers: Haurie, Başar, Chair: Haurie		
	Pourtallier, *Approximations in Dynamic Zero-Sum Games*	Başar, *Iterative Computation of Nash Equilibria in Differential Games with Switching Dynamics*	Carlson, *Infinite Horizon Dynamic Games with Coupled State Constraints*
TH3-I-CM4	**Perfect Graphs II**, Chair: Maffray		
	Gravier, *A Sequential Algorithm for Coloring some Perfect Graphs*	Sanchez-Arroyo, *Some Results on a Conjecture of Chvatal*	Zemirline, *Minimally Imperfect Graphs and Cutsets*
TH3-I-CM120	**Network design and routing II**, Organizers: Ravi, Tayi, Chair: Tayi		
	Noltemeier, *Modifying Edges in a Network to Obtain Low Cost Trees*	Myung, *On the Hub Cover Network Design Problem*	Iri, *Topics from the Theory of Uncontrollable Flows*
TH3-I-CM5	**Discrete Algorithms and Applications III**, Organizers: Recski, Wagner, Nishizeki, Chair: Wagner		
	Recski, *Channel Routing in the Dogleg-Free Multilayer Manhattan Model*	Hartmann, *On Wire Length Minimization in VLSI Design*	Lovász, *The Necessary Width for Channel Routing in the 2k (k>1) Layer Dogleg-Free Manhattan Model*
TH3-I-CM200	**Enumeration and K-best problems on combinatorial optimization**, Organizer: Matsui, Chair: Matsui		
	Deza, *Solitaire Cones*	Bremner, *New Analysis of some Old Methods for Vertex and Facet Enumeration*	Lübbecke, *The Vertex Set of a 0/1-Polytope is Strongly P-Enumerable*
TH3-I-CM121	**Boolean and Pseudo-Boolean Functions IV: Logical Analysis of Data**, Organizer: Hammer, Chair: Crama		
	Anthony, *Using Linear Threshold Functions Sequentially in Data Classification*	Blazewicz, *Using LAD Method for Classifying into more than Two Classes*	Mayoraz, *Logical Analysis of Data for Multi-Class Learning*
TH3-L-CM201	**Parallel Sparse Simplex (SSX) Algorithms**, Organizer: Mitra, Chair: Mitra		
	Hall, *PARSMI, a Parallel Revised Simplex Algorithm incorporating Minor Iterations and Devex Pricing*	Maros, *Exploring Sparse Simplex Algorithms on Distributed Memory Multiprocessor*	Loute, *A Parallel Cholesky Factorization for Block Structured LP Problems*
TH3-P-IN201	**Approximation Algorithms for Machine Scheduling**, Organizer: Schulz, Chair: Schulz		
	Wein, *Scheduling to Provide Good Average Service to Jobs That Arrive Over Time*	Goemans, *One Machine Scheduling with Release Dates*	Woeginger, *Approximation Algorithms for Shop Scheduling Problems*
TH3-U-IN10	**Stochastic Programming in telecommunications**, Organizer: Wallace, Chair: Gaivoronski		
	Higle, *Stochastic Network Optimization for Control of Nested Demands*	Tomasgard, *Modelling in Distributed Telecommunications Networks*	Gaivoronski, *Optimal design of backbone ATM network with dynamic capacity reallocation using stochastic programming*
TH3-W-CO15	**Modeling Languages and Approaches/Modeling Issues**, Organizers: Pollatschek, Fourer, Chair: Mousavi		
	Dresbach, *Modeling by Construction — an Example-Based Introduction*	Sekiguchi, *Generic Approach to Problem Specification for Mathematical Models*	Mousavi, *Optimisation Based Decision Modelling: Introducing Structure, Interaction and Customisation*

Parallel sessions : Thursday afternoon 17:00 - 18:30

	17:00 - 17:30	17:30 - 18:00	18:00 - 18:30
TH4-A-IN2	**Integer Programming/Cutting Planes II**, Organizers: Ceria, Wolsey, Chair: Balas		
	Avella, *Lift and Project Cuts for Mixed 0-1 Programs: New Computational Results*	Pataki, *If You Can Branch, You Can Cut: Disjunctive Cuts for Mixed Integer Programs*	Soares, *Generating Disjunctive cuts for mixed 0-1 programs*
TH4-B-CO10	**Decomposition Based on Nondifferential Optimization I**, Organizers: Golshtein, Beer, Chair: Beer		
	Golshtein, *A Primal-Dual Decomposition Method for Solving Linear Programming Problems*	Mangasarian, *Feature Selection by Mathematical Programming*	a Campo, *Bundle Methods for Problems with not Everywhere Defined Objective Function*
TH4-C-CO2	**Generalized Convexity IX**, Organizer: Martínez-Legaz, Chair: Craven		
	Singer, *Abstract Convex Analysis*	Aussel, *On the Use of Mean Value Theorems in Generalized Convexity*	Carrizosa, *Locating un Undesirable Facility by Generalized Cutting Planes*
TH4-C-CO122	**Recent Advances In Global Optimization II**, Organizer: Floudas, Chair: Floudas		
	Zlobec, *Optimality and Duality in Parametric Convex Lexicographic ØProgramming*	Pardalos, *Continuous Characterization of Graph Coloring*	
TH4-C-CO3	**Trust Region Methods for Nonlinear Programming**, Organizer: Yuan, Chair: Yuan		
	Zhang, *A Scaled Optimal Path Trust Region Algorithm*	Ulbrich, *Global Convergence of Trust-Region Interior-Point Algorithms for Infinite-Dimensional Nonconvex Minimization Subject to Pointwise Bounds*	Li, *A Trust Region and Affine Scaling Method for Nonlinear Minimization with Linear Constraints*
TH4-D-CO124	**Interior Point Methods in Decomposition VI**, Chair: Vial		
	Dikin, *Acceleration of the Affine Scaling Method Convergence for Optimisation Problems of Thermodynamics*	du Merle, *An Interior Point Algorithm For Minimum Sum-of-Squares Clustering*	Oliveira, *Stabilizing Cutting Planes Method with Analytic Center for Nonsmooth Convex Programming*
TH4-D-CO123	**Homotopies for Nonlinear Problems II**, Organizer: Eaves, Chair: Huber		
	Eaves, *Computing on the Grassmannian Manifold*	Verschelde, *A Software Package for Polynomial Homotopy Continuation*	
TH4-E-CO11	**Homotopy Algorithms and Applications III**, Organizer: Forster, Chair: van Maaren		
	Isac, *Zero-Epi Mappings and Complementarity Theory*	Kalashnikov, *Application of Topological Degree Theory to Complementarity Problem*	Kabadi, *Integer Solution for Linear Complementarity Problem*
TH4-E-CO21	**On complementarity problems and Quasi-Newton methods**, Chair: Adler		
	Perez, *On the Convergence of Quasi-Newton Methods for Nonlinear Complementary Problems*	El-Farouq, *Pseudo-Monotone Variational Inequalities Convergence of the Auxiliary Problem Method*	Morales-Perez, *Automatic Preconditioning by Quasi-Newton Updating*
TH4-F-IN203	**Production Planning and Inventory Management**, Organizer: Sethi, Chair: Sethi		
	Moresino, *A Stochastic Programming Approach to Manufacturing Flow Control*	Sethi, *Some Insights into Near-Optimal Plans for Stochastic Manufacturing Systems*	Basak, *Control of Random Singular Diffusions Under Long-Term Average Cost*
TH4-G-IN11	**Applications of Multistage Stochastic Programming I**, Organizer: Frauendorfer, Chair: Frauendorfer		
	Gaese, *No Arbitrage Conditions in Multiperiod Pricing Models*	Siede, *Mean-Variance Analysis in a Multiperiod Setting*	Steinbach, *Solving Portfolio Management Problems with Optimal Complexity*
TH4-H-CO22	**Multi-agent optimization**, Chair: Korhonen		
	Audet, *Enumeration of All Extreme Equilibrium Strategies of Bimatrix Games*	Miettinen, *Comparison of Some Reference Point-based Methods for Multiobjective Optimization*	Alves, *Multiobjective mixed-integer programming: an interactive approach*
TH4-I-CM5	**The travelling Salesman Polytope and related topics**, Organizer: Naddef, Chair: Naddef		
	Pochet, *A Lifting View of the Traveling Salesman Polytope*	Boyd, *Worst Case Comparisons of the Metric TSP with Two of its Relaxations*	Carr, *Separation and Lifting of TSP Inequalities*
TH4-I-CM120	**Network Design Problems with Bounded Paths**, Organizer: Gouveia, Chair: Gouveia		
	Fortz, *Designing Reliable Networks with Bounded Ring*	Dahl, *Approximation of Piecewise Linear Functions and Constrained Shortest Paths*	Gouveia, *Using Variable Redefinition For Computing Minimum Spanning and Steiner Trees With Hop Constraints*
TH4-I-CM4	**Hypergraphs, directed hypergraphs and applications**, Organizer: Gallo, Chair: Gallo		
	Gallo, *Hypergraph Models in Production Scheduling*	Pretolani, *A Computational Study of Shortest Hyperpath Algorithms*	Levin, *Cutpoints of Hypergraph Realizations*
TH4-I-CM121	**Boolean and Pseudo-Boolean Functions V: Quadratic Optimization**, Organizer: Hammer, Chair: Franco		
	Boros, *Optimal Cell Flipping to Minimize Channel Density in VLSI Design*	Hansen, *Maximizing the Product of Two Linear Functions in 0-1 Variables*	Resende, *Approximate Solution of Weighted MAX-SAT Problems using GRASP*
TH4-I-CM200	**Knapsack problems**, Chair: Tsevendorj		
	Barcia, *An Algorithm for the Subset Sum Problem*	Soutif, *A New Upper-Bound and an Exact Algorithm for the 0-1 Quadratic Knapsack Problem*	Pisinger, *Exact Solution of Large Scale Quadratic Knapsack Problems*
TH4-L-CM201	**COMPSys: Combinatorial Optimization Multi-Processing System**, Organizer: Trotter, Chair: Trotter		
	Ladanyi, *COMPSys: Combinatorial Optimization Multi-Processing System*	Ralphs, *Parallel Branch-and-Cut for Capacitated Vehicle Routing*	Eso, *Parallel Branch-and-Cut for Set Partitioning*
TH4-P-IN201	**Single machine scheduling**, Chair: Queyranne		
	Gordon, *Due Date Assignment for Single Machine Scheduling Problems*	Tanaka, *Single Machine Scheduling with Positional Due and Release Dates*	Simonetti, *A Linear Time Algorithm for One-Machine Scheduling with Set Up Times and Time Windows*
TH4-U-IN1	**Math Programming in Radiation Oncology and Radiology**, Organizers: Newman, Holder, Chair: Newman		
	Newman, *A Robust Linear Programming Approach to the Optimal, Placement and Intensity of Radiotherapy Beams in the Treatment of Benign and Malignant Lesions*	Holder, *Parametric Programming, Analytic Centers, and Radiotherapy*	Billups, *Medical Image Segmentation via Linear Programming*
TH4-U-IN10	**Column generation: applications**, Chair: Gademann		
	Shaw, *A Unified Limited Column Generation Approach for Facility Location Peroblems on Trees*	Christiansen, *A Column Generation Approach for an Inventory Pickup and Delivery Problem with Time Windows*	Gademann, *Order Batching in a Parallel-Aisle Warehouse*
TH4-V-CM106	**Applications of financial optimization**, Organizer: Rosen, Chair: Rosen		
	King, *Strategic Risk Management using Stochastic Programming*	Jensen, *Automatic Regulatory Compliance using Optimization Techniques*	Rosen, *Applications of Scenario Optimization for Hedging and Estimating Implied Parameters*
TH4-W-CO15	**Optimization Modeling Interfaces**, Organizer: Entriken, Chair: Entriken		
	Gay, *The Evolving AMPL/Solver Interface*	Kristjansson, *The Impact of Distributed Computing on Optimization Modeling Interfaces*	Entriken, *A Java-Based Programming Interface for Optimization Modeling*

Parallel sessions : Friday morning 08:15 - 09:45

	08:15 - 08:45	08:45 - 09:15	09:15 - 09:45
FR1-A-IN2	**Methodological Aspects of DEA**, Organizer: Pastor, Chair: Pastor		
	Pastor, *Radial DEA Models Without Inputs or Without Outputs*	Sirvent, *A New Global Efficiency DEA Measure*	Ruiz, *A Statistical Test for Detecting Influential Observations in DEA*
FR1-B-CO10	**Semi-Infinite Programming and Applications II**, Organizer: Goberna, Chair: Reemtsen		
	Weber, *Generalized Semi-Infinite Optimization: on Foundations and Iteration Procedures*	Ito, *A Dual Parametrization Method for Convex Semi-Infinite Programming*	
FR1-C-CO122	**Global optimization of problems with indefinite quadratic constraints**, Organizer: Horst, Chair: Horst		
	Horst, *Lagrange-Duality and Partitioning Techniques in Nonconvex Global Optimization*	Thoai, *A Duality Bound Method for the General Quadratic Programming Problem with an Additional Quadratic Constraint*	Raber, *A Simplicial Branch-and-Bound Method for Solving Nonconvex All-Quadratic Programs*
FR1-C-CO3	**D.c. (difference of convex functions) programming I**, Organizer: Pham Dinh, Chair: Fülöp		
	Pham Dinh, *D.C. (Difference of Convex Functions) Optimization: Theory, Algorithms and Applications*	Le Thi, *D.c. Optimization Algorithm for Solving the Trust Region Subproblem*	Muu, *D. C. Optimization and Convex-Concave Programming Approaches to Optimizing over the Efficient Set*
FR1-C-CO2	**Application of nonsmooth optimization methods**, Chair: Silva		
	Bardadym, *On the Use of Nonsmooth Optimization Methods in Statistics and Stochastic Programming*	Makela, *Nonsmooth Optimization Methods Applied to Hemivariational Inequalities*	
FR1-D-CO123	**Primal-Dual Interior-Point Algorithms for Semidefinite Programming II**, Organizers: Kojima, Zhang, Chair: Kojima		
	Monteiro, *Polynomial Convergence of a New Family of Primal-Dual Algorithms for Semidefinite Programming*	Saigal, *Semidefinite Programming and the Quadratic Assignment Problem*	Zhang, *Analysis for a Class of Long-step Primal-Dual Interior-Point Algorithms for SDP*
FR1-D-CO124	**Interior Point Methods**, Chair: Dikin		
	Popova, *Acceleration of the Affine Scaling Method Convergence for Optimisation Problems of Thermodynamics*	Tobin, *Accelerating Convergence of a Potential Reduction Method*	Kovačević-Vujčić, *Partial Pivoting as a Stabilization Technique in Interior Point Methods*
FR1-E-CO11	**The Linear Complementarity Problem III**, Organizer: Cottle, Chair: Mohan		
	Sriparna, *Lipschitzian Q_0-Matrices*	Stone, *Lipschitzian Matrices and Nondegenerate INS-Matrices*	Venkateswaran, *An Algorithm for the Block Z-Matrix GLCP*
FR1-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods X**, Organizers: Qi, Fukushima, Chair: Robinson		
	Kleinmichel, *A New Class of Semismooth Newton-Type Methods for Nonlinear Complementarity Problems*	Womersley, *Reformulation Methods for Box Constrained Variational Inequalities*	Salmon, *A Family of Perturbed Forward-Backward Methods for Solving Variational Inequalities*
FR1-F-IN203	**Numerical solution of large scale optimal control problems I**, Organizers: Betts, Pesch, Chair: Pesch		
	Gill, *An SQP Method for the Optimization of Dynamical Systems*	Betts, *Exploiting Sparsity in the Direct Transcription Method for Optimal Control*	Leibfritz, *Inexact SQP Interior Point Method and Large Scale Optimal Control*
FR1-G-IN11	**SP methods and applications**, Organizer: Kall, Chair: Prékopa		
	Szántai, *Probabilistic Constrained Programming with Different Multivariate Probability Distributions*	Gaivoronski, *Nonstationary Stochastic Optimization with Applications to Optimal Portfolio Selection*	Zakeri, *Inexact Cuts in Benders' Decomposition*
FR1-H-CO22	**Mathematical Programming for Multicriteria Decision Aiding I**, Organizer: Roy, Chair: Slowinski		
	Korhonen, *A value Efficiency Approach to Incorporating Preference Information in Data Envelopment Analysis*	Slowinski, *Aggregation-Disaggregation Approach to Preference Modelling in Multi-Criteria Sorting*	Teghem, *Bicriteria Assignement Problem*
FR1-I-CM3	**Applied Combinatorial Online Optimization**, Organizers: Grötschel, Zimmermann, Chair: Zimmermann		
	Winter, *On-Line Dispatching in Llocal Transport*	Ascheuer, *Optimization of an Automatic Storage System under Online Conditions*	Grötschel, *On-Line Optimization of a System of Automated Guided Vehicles*
FR1-I-CM121	**Boolean and Pseudo-Boolean Functions VI: Simple Games**, Organizer: Hammer, Chair: Hammer		
	Zwicker, *Order Relations on Sets of Boolean Variables*	Taylor, *Pseudo-Weightings for Classes of Boolean Functions*	
FR1-I-CM120	**Methods for Tree Network Design II**, Organizer: Gouveia, Chair: Voss		
	Dahl, *The 2-Hop Spanning Tree Problem and Associated Polytopes*	Vigo, *A Granular Tabu Search Heuristic for Constrained Arborescence Problems*	Gouveia, *A Comparative Study of Flow Based models for the Capacitated Minimum Spanning Tree Problem*
FR1-I-CM4	**Max-cut**, Organizer: Rinaldi, Chair: Rendl		
	Rendl, *Max-Cut Approximations in Graphs with Triangles*	Jünger, *Max-Cut on Sparse Graphs*	Jünger, *Solution of Large Max-Cut Instances Arising from Statistical Physics*
FR1-I-CM200	**Assignment problems**, Chair: Starke		
	Iwamoto, *An Inversion of Beckmann's Plane Assignment Problem*	Balogh, *Computational Research of Latin Squares*	Starke, *Combinatorial Optimization Based on Coupled Selection Equations*
FR1-L-CM201	**Algorithms for large-scale optimization**, Chair: Kallio		
	Contesse, *A General Quadratic Penalty Lagrangean Decomposition Algorithm in Non-Convex Optimization*	Krivonozhko, *Compound Decomposition Approach in Large-Scale Optimization*	Palagi, *A Superlinearly and Globally Convergent Algorithm for Large Scale Trust Region Problems*
FR1-P-IN201	**Single Machine Scheduling and FMS**, Organizer: Margot, Chair: Margot		
	Queyranne, *Decompositions, Network Flows and a Precedence Constrained Single Machine Scheduling Problem*	Margot, *A Branch-and-Cut Algorithm for a Precedence Constrained Single Machine Scheduling Problem*	Vizvari, *Classification of FMS Scheduling Problems*
FR1-U-IN1	**Network Equilibrium Models and Algorithms II**, Organizers: Hearn, Florian, Chair: Hearn		
	Florian, *Methods for Analysing the Demand for Toll Highways*	Lindberg, *Traffic Equilibrium Problems with Nonlinear Time/Money Relations*	Marcotte, *Strategic Approach to Capacitated Traffic Assignment.*
FR1-U-IN10	**Inter-disciplinary Applications of Discrete Optimization**, Organizer: Trotter, Chair: Trotter		
	Amaldi, *A Combinatorial Optimization Approach for Extracting Piecewise Linear Structure in Nonlinear Data*	Günlük, *Parallel Branch-and-cut: A Comparative Study*	Pusztaszeri, *Combinatorial Multiple-Target Tracking*
FR1-V-CM106	**Financial optimization**, Chair: Frauendorfer		
	Calvillo, *Use of Combinatorial Optimization to Improve pon Clearing and Settlement of Large-Value Payment Systems*	Barle, *On the Constraints and Objective Functions in Financial Optimization*	Adler, *Arbitrage and Growth Rate for Riskless Investments*
FR1-W-CO15	**Modeling Languages and Approaches/Nonlinear Problems**, Organizers: Pollatschek, Fourer, Chair: Gay		
	Gay, *Making Use of Hessians Easy and Efficient with Automatic Detection of Partially Separable Structure*	Drud, *A General Pre-processor for Nonlinear GAMS Models*	Pinter, *Model Management and Solver Systems in Global Optimization*

Parallel sessions : Friday morning 11:15 - 12:45

	11:15 - 11:45	11:45 - 12:15	12:15 - 12:45
FR2-A-IN2	**Integer Programming/Computations II**, Organizers: Ceria, Wolsey, Chair: Savelsbergh		
	Günlük, *A Branch-and-cut Algorithm for Capacitated Network Design Problems*	Fischetti, *0-1/2 Chvátal-Gomory Cuts for Integer Programming: A Preliminary Computational Study*	Martin, *Decomposing Matrices into Blocks*
FR2-B-CO10	**Eigenvalue optimization II**, Chair: Shapiro		
	Hiriart-Urruty, *First and Second Order Sensitivity of all Eigenvalues of a Symmetric Operator*	Oustry, *Globalization of the $\mathcal{U}$-Newton Algorithm to Minimise the Maximum Eigenvalue Function*	Stefanov, *Approximations with Respect to l_1 and l_∞ Norms: An Application of Convex Nonsmooth Programming*
FR2-C-CO2	**Generalized Convexity X**, Organizer: Martínez-Legaz, Chair: Gutierrez-Diez		
	Jarre, *On Self-Concordant Barrier Functions for Conic Hulls and Fractional Programming*	Llinares, *Abstract Convexity. A Fixed Point Result*	
FR2-C-CO3	**Lagrangian Methods in Nonlinear Programming IV**, Organizer: Di Pillo, Chair: Di Pillo		
	Polyak, *Nonlinear Rescaling vs. SUMT in Constrained Optimization (Exterior-Interior Point Methods)*	Smaoui, *Determination of Sensitivity of Nonregular Optimum Solutions in Nonlinear Programming*	
FR2-C-CO122	**Global optimization problems with special structures I**, Organizer: Rapcsak, Chair: Rapcsak		
	Friedler, *Combinatorial Analysis of Process Network Synthesis*	Fülöp, *A Global Optimization Approach for Solving Process Network Synthesis Problems*	Komlosi, *Second Order Global Optimality Conditions for Problems with Equality Constraints*
FR2-C-CO123	**Nonsmooth analysis and economics**, Organizer: Jofré, Chair: Jofré		
	Bonnisseau, *Oligopoly Equilibria in Large but Finite Linear Exchange Economies*	Cornet, *Smooth Normal Approximation of Epi-Lipschitzian Subsets of $\Re^n$*	Jofré, *A Nonconvex Separation Property in Banach Spaces and its Applications to Economics*
FR2-D-CO124	**Interior Point Methods**, Chair: Hribar		
	Hribar, *The Design and Implementation of an Interior Point Method for Nonlinear Programming*	Leontiev, *A Limited Memory Interior Point Method for Nonlinearly Constrained Optimization*	
FR2-E-CO11	**The Linear Complementarity Problem IV**, Organizer: Cottle, Chair: Neogy		
	Adler, *A Matrix Parametrization Algorithm for the Linear Complementarity Problem*	Kanzow, *On Block Pivoting and Line Search Methods for Linear Complementarity Problems*	Tutuncu, *Infeasible-Interior-Point Algorithms for the LCP*
FR2-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods XI**, Organizers: Qi, Fukushima, Chair: Ferris		
	Auslender, *Asymptotic Analysis for Penalty and Barrier Methods in Non Coercive Variational Inequalities*	Martínez, *Solving Complementarity Problems by Means of a New Smooth Constrained Nonlinear Solver*	Jiang, *Global Convergence of Numerical Approaches to Mathematical Programs with Equilibrium Constraints (MPEC)*
FR2-F-IN203	**Numerical solution of large scale optimal control problems II**, Organizers: Betts, Pesch, Chair: Betts		
	Chudej, *Comparing Different Boundary-Value Problems for Solving a Complicated Trajectory Optimization Problem*	Bell, *A New Algorithm for State Constrained Optimal Control*	Hinsberger, *Optimal Control of Large Scale DAE Systems in Chemical Engineering by a Direct Multiple Shooting Method*
FR2-G-IN11	**Applications of Multistage Stochastic Programming II**, Organizer: Frauendorfer, Chair: Gaese		
	Marohn, *Refinement Strategies in Stochastic Multistage Linear Programming*	Haarbrücker, *Solving a Sequence of Deterministic Equivalent Problems*	Schmid, *Cash-Management with Stochastic Programming*
FR2-H-CO22	**Mathematical Programming for Multicriteria Decision Aiding II**, Organizer: Roy, Chair: Mousseau		
	Figueira, *A Posteriori Studies in Multicriteria Network Flow Interactive Procedures*	Bolintineanu, *Efficient and Kuhn-Tucker Sequences in Constrained Vector Optimization Problems*	Ball, *Multiobjective Optimization Models For Product Design*
FR2-I-CM121	**Binary Matroids II**, Organizers: Gerards, Laurent, Chair: Laurent		
	Guenin, *Weakly Bipartite Graphs: A Proof of a Conjecture by Seymour*	Gerards, *The Matroids Representable over the 4-Element Field*	Lee, *On Dyadic Matrices*
FR2-I-CM4	**Stable Matchings and Extensions I**, Organizers: Balinski, Rothblum, Chair: Balinski		
	Rothblum, *Strategic Behavior in Matching Markets with Lack of Information, in Search of Practical Advice for Participants*	Sotomayor, *Existence of Stable Outcomes for a Unified Matching Market*	Balinski, *Marriage and Admissions via Graphs*
FR2-I-CM120	**Network Design**, Organizer: Mahjoub, Chair: Mahjoub		
	Mahjoub, *On the Linear Relaxation of the 2-Node Connected Subgraph Polytope*	Barahona, *Plant Location with Minimum Inventory*	Baïou, *The Partition Inequalities and the 2-Edge Connected Subgraph Problem*
FR2-I-CM200	**On some specific mathematical programming problems**, Chair: Park		
	Świtalski, *On Extremal GTT Matrices*	Brutman, *On an Extremal Problem of Erdos in Interpolation Theory*	Puschmann, *On a Cyclic Supervision Problem*
FR2-L-CM201	**Parallel Branching Methods**, Organizers: Eckstein, Savelsbergh, Chair: Bixby		
	Cung, *Constrained Two-Dimensional Cutting Stock Problems and the BOB library*	Eckstein, *An Adaptable Parallel Toolbox for Branching Algorithms*	
FR2-P-IN201	**Scheduling with Batching**, Organizer: Potts, Chair: Strusevich		
	Glass, *Shop Scheduling with Batching to Minimize the Makespan*	Potts, *Scheduling a Batching Machine*	Tautenhahn, *On the Complexity of Shop Scheduling Problems with Batching Machines*
FR2-U-IN10	**Assignment Ranking Applications**, Organizer: Murty, Chair: Iwamoto		
	Stone, *An Application of Murty's k-best assignment method to Reid's Multiple Hypothesis Tracking Algorithm*	Kuipers, *Lagrange Relaxation and Assignment Ranking on an Assignment Problem with a 0-1 Side Constraint*	
FR2-U-IN1	**Vehicle routing** , Chair: Mingozzi		
	Larsen, *Solving the Multiple Depot Vehicle Scheduling Problem in a Major Scandinavian City*	Madsen, *K-Path Cuts for the Vehicle Routing Problem with Time Windows*	
FR2-V-CM106	**Computation of Equilibria**, Organizer: Talman, Chair: Talman		
	von Stengel, *New LowerBounds for the Number of Equilibria in Bimatrix Games*	Kremers, *A Tâtonnement Price-Quantity Adjustment Process in Semi-Algebraic Nonconvex Production Economies*	Yang, *Portfolio Optimization under Minimax Risk Measure*
FR2-W-CO15	**Object-oriented optimization software, environments, and strategies**, Organizers: Michelena, Papalambros, Chair: Michelena		
	Hart, *SGOPT: A C++ Library of Global Optimization Algorithms*	Deng, *The CWP Object-Oriented Optimization Library: A Tool for Studying Optimization Problems*	Symes, *The Hilbert Class Library: Abstract Base Classes for Optimization and Inversion*

Parallel sessions : Friday afternoon 14:00 - 15:30

	14:00 - 14:30	14:30 - 15:00	15:00 - 15:30
FR3-A-IN2	**Advance in 0-1 Nonlinear Programming**, Organizer: Mauricio, Chair: Mauricio		
	Mauricio, *A Boolean Penalty for Zero-One Global Optimization*	Maculan, *A Trust Region Algorithm for Mixed Zero-One Nonlinear Programming*	Poggi, *An Algebraic-Enumerative Algorithm for Nonlinear 0-1 Programming*
FR3-B-CO10	**Proximal Methods in Optimization III**, Organizer: Théra, Chair: Nguyen		
	Davidson, *Prox-Regularized Primal-Dual Method with Constraint Aggregation*	Silva, *Proximal Point Methods and Separators*	
FR3-C-CO3	**Math Programs with Equilibrium Constraints III**, Organizer: Ralph, Chair: Ralph		
	Stavroulakis, *Numerical Experiments with Multilevel Optimization Techniques*	Ralph, *A Survey of Quadratic Programs with Equilibrium Constraints (QPEC)*	
FR3-C-CO122	**Stochastic Approaches to Global Optimization**, Organizer: Zabinsky, Chair: Zabinsky		
	Romeijn, *Simulated Annealing for Mixed Integer/Continuous Global Optimization*	Wood, *How Long Must we Wait ?*	Korotkich, *A Systematic Build-Up Method for Global Optimization of Large Molecular Structures*
FR3-C-CO123	**Multiobjective optimization**, Chair: Cambini		
	Tharwat, *On Solving Inverse Multobjective Max-Separable Optimization Problems*	Nakayama, *Pattern Classification by Mathematical Programming*	
FR3-C-CO2	**Convergence analysis and optimality conditions**, Chair: Mayergoiz		
	Scheimberg, *Mathematical Program with a Generalized Equilibrium Constraint*	Lucidi, *On the Convergence of Derivative Free Methods for Unconstrained Optimization*	Penot, *Optimality Conditions in Mathematical Programming with General Constraints*
FR3-D-CO124	**Interior-point methods for convex problems**, Organizer: Jarre, Chair: Jarre		
	Kocvara, *Truss Topology Desing Problems solved by Interior-Point and Penalty-Barrier Methods*	Terlaky, *Initialization in Semidefinite Optimization by Self-Dual Embedding, Central Path, Maximally Complementary Solution*	Sturm, *Error Bounds for Semidefinite Programming*
FR3-E-CO21	**Nonsmooth, Piecewise Smooth, Semismooth and Smoothing Methods XII**, Organizers: Qi, Fukushima, Chair: Pang		
	Tseng, *Analysis of Some Continuation Methods for Complementarity Problems*	Scholtes, *Mathematical Programs with Equilibrium Constraints: Stationarity, Optimality, and Sensitivity*	Svaiter, *A Hybrid Projection-Proximal Point Algorithm*
FR3-F-IN203	**Equilibrium problems**, Chair: Konnov		
	Konnov, *Combined Relaxation Methods: Complexity Estimates and Applications*	Johansson, *Estimation of Formation Constants in Chemical Equilibrium Analysis*	
FR3-H-CO22	**Game theory**, Chair: Droste		
	Potter, *A New Value for Games in Partition Function Form*	Mignanego, *Optimality and Credibility in Stackelberg Games with Reversed Information Structures*	Ivanov, *Ellipsoidal Approximation Technique for Differential Games with Integral-Terminal Payment*
FR3-I-CM120	**Domination Analysis in Combinatorial Optimization**, Organizers: Punnen, Kabadi, Chair: Punnen		
	Deineko, *Polynomially Solvable Cases, Exponential Neighborhoods and Heuristics for NP-hard Combinatorial Problems*	Vale Rego, *A Decomposition algorithm for the Complete Crew Scheduling Problem*	Punnen, *Traveling Salesman Problem: New Heuristics and Domination Analysis*
FR3-I-CM4	**Graph Theory II**, Organizer: Szwarcfiter, Chair: Gutierrez		
	Prisner, *Distance and Eccentricity Approximating Spanning Trees*	Szwarcfiter, *On Clique Graphs of Some Classes of Graphs*	Wakabayashi, *Circuit Covers in Series-Parallel Mixed Graphs*
FR3-I-CM121	**Matchings, Matroids, and Extensions**, Organizer: Cunningham, Chair: Cunningham		
	Geelen, *An Algebraic Matching Algorithm*	Iwata, *The Parity Problem for Linear Delta-Matroids*	Cunningham, *The Optimal Path-Matching Problem*
FR3-I-CM5	**Routing Problems**, Organizer: Toth, Chair: Fischetti		
	Fleischmann, *Lower Bounds for the VRP with Time Windows*	Naddef, *Solving Symmetric Traveling Salesman Problems to optimality: where do we go now?*	Balas, *Lifted Inequalities for the Asymmetric Traveling Salesman Problem*
FR3-I-CM200	**On some specific mathematical programming problems**, Chair: Brutman		
	Yakovlev, *Theory and Methods of Optimization on Euclidean Combinatorial Sets*	Bosch, *Integer Programming and the Game of Life*	Main, *Short-Term Modelling In Refinery Planning*
FR3-I-IN202	**Frequency Assignment in Telecommunication**, Organizer: Van Hoesel, Chair: Van Hoesel		
	Koster, *The Partial Constraint Satisfaction Problem: Facets and Lifting Theorems*	Van Hoesel, *A Branch-and-Cut Algorithm for the Frequency Assignment Problem*	
FR3-L-CM201	**Parallel Stochastic Programming**, Organizer: Mitra, Chair: Dempster		
	Dempster, *Parallel Solution of Large Scale Dynamic Stochastic Programmes*	Escudero, *A Parallel Computing Approach for Water Resources Utilization Planning under Uncertainty*	Mirhassani, *Integer Stochastic Programming (ISP) for Planning and Scheduling: Parallel Computational Solution*
FR3-P-IN201	**Combinatorial models in scheduling**, Organizer: Crama, Chair: Crama		
	Ibaraki, *Scheduling RMG (rail mounted gantry crane) shift operations in a container terminal*	Lancia, *Job Shop Scheduling with Deadlines*	van de Klundert, *Scheduling in Robotic Flow Shops*
FR3-P-IN11	**Lot sizing**, Chair: Ingold		
	Sastry, *Valid Inequalities and Facets for Multi Item Lot Sizing With Changeover Costs*	Agra, *Lotsizing with Backlogging and Start-ups: The Case of Wagner-Whithin Costs*	Vanderbeck, *Lot-sizing with Start-up Times*
FR3-U-IN1	**Large-scale multidisciplinary optimization for engineering design**, Organizers: Papalambros, Michelena, Chair: Michelena		
	Michelena, *Decomposition and Coordination for Large Systems Design Optimization*	Alexandrov, *On Multilevel Optimization Algorithms for Engineering Design Problems*	Rao, *Bilevel Models in Worst-Case and Topology Problems in Structural Design*
FR3-U-IN10	**Mathematical programming approaches for scheduling problems**, Chair: Mazzola		
	Felici, *Logic Programs for Urban Traffic Control*	Mohammed, *Mixed-Integer Programming Fleet Management Models and Algorithms for an Oil Tanker Routing and Scheduling Problem*	Dotzauer, *Optimal Scheduling of Cogeneration Plants*
FR3-V-CM106	**Portofolio management**, Chair: Fleten		
	Fleten, *Portfolio Management in the Electricity Industry*	Siokos, *Static and Dynamic Modeling of International Financial Equilibrium with Hedging*	
FR3-W-CO15	**Modeling Languages and Approaches/New Directions**, Organizers: Pollatschek, Fourer, Chair: Pollatschek		
	Fourer, *General-Purpose Modeling Languages for Combinatorial Optimization*	Bockmayr, *Algebraic Modeling and Constraint Logic Programming*	Pollatschek, *Algebraic Description of Discrete Event Simulation Models*

Parallel sessions : Friday afternoon 15:45 - 17:15

	15:45 - 16:15	16:15 - 16:45	16:45 - 17:15
FR4-A-IN2	**Integer Programming/Computations III**, Organizers: Ceria, Wolsey, Chair: Atamturk		
	De Vitis, *Cutting Plane Techniques for the Capacitated Vehicle Routing Problem*	Atamturk, *The Mixed Node Packing Problem*	McDonnell, *Sketches on Reformulating Linear Integer Programs and the Fibonacci Sequence*
FR4-B-CO10	**Decomposition Based on Nondifferential Optimization II**, Organizers: Golshtein, Beer, Chair: Golshtein		
	Beer, *Decomposition – a Way for Finding a Solvable Problem in the Neighbourhood of an Inconsistent One*	Lemaréchal, *Variation of the Duality Gap with Vvarious Dualization Schemes*	Shor, *Using of Nonsmooth Optimization Methods for Solving Quasiblock Structured Problems of Semidefinite Programming*
FR4-C-CO2	**Generalized Convexity XI**, Organizer: Martínez-Legaz, Chair: Pini		
	Martínez-Legaz, *Characterization of R-evenly quasiconvex functions*	Ellero, *Convexity and Quasi-Convexity of Marginal Functions for Problems with Bounded or Unbounded Feasible Region*	Jofré, *Monotonicity Properties of Subgradients and Well-Behavioured Nonconvex Functions*
FR4-C-CO122	**Global optimization problems with special structures II**, Organizer: Rapcsak, Chair: Rapcsak		
	Strekalovsky, *On Global Optimality Conditions for D.C.-programming*	Le Thi, *A Branch and Bound Method via D.C. Optimization Algorithms and Ellipsoidal technique for Box Constrained Nonconvex Quadratic Problems*	
FR4-C-CO3	**D.c. (difference of convex functions) programming II**, Organizer: Pham Dinh, Chair: Pham Dinh		
	Pham Dinh, *D.C. Programming Approach for Solving the Multidimensional Scaling Problem*	Mahey, *Capacity and Flow Assignment of Data Networks by Generalized Benders Decomposition*	Phan Quoc, *Sufficient Optimality Conditions and Duality for Problems with invex-convelike functions*
FR4-C-CO123	**Nonlinear optimization techniques**, Chair: Gfrerer		
	Terpolilli, *Upper Convex Approximation and Convergence of Algorithms to Solve Nonsmooth Optimization Problems*	Armand, *A Line Search Technique with Sufficient Decrease and Curvature Conditions*	
FR4-D-CO124	**Interior Point Methods and Scalings**, Chair: Todd		
	Muramatsu, *Prima-Dual Affine-Scaling Algorithm Fails for Semidefinite Programming*	Ariyawansa, *Projective Maps, Davidon's Collinear Scalings and Karmarkar's Projective Transformations*	Dikin, *Determination of Interior Point of Linear System*
FR4-F-IN203	**Dynamic programming in combinatorial optimization**, Chair: Koslik		
	Guu, *Lot-Sizing Problem with Interrupted Geometric Yiled, Rigid Demand, and General Cost Stuctures*	Chu, *Dynamic Programming Techniques to Solve Real Life Cutting Stock Problems*	Hochstättler, *Tree Partitioning under Constraints*
FR4-H-CO22	**Game theory**, Chair: Mignanego		
	Droste, *Evolution with a Varying Stage Game: An Economic Approach to Mutational Models*	Funaki, *The Tragedy of the Commons and the Core: A Partition Function Form Approach*	Ivanov, *A Minimax Principle for Differential Games*
FR4-I-CM121	**Valuated matroids and polymatroids**, Organizers: Dress, Murota, Chair: Dress		
	Murota, *Discrete Convex Analysis through Valuated Matroids*	Shioura, *Minimization of M-convex function*	Kashiwabara, *The Cone of Envelopes*
FR4-I-CM5	**Real-World Transportation Problems**, Organizer: Toth, Chair: Lawphongpanich		
	Soumis, *Locomotive Assignment with Heterogeneous Consists*	Desaulniers, *Crew Pairing for a Regional Carrier*	Lawphongpanich, *Deployment Scheduling for Aircraft Carriers*
FR4-I-CM4	**Problems on Matchings**, Chair: Abeledo		
	Fleiner, *Covering a Symmetric Poset by Symmetric Chains*	Fremuth-Pager, *A Network Flow Based Theory for Generalized Matching Problems*	
FR4-I-CM120	**Knapsack, Cutting and Bin Packing Problems**, Chair: Rebetez		
	Vigo, *Exact Method for Orthogonal Two-Dimensional Cutting Problem*	Pisinger, *The three-Dimensional Bin Packing Problem*	Tsevendorj, *On Continuous Approach to Knapsack Problem with Several Constraints*
FR4-L-CM201	**Computational Mixed Integer Programming II**, Organizers: Lee, Mitra, Chair: Lee		
	Mitra, *Constraint Classification, Preprocessing and a Branch and Relax Approach to solving Mixed Integer Programming Models*	Nygreen, *Modelling of Augmented Makespan Problems (AMAPs): Computational Experience of Applying Integer Presolve at the Modelling Stage*	Vance, *Network Design Problems is Rail and Air Freignt Applications*
FR4-L-CM200	**Large-scale convex programming**, Chair: Altman		
	Kallio, *Large-Scale Convex Optimization via Saddle Point Computation*	Altman, *QHOPDM - A Package for Large Scale Convex Quadratic Programming using Primal-Dual Method*	
FR4-P-IN201	**Resource-Constrained Machine Scheduling**, Organizer: Weglarz, Chair: Weglarz		
	Giordani, *Solution Algorithms for the Multimode Scheduling Problem with Dedicated Resources*	Janiak, *Flow-Shop Scheduling with Resources - Exact and Approximation Algorithms*	Weglarz, *Discrete-Continuous Scheduling - Mean Flow Time Results*
FR4-P-IN11	**Timetabling and crew scheduling**, Chair: Klabjan		
	Nõu, *Railway Timetabling using Lagrangian Relaxation*	Hjorring, *Column Generation with a Rule System for Crew Scheduling Problems*	Loiseau, *On the Solution of a Large Scale Timetabling University Problem*
FR4-U-IN1	**Application of Optimization**, Organizer: Lemaréchal, Chair: Billups		
	Allione, *Application of Optimization in Computer-aided Ophthalmic Lens Design*	Soulie, *Nonlinear Least Squares and Electron Paramagnetic Resonance*	Renaud, *A New Model for Stochastic Optimization of Weekly Generation Schedules*
FR4-U-IN10	**Mathematical programming approaches for network problems**, Chair: Holmberg		
	Stein, *Approaches for Solving the Cable Management Problem*	Xu, *Mixed Integer Programming in Backbone Network Design*	Costa, *Solving the Shortest Edge Disjoint or Capacited Undirected Paths Problems*
FR4-V-CM106	**High-Performance Computing for Financial Planning Under Uncertainty**, Organizer: Zenios, Chair: Gaivoronski		
	Dupačová, *Bond Portfolio Management – Sensitivity with respect to the Model Input*	Consigli, *Sequantial Importance Sampling of Dynamic Stochastic Programmes Using EVPI Criteria*	Stella, *Defining Universal Portfolios via Stochastic Programming*
FR4-W-CO15	**Modeling Languages and Approaches: Internet Services**, Organizers: Müller, Fourer, Pollatschek, Chair: Müller		
	Müller, *MatSe: Optimization Services on the Internet*	Becker, *Using MatSe Internet Services as Solvers in Progress Optimization Models*	More, *The Network-Enabled Optimization System (NEOS) Server*
FR4-X-IN202	**Last MP (last minute papers)**, Chair: Lewis		
	Lewis, *Convex Spectral Functions of Compact Operators*		

Abstracts

TH4-B-CO10

Bundle Methods for Problems with not Everywhere Defined Objective Function

a Campo Frank Wilfried

Keywords: bundle methods - decomposition - nondifferential optimization

If we use a decomposition approach in order to solve a minimization problem we often get an objective function Φ in such a way that its domain dom $\Phi \neq \Re^n$ is not given explicitely to us. A variation of bundle methods is presented by means of which such a type of problems can be solved.In this variation a dynamic polyhedral model of dom Φ is generated by means of normal vectors.In addition to the well known serious steps und null steps of bundle methods a third type of steps is used to generate the model of dom Φ. It is shown that for the success of the variant dom Φ must fulfill a regularity property and that the choice of the normal vectors must meet some demands.Both requirements are fulfilled if dom Φ is polyhedral. Finally I report numerical results of a comparison between the variant and a minimization approach using penalty functions.

WE1-A-IN2

A Basis Reduction Algorithm for Solving an Integer Feasibility Problem Arising in Video Signal Processing

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Hurkens Cor A.J. - Lenstra Arjen K.

Keywords: basis reduction - integer programming - lattices

In a so-called video algorithm that is used in video signal processing there are sets of multidimensional loops in which certain functions are evaluated. The computation of the function values are processed by an operator. An important part of the considered video algorithm is conflict detection, where it is determined whether function evaluations in a pair of nested loops with given start time and periodicity ever occur simultaneously. If they do, then the evaluations have to be scheduled on different operators to avoid conflict. It is possible to model the conflict detection problem as an integer feasibility problem of the form "does there exist an integer vector x satisfying $\sum_{j\in N} a_j x_j = a_0,\ 0 \leq x \leq u$?". The sizes of the coefficients a_j differ by large amounts, the right-hand-side a_0 is of the order 10^9, and the vector u has components of the order 10^2. Solving such a problem by standard branch-and-bound is very difficult unless substantial preprocessing is applied, and in the studied application the problem has to be solved very fast. We have developed an algorithm that is based on lattice basis reduction and used it to solve several real-life instances. The computing times are encouraging.

TU4-P-IN201

Scheduling Identical Parallel Machines including Setups and a Single Operator

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Wirth Andrew

Keywords: machine interference - parallel machines - scheduling

We study the problem of scheduling independent nonpreemptable jobs, where each includes a setup and a processing period, on two identical parallel machines where the presence of a unique operator is only required for performing the setup. The objective is to minimise maximum completion time or makespan. This study is motivated by a problem observed at an automobile parts manufacturer who uses semi-automatic machines. We discuss the computational complexity of the problem. An integer programming model based on an analytical formulation is developed. Heuristics for special cases such as equal setup time or equal processing time jobs are presented and their performance discussed. An algorithm with computational complexity of $O(nlogn)$ for a solvable case where the sum of the setup times and processing times are equal for all jobs is suggested.

WE4-D-CO124

Interior Point Algorithms for Linear Programming from some New Potential Functions

Abdessamad Barbara

Université Blaise Pascal, Dept de Mathématiques

Coulibaly Adama

Keywords: Newton method - concave gauge functions - potential function

Newton-like descent algorithms based on some new potential functions for linear programming are proposed. The proposed algorithms give local superlinear convergence, followed by numerical results. To be more precise, consider the linear optimization problem

$$(LP) \quad \text{minimize } \langle c, x\rangle \text{ subject to } x \in \Re^n,\ Ax = b,\ x \geq 0.$$

We assume that the optimal solution value to the problem is known to be equal to zero. Let φ be a concave gauge function of $K = [0, +\infty)^n$. Hence (LP) can be formulated such as

$$\text{minimize } \langle c, x\rangle \text{ subject to } Ax = b,\ \varphi(x) \geq 0.$$

This problem can now be solved by classical barrier methods. Such methods are based on the minimization of penalty functions, in order to get rid of the constraint $\varphi(x) \geq 0$. As a penalty function we can take for instance

$$\langle c, x\rangle - \mu ln\varphi(x)$$

where μ is a positive parameter which tends to 0. Taking the Karmarkar's potential function as a model, Barbara-Crouzeix [1] have proposed other types of penalty functions, also called potential functions. These potential functions are defin

$$F_{p,\varphi,r}(x) = \begin{cases} \frac{t^p}{[\varphi(x)]^r} & \text{if } \langle c, x\rangle \geq 0,\ \varphi(x) > 0, \\ 0 & \text{if } \langle c, x\rangle = 0,\ \varphi(x) \geq 0, \\ +\infty & \text{elsewhere.} \end{cases}$$

The problem (LP) admits the same optimal solutions as the problem (P)

$$0 = \inf\{F_{p,\varphi,r}(x) : \; Ax = b\}.$$

The algorithms we propose consist in solving (P) with the concave gauge function $\varphi = \xi_q$ for $q \le 0$ defined as follows

$$\xi_q(x) = \begin{cases} (\frac{1}{n}\Sigma x_i^q)^{1/q} & \text{if } x \in (0,+\infty)^n , \\ 0 & \text{if } x \in Bd([0,+\infty)^n), \\ -\infty & \text{elsewhere,} \end{cases}$$

by using Newton method.

With the assumption of a unique primal nondegenerate optimal solution we prove the algorithms converge locally and superlinearly, i.e., if $\overline{x}$ denotes the optimal solution of (LP) and $\{x^k\}$ the sequence of the points generated by the algorithm, then if $\overline{x}$ is primal nondegenerate, for $||x^k - \overline{x}||$ sufficiently small, we have

$$||x^{k+1} - \overline{x}|| = \begin{cases} O(||x^k - \overline{x}||^{1-q}) & \text{when } q < 0 \\ & \text{and } p - r - 1 > 0, \\ O(||x^k - \overline{x}||^2) & \text{when } q = 0 \\ & \text{and } p + \frac{m}{n}r - r - 1 > 0. \end{cases}$$

WE4-S-IN202

Benzenoid Hydrocarbons and Integral Polyhedra

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Atkinson Gary

Keywords: combinatorial optimization - polyhedral combinatorics

Benzenoid hydrocarbon molecules are usually represented as subgraphs of the hexagonal lattice. Some chemical properties of benzenoid hydrocarbons can be understood in terms of the maximum number of mutually resonant hexagons, or *Clar number*, of the molecules. The Clar number of a benzenoid can be computed solving a partitioning problem on its associated graph. Hansen and Zheng (1993) studied an integer programming formulation of this problem and observed that, in practice, solving its linear relaxation consistently gave integral solutions. Here, we establish the integrality of the linear relaxation polytope by proving that its constraint matriz is unimodular. We remark that, in general, the constraint matrix of this problem is not totally unimodular or perfect.

TU1-I-CM4

Stable Matchings and Linear Programming

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Blum Yosef

Keywords: combinatorial optimization

We continue here the study of non-bipartite stable matching problems from a polyhedral perspective. We establish new properties of fractional stable matchings and use linear programming to derive an alternative polynomial algorithm for solving stable matching problems.

FR2-E-CO11

A Matrix Parametrization Algorithm for the Linear Complementarity Problem

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IEOR Department, UC Berkeley

Beling Peter - Verma Sushil

Keywords: linear complementarity problem - matrix parametrization - penalty function

We present a matrix parametrization algorithm for the Linear Complementarity problem. This parameterization was motivated by considering a path-following scheme in which a penalty function replaces the extensively studied logarithmic barrier function. The proposed algorithm has a unique, readily available, starting point while each step requires isolating a root of a certain polynomial function of a single parameter. We show that the algorithm is finitely convergent for a class of problems containing the class of column sufficient matrices. In addition, we show that for P_0 matrices and under a sign-invariant distribution for the input matrices and vectors, the algorithm, in the average, converges in a (strongly) polynomial running time.

FR1-V-CM106

Arbitrage and Growth Rate for Riskless Investments

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IEOR Department, UC Berkeley

Gale David

Keywords: arbitrage - investments - mathematical finance

A sequential investment is a vector of payments over time. Given a collection of such investments it may be possible to assemble a portfolio from which an investor can get "something for nothing", meaning that without investing any money of his own he can receive a positive return after some finite number of time periods. We present a simple necessary and sufficient condition for a set of investments to have this property. If arbitrage is not possible our result leads to a simple derivation of the expression for the long run growth rate of the set of investments in terms of its "internal rate of return".

FR3-P-IN11

Lotsizing with Backlogging and Start-ups: The Case of Wagner-Whithin Costs

Agra Agostinho

Instituto Superior de Engenharia de Coimbra

Constantino Miguel

Keywords: extended formulation - lot sizing - mixed integer programming - polyhedral combinatorics

We examine the uncapacitated single-item lotsizing problem with backlogging. We consider both set-up costs, which occur whenever the machine is able to produce, and start-up costs which occur when the machine is set-up in some period and

was not set-up in the previous period. We also consider unit production costs, p_t, holding costs, h_t^+, and backlogging costs, h_t^-.

We generalize known theoretical results on the polyhedral description of the convex hull of feasible soluctions, for models that can be viewed as particular cases of this model (models without start-up costs and models for which backlogging is not allowed). In the presence of Wagner-Whitin costs (which satisfy $p_t + h_t^+ - p_{t+1} \geq 0$ and $p_{t+1} + h_t^- - p_t \geq 0$, for $t = 1, \ldots, n$), we obtain a linear programming extended formulation with $O(n)$ variables and $O(n^2)$ constraints. By projection, we obtain a formulation in the space of natural variables, with an exponential number of constraints.

TU2-L-CM201

A New Simultaneous Block Projection Algorithm for the Linear Feasibility Problem

Akgül Mustafa

Bilkent University, Dept of Industrial Engineering

Özaktaş Hakan - Pınar Mustafa Celebi

Keywords: Cimmono's method - block projections - linear feasibility - parallel algorithms - relaxation method - sequential and parallel algorithms - surrogate constarints

We present a new block projection algorithm with a new step size policy for the linear feasibility problem. New step size gives an order of magnitude improvement in the performance of the algorithm within its class. Convergence of the modified algorithm is established and supporting computational results are given.

TU3-R-IN203

Cycle Time Optimization for VLSI-Chips

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Keywords: VLSI design - clocktree - combinatorial optimization - cycle time

Minimizing the cycle time is the overall aim in the design of VLSI-Chips.

As a part of its logic the chip has synchronizing elements (memory elements, latches or flip-flops), which are driven by a special network, the clocktree. We will describe the chip in a simple model: A directed graph with nodes representing primary inputs, primary outputs and latches and edges representing data paths. The optimal cycle time (clock period) can be computed very efficiently by solving a parametric shortest paths problem.

Due to process variations the actual arrival time of a clock signal at a latch on a produced chip will vary from the computed arrival time. We will show how the length of the time intervals for possible arrival times of the clock signals can be distributed equally by solving a minimum balance problem. This is also a crucial point in the design of the clocktree: The network has to be built up with respect to the critical data paths.

TU2-C-CO3

An Evaluation of some Methods for Solving Systems of Nonlinear Equations.

Alder Hermann

Universidad de Concepción

Figueroa Ernesto - Saavedra Marcelo - Garrido Cristian

Keywords: abs and multigrid algorithms - mathematical software - nonlinear systems of equations - numerical experiments

The purpose of this article is to evaluate some methods for solving systems of nonlinear equations F(x) = 0. We consider the local methods of Broyden and ABS and the global methods of Bittner and Zirilli. As test problems we took the systems of nonlinear equations of Rosenbrock, Powell, Brown, the equations from the Engineering Sciences of Combustion of Propane, and the H-equations arising in the study of Radiative Transfer. The last problem was also solved by the Multigrid Method. The performance of the codes was measure by considering the CPU time on the of the approximate solution.

FR3-U-IN1

On Multilevel Optimization Algorithms for Engineering Design Problems

Alexandrov Natalia M.

NASA Langley Research Center

Keywords: engineering design - large scale optimization - multilevel algorithms - nonlinear programming - trust region

This talk concerns two basic approaches to solving the engineering design optimization problem: on the one hand, a conventional distributed approach based on intuitive system decomposition and synthesis, on the other - a recently proposed class of multilevel hybrid methods based on nonlinear programming formulations of the engineering design problem. Analytical properties of both approaches as well as computational examples are presented.

MO4-T-CO22

On Using Approximations in Engineering Optimization

Alexandrov Natalia M.

NASA Langley Research Center

Lewis Robert Michael

Keywords: approximation algorithms - engineering applications - models - nonlinear programming

This talk deals with managing approximation models of varying fidelity in an engineering optimization process. Lower-fidelity, cheaper approximation models are used in the iterative process of generating search directions in optimization algorithms. More computationally expensive models of higher physical fidelity are used to update the validity of the resulting design. Strong convergence properties of this model management technique as well as application examples are discussed.

WE2-I-CM200

Facets of an Assignment problem with a 0-1 Side Constraint

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Yi Tongnyoul - Murty Katta G.

Keywords: constrained assignment problem - facet-defining inequalities - facet-lifting - integer hull

We consider the problem of finding a perfect matching satisfying a single equality constraint with 0-1 coefficients in an $n \times n$ incomplete bipartite graph. We show that this problem polynomially reduces to a special case of the same problem called the *partitioned case*. We investigate the polyhedral characterization of $Q^{n;r_1}_{n_1,n_2}$, the polytope associated with this problem. In particular, we present two large classes of facet-defining inequalities and a facet-lifting scheme for $Q^{n;r_1}_{n_1,n_2}$.

TH3-D-CO123

Optimization over the Ice-Cream Cone

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RUTCOR, Rutgers University

Haeberly Jean-Pierre - Overton Michael L. - Nayakkankuppam Madhu Vairy - Schmieta Stefan

Keywords: interior point methods - quadratic programming - semidefinite programming

It has been observed that many of the techniques for studying linear programs can be extended-sometimes word by word-to the more general venue of semidefinite programming. These include duality theory, degeneracy and strict complementarity and interior point methods. In this talk we study similar extensions to the study of quadratically constrained convex quadratic programs. It turns out that these problems can be formulated as optimization over "ice cream" cones (also known as Lorenz cone, second order cone or quadratic cone). We examine in particular the duality theory, nondegeneracy and strict complementarity and primal-dual interior point methods for such problems with emphasis on analogy to linear programs. We will also discuss combined linear, semidefinite and quadratically constrianed programs.

FR4-U-IN1

Application of Optimization in Computer-aided Ophthalmic Lens Design

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Essilor International, Recherche et Developpement Optique

Ahsbahs Francoise - Le Saux Gilles

Keywords: aberration - ophthalmic lens - optic - optimization

Optimization methods have been used for a long time in computer-aided design. In most of the cases, the problems to treat are uni-dimensionnal because of the rotationnal symmetry of the optical systems. Furthermore, the number of parameters we can vary is relatively few. The ophthalmic lens designs, and particularly the Progressive Addition Lens (PAL) designs are very different from the classical optical conceptions. Actually, PAL conception needs the use of non-symmetrical diopters defined by several hundreds of parameters. Moreover, the cost function is described by geometrical, optical or physiological quantities defined on each point of the lens to optimize. All these quantities are directly obtained from Ray-Tracing methods. The important number of parameters, the complexity of the cost function estimation and the large constraints required (center or peripherical thickness, esthetic looks,...) oblige us to implement descent methods, optimization methods and differentiation methods rarely used up to now in computer-aided optical design.

FR4-L-CM200

QHOPDM - A Package for Large Scale Convex Quadratic Programming using Primal-Dual Method

Altman Anna

Systems Research Institute, Polish Academy of Sciences

This paper extends a higher order primal-dual method fo LP (HOPDM) to the case of separable convex quadratic programming with linear constraints. A symmetric indefinite system arising in this method is solved using an approach based on reducing to a quasidefinite system. Further a symmetric definite subsystem is solved using the same techniques as for LP, i.e. Cholesky factorization. Some presolving ideas for LP were modified for QP.

TH4-H-CO22

Multiobjective mixed-integer programming: an interactive approach

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Faculty of Economics of University of Coimbra / INESC

Climaco Joao

Keywords: branch and bound - mixed integer programming - multiobjective

Multiple objective mixed-integer programming (MOMIP) models are widely used in many application areas, such as communication, transportation/location, scheduling, etc. The purpose of our work has been the development of interactive MOMIP procedures attempting to satisfy two requirements: low computational effort and a simple interactive protocol that does not demand, at each stage, too much information about the decision maker's preferences. An interactive algorithm to solve MOMIP problems is proposed, which combines the use of the Tchebycheff metric and branch and bound techniques. Tchebycheff metric-based procedures, unlike weighted function procedures, have the advantage of being able to reach non-supported efficient solutions (that is, solutions that do not belong to the convex-hull of the feasible region) for the MOMIP problem . At each iteration, a surrogate single objective mixed-integer problem (scalarizing problem) is solved

yielding a new efficient solution. This solution is the closest one to the current reference point according to the Tchebycheff metric. In each dialogue phase, the decision maker may select the objective function he/she wants to improve (with respect to the current solution) and this information is used to adjust the reference point for the next computation phase. Postoptimality techniques have also been developed enabling the algorithm to take advantage of previous computations in solving the next scalarizing problem. Considering an outline of the previous branch and bound tree as a warm start, some operations of simplification (cutting deeper branches rather than simple pruning) and spreading (splitting nodes) are performed until a new efficient solution is obtained. The time needed to solve these single-objective problems can thus be reduced and ranges for reference points which lead to the same efficient solution are easily identified. Computational results will be presented and discussed.

FR1-U-IN10

A Combinatorial Optimization Approach for Extracting Piecewise Linear Structure in Nonlinear Data

Amaldi Edoardo

School of OR and Center for Applied Mathematics

Mattavelli Marco

Keywords: consistent subsystems - inconsistent linear systems - motion analysis - piecewise linear models - time series modeling

Although linear models play an important role in the study of a number of signal and image processing problems, discontinuities often convey crucial information that needs to be taken into account. In many situations, piecewise linear models are attractive but determining simultaneously the piecewise domain decomposition and the corresponding model parameters is a challenging problem. We formulate this problem as that of Partitioning an inconsistent linear system into a MINimum number of Consistent Subsystems (MIN PCS). We describe a greedy algorithm, based on a simple variant of Agmon-Motzkin relaxation method for solving systems of linear inequalities, which provides good approximate solutions in a short amount of time. Our MIN PCS-based approach presents several advantages compared with conventional alternatives. It has so far been used to determine the linear motion structure of multiple moving objects from a sequence of images and to estimate piecewise linear autoregressive models for time series.

TU3-N-CO15

Computational Complexity of Resolving LP Infeasibility by Relaxing Constraints

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School of OR and Center for Applied Mathematics

Kann Viggo

Keywords: approximability - computational complexity - feasible subsystem

In recent years several methods have been proposed to help analyzing and repairing infeasible Linear Programs. While earlier methods look for minimal infeasible subsystems, the later ones aim at removing as few constraints as possible to achieve feasibility. The problem can also be viewed as that of satisfying as many constraints as possible. Since these complementary problems are NP-hard and close-to-optimal solutions suffice for practical purposes, we investigate the approximability of these minimization and maximization problems for equality and inequality systems. How close to the optimum one can get in polynomial time varies substantially depending on the type of constraints and of the objective function. We also discuss the variants in which the variables are restricted to take discrete values or in which a weight is assigned to each constraint and the goal is to maximize (minimize) the total weight of the satisfied (unsatisfied) constraints.

TU3-B-CO10

The Homogeneous Algorithm for Convex Optimization

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Keywords: convex optimization - homogeneous algorithm - interior point methods

In this presentation we discuss the generalization of the homogeneous interior-point algorithm for LP to convex optimization. The main advantage of the homogeneous algorithm is that it detects a possible primal or dual infeasibility reliably without using any Big-M parameter or two-phase method.

We will present an implementation of the homogeneous algorithm intended for efficient solution of large-scale sparse problems.

Finally,computational results for several classes of problems are presented. These classes include quadratic constrained problems, geometric programming problems, and some problems arising in finance. Our conclusion is that the homogeneous algorithm is an efficient general purpose algorithm for convex optimization.

TU3-B-CO10

QCOPT a Large Scale Interior-Point Code for Solving Convex Quadratically Constrained Quadratic Problems on Self-Scaled Cone Form

Andersen Knud D.

CORE, Université Du Louvain

Keywords: interior point methods - large scale optimization - quadratic constraints

The problem of concern is to minimize a linear function subject to quadratic and linear constraints (QCQP). However, we will limit our discussion to the class of QCQP problems, where the convex quadratic constraints can be written as self-scaled cones as defined by Y. Nesterov and M. Todd. The advantage of restricting the class of problems is it makes it possible to solve problems which are only convex on the feasible domain efficiently.

Several algorithms can be developed for the QCQP problems using self-concordant barriers, but we will restrict the attention to the primal-dual methods. We will discuss a primal-dual method based on the scaling point idea proposed by Nesterov and Todd. Also a primal-dual method based on solving a convenient form of the first order conditions for the barrier problem is discussed. Ideally a primal-dual algorithm should solve the complementarity conditions directly as in linear programming, however this approach is only valid in certain cases (i.e. the Jacobiant may not be positive definite). A high-order extension to the primal-dual method is also presented.

The methods have been implemented in a portable C-code called QCOPT which is intended for solution of large sparse (QCQP) problems. Some implementational details of QCOPT is discussed.

Finally, we present computational results for applications arising in plastic collapse analysis, soap dual films, multifacility location, and truss topology design.

A manual for the QCOPT code is available from the author for anyone who is interested.

MO4-L-CM201

A Parallel Interior-Point Based Linear Programming Solver for Shared-Memory Multiprocessor Computers: A Case Study Based on the APOS LP Solver

Andersen Knud D.

CORE, Université Du Louvain

Andersen Erling D.

Keywords: interior point methods - linear programming - parallel Cholesky factorization

The computationally most expensive step in an interior-point code for linear programming is computation of a Cholesky factorization and the subsequent solve step. Therefore, in this presentation it is discussed how these two steps have been parallelized in the APOS LP solver for a Silicon Graphics multi proccesor computer. (The APOS LP solver is integrated in the commercially available XPRESS-MP optimization packages).

In particular we discuss in detail a parallel version of the supernodal Cholesky factorization and techniques for obtaining a speed-up in the solve phase. Moreover, a method for handling of dense columns in the LP constraint matrix is presented leading to better results on some classes of problems such as stochastic LPs.

Finally numerical results are presented.

It should be emphasized that the discussed method can be applied to solution of large-scale sparse linear least squares problems.

MO3-E-CO21

A Direct Search Algorithm for Optimization with Noisy Function Evaluations

Anderson Edward James

A.G.S.M. , University of New South Wales

Ferris Michael C.

Keywords: direct search methods - noise - simplicial methods

We consider the unconstrained optimization of a function when each function evaluation is subject to some random noise. Our model of computation assumes that averaging repeated observations at the same point can lead to a better estimate of the underlying function value. In practice problems of this form may occur when choosing the best settings for the controls in a processing plant, or in choosing the parameters in an experiment of some kind. We consider direct search methods with the possibility of repeated function evaluations at the same point. We describe an algorithm of this type which has reasonable computational performance and for which convergence can be established.

One unusual feature of the algorithm is that it includes a stochastic element. This is found to be advantageous in practice, and is easily incorporated into the stochastic framework of our analysis. It is interesting that the stochastic nature of the function noise actually acts as an advantage in proving convergence. Paradoxically we do not have a proof of convergence for this algorithm in the case that there is no function noise.

WE3-K-CM106

Local Search for Scheduling Problems: Exploring Basins of Attraction

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A.G.S.M. , University of New South Wales

Burtonclay Damien

Keywords: local search - scheduling - solution surface

When local search methods are applied to combinatorial optimization problems it is the characteristics of the solution surface which will determine the effectiveness of the method. However, surprisingly little is known about the nature of the solution surface for such problems. This paper aims to advance our understanding of the solution surface characteristics. The focus is on the basin of attraction associated with each local minimum; that is the set of solutions from which a particular local minimum is reached by following downhill local search.

A Markov-chain model is proposed for the behaviour of the function values occurring in a random walk on the solution surface. The probability transition matrix can be estimated and this is used to estimate both the shape and the size of the basins of attraction. This provides one route to an estimate of the number of local minima, which is hard to estimate by other means. In order to test this approach a study is made of the problem of minimizing weighted flowtime on unrelated parallel machines.

MO3-C-CO2

Cutting Angle Methods for Minimizing Increasing Convex-Along-Rays Functions

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University of Ballarat

Rubinov Alexander M. - Glover Bevil Milton (Barney)

Keywords: abstract convexity - cutting angle method - global optimization

We study the following problem of global optimization:

$$f(x) \longrightarrow \min \quad \text{subject to} \quad g(x) \geq 0, \; 0 \leq x_i \leq c, \; i = 1, \ldots, n$$

where c is a constant, and f and g are increasing functions defined on $\mathbb{R}^n_+$. In addition we assume that f is a convex-along-rays (CAR(X)) function, that is the restriction of f to each ray starting from zero is a convex function of one variable. The class of such problems is very broad. It contains, for example, problems with reverse convex increasing constraints and polynomial objective functions with nonnegative coefficients. We propose a cutting angle method for the solution of this problem based on the representation of an increasing CAR(X) function as the upper envelope of a set of functions of the form $\langle \ell, x \rangle = \min_{i:\ell_i>0} \ell_i x_i$ with $\ell \in \mathbb{R}^n_+$. We prove convergence of this method and discuss an algorithm for solving auxiliary subproblems which arise in the implementation. We also discuss the results of numerical experiments.

TH3-I-CM121

Using Linear Threshold Functions Sequentially in Data Classification

Anthony Martin H. G.

Department of Mathematics, London School of Economics

Abstract: A linear threshold function is a 0,1-valued function whose positive and negative examples are separated by a hyperplane. In this talk I shall present some theoretical results on the sequential use of such functions in data classification. The techniques discussed have potential applications to the logical analysis of data, and the theory has links with the theory of simple artificial neural networks.

WE2-I-CM5

A New Paradigm for Finding Cutting Planes in the TSP

Applegate David

Rice University, CAAM Dept

Bixby Robert Eugene - Chvátal Vasek - Cook William J.

Keywords: traveling salesman problem

A traditional paradigm for finding cutting planes in the TSP is this: having identified classes of linear inequalities (such as comb inequalities or clique-tree inequalities) that are satisfied by all tours, one designs "separation algorithms" for each individual class and finally applies these algorithms to an optimal solution of the current LP relaxation of the TSP instance. We shall present another way of finding cutting planes, which does not fit this paradigm; preliminary computational experience with its implementation is encouraging.

TH1-A-IN1

Forward Chaining is Simple(x)

Aráoz Julián A.

Universidad Simón Bolívar, Caracas

Keywords: analysis of algorithms - knowledge bases - simplex

We show that Forward Chaining in Horn's Systems is only the Simplex Algorithm, notwithstanding they look completely different. But this difference is like the one with the Transportation Algorithm which take advantage of the special structure of the problems. In the same way Backward Chaining is the Dual Simplex Algorithm.

FR4-D-CO124

Projective Maps, Davidon's Collinear Scalings and Karmarkar's Projective Transformations

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Department of Pure and Applied Mathematics

Keywords: collinear scalings - interior point methods - linear programming - nonlinear programming - projective transformations

In 1980, Davidon used a class of maps termed collinear scalings to derive a class of algorithms for nonlinear optimization. Later, Karmarkar (1984) proposed his now-famous linear programming algorithm. In the derivation of his algorithm Karmarkar used a class of maps on the unit simplex that are now commonly referred to as projective transformations. Both these classes of maps are special cases of a class of maps which we refer to as projective maps that have roots in projective geometry. In this talk, we present relationships among projective maps, Davidon's collinear scalings and Karmarkar's projective transformations.

FR4-C-CO123

A Line Search Technique with Sufficient Decrease and Curvature Conditions

Armand Paul

Université de Limoges - France

Keywords: conjugate gradient - line search - nonlinear programming

We present a new line search technique that is guaranteed to satisfy sufficient decrease and curvature conditions. The technique is quite simple and natural since it generates iterates that congerge to a stationary point of the line search function. In particular we show how it can be used to provide the descent property for the Polak-Ribière conjugate gradient method.

TH3-F-IN203

Optimal Control Application for Operational Water Management of a Canal System

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Linke Hartmut - Franke Ruediger

Keywords: large scale system - operational control - optimal control

The paper presents an optimization based decision support system for operational water management of a large navigation canal system in northern Germany which consists of three sections with different heights above sea level and with a total length of about 380 km. According to the dynamics of the system, operational management means a control horizon of several days and an update of the control decision within several hours.

The main purpose of the operational water management is to guarantee navigable water levels with minimum electrical energy (pump) costs. This can be formulated as a discrete-time optimal control problem with a suitable control horizon, the pump and discharge flows as decision variables, and a process model based on discretized St. Venant equations.

The discrete-time optimal control problem is numerically solved as a large-scale structured nonlinear programming problem with a SQP method and an interior point solver for the linear-quadratic approximations.

The decision support system includes a receding horizon or model-based predictive control structure. The state estimation and optimal control calculation is repeated after a fixed time to take into account model and prediction uncertainties.

TU3-I-CM5

Approximation Algorithms for MAX SAT: A Framework of Hybrid Approaches

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Chuo University, Department of Information and System Engineering

Hori Kuniaki - Ono Takao - Hirata Tomio

Keywords: approximation algorithms - max sat - network flow - semidefinite programming

MAX SAT (the maximum satisfiability problem) is stated as follows: given a set of clauses with weights, find a truth assignment that maximizes the sum of the weights of the satisfied clauses. MAX SAT is a well-known NP-hard problem and thus, many researchers have proposed approximation algorithms for MAX SAT. Yannakakis and Goemans-Williamson proposed 0.75-approximation algorithms. While, based on semidefinite programming, Goeman-Williamson improved the bound 0.75 to 0.7584. Asano-Ono-Hirata also improved the bound and the best approximation algorithm for MAX SAT has the performance guarantee 0.765.

In this paper, we present a framewok of hybrid approaches combining the algorithms of Goemans-Williamson and Yannakakis. This framework leads to a unified analysis of the performance guarantees of proposed algorithms and also leads to better approximation algorithms with performance guarantees 0.767 and 0.770, if we use refinements of Yannakakis' algorithm.

FR1-I-CM3

Optimization of an Automatic Storage System under Online Conditions

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Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB)

Grötschel Martin

Keywords: TSP - automatic storage systems - online optimization - time windows

We report on a joint project with industry that had the aim to sequence transportation tasks within an automatic storage system in such a way that the overall travel time is minimized. This is modelled as an Asymmetric Travelling Salesman Problem (ATSP). The ATSP have to be solved under on-line conditions. Several heuristics for the on-line ATSP are compared computationally within a simulation environment. Compared to the priority rule used so far, the optimization package reduced the unloaded travel time by about 40%.

We derive lower bounding schemes for an "optimal" on-line strategy that are evaluated with real-life data. These schemes lead to the solution of ATSP with side constraints (time windows, precedence constraints).

TU4-L-CM201

The XPRESS-MP Parallel MIP System

Ashford Robert William

Dash Associates

Laundy Richard

Keywords: MIP - high performace computing - parallelism

Large scale MIPs present a particular challenge for industrial modellers. Their application is often limited by the computational time taken to optimise them - or even obtain a feasible solution. Parallel processing offers one of the best opportunities for accelerating the optimisaton process and thereby extending their range of application. The integer programming code XPRESS-MP has been implemented on networks of workstations and PCs, which can deliver a linear or near-linear speedup in optimisation time. Supercomputer performance is thus available from ordinary office networks. We discuss parallel XPRESS and consider how serial search strategies need to be re- thought in a parallel environment. Results of solving a number of large scale industrial applications will be given.

WE1-O-IN202

Rare Events Simulation for Heavy-Tailed Distributions

Asmussen Soren

University of Lund, Mathematical Statistics

Efficient simulation of the probabilities of rare events is well understood when the underlying distributions possess exponential moments. The simulation is typically carried out by importance sampling via an exponential change of measure which can be identified with large deviations techniques. A corresponding methodology for the heavy-tailed case is only at its infancy. We present some counterexamples that the approach of simulating using an approximate description of the conditional measure given the rare event does not work, as well as we present some algorithms with efficiency properties similar to what has been developed for the light-tailed case; one involves importance sampling from a distribution with infinite mean and the other one a conditional Monte Carlo idea implemented via order statistics. The talk is based upon joint work with Klemens Binswanger, Zurich, and Bjarne Hojgaard, Aalborg.

FR4-A-IN2

The Mixed Node Packing Problem

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ISyE, Georgia Institute of Technology

Nemhauser George - Savelsbergh Martin W.P.

Keywords: facets - node packing - polyhedron

We study a generalization of the node packing problem having both binary and continuous variables, which we call the mixed node packing problem. The main motivation for studying this problem is that it is possible to derive a mixed node packing relaxation from any general 0-1 mixed integer problem. We study the complexity and the polyhedral structure of the mixed node packing problem. We present polynomially separable facets of its convex hull.

TH4-H-CO22

Enumeration of All Extreme Equilibrium Strategies of Bimatrix Games

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Hansen Pierre - Jaumard Brigitte - Savard Gilles

Keywords: bimatrix game - extreme equilibrium strategy - game theory - implicit enumeration - two-person nonzero-sum game

The set of equilibrium points of a bimatrix game is the union of polytopes which may not be disjoint. Knowledge of the extreme points of these polytopes is sufficient to identify all equilibria. We present an algorithm that enumerates all extreme equilibria by exploiting KKT optimality conditions of two pairs of parameterized linear programming problems. The algorithm is applied to randomly generated problems of size up to 29 by 29 when both dimensions are equal, and up to 700 by 5 when the second dimension is fixed. The number of extreme equilibria grows exponentially with the problem size but remains moderate for the instances we considered. Therefore, the results could be useful for further refinements of Nash equilibria.

TH1-F-IN203

Stability and Sensitivity Analysis of Optimal Control Problems Subject to Pure State Constraints

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Malanowski Kazimierz - Maurer Helmut

Keywords: optimal control - real-time control - stability analysis - state constraints

Parametric nonlinear optimal control problems subject to *pure* state inequality constraints are considered. Regularity conditions are formulated under which the original problems are locally equivalent to some other problems subject to *equality* type constraints only. The classical implicit function theorem is applied to these new problems to prove Frechet differentiability of optimal solutions with respect to the parameter. Sensitivity differentials of optimal solutions and adjoint variables are obtained by solving an associated linear boundary value problem. Several numerical examples are provided illustrating different phenomena arising from the order of the state constraint.

FR2-E-CO21

Asymptotic Analysis for Penalty and Barrier Methods in Non Coercive Variational Inequalities

Auslender Alfred

École Polytechnique, Paris

Keywords: maximal monotone operator - penalty and barrier mmethods - recession analysis - variational inequalities

We extend to variational inequalities with maximal monotone operators a very general class of penalty and barrier methods,which includes a number of specific functions proposed in literature.Primal convergence is given under weaker conditions than the usual:the solution set is supposed to be the sum of a compact set and a linear space.Dual convergence is also analyzed.This is made possible by the introduction of a new formula related with recession analysis.

TH-am-CO2+3

How to Deal with the Unbounded in Optimization: Theory and Algorithms

Auslender Alfred

École Polytechnique, Paris

Keywords: convex and non linear programming - noncoercive problems - penalty and barrier mmethods - recession analysis

The aim of this survey is to show how the unbounded arises in optimization problems and how it leads to fundamental notions which are not only useful for proving theoretical results as convergence for algorithms,or the existence of optimal solutions but also for constructing new methohds.....

TH4-C-CO2

On the Use of Mean Value Theorems in Generalized Convexity

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Dep. Mathématiques, Université de Perpignan

Corvellec Jean-Noel - Lassonde Marc

Keywords: constrained variational principle - mean value inequality - subdifferential

We first present a brief survey of the use of Mean Value Theorems in the characterization of generalized convexity. Then we present a new type of MVT called multidirectional mean value

inequality. Here, the classical segment of MVT is replaced by a 'drop' (convex hull of a point and of a convex subset). This mean value inequality and an associated constrained variational principle are established for nonsmooth functions. An abstract concept of subdifferential is used thus covering a large number of situations.

TH4-A-IN2

Lift and Project Cuts for Mixed 0-1 Programs: New Computational Results

Avella Pasquale

DIIMA, Universitá di Salerno

Ceria Sebastián - Rossi Fabrizio

Keywords: u, v-normalization - lift and project - slope constraints

In this talk we investigate computational issues related to the generation of deep lift-and-project or disjunctive cuts for mixed 0-1 programs. We show that the best strategies in practice involve the generation of several cutting planes for the same disjunctive programming relaxation of the problem. This means that the fractional point is separated by several cutting planes from the same family, with different characteristics, such as density, support, and depth. Computational results on the MIPLIB data set will be reported.

TU1-I-CM200

Large Symmetric Convex Hull Problems

Avis David

Computer Science - McGill University

Keywords: combinatorial polytopes - convex hulls - symmetry - vertex enumeration

Combinatorial Polyhedra provide examples of important but notoriously difficult convex hull/vertex enumeration problems. Even combinatorial polyhedra with relatively few facets can have very large numbers of vertices and extreme rays. However, these polyhedra also have high degrees of symmetry and the output of a convex hull problem can often be represented very compactly as a set of orbits. For example, Grishukhin, A. Deza, M. Deza and K. Fukuda showed that the metric cone on 7 points, defined by 105 facets in 21 dimensions, has 55,226 extreme rays which fall into only 41 orbits under permutation.

Current general purpose convex hull codes, such as the double description method or reverse search, do not take symmetry into consideration, and hence are not suitable for these types of problems. In this talk, we describe how these problems may be attacked by combining methods for generating isomorph-free combinatorial objects, pioneered by R. Read, B. McKay and others, with the reverse search vertex enumeration method.

TU2-C-CO3

Piece-wise Linear Approximation of Functions of two Variables

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U.S. West Advanced Technologies

Keywords: mixed integer programming - nonlinear functions - piecewise linear approximation

The goal of increasing computational efficiency is one of the fundamental challenges of both theoretical and applied research in mathematical modeling.

The pursuit of this goal has lead to wide diversity of efforts to transform a specific mathematical problem into one that can be solved efficiently. Recent years have seen the emergence of highly efficient methods and software for solving Mixed Integer Programming Problems, such as those embodied in the packages CPLEX, MINTO, XPRESS-MP.

The paper presents a method to develop a piece-wise linear approximation to an arbitrary continuos function of two variables. The approximation generalizes the widely known model for approximating single variable functions, and significantly expands the set of nonlinear problems that can be efficiently solved by reducing them to Mixed Integer Programming Problems. By the present development any nonlinear programming problem, including non-convex ones, with an objective function and/or constraints, that can be expressed as sums of component nonlinear functions of no more than two variables, can be efficiently approximated by a corresponding Mixed Integer Programming Problem.

TU3-C-CO3

Continuous Approximations to Subdifferential and Monotonous Methods of Nondifferentiable Minimization

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Keywords: Clarke subdifferential - Demyanov-Rubinov quasidifferential - continuous approximation - nondifferentiable optimization

In this report we study continuous approximations to the Clarke subdifferential and Demyanov-Rubinov quasidifferential of locally Lipschitz functions and monotonous minimization methods, based on such approximations. The lack of continuity of the subdifferential mapping creates difficulties in the study of methods for the minimization of locally Lipschitz functions. Sometimes it is possible to apply various kinds of continuous approximations to the subdifferential mapping.

We introduce and study a new kind of continuous approximation to the Clarke subdifferential and Demyanov-Rubinov quasidifferential. We also describe a method for construction of a continuous approximations for semismooth functions. This method is based on the concept of the discrete gradient introduced and studied by the author.

In further an algorithm for the calculation of the descent direction of Lipschitz functions at the given point by using the discrete gradient is described.Using this algorithm monotonous methods for the minimization of locally Lipschitz functions are proposed. The numerical experiment by using these methods was carried out. Results of this experiment are presented.

FR2-I-CM120

The Partition Inequalities and the 2-Edge

Connected Subgraph Problem
Baïou Mourad

Université de Bretagne Sud

Barahona Francisco - Mahjoub Ali Ridha

Keywords: 2-edge connected subgraph - branch and cut - partition inequalities - polytope - separation problem

Given a graph $G = (V, E)$ and a weight function on its edges, the 2-edge connected subgraph problem (TECP) is the problem of finding a minimum weight 2-edge connected subgraph of G spanning V. Let x be a nonnegative weight vector associated with the edges of G, a partition inequality is of the form $x(\delta(S_1, ..., S_p)) \geq ap + b$. Here $\delta(S_1, ..., S_p)$ denotes the multicut defined by a partition $S_1, ..., S_p$ of V and a and b are scalars . Partition inequalities are valid for the TECP. We give a plynomial algorithm for the associated separation problem. This is based on an algorithm for finding the minimum of $x(\delta(S_1, ..., S_p)) - p$ that reduces to minimizing a symmetric submodular function. This is handled with a recent algorithm of Queyranne. The partition inequalities are used together with the cut and the trivial inequalities in a branch&cut algorithm for solving instances of the 2-edge connected subgraph problem and the closely related traveling salesman problem. We present some computational results obtained by this algorithm.

TU3-N-CO15

Building the MIMI Wizard
Baker Thomas E.

Chesapeake Decision Sciences

The MIMI (Manager for Interactive Modeling Interfaces) tool kit combines the relative strengths of mathematical programming, simulation, expert systems, operations research, interactive graphics and database technology. Faced with the curse of great flexibility, Chesapeake has been developing the MIMI Wizard-a knowledge base for guiding model developers (with a wide variety of experience levels) through the application development process. We discuss the development of the Wizard and demonstrate the Wizard's help in building an LP application.

TU4-P-IN201

Some Problems in One-Operator Scheduling
Baki Mohammed Fazle

University of Waterloo

Vickson Raymond

Keywords: NP-hard - one-operator - polynomial time - regular objective - scheduling

In this paper, we discuss a class of problems that arises in an m-machine flow-shop operated by a single operator. We consider various cases of the problem including ready times, due dates, time lags, and setup times. Also, we consider a number of regular objectives such as makespan, maximum flowtime, maximum lateness, total weighted completion time, etc. As it can be expected, a large number of cases are NP-hard. However, there exists quite a few cases which are solved with polynomial time algorithms.

WE4-I-CM5

Pyramidal Traveling Salesman Problem
Baki Mohammed Fazle

University of Waterloo

Kabadi Santosh Narayan

Keywords: polynomial algorithm - pyramidal tour - traveling salesman problem

One of the polynomially solvable classes of TSP is the one for which there exists an optimal tour which is pyramidal. During the last four decades a number of polynomially testable conditions have been identified which are sufficient for an instance of TSP to be pyramidally solvable. The most general conditions known for the asymmetric matrices are (i) Demidenko condition and (ii) eight sets of conditions by Warren. We generalize and unify all these conditions into one polynomially testable condition. In addition, we identify four new sets of conditions.

TU-pm-CO2+3

Recent Advances in Lift-and-Project
Balas Egon

Carnegie Mellon University, GSIA

In recent years the lift-and-project approach has been used successfully within a branch-and-cut framework to solve large, difficult pure and mixed 0-1 programs that have resisted solution efforts by pure branch and bound codes. The approach uses a linear description in a higher dimensional space of the convex hull of the disjunctive set created by imposing one or several 0-1 conditions. By solving a linear program derived from this higher dimensional representation – the cut generating linear program (CGLP) – the standard lift-and-project procedure obtains a deepest cut in a well defined sense. We propose a modification of CGLP that allows us to generate not just one deepest cut, but a class of cuts with desirable properties, each at the cost of one extra pivot in the optimal tableau of the modified CGLP.

FR3-I-CM5

Lifted Inequalities for the Asymmetric Traveling Salesman Problem
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Carnegie Mellon University, GSIA

Fischetti Matteo

We investigate the family of facet defining inequalities for the Asymmetric Traveling Salesman (ATS) polytope obtainable by lifting the cycle inequalities. We establish several properties of this family that earmark it as the most important among the asymmetric inequalities for the ATS polytope known to date: (i) The family is shown to contain members of unbounded Chvatal rank, whereas most known asymmetric inequalities are of Chvatal rank 1. (ii) For large classes within the family a coefficient pattern is identified that makes it easy to develop

efficient separation routines. (iii) Each member of the family is shown to have a counterpart for the symmetric TS (STS) polytope that is often new, and is obtainable by mapping the inequality for the ATS polytope into a certain face of the STS polytope and then lifting the resulting inequality into one for the STS polytope itself.

FR2-I-CM4

Marriage and Admissions via Graphs

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Keywords: admissions - graph - marriage - stable matching

This paper describes a new approach to the analysis of the stable matchings of marriage and admissions games. Formulating the problem in terms of directed graphs at once unifies and simplifies the presentation, and renders it more symmetric. In addition, it yields a new algorithm and a new proof for the existence of stable matchings, new proofs for many known facts, and some new results notably concerning players' strategies and the properties of the stable marriage polytope.

FR2-H-CO22

Multiobjective Optimization Models For Product Design

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Keywords: integer programming - manufacturing - multiobjective optimization

The advent of the concurrent engineering approach to product development has stimulated research on automated tools to support various product life cycle considerations at the design stage. In this paper we develop integer programming based multiobjective optimization models for decision making during product design.

First, we describe a bi-criteria model that determines components and processes for given conceptual designs of microwave modules, complex devices with both electrical and mechanical attributes. Specifically, our model outputs a set of solutions that are Pareto optimal with respect to a cost and a yield metric. While this work was motivated by a collaboration with a manufacturing firm, the models that we develop are general in nature and can be used in the design of any hierarchical system.

The basic model involves making choices in the context of an 'AND/OR tree'. However, problem specific considerations lead to the introduction of global constraints that result in a formulation resembling that of the uncapacitated facility location problem. We discuss some useful theoretical properties of the model and outline an integer programming based solution strategy.

Next, we extend our bi-criteria model to support tradeoff analysis over a much broader set of criteria, including 'business' metrics such as number of suppliers, lead time, and quantity discounts. We develop an interactive solution procedure that generates efficient solutions, and can be easily incorporated into a high-level product design and process planning system. We report our computational experience with this model and conclude with a discussion of some of the theoretical issues underlying this procedure.

FR1-I-CM200

Computational Research of Latin Squares

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Illés Tibor - Fábián Csaba István

Keywords: 0-1 programming - latin square

An analysis and computational solution of an interesting problem of the combinatorial mathematics will be described in this paper. The conditions of the existence of a pair of orthogonal latin squares of a given order and the conditions of the existence of a third orthogonal latin square to the other two existing one are formulated in integer linear programming problems, which are similar to the structure of the assignment problem. The problem is NP-complete, and because of its dimensions its solution requires much computational time. In the solution we use the branch and bound method.

WE1-T-CO22

Testing Tradeoffs between Performance Dimensions

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Keywords: DEA - performance - statistical tests - tradeoffs

Do organisations need to tradeoff between different performance dimensions such as cost and quality, or are there organisations that excel at all performance dimensions? This paper presents statistical tests based on Data Envelopment Analysis to evaluate such alternative hypotheses.

MO3-I-CM120

Separation of Partition Inequalities and the k-cut problem

Barahona Francisco

IBM Watson Research Center

Given a graph $G = (V, E)$ with nonnegative weights $x(e)$ for each edge e, a partition inequality is of the form $x\left(\delta(S_1, ..., S_p)\right) \geq ap + b$. Here $\delta(S_1, ..., S_p)$ denotes the multicut defined by a partition $S_1, ..., S_p$ of V. We give a polynomial algorithm for the associated separation problem. This is based on an algorithm for finding the minimum of $x\left(\delta(S_1, ..., S_p)\right) - p$ that reduces to minimizing a symmetric submodular function. This is handled with the recent algorithm of Queyranne. We use the same approach to produce lower bounds for the k-cut problem.

FR2-I-CM120

Plant Location with Minimum Inventory

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IBM Watson Research Center

Jensen David

Keywords: plant location

We present an integer programming model for plant location with inventory costs. The linear programming relaxation has been solved by Dantzig-Wolfe decomposition. In this case the subproblems reduce to the minimum cut problem. We have used subgradient optimization to accelerate the convergence of the D-W algorithm. We present our experience with problems arising in the design of a distribution network for computer spare parts. In most cases, from a fractional solution we were able to derive integer solutions within 4% of optimality.

WE3-A-IN1

A Minimax Theorem for Test Sets in Integer Programming

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Lovász László - Scarf Herbert E.

Keywords: homology groups - integer programming - test sets

Given a generic $(n+1)\times n$ matrix A, the simplicial complex $K(A)$ is defined to be the collection of matrices representing maximal lattice point free convex bodies of the form $\{x : Ax \leq b\}$. It is known that the topological space associated with $K(A)$ is homeomorphic with R^n. Since $K(A)$ is invariant under translations T_z by $z \in Z^n$, the factored–out space $K^* = K(A)/\{T_z\}$ is the n–torus and so $H_{n-1}(K^*) = Z^n$. Here we give a natural isomorphism $H_{n-1}(K^*) \to Z^n$. A consequence is a minimax theorem relating this isomorphism to the norm $|x| = \max\{hx \ : h \in N(A)\}$, where $N(A)$ is the set of neighbours, that is, the test set of a certain integer program. This is joint work with L. Lovász and H.E. Scarf.

WE4-U-IN10

Simplicial Secomposition with Disaggregated Representation to Solve the Capacity Multicommodity Network Problem

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Marin Angel

Keywords: capacity multicommodity network - disaggregated representation - freight rail network design - large scale mathematical programming - scheduling - simplicial decomposition

The services scheduling problems generate a space-temporary network with capacity, which is defined in terms of the tentative optimal scheduling. These networks have the majority of their arcs with capacity zero. The optimal primal solution is defined using only the arcs with positive capacity. But if the optimal dual solution is needed, the whole network must be used, given that some arcs with capacity zero are active at the optimal solution and their Lagrange multipliers are positives.

These Lagrange multipliers are needed to know the fit of the tentative solutions of the scheduling problem to the capacity constraints, if for instance a Benders decomposition is used to fix the capacity of the arcs in function of the departure time of the services, those multipliers are used to define the Benders cuts.

The methodology proposed permits to obtain the whole Lagrange multiplier set solving only the reduced network. The algorithm in a first phase determines the Lagrange multipliers of the arcs with non zero capacity, and in a second phase those are used joint with the disaggregated representation of the extreme points of the multicommodity space-temporal network (without capacity) to obtain the Lagrange multipliers of the arcs with capacity zero.

The algorithm has been implemented in the context of a Freight Rail Services Scheduling problem and the results using the whole and the reduced networks are presented in a comparative way.

TH4-I-CM200

An Algorithm for the Subset Sum Problem

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Keywords: knapsack problem - matroid - subset sum

We present a new algorithm for the subset sum problem which uses inequalities derived from ordered matroids. We give computational results comparing the performance of this algorithm with the one of Martello and Toth.

FR1-C-CO2

On the Use of Nonsmooth Optimization Methods in Statistics and Stochastic Programming

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Keywords: l_α-estimator - nonsmooth optimization - stochastic programming

It is well known that the wide use of least squares estimator in statistics is explained by excellent computational properties of the considered functional and it's close connection with normal distribution. Nevertheless, there are the cases when the robustness and good statistical properties of other estimators are theoretically proved. For example, l_α-estimator, minimising a sum of αth powers of residuals, is the maximal likelyhood estimator for some families of distribution functions of random errors. Developed in V.M.Glushkov Institute of Cybernetics methods of nonsmooth optimization help to overcome the computational difficulties, connected with finding l_α-estimator, particularly in the non-linear regression models.

These methods may be used also in stochastic optimization and identification problems, for example, in the problem of

minimization of the mean of a function depending on random parameter. It is proved, that this problem may be approximated by the problem of finding the minimum of averaged realizations of initial function. The use of nonsmooth optimization methods enables to enlarge the class of considered functions.

These methods can be immediately used for solving specially structured problems arising in two-stage stochastic programming. We developed (under support of Swiss National Scientific Foundation) an external solver based on nonsmooth optimization methods for SLP-IOR. It gives comparable with the use of specialized methods results and is effective in nonlinear case.

The perspectives of use nonsmooth optimization methods in time series analisys are also discussed.

FR1-V-CM106

On the Constraints and Objective Functions in Financial Optimization

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Grad Janez

The optimization of the production process is certainly one of the most desirable goals of any business enterprise. The banks and other financial organization are not exception to this rule. Here the contents of optimization should be understood in a very broad sense. Among others this could mean an aspiration to search for a new, presumably more efficient organizational form of a financial institution. The more specific goal is the optimization of relationship between the amount of risk which is taken and the expected profit. This can be done on the level of particular financial organization as a whole or on the level of some portfolio of financial instruments. The typical feature of many financial optimization problems is the presence of numerous explicit and implicit constraints which must be taken into account. Among others, these constraints are originated from transaction costs connected with organizational or portfolio revisions and from numerous business, regulatory, legal and even political limitations. A consequence is that in the banking and finance we often deal with the optimization of an overconstrained systems. Prior to applying some mathematical programming technique to such kind of system, it is worthwhile to analyze its constraints and possible objective functions. The results of such analysis can give valuable insights into properties of the solutions of financial optimization problems such as marginal values, sensitivity analysis and feasibility. In the paper we shall investigate different types of constraints and objective functions which appear within the financial optimization models. These constraints and objective function can be linear or nonlinear (quadratic, bilinear, integer) and are often of stochastic nature.

WE2-I-CM4

Bounds for the Largest Clique in a Graph

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It is well-known that the problem of determining the largest clique in a graph reduces to a nonconvex quadratic programming problem whose coefficient matrix is the adjacency matrix for the graph. In this talk we show that this quadratic programming problem becomes convex if the off-diagonal zeros in the adjacency matrix are replaced by certain numbers between zero and one. Solving this convex problem gives a clique which, in almost all our experiments, is the largest clique in the graph.

WE1-U-IN10

Airline Fleet Assignment with Time Windows

Barnhart Cynthia

Massachusetts Institute of Technology

Rexing Brian - Kniker Timothy - Jarrah Ahmad

Given a set of flights to be flown be an airline and departure time-windows for each flight, we consider the problem of simultaneously determining the type of aircraft to assign to each flight and the exact departure time of each flight. We present a model, an iterative solution approach and computational results achieved in solving instances of this problem for a large U.S. airline. We compare our results to those achieved using conventional models that assume departure times to be fixed.

WE4-T-CO22

Decomposition Methods Applied to Integer Programming

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Levin Genrikh M.

As an alternative to traditional LP-based branch-and-bound methods for integer programming, we propose branch-and-bound approaches that directly use the constraints' structure, as in "logic programming." The original problem is broken down into sub-problems, some of which provide bounds for the optimal solution. Two industrial applications, in logistics and production, will be discussed.

FR-am-SPO

Measure Concentration in Optimization

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Keywords: Monte Carlo integration and counting - combinatorial optimization - measure concentration - semidefinite programming

We discuss some consequences of the measure concentration phenomenon for optimization and computational problems. Topics include average case analysis in optimization, efficient approximate counting, computation of mixed discriminants and permanents, and semidefinite relaxation in quadratic programming.

TH4-F-IN203

Control of Random Singular Diffusions Under Long-Term Average Cost

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Hong Kong University of Science and Technology

Bisi Arnab - Ghosh Mrinal K.

Keywords: HJB equation - Markov chains - optimal control - random diffusions - viscosity solution

We study the ergodic control problem of degenerate random diffusions representing a typical hybrid system that arises in numerous applications such as fault tolerant control systems, flexible manufacturing systems etc. Under a certain Liapunov type stability condition we establish the existence of an optimal control. We then study the corresponding HJB equation and establish the existence of a unique viscosity solution in a certain class. A characterization of the optimal control in terms of the unique viscosity solution is obtained.

TH3-H-CO22

Iterative Computation of Nash Equilibria in Differential Games with Switching Dynamics

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Altman Eitan

Keywords: Markov chains - Nash equilibrium - computation - differential games

We consider a class of M-player noncooperative differential games defined on an infinite horizon, where both the system dynamics and the utility functions of the players depend on the state of a finite state Markov chain. This models situations where the game dynamics experiences structural changes (out of a given finite set) at random points in time, and so does the quantification of the players' preferences. Adopting the feedback Nash equilibrium concept, where feedback is from both the state of the continuous dynamics and the state of the Markov chain, we prove the existence of a unique equilibrium for a particular subclass, and develop convergent iterative techniques (reminiscent of the *greedy* algorithm) for its on-line computation. We also discuss an application of this framework and the results obtained to a problem of rate-based flow control in a communication (ATM) network with several users and traffic types.

TU2-U-IN10

A Capacitated Facility Location Problem with Integer Decision Variables

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Enders Reinhard

Keywords: combinatorial optimization - facility location - integer programming

We consider a facility location problem, where for each possible location, we not only decide whether to open a facility or not but also determine the size of the facility which can be any multiple of a given standard capacity z.

Hence, we have a capacitated facility location problem with identical capacities z where the decision variables are not binary but general integer variables.

For the case where the objective function only depends on the decision variables, we present an algorithm that is based on a decomposition of the problem and involves the solution of maximum flow problems within a branch and cut framework.

For a special case of the objective function and the graph representing the feasible assignments of locations to clients, we give a combinatorial algorithm that runs in time $O(|C||L|)$ where C is the set of clients and L the set of locations.

For the general case, we introduce valid inequalities, in particular "integer" flow cover inequalities that are related to the well known flow cover inequalities for variable upper bound flow models.

TU4-I-CM120

A Branch and Bound Algorithm for the Capacitated Minimal Spanning Tree Problem Using a Directed-Flow Formulation

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Hindi K.S.

The capacitated minimal spanning tree problem is encountered in many applications including centralised network design. The problem can be solved as an integer program by using either directed or undirected link variables. We propose a Lagrangean relaxation based branch and bound strategy using a directed flow formulation. The solution of the minimum directed tree problem is required as a subproblem and we use specific problem reduction and branching rules and appropriate penalties extracted from the literature. First, the lower bounding component of a previously known branch and bound scheme is evaluated and then the effectiveness of the proposed branch and bound scheme is investigated. Computational experiments onthe unit demand case are reported.

FR4-W-CO15

Using MatSe Internet Services as Solvers in Progress Optimization Models

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Keywords: internet - modeling - scheduling - value added services - www

This lecture presents the software system Progress, which facilitates in an easy way the provision, usage, and combination of algorithms, data, and models via various Internet services, especially the WWW. Progress is based on a shell-like object-oriented language and a server program for using and providing such distributed computational services. It supports especially the provision and usage of models via the Internet.

Models, which can be seen as abstract data types, serve for the modeling of problem classes and especially for the representation of associated solution knowledge.

This lecture emphasizes the modeling capabilities of Progress in the context of the MatSe (Linkup of Mathematical Servers in the Internet) project. MatSe aims to set up an infrastructure for cooperative research in project scheduling. Such an infrastructure can benefit from various types of services offered by Progress.

In this lecture, it is shown, which types of value added services are offered and how value added services for MatSe can be constructed from the various Progress service types and other MatSe services. Moreover, we give an overview of the technical realization of this services.

FR4-B-CO10

Decomposition – a Way for Finding a Solvable Problem in the Neighbourhood of an Inconsistent One

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Baumgart Ralf

Keywords: decomposition - linear programming - nondifferential optimization

For the data of a given insolvable LP

$$\max\{\langle c,x\rangle : Ax \le d,\ Bx = g,\ x \ge 0\} \tag{1}$$

we are looking for vectors $[p,q,r] \in Z$ and matrices $H(\alpha)$, $L(\alpha)$ with $\alpha \in K$, such that

$$\begin{aligned}\max\{\langle c+p,x\rangle : (A+H(\alpha))x \le d+q,\\ (B+L(\alpha))x = g+r,\ x \ge 0\}\end{aligned} \tag{2}$$

is solvable and the sum

$$\sum_{i=1}^{l} w_i^1(\alpha_i)^2 + \sum_{j=1}^{n} w_j^2(p_j)^2 + \sum_{i=1}^{k_1} w_i^3(q_i)^2 + \sum_{i=1}^{k_2} w_i^4(r_i)^2 \tag{3}$$

becomes minimal. Here the w's denote some nonnegative weights.
We minimize (3) in a two-level approach. For fixed $\alpha = \{\alpha_i\}$ (3) decomposes into two independently solvable least-squares problems, which determine $\{p_j\}$, $\{q_i\}$ and $\{r_i\}$ (the lower level problems). The upper level problem consists in the minimization of (3) as a function of α (through the lower level problems the $\{p_j\}$, $\{q_i\}$ and $\{r_i\}$ depend on α). This upper level problem is a nonconvex problem with a nondifferentiable objective function. We give the theory of the resulted decomposition algorithm and report on some numerical experiments.

FR2-F-IN203

A New Algorithm for State Constrained Optimal Control

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IMPERIAL COLLEGE

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Keywords: optimal control - receding horizon control - state constraints

Receding horizon optimal control is a promising technique for application in the process industries due to its ability to allow directly for process operating constraints and to the possibility of choosing a "performance function" directly related to the profitability of the process, while with todays computing power, typical process response times allow time for making the necessary computations on-line in real time, eliminating the need for precomputed feedback control laws.

However, the optimal control problem involves in general inequality state constraints and for on-line use it is necessary to use a fine discretisation of the control, resulting in large problems for algorithms based on collocation or control parameterisation. We describe a new algorithm based on solving by integration the two point boundary value problem representing the necessary conditions for an optimal control, extended to deal with inequality state constraints both along the trajectory and at the endpoint for general DAE systems. We also present results for several interesting test problems.

TU1-B-CO10

Robust Convex Optimization

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Keywords: convex optimization - data uncertainty - interior point methods - semidefinite programming

We study Convex Optimization problems for which the data is not specified exactly and it is only known to belong to a given uncertainty set $\mathcal{U}$, yet the constraints must hold for all possible values of the data from $\mathcal{U}$. The ensuing optimization problem is called Robust Optimization. In this paper we lay the foundation of Robust Convex Optimization. In the main part of the paper we show that for some of the most important generic Convex Optimization problems (Linear Programming, Quadratically constrained Programming, Semidefinite Programming and others), if $\mathcal{U}$ is ellipsoidal uncertainty set, the corresponding robust convex program is either exactly, or approximately, a tractable problem which lends itself to efficient algorithms such as polynomial time interior point methods.

MO3-K-CM106

A Support Vector Method for Global Induction of Decision Trees

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Blue Jennifer

Keywords: classification - data mining - kernels - nonlinear programming

We examine how Vapnik's Support Vector Machines (SVMs) can be used within decision trees (DTs) for classification problems. The SVM constructs a nonlinear discriminant function by mapping the problem to a high dimensional Hilbert space and constructing a linear discriminant in the new space. By using kernels and solving the dual problem, very large classification problems such as those in data mining are tractable. Overfitting is avoided by maximizing the classification margin according to the principles of Structural Risk Minimization (SRM). We propose a new method for constructing decision trees in which each decision is a SVM. The logical structure of the tree is fixed. Then we formulate an optimization problem that simultaneously minimizes the classification error of the entire tree and maximizes the classification margin of each decision. Kernel methods can be readily introduced into this formulation. A dual method with support vectors is proposed to solve the problem efficiently.

Our proposed DT-SVM approach utilizes the flexibility and theory of SVMs while maintaining the logical interpretability of the decision tree. By using more powerful decisions, very small decision trees can be used, greatly reducing the combinatorial aspect of DT induction. Computationally, DTs trained using the SRM principle generalized better. We found excellent results on practical problems using only three decisions. A data visualization method based on the three-decision trees further enhances the interpretability and usefulness of the method.

WE1-I-CM121

Software for Boolelan Functions

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This software develops all the usual tools for manipulating boolean functions (which are described by disjonctive or cunjunctive forms). In particular :
- dualization
- getting all prime (implicants or implicata)
- getting minimal forms
- all tests (regular monotone, Horn, hidden Horn ..) and future others
- many tranformations (regularizations, disjoint forms, best minorants or majorants of some kinds)

TU1-A-IN1

Basis- and Tripartition Identification for Quadratic Programming and Linear Complementarity Problems

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Keywords: Balinski-Tucker tableaus - basis recovery - criss-cross method - crossover - interior point methods - linear complementarity problem - principal pivot transforms - quadratic programming - sufficient matrices - tripartitions

Optimal solutions of interior point algorithms for linear and quadratic programming and linear complementarity problems provide maximal complementary solutions. Maximal complementary solutions can be characterized by optimal (tri)partitions. On the other hand, the solutions provided by simplex–based pivot algorithms are given in terms of complementary bases. A basis identification algorithm is an algorithm which generates a complementary basis, starting from any complementary solution.

A tripartition identification algorithm is an algorithm which generates a maximal complementary solution (and its corresponding tripartition), starting from any complementary solution. In linear programming such algorithms were respectively proposed by Megiddo in 1991 and Balinski and Tucker in 1969. In this paper we will present identification algorithms for quadratic programming and linear complementarity problems with sufficient matrices.

The presented algorithms are based on the principal pivot transform and the orthogonality property of basis tableaus.

MO4-I-CM5

Air Traffic Flow Management Problems

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Stock Sarah

Throughout the United States and Europe, demand for airport use has been increasing rapidly, while airport capacity has been stagnating. Over the last ten years the number of passengers has increased by more than 50% and is expected to continue increasing at this rate. Acute congestion in many major airports has been the unfortunate result. For U.S. airlines, the expected yearly cost of the resulting delays is currently estimated at $3 billion. In order to decrease the effects of congestion, we propose optimization models for optimally controlling the flow of aircraft (a) by adjusting their release times into the network (ground-holding) or their speed once they are airborne, and (b) by rerouting them to avoid areas of low capacity.

Using a combination of optimization methodologies (integer programming, dynamic multicommodity network flows and decomposition techniques), we solve large scale realistic size problems fast. We used real data that we obtained from the Federal Aviation Administration (FAA) and Euro Control.

TU2-P-IN201

Optimization of Multiclass Queueing Networks via Infinite Linear Programming and Singular Perturbation Methods

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Keywords: infinite linear programming - optimization - queueing networks - singular perturbation methods

We propose methods for optimization of multiclass queueing networks that model manufacturing systems. We combine ideas from optimization and partial differential equations.

The first approach aims to explore the dynamic character of the problem by considering the fluid model of the queueing network. We propose an algorithm that solves the fluid control problem based on infinite linear programming. Our algorithm is based on nonlinear optimization ideas, and solves large scale problems (50 station problems with several hundred classes) very efficiently.

The second approach aims to shed light to the question of how stochasticity affects the character of optimal policies. We use singular perturbation techniques from the theory of partial differential equations to obtain a series of optimization problems, the first of which is the fluid optimal control problem mentioned in the previous paragraph. The second order problem provides a correction to the optimal fluid solution. This second order problem has strong ties with the optimal control of Brownian multiclass stochastic networks. We solve the problem explicitly in many examples and obtain that the singular perturbation approach leads to insightful new qualitative behavior. In particular, we obtain explicit results on how variability in the system affects the character of the optimal policy.

FR1-F-IN203

Exploiting Sparsity in the Direct Transcription Method for Optimal Control

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Keywords: optimal control - sparse nonlinear programming

The Direct Transcription Method constructs a large sparse nonlinear programming problem by discretization of an optimal control problem. The efficiency of the underlying NLP is dictated by the calculation of sparse Jacobian and Hessian matrices. This paper describes how the sparse matrices are constructed. We also investigate the impact of sparsity in the right hand sides of the original differential-algebraic equations. This work suggests alternate forms for discretizing the dynamics which exploit sparsity, thereby improving the efficiency of the overall process.

MO3-T-CO22

Point to Point Path Optimization

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Keywords: optimal control - sparse nonlinear programming

The problem of moving from one point to another as efficiently as possible can be described as an optimal control problem. The motion is subject to dynamic constraints described by nonlinear ordinary differential equations, and geometric constraints described by parametric B-splines. We describe the solution of one such application arising from the optimal design of a machine tool path. The underlying numerical problem is posed as a large sparse nonlinear programming problem involving a large number of complex path inequality constraints.

WE2-A-IN2

Modeling and Solving ATM Network Design Problems

Bienstock Daniel

Columbia University

We describe ongoing work on modeling and solving difficult mixed-integer programs arising in ATM network design. The formulations tend to be very large, involving hundreds or thousands of integer variables of different types and hundreds of thousands or millions of continuous variables, and can be fairly weak. The approach we use involves cutting, branching and heuristics. We will describe some computational experience with real-life data.

WE3-U-IN10

Solving flow-survivable network design problems

Bienstock Daniel

Columbia University

Keywords: mixed integer programming - network design

We consider network design problems with flow-survivability constraints that broadly, specify that if a node should be removed then at least a certain fraction of each commodity is still being routed. In particular, we consider such problems as they arise in ATM network design, where the routing uses short paths. We study several polyhedra arising in the study of these problems. If time permits, we will present computational results using real-life data.

WE1-A-IN2

Experiments with a Network Design Algorithm Using Epsilon-Approximate LPs

Bienstock Daniel

Columbia University

Keywords: mixed integer programming - network design

We describe an upper-bound algorithm for multicommodity network design problems that relies on recent results of Grigoriadis and Khachiyan, and Plotkin, Shmoys and Tardos, for approximately solving certain linear programs in polynomially many iterations. The approach appears successful on difficult instances.

TU4-C-CO2

Superadditive extension of games

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ETS Ingenieros

López Jorge - Algaba Encarnacion - Fernandez-Garcma Julio R.

Keywords: cooperative games - core - set systems

In this paper we study cooperative games with restricted cooperation. Myerson introduced a graph $G = (N, E)$, whose vertex set N is formed by the players and the edge set E is given by bilateral agreements among the players. The associated game is called graph-restricted game. This line of research was continued by Borm, Owen and Tijs and Potters and Reijnierse. However, any situation that are derived from a partial cooperation can not be represented by a graph. A *feasible coalition system* is a pair $(N, \mathcal{F})$, $\mathcal{F} \subseteq 2^N$ such that $\emptyset \in \mathcal{F}$, and $\{i\} \in \mathcal{F}$ for all $i \in N$. The set of all partitions of $S \subseteq N$ in nonempty

feasible coalitions is denoted by $\mathcal{P}_{\mathcal{F}}(S)$, $S \neq \emptyset$. Let (N, v) be a cooperative game, the associated game with restricted cooperation by $(N, \mathcal{F})$ is a pair $\left(N, \tilde{v}^{\mathcal{F}}\right)$, where $\tilde{v}^{\mathcal{F}} : 2^N \longrightarrow \mathbf{R}$, is defined by $\tilde{v}^{\mathcal{F}}(S) = \max\left\{\sum_i v(T_i) \mid \{T_i\}_{i\in I} \in \mathcal{P}_{\mathcal{F}}(S)\right\}$. This superadditive extension, that was named partitioning games by Kaneko, and Wooders, is studied by Kuipers.

A *partition system* is a feasible coalition system $(N, \mathcal{F})$ such that for all $S \subseteq N$, the $\mathcal{F}$-components of S (maximal subsets of S in $\mathcal{F}$) form a partition of S. A family of feasible coalitions $\mathcal{F}$ is called *union stable* if for all $A, B \in \mathcal{F}$ with $A \cap B \neq \emptyset$ it is satisfied that $A \cup B \in \mathcal{F}$. Let (N, v) be a cooperative game and $\mathcal{F} \subseteq 2^N$ a union stable family. Let $\mathcal{B}$ be the basis of $\mathcal{F}$ and $\widehat{\mathcal{B}} = \{S \in \mathcal{B} \mid |S| \geq 2\}$. The *conference game* $v^{\widehat{\mathcal{B}}} : 2^{\widehat{\mathcal{B}}} \longrightarrow \mathbf{R}$ is given by $v^{\widehat{\mathcal{B}}}(\mathcal{A}) = v^{\varphi(\mathcal{A})}(N)$, $v^{\widehat{\mathcal{B}}}(\emptyset) = 0$.

TU4-C-CO2

The Shapley value on matroids

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ETS Ingenieros

Lebron Esperanza - Jimenez Andres - Jimenez Nieves

Keywords: matroid - shapley value

In the classical model of cooperative games, it is considered that each subgroup of players can form and cooperate to obtain its value. However, we can think that in some situations this assumption is not real, that is, all the coalitions are not feasible. Faigle and Kern proposed a model in which cooperation among players is restricted to a distributive lattice of subsets of players. Their model is a special case of the games on convex geometries studied by Bilbao and Edelman. In this paper, we will define the feasible coalitions by using combinatorial geometries called *matroids*.

A game on a matroid $\mathcal{M}$ is a function $v : \mathcal{M} \longrightarrow \mathbf{R}$ with $v(\emptyset) = 0$. We denote by , $(\mathcal{M})$ the vector space of all games on the matroid. The feasible set $B \in \mathcal{M}$ is called a basis of S if B is a maximal feasible subset of S. In a matroid, all the basis of S have the same cardinality. We call *basic coalitions* $\mathcal{B}$ of the matroid $(N, \mathcal{M})$ to the basis of N and its cardinal is $b = |\mathcal{B}|$. The *rank* of the matroid is the cardinal of the basic coalitions. Then we have $\mathcal{B} = \{B \in \mathcal{M} : |B| = r\}$, where r is the rank of $\mathcal{M}$.

The influence set of $S \in \mathcal{M}$ is the set $\mathcal{B}_S = \{B \in \mathcal{B} : S \subseteq B\}$, of the basic coalitions that contain S and its influence worth is the quotient b_S/b, where $b_S = |\mathcal{B}_S|$. We obtain the following generalization of the *Shapley value* for games on matroids.

There exists a unique function $\Phi :$, $(\mathcal{M}) \longrightarrow \mathbf{R}^n$ satisfying linearity, dummy, efficiency and symmetry. Moreover, Φ is given by

$$\Phi_i(v) = \sum_{\{S\in\mathcal{M} : i\in S\}} \frac{b_S}{b} \frac{(r-s)!(s-1)!}{r!} \left[v(S) - v(S \setminus i)\right].$$

TH4-U-IN1

Medical Image Segmentation via Linear Programming

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Speight Adam Lee

Keywords: Haralick transforms - linear programming - multicategory discrimination - segmentation

To address the problem of automatically identifying organ boundaries from CAT scan images, we use linear programming techniques to analyze textural information, which is calculated directly from digitally stored CAT scan images. At each pixel in the image, a set of texture numbers called Haralick transforms is calculated. We attempt to identify organs based on these texture numbers. So modeled, the problem reduces to a multicategory discrimination problem, which we solve via linear programming.

WE2-I-CM121

Monotonocity, Decision Trees and Pseudo-Boolean Functions

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Erasmus University, Dpt. of Computer Science

In many real-world classification problems in which the classes have a natural ordering it is necessary that objects with better attribute values are classified in higher classes. However, existing methods for decision tree generation in general yield non-monotonic decision trees. We discuss the problem of building monotone decision trees. Since a clasification tree can be seen as a representation of a pseudo-Boolean function, we also discuss other possible better methods to represent montone classification problems.

WE3-G-IN11

Recent Results in Large-scale Stochastic Programming Implementations

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University of Michigan

Keywords: computation - stochastic programming

Recent implementations of stochastic programming methods have included many large problems with variable numbers in the billions. We will describe a nested decomposition method that uses a compact tree representation and an advanced solution to increase computational efficiency. We will describe a variety of applications in the areas of finance, transportation, and manufacturing.

TH2-U-IN10

The Capacitated Prize-Collecting Traveling Salesman Problem

Bixby Ann Elizabeth

Northwestern University

Coullard Collette R. - Simchi-Levi David

In this paper we look at the capacitated prize-collecting traveling salesman problem, an NP-hard combinatorial optimization problem closely related to the capacitated vehicle routing problem. We develop an integer programming formulation of the problem and a cutting plane algorithm for its solution. Computational results are discussed.

WE2-I-CM5

A New Paradigm for Finding Cutting Planes in the TSP

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Applegate David - Chvátal Vasek - Cook William J.

Keywords: traveling salesman problem

A traditional paradigm for finding cutting planes in the TSP is this: having identified classes of linear inequalities (such as comb inequalities or clique-tree inequalities) that are satisfied by all tours, one designs "separation algorithms" for each individual class and finally applies these algorithms to an optimal solution of the current LP relaxation of the TSP instance. We shall present another way of finding cutting planes, which does not fit this paradigm; preliminary computational experience with its implementation is encouraging.

TH3-I-CM121

Using LAD Method for Classifying into more than Two Classes

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Hammer Peter L. - Kwiatek R.

In the paper the LAD (Logical Analysis of Data) method for classifying examples into more than 2 classes, is considered. After standard binarization, decision atribute is also binarized, creating datasets related to decision classes. In these datasets decision attribute is binary and denotes a positive point if a given example supports the class related to the dataset, otherwise binary decision denotes the point as a negative example. Next step of analysis is pattern generation and formulation of theorems for each dataset. Then discrimination functions describing decision classes, are obtained. These functions give one scores of memberships for all decision classes. These scores are then treated as new attributes (continuous) and methods borrowed from decision support systems may be used for making final decisions. An application of this approach to the recogniton of DNA chain functions is also presented.

FR3-W-CO15

Algebraic Modeling and Constraint Logic Programming

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Barth Peter

Keywords: combinatorial optimization - constraint logic programming - modeling

We discuss the role of constraint logic programming in modeling discrete optimization problems. First we show that the basic functionality of algebraic modeling languages is naturally available in logic programming and explain the additional expressive power that we can get from using a logic programming environment. Then we focus on the symbolic constraints offered by constraint logic programming systems and present an algebraic modeling approach for constraint logic programming over finite domains.

TH3-A-IN1

A Parallel SAT Solver: Theoretical Analysis and Practical Performance

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Speckenmeyer E.

Keywords: SAT - load balancing

We present an efficient implementation for solving the satisfiability problem in parallel on MIMD machines. It is based on a decomposition of the search tree. Small subproblems are solved by a fast sequential SAT-solver. An algorithm, called "Precomputation-based Load Balancing" (PLB) is introduced, which redistributes workload in a processor network N in order to supply every processor of N with (about) the same amount of workload. PLB is defined in its basic form for trees, but can be extended to other topologies. The redistribution is done locally on the basis of information of over- or underload in subnetworks of N. We show that PLB performs only $O(\Delta)$ steps where Δ denotes the diameter of N. On the average, complete binary trees require at most four times the amount of moved workload needed in the optimal clique networks. Extensive practical experiments on random instances as well as DIMACS benchmark instances confirm that the theoretical model closely reflects the actual behavior of the parallel implementation.

WE3-L-CM201

Theoretical Analysis and Applications of a Large Scale SQP Algorithm for Nonlinear Optimization

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National Institute of Standards and Technology

For several years we have been developing and testing an SQP algorithm for solving large inequality constrained nonlinear programming problems. A specialized interior-point method is employed for the solution of large and sparse quadratic programming subproblems. Globalization is forced through merit functions and a trust region. In this talk we will describe our new global convergence analysis under mild assumptions. Problem specific algorithmic enhancements will also be described with numerical results on the solution of an optimization problem arising in the study of micromagnetic materials.

FR2-H-CO22

Efficient and Kuhn-Tucker Sequences in Constrained Vector Optimization Problems

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Université de Perpignan

Benaissa Bernoussi - Mounir El Maghri - Ching Cheng Chou

Keywords: convex analysis - efficiency - minimizing sequences - stationary sequences - vector optimization

We deal with constrained convex smooth vector optimization problems where the solution set (the weakly efficient set) may be empty. Thus we introduce the weakly infimal set and the concepts of weakly efficient and weakly Kuhn-Tucker sequences. Note that these sequences may be unbounded. We show that under certain hypothesis, a weakly Kuhn-Tucker sequence is a weakly efficient one. On the other hand we show that, given a weakly efficient sequence, there exists a nearby weakly Kuhn-Tucker sequence.

WE4-S-IN202

Predicting Stable and Metastable Structures of Crystalls and Molecules

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Keywords: crystall structure prediction - global optimization - molecular modelling

Three dimensional structures of crystals, proteins and nucleic acids can be characterized by nonlinear energy potentials. It is well known that these structures often cannot be predicted sufficiently well by local deterministic optimization strategies. Their energy surfaces exhibit a high number of local minima that grows exponentially with the size of the problem. Therefore, a successful prediction often requires an analysis of the chemical properties.

In our presentation we use different global optimization strategies to find global and low energy local minima. These characterize stable and metastable structures of chemical interest. A special focus will be on the discussion of crystal structures where the stochastic Simulated Annealing method allows a comparison to the annealing process of crystals in nature. In addition to this also methods of predicting molecular structures are considered.

Several examples of crystal structures and organic molecules are explained.

TU3-C-CO122

Global Escape Strategies for Standard Quadratic Programming Problems

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I.S.O.C., University of Vienna

Keywords: global optimization - maximum clique problem - replicator dynamics

A standard quadratic problem (QP) consists of maximizing a quadratic form over the standard simplex. Problems of this type occur, e.g. in the search for the maximum (weighted) clique in an undirected graph. But also in general QPs, copositivity-based escape steps from inefficient local solutions can be reformulated into standard QPs (another reason for this terminology).

Several recent publications propose procedures to obtain (local) solutions to this kind of problems with the help of replicator dynamics. Following trajectories under these dynamics, one obtains a sequence of feasible points with strictly increasing objective values, which approach stationary points. Here, the global escape strategies addressed above are rephrased into lower-dimensional subproblems which are again standard QPs. As a result, an algorithm is obtained which tries to exploit favourable data constellations in a systematic way, and to avoid the worst-case behaviour of such NP-hard problems whenever possible. First empirical results on finding large cliques in DIMACS benchmark graphs are encouraging.

TU1-B-CO10

Second-Order Analysis of Optimization Problems: Optimality Conditions and Sensitivity Theory

Bonnans Frédéric

INRIA

Cominetti Roberto M. - Shapiro Alexander

Keywords: directional constraint qualification - parametric optimization - second order optimality conditions - semidefinite programming - sensitivity analysis

The talk will present some ideas developped in the last decade concerning the second-order analysis of optimization problems. Starting from elementary examples of nonlinear programming problems, we will show the link between the second-order conditions and the approach of upper and lower estimates of the value function for sensitivity analysis. Turning to general optimization problems, we will discuss the concept of curvature of convex sets, and show how the analysis may be completed when the second order regularity hypothesis is satisfied, with application to semi-definite programming.

FR2-C-CO123

Oligopoly Equilibria in Large but Finite Linear Exchange Economies

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University Paris 1

Florig Michael

Keywords: Pareto optimum - exchange economies - linear utility functions - oligopoly equilibrium - replication

We consider a linear exchange economy and its successive replicas. We study the notion of oligopoly equilibria in which the consumers use the quantities of commodities put on the market as strategic variables.

We show that the prices and the utility levels of successive oligopoly equilibria converge to the prices and the utility levels of the Walrasian equilibrium of the basic economy when the number of replicas tends to infinity.

This allows us to prove that if the economy is sufficiently replicated, then every allocation associated to the oligopoly equilibrium is Pareto optimal and under a regularity condition on the cluster points of the sequence of oligopoly equilibria, the prices and the utility levels associated with the oligopoly equilibria are thoses associated with the Walrasian equilibrium of

the basic economy. In particular the strategy defined by the fact that every consumer put his initial endowment on the market is an oligopoly equilibrium.

This implies the existence of oligopoly equilibria, at least for large exchange economies. Later, we give an example where the Walrasian price is never attained for finite replica, but the outcome is Pareto optimal, although different from the one associated to the Walrasian equilibrium.

MO4-I-CM4

Has Edge Numbering an Effect on the Performance of the Criss-Cross Method in a Directed Graph?

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Keywords: criss-cross method - directed graphs

Let us consider a directed graph $\mathcal{G} = (\mathcal{N}, \mathcal{A})$, let A be its node-arc incidence matrix and $b = (n-1, -1, \ldots, -1)$ where n is the number of nodes in $\mathcal{G}$. Then the following lemma is well-known for directed graphs: There is an arborescence in $\mathcal{G}$, rooted at a source node iff $Ax = b$, $x_j \geq 0$ integer $j = 1, \ldots, n$ has a solution. A proof of the lemma is shown by using criss-cross algorithm on the graph and the effect of edge numbering on the number of pivoting is studied. Numerical experiments with different strategies in edge numberings is presented.

TU4-A-IN1

A Sharp Upper Bound for the Expected Number of Shadow Vertices in an LP-Quadratic in the Smaller and Sublinear in the Larger Dimension

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Keywords: average-case complexity - linear programming - stochastic geometry

In this paper we sharpen our polynomiality-proof from 1982 resp. 1987 for $E_{m,n}(S)$, which is the expected number of shadow-vertices in linear programming problems of the type

$$\text{maximize } v^T x$$
$$\text{s.t. } a_1^T x \leq 1, \ldots, a_m^T x \leq 1$$
$$\text{where } \; x, v, a_1, \ldots, a_m \in \Re^n \; \text{ and } m \geq n.$$

We assume a distribution of the linear programming problems corresponding to the Rotation-Symmetry-Model:

The vectors $a_1, \ldots, a_m, v$ and an auxiliary vector u are distributed on $\Re^n \backslash \{0\}$ independently, identically and symmetrically under rotations.

In 1982 and 1987 we had found an upper bound of $m^{\frac{1}{n-1}} \cdot n^3 \cdot Const.$, valid for all RSM-distributions and all pairs $(m \geq n)$. This bound had recently (1994) been improved to $m^{\frac{1}{n-1}} \cdot n^{\frac{5}{2}} \cdot Const.$ by use of a refined evaluation technique for space-angles. Based on these papers and on a reorganization of the proof, which avoids some crude estimations, we are now able to confirm a bound

$$E_{m,n}(S) \, \leq \, m^{\frac{1}{n-1}} \cdot n^2 \cdot Const.$$

This result had been desired strongly, because also in 1982 , a bound $m^{\frac{1}{n-1}} \cdot n^2 \cdot Const.$ had been derived only for the situation, where n is fixed and m tends to infinity. All the time the question had been open, whether the asymptotical behaviour would be better than the behaviour in moderate dimensions, or whether the moderate bound was crude.
In addition, we know – also from asymptotic analysis of 1987, that for a special RSM-distribution, namely the uniform distribution on the unit sphere, there is a lower bound for $E_{m,n}(S)$ of type $m^{\frac{1}{n-1}} \cdot n^2 \cdot Const.$ The combination of this result and the new upper bound shows that the new bound is sharp.

TH2-I-CM3

Set Partitioning Methods for Dial-a-Ride Systems

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Keywords: dial-a-ride systems - set partitioning

Telebus is Berlin's dial-a-ride system for handicapped people that cannot use the public transportation system: About 1,500 transportation requests per day are serviced by a fleet of 100 mini-busses, rented on a daily basis depending on the demand. The task of vehicle scheduling is to rent a suitable set of vehicles and to determine for each vehicle a tour of operation, such that (i) each request is serviced by a suitable vehicle and (ii) the mini-bus tours respect a couple of side-constraints, for example, prescribed shift lengths, break rules, and punctual service. The objective is to minimize operational costs.

We use a *set partitioning* approach to solve the bus scheduling problem that consists of two steps. The first *clustering* step identifies segments of possible bus tours ("orders") such that more than one person is transported at a time. In the second step the selected orders are *chained* to possible bus tours. Both steps require the solution of a set partitioning problem: First, to select a set of orders such that the traveling distance of the vehicles within the orders is minimum, and second, to select a set of tours that minimizes the total traveling distance of the vehicles.

Our computer system for the solution of the bus scheduling problem is based on a branch-and-cut algorithm for the solution of set partitioning problems. Important issues are tour generation, iterative problem reduction, and the use of cutting planes. A first stage of this system is in operation since July 1, 1995. Its use made it possible that Telebus can service today about 30% more requests per day for the same amount of money than before.

WE2-I-CM121

Maximum Renamable Horn Sub-CNFs

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RUTCOR, Rutgers University

A polynomial time approximation algorithm is presented for the problem of finding the largest renamable Horn sub-CNF of a given CNF.

It is shown that for cubic CNFs, the algorithm guarantees at least 59.7% of the optimum.

TH4-I-CM121

Optimal Cell Flipping to Minimize Channel Density in VLSI Design

Boros Endre

RUTCOR, Rutgers University

Hammer Peter L. - Minoux Michel - Rader David J.

Cell flipping in VLSI design is an operation in which some of the cel ls are replaced with their "mirror images" with respect to a vertical axis, while keeping them in the same slot. After the placement of all the cells, one can apply cell flipping in order to d ecrease the total area, approximating this objective by minimizing total wire length, channel width, et c. However, finding an optimal set of cells to be flipped is usually a difficult problem. I n this paper we show that cell flipping can be efficiently applied to minimize channel density in th e standard cell technology. We prove that an optimal flipping pattern can be found in $O(p(\frac{n}{c})^c)$ time, where n, p and c denote the number of nets, pins and channels, respectively. Mo reover, in the one channel case (i.e. when $c = 1$) the cell flipping problem can be solved in $O(p$
$logn)$ time. We also provide an integer programming formulation for the multi-channel case, and present computational results on examples up to 139 channels.

FR3-I-CM200

Integer Programming and the Game of Life

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Keywords: integer programming

In early 1970, John Horton Conway of the University of Cambridge invented a simple one-player game called Life. Later that year, Martin Gardner popularized Conway's game by making the subject of one of his columns in *Scientific American*. Since 1970, a great number of individuals – some of them professional scientists, some of them amateurs – have contributed to a greater understanding of Life. (Conway himself proved that Life can serve as a universal model of computation.)

In this talk, we will discuss how integer programming can be used to answer a number of questions concerning Life. We will describe integer programming formulations for finding "still lifes" (Life patterns that never change), low-period oscillators, and other interesting patterns. We will also describe the strategies and techniques we employed to solve these integer programs.

TU4-N-CO15

Solutions Analysis in Complex Planning Models for the Oil Industry

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Shell International Oil Products BV

Pieterse Seppo

Keywords: mathematical programming - refinery planning - solutions analysis

At refineries, linear programming models are used to support planning decisions. Over the years, these models have become more accurate, but also larger and more complex. As a result, the understanding and interpretation of these models and their solutions has become more and more complicated. A proper solution interpretation requires intimate knowledge of the model, understanding of its (mathematical) solution and insight in the related planning and scheduling environment. Unfortunately, this last source of knowledge is usually not well structured and often spread over different persons or even different departments.

In this context Shell Research has initiated a research project to provide functionality to enhance the user understanding and interpretation of the solutions of mathematical programming models used for refinery planning. A survey of the state of the art of existing techniques, academic approaches and commercially available tools for solution analysis and interpretation is given. One approach, to provide functionality to enhance the user understanding of the solutions of mathematical programming models, is the "intelligent" interpretation of the results generated by the optimisation process, and is based on techniques in the area of Artificial Intelligence (e.g. Expert Systems and Knowledge Technology). The viability of these techniques within a solution interpretation framework was investigated, partly in co-operation with the academic world. Moreover the use of IIS (Irreducible Inconsistent System) will be discussed. An IIS is a set of constraints within an LP that cannot be satisfied simultaneously. Irreducible means that removing any one constraint will permit all the others to be feasible. The IIS may contain both row and column bounds. Finding an IIS in a large LP provides a mechanism to locate the infeasibility. This isolation normally is remarkably small and therefore can help to speed the diagnosis of an infeasibility and its repair. Finally the use of the ANALYZE package will be discussed. The latter one is the only commercially available package for solution analysis.

TU3-I-CM121

Chain-Group Representations of Multimatroids

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Keywords: chain-group symplectic - delta-matroid - linear representation - matroid - multimatroid

We define a notion of linear representation for multimatroids that generalizes the linear representations of matroids by chain-groups, the linear representations of 2-matroids and delta-matroids by symmetric matrices and antisymmetric matrices. We show that every Eulerian multimatroid is representable with a symplectic vector space over GF(2). Finally we adapt the construction to symplectic matroids.

WE1-I-CM120

Low Rank Quadratic Assignment Problems

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Finke Gerd

Keywords: complexity - eigenvalue formulation - quadratic

assignment problem - rank

The quadratic assignment problem (QAP) is a well-known notoriously difficult problem, describing layout problems with spatial interactions. We shall classify QAPs according to the ranks of the underlying distance and flow matrices, A and B. We are in particular interested in cases for which one of these two matrices has rank one.

Different important problems are shown to be instances of QAPs with this particular form; for example certain traveling salesman problems related to the autocorrelation coefficient, the problem to assign blades on a cylinder or the hydraulic turbine problem and the storage of files on a hard disk.

The problem remains very difficult for matrices A and B of small rank. In fact, even if both matrices are of rank one and unrestricted in sign, the problem is NP-hard. We shall identify further NP-hard cases and give exact solution methods for matrices A and B with special structures.

TU3-K-CM106

A Tabu Search Heuristic for the Capacitated Lot Sizing Problem with Setup Carryovers

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Ding Ke - Gopalakrishnan Mohan

Keywords: lot sizing - production planning - setup - tabu search

This paper presents a Tabu Search heuristic for the Capacitated Lot Sizing Problem (CLSP) with setup carryovers. The single level CLSP with setup carryovers is a class of production planning problems in which multiple items can be produced within a time period, and setups can be carried over from one period to the next to address the problem of large setup times incurred by production changeovers from one item to another. Two types of decisions, lot sizing and partial sequencing, are interrelated in this problem. We designed three move types to deal with partial sequencing and two move types to deal with lot sizing. Together, the five move types define the move mechanisms used for local search. Global search strategies such as dynamic Tabu list, intensification and diversification are used. A bounding procedure for the problem is also proposed. The computational study carried out on a large number of test problems indicates that our heuristic performs well in solving this computationally hard problem.

TU1-L-CM201

Parallel Branch and Cut for Symmetric Traveling Salesman Problem

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Naddef Denis Joseph

Keywords: branch and cut - parallel computing - symmetric traveling salesman problem

The Branch and Cut method has been very successful in solving large symmetric traveling salesman instances. The time needed to solve these instances is very high, therefore one may want to consider the possibility of using parallel machines or a set of heterogeneous work stations, to perform the computations. In doing so, some strategic choices have to be made: high or low level parallelism, central or distributed control scheme. Some research has been already carried out on the Branch and Bound method which is a related method. Branch and Cut has its specificities that have to be accounted for when thinking of parallelization. We will talk about these specificities and we will comment on the choices we have made.

TH4-I-CM5

Worst Case Comparisons of the Metric TSP with Two of its Relaxations

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Keywords: 2-matching - subtour elimination problem - traveling salesman problem

Consider the TSP defined on a complete graph where the edge costs satisfy the triangle inequality. Let TOUR denote its optimal solution value. Two well known relaxations for the TSP are the subtour elimination problem and the 2-matching problem. If we let SUBT and 2M represent the optimal solution values for these two relaxations, then it has been conjectured that TOUR/SUBT is at most 4/3, and that 2M/SUBT is at most 10/9.

In this paper we discuss results which support the above conjectures. In particular, we show that for certain specified classes of cost functions, the above two conjectures are true, and for such classes we give a 4/3 (or better) approximation algorithm for the TSP.

TH2-U-IN10

Approximation Algorithms for the Capacitated Traveling Salesman Problem with Pick-ups and Deliveries

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Anily Shoshana

We consider the capacitated Traveling Salesman Problem with Pick-ups and Deliveries (CTSPPD). This problem is characterized by a set of n pick-up points and a set of n delivery points. A single product is available at the pick-up points which must be brought to the delivery points. A vehicle of limited capacity is available to perform this task. The problem is to determine the tour the vehicle should follow so that the total distance traveled is minimized, each load at the pick-up point is picked-up, each delivery point receives its shipment and the vehicle capacity is not violated. We present two polynomial-time approximation algorithms for this problem and analyse their worst-case bounds.

WE1-I-CM5

A Linear Time Algorithm for the Arc Disjoint Menger Problem in Planar Directed Graphs

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Keywords: disjoint paths - graph algorithms - planar graphs

Given a graph $G = (V, E)$ and two vertices $s, t \in V$, $s \neq t$, the Menger problem is to find a maximum number of disjoint paths connecting s and t. Depending on whether the input graph is directed or not, and what kind of disjointness criterion is demanded, this general formulation is specialized to the directed or undirected vertex, and the edge or arc disjoint Menger problem, respectively.

For planar graphs the edge disjoint Menger problem has been solved to optimality, while the fastest algorithm for the arc disjoint version is Weihe's general maximum flow algorithm for planar networks, which has running time $\mathcal{O}(|V| \log |V|)$. We present a linear time, i.e. asymptotically optimal, algorithm for the arc disjoint version in planar directed graphs.

TH2-D-CO123

Semidefinite Programming Formulations and an Interior Point Method for Truss Topology Design

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Svanberg Krister

Keywords: compliance constraints - interior point methods - minimum weight - semidefinite programming - truss topology

We discuss different semi-definite programming formulations of the multi-load truss topology design problem and describe an implementation of Boyd and Vandenberghe's potential reduction method for these.

WE2-R-IN203

Primal/Dual Methods for Convex Hulls

Bremner David Dylan

Mc Gill University

A *polytope* is the bounded intersection of a set of halfspaces. The *vertices* of a polytope are those feasible points that do not lie in the interior of a line segment between two other feasible points. Every polytope P can be represented as the intersection of a non-redundant set of halfspaces $H(P)$ and as the convex hull of its vertices $V(P)$. The problem of transforming from $H(P)$ to $V(P)$ is called *vertex enumeration*; transforming from $V(P)$ to $H(P)$ is called *facet enumeration* or *convex hull*. These two problems are polynomially equivalent, but for a particular problem instance one transformation may be much easier (with current technology) than the other. In this talk, I will discuss a new class of algorithms that take advantage of this phenomenon. Loosely speaking, *primal-dual* algorithms use a solution to the easy direction as an oracle to help solve the hard direction.

TH3-I-CM200

New Analysis of some Old Methods for Vertex and Facet Enumeration

Bremner David Dylan

Mc Gill University

Keywords: enumeration - facets - polynomial time - polytope - vertex

Vertex and facet enumeration are the (essentially equivalent) problems of transforming between the two representations of a convex polytope, namely its vertices (or extreme points) and its facet defining halfspaces. Vertex/facet enumeration algorithms can be broadly divided into those based on incremental construction and those based on the pivot operation of the simplex method. Both of these classes can be seen as developments of ideas first proposed by J.B.J. Fourier over 150 years ago. A longstanding open problem is whether either of these methods can provide an algorithm polynomial in the input and output size. In this talk I survey some recent results that show that incremental algorithms will not provide such an algorithm and pivoting algorithms are unlikely to either.

TH3-C-CO122

Necessary Conditions for Extremal Problems

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Keywords: Banach spaces - Lagrange multipliers - perturbation function - principle of Lagrange - smooth-convex problems

A necessary condition - the Principle of Lagrange - is offered for mixed smooth-convex optimization problems depending on parameters. This generalizes and unifies most of the known necessary conditions for concrete finite and infinite dimensional optimization problems. The following features are novel in comparison with the well-known version of Tikhomirov and others: a simple geometric formulation of this condition is given for an arbitrary setup, constraints are not mentioned explicitly, the feasibility set is allowed to vary in a non-standard way and the objective function is also allowed to vary.

MO4-P-IN201

Preemptive Job-Shop Scheduling Problems with a Fixed Number of Jobs

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Universität Osnabrück

Kravchenko Svetlana - Sotskov Yuri

Keywords: job shop - scheduling

It is shown that the two machine preemptive job-shop problem with mean flow-time or makespan objective function and three jobs is NP-hard. This contrasts the fact that the nonpreemptive versions of these problems are polynomially solvable if the number of jobs is arbitrary but fixed. It is also shown that the preemptive problems can be solved pseudopolynomially if both the number of machines and the number of jobs are fixed.

FR2-I-CM200

On an Extremal Problem of Erdos in Interpolation Theory

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Science

Toledano Dvora

Keywords: Lagrange interpolation - Richardson extrapolation - optimization methods

One of the intriguing problems of interpolation theory posed by Erdös in 1961 is the problem of finding a set of interpolation nodes in $[-1, 1]$ minimizing the integral I_n of the sum of squares of the Lagrange fundamental polynomials. The guess of Erdös that the optimal set corresponds to the set F of the Fekete nodes (coinciding with the extrema of the Legendre polynomials) was disproved by Szabados in 1966.

Another aspect of this problem is to find a sharp estimate for the minimal value $I_n^\star$ of the integral. It was conjectured by Erdös, Szabados, Varma and Vertesi in 1994 that asymptotically $I_n^\star - I_n(F) = o(1/n)$.

In the present paper we use a numerical approach in order to find the solution of this problem. By applying an appropriate optimization technique, we found the minimal values of the integral with high precision for n from 3 up to 100. On the basis of these results and by using Richardson's extrapolation method we found the first two terms in the asymptotic expansion of $I_n^\star$ and thus disproved the above-mentioned conjecture. Moreover, by using some heuristic arguments we give an analytic description of nodes which are, for all practical purposes, as useful as the optimal nodes.

MO4-C-CO122

Some Special Problems of Operations Research and Numerical Methods of Global Optimization

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Keywords: cutting plane methods - equilibrium models - implicit problems of global optimization - inverse mathematical programming

We consider some economical-mathematical equilibrium models, Pareto optimization models, and inverse problems of mathematical programming as well. A reduction of the models to some special implicite problems of mathematical programming is studied. Complexity analysis is carried out and a connection between considered problems is discovered. All obtained problems of mathematical programming are multiextremal. For solving these problems, we propose special global optimization methods where the idea of cutting in E^{n+1} is used.

TU1-B-CO11

Submonotone Enlargements and bundle methods for Maximal Monotone Operators

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Sagastizábal Claudia - Svaiter Benar Fux

Keywords: bundle methods - enlargements - maximal monotone operator

Given a maximal monotone operator $T : R^n \to \mathcal{P}(R^n)$, the problem

$$\text{find } \bar{x} \text{ such that } \quad 0 \in T(\bar{x}) \qquad (P)$$

is a generalization of finding a minimum of a proper closed and convex function f, (where (P) reads $0 \in \partial f(\bar{x})$). In the case in which T is a point to set operator, the available methods for solving the problem are either theoretic or not very efficient. Considering the good performance of bundle methods, it seems to adapt them to the resolution of (P).

In order to construct bundle-like methods for solving (P), we first define *continuous* enlargements of the point-to-set application T. These enlargements extend to the class of maximal monotone operators the concept of $\partial_\varepsilon f$, the ε subdifferential of a convex function f.

We prove some useful properties for these enlargements, like outer and inner semicontinuity in the interior of the domain of T. A generalization of the Brönsted-Rockafellar Theorem for such enlargements is also established.

We propose an implementable algorithm, inspired from the bundle methods, for solving problem (P). A sequence $\{x^k\}$, which is Fejer convergent to the solution set of (P) is generated. In each iteration, either a better polyhedral approximation of the T_ε is obtained or, in the case of a serious step, a new x^k closer to the solution set, is generated.

We establish convergence of the algorithm. Finite termination can also be obtained using as stopping criteria $v \in T_\varepsilon(x)$ with ε and $|v|$ small.

TH1-I-CM4

A Greedy Algorithm for the Optimal Basis Problem

Burdakov Oleg

CERFACS

Keywords: greedy algorithm - interpolation - minimum spanning trees - optimal basis - secant approximation of derivatives

The following problem is considered. Given $m+1$ points $\{x_i\}_0^m$ in R^n which generate an m-dimensional linear manifold, construct for this manifold a maximally linearly independent basis that consists of vectors of the form $x_i - x_j$. This problem is present in, e.g., stable variants of the secant and interpolation methods, where it is required to approximate the Jacobian matrix f' of a nonlinear mapping f by using values of f computed at $m+1$ points. In this case, it is also desirable to have a combination of finite differences with maximal linear independence. As a natural measure of linear independence, we consider a functional which is maximized to find an optimal combination of m pairs $\{x_i, x_j\}$. We show that the problem is not NP–hard, but can be reduced to the minimum spanning tree problem, which is solved by the greedy algorithm in $O(m^2)$ time. The complexity of this reduction is equivalent to one $m \times n$ matrix–matrix multiplication, and according to the Coppersmith–Winograd estimate, is below $O(n^{2.376})$ for $m = n$.

FR-am-CO1

Efficiently Solvable Special Cases of Hard Combinatorial Optimization Problems

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Graz

We survey some recent advances in the field of polynomially solvable special cases of hard combinatorial optimization problems like the travelling salesman problem, quadratic assignment problems and Steiner tree problems. Such special cases can be found by considering special cost structures, the geometry of the problem, the special topology of the underlying graph structure or by analyzing special algorithms. In particular we stress the importance of recognition algorithms. We comment on open problems in this area and outline some lines for future research in this field.

TH3-F-IN203

Modelling and Solution of Optimization Problems with Differential Equation constraints

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University of Dundee, Dept of Mathematics and Computer Science

Middleton Roy

Keywords: differential algebraic equations - nonlinear programming

The solution of nonlinear optimization problems with differential algebraic equation (DAE) constraints is considered. These arise in many fields, including chemical engineering and trajectory problems. A new modelling language for the description of this type of problem is being developed. This language is based on OTL, which is designed for the modelling of nonlinear programming problems. Existing modelling packages such as CUTE and AMPL do not allow the modelling of DAE constraints. The problems are solved by approximating the functions using collocation over finite elements resulting in large nonlinear programming problems. These discretized problems are solved by a sequential quadratic programming method. The discretization is then refined using an iterative scheme.

TH1-F-IN203

Sensitivity Analysis and Real-Time Control of Nonlinear Control Systems via Nonlinear Programming Methods

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Westfälische Wilhelms-Universität Münster

Maurer Helmut

Keywords: control-state constraints - nonlinear programming - optimal control - real-time control - sensitivity analysis

Nonlinear optimal control problems subject to control and state constraints are studied. Disturbances or perturbations of system data are modelled by parameters in the system dynamics or cost function. Based on recent stability results we propose a robust nonlinear programming method to compute sensitivity derivatives of optimal solutions with respect to parameters. Real-time control approximations of perturbed solutions are obtained by evaluating a first order Taylor expansion of the perturbed solution. The numerical methods are illustrated by two benchmark problems in optimal control: the maximum range flight of a hang glider and the optimal control of an industrial robot.

WE3-I-CM3

Design in Periodic Transportation Systems: Line planning

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Math. Opt. TU Braunschweig

Zimmermann Uwe T.

Keywords: discrete optimization - mixed integer programming - rail

We discuss the optimal choice of traffic lines in public transport systems with a regular schedule of service. A *line plan* has to offer sufficient capacity in order to serve the known amount of traffic of the system. The *line optimization problem* aims at the construction of a feasible line plan which optimizes certain objectives. We present as well separate models for construction and evaluation of line plans as a combined model. For real world data we succeed in solving this linear mixed integer program by means of suitable relaxations and facet defining inequalities with the commercial MIP solver CPLEX. Furthermore we conclude with some nice properties of the associated polyhedra.

TH2-E-CO11

A Method of Computing almost Common Points for Relatively Nonexpansive Families of Operators with Application to Variational Inequalities

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Iusem Alfredo Noel

Keywords: almost common fixed point - relatively nonexpansive operator - variational form

Consider a measurable family of operators T(w,.):C—¿C, where w runs over a probability space W and C is a closed convex subset of the reflexive Banach space B. Assume that there exists a totally convex function f with respect to which each T(w,.) is relatively nonexpansive. We show that under some additional quite unrestrictive conditions the algorithm x(k+1)=Integral(T(w,x(k))dw) with x(0) in C, converges to an almost common fixed point of the operators T(w,.). This fact applies to solving variational inequalities associated to some nonlinear optimization problems

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TH1-C-CO2

Generalized Convexity Criteria, Convex Transformability and Global Optimization

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Keywords: approximation algorithms - convex transformability - graph interpretation - interpolation - quasiconvexity - second order criteria

Generalized convexity (quasiconvexity, pseudoconvexity) criteria for various classes of differentiable functions are established. These classes are characterized by the property that the known necessary second order quasiconvexity condition (namely, positive semidefiniteness of Hessian on a subspace)

is also sufficient. The special attention is given to sums of linear fractional functions (SLFF). The results are extended to the class of functions which can be represented as ratio of polynomials of several variables. Thus the known quasiconvexity criteria for quadratic and cubic functions are generalized. A simplified representation of quasiconvex SLFF is obtained; this allows to describe the new classes of quasiconvex SLFF. An interpretation of SLFF in terms of orientate graphs is found fruitful; this allows to suggest a classification of quasiconvex SLFF. The results are generalized for the case of homogeneous functions. Moreover, quasiconvexity property is shown for the function given by sum of SLFF and product of linear functions. The problem of convex transformability is studied. Namely, for SLFF some classes of convex transformable functions (under either range transformation or both domain and range transformation) are extracted.

An iterative algorithm for global optimization of monotone compositions (sums, products) of generalized convex functions is suggested. The special attention is given to the case of composition of two and three functions. The efficiency of the algorithm are studied and some modifications (using interpolation or approximation of a curve in "Image space") are suggested.

TU3-C-CO122

A Limited Memory Symmetric Rank-One Method

Byrd Richard H.

University of Colorado

Xuehua Lu

Keywords: limited memory methods - unconstrained optimization

In this talk we consider an algorithm for unconstrained optimization using a limited memory SR1 approximation to the Hessian of the objjective. Because of possible indefiniteness of this approximation we use a trust region strategy. We use a compact form of the limited memory rank-one matrix which allows us to exctly solve the trust region problem very efficiently. However, to get good performance from this method, we find it is necessary to modify the SR1 matrix to make it positive definite near the solution. We show why such a modification is essential with limited memory SR1.

FR1-V-CM106

Use of Combinatorial Optimization to Improve pon Clearing and Settlement of Large-Value Payment Systems

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Banco de Mexico

Romero David - Solis Francisco

Keywords: integer programming - knapsack problem - large-value payment system

Clearing and settlement of payments are instances of the process that allows interbank payments to occur. The most common example is a check clearing house where every night each bank delivers to its counterparts their checks collected through its tellers. The clearing house then nets the bilateral debts determined by the banks to obtain a zero-sum vector whose entries represent the debits and credits to be made to the banks in the settlement stage. Usually, the settlement is made against the accounts hold by the banks at the settlement bank. Esentially the same process is followed to clear and settle the payments brought through electronic interbank payment systems working under a multilateral netting system. There are, however, some interbank payment systems where no credit is allowed to the banks and each payment is made in real time without netting.

The work dealt with here is an intermediate solution between the two procedures mentioned. An integer programming model was devised in the form of a flow network, whose nodes correspond to banks, and for each payment there is an arc with flow either zero or the payment amount.

The nature of the real problem allows any good approximation to be very useful. Our first approach uses then linear programming relaxation and approximates its fractional solution to an integer one by solving several knapsack problems with a Martello-Toth algorithm. Also, a greedy-like heuristic was implemented for this problem. The relaxation approach proved to be best most of time, but not always. Therefore, the final software implementation to solve the clearing and settlement problem incorporates both methods. This software will be used in the large-value payment system of Mexico, starting this year.

TH3-C-CO2

Generalized Concavity in Multiobjective Programming

Cambini Alberto

University of Pisa - Department of Statistics and Applied Mathematics

Martein Laura

Keywords: generalized concavity - optimality conditions - vector optimization

In this talk we present the fundamental ideas and results related to the role played by generalized concavity in stating sufficient optimality conditions, in studying local and global efficiency, in finding relationships between local efficiency and efficiency along feasible directions, and in establishing the connectedness of the efficient point sets.

TH3-C-CO2

Nonsmooth Generalized Concave Scalar Functions

Cambini Riccardo

University of Pisa - Department of Statistics and Applied Mathematics

Keywords: generalized concavity

The aim of this talk is to present some results regarding to generalized quasi-concave nonsmooth functions. The absence of any continuity hypothesis allow us to introduce three more classes of quasi-concave type functions; the inclusion relationships among the various quasi-concave type classes of functions are studied and the differences among the classes themselves are fully characterized. A comparison of these results with others given in the literature is also provided.

WE3-K-CM106

Variable Neighbourhood Search for Extremal Graphs

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École polytechnique de Montréal

Hansen Pierre

Keywords: automated system - conjectures - extremal - graph - refutations

Finding extremal graphs for expressions involving one or more invariants is viewed as a problem of global optimisation. The recent Variable Neighbourhood Search metaheuristic is used to solve it. Neighbourhoods are defined by addition, removal or exchanges of edges, removal of pendant vertices and so forth. First results, obtained with the program Autographix are presented: three conjectures from Graffiti are refuted, other conjectures are sharpened and new ones proposed.

WE2-S-IN202

Sorting Permutations by Reversals through Branch-and-Price

Caprara Alberto

DEIS - University of Bologna

Lancia Giuseppe - Ng See-Kiong

Keywords: Eulerian cycle decompositions - branch and price - column generation - matchings - sorting by reversals

We consider the problem of *sorting a permutation by reversals* (SBR), calling for the minimum number of reversals transforming a given permutation of $\{1, \dots, n\}$ into the identity permutation. SBR was inspired by computational biology applications, in particular genome rearrangement. We propose an exact branch-and-price algorithm for SBR. A lower bound is computed by solving a linear program with a possibly exponential (in n) number of variables, by using column generation techniques. An effective branching scheme is described, which is combined with a greedy algorithm capable of producing near-optimal solutions. The algorithm presented can solve to optimality SBR instances of considerably larger size with respect to previous existing methods.

TU2-I-CM120

Exact and Heuristic Algorithms for the 2-Dimensional Vector Packing Problem

Caprara Alberto

DEIS - University of Bologna

Toth Paolo

The 2-Dimensional Vector Packing Problem (2-D VPP) is a generalization of the well-known Bin Packing Problem, where each item has 2 weights, and each bin has 2 capacities: the items have to be packed in the minimum number of bins so as to satisfy the capacity constraint for each weight. We describe new lower bounding and heuristic procedures, and exact algorithms based on both the branch-and-bound and the branch-and-prize approaches. Computational results on instances from the literature are presented.

TH3-H-CO22

Infinite Horizon Dynamic Games with Coupled State Constraints

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The University of Toledo

Haurie Alain

Keywords: differential games - existence of equilibrium - games with coupled constraints - strict diagonal convexity

We consider a class of noncooperative open-loop differential games defined over an infinite time horizon with decoupled controls. These games enjoy the so-called turnpike property under strict diagonal convexity assumptions. We investigate the case where a coupled state constraint is linking all the players in their strategy choices. Taking advantage of the asymptotic stability property of the class of differential games under consideration we define a relaxed asymptotic version of the coupled constraint and show how an equilibrium for an associated decoupled differential game, involving a common penalizing term for the asymptotic coupledconstraint, can be computed as a solution to the relaxed problem. Both discounted and undiscounted problems are considered. An application to the modeling of economic competition under a common environmental constraint is discussed.

WE1-G-IN11

Dual Decomposition in Stochastic Integer Programming

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Schultz Ruediger

Keywords: Lagrangean relaxation - branch and bound - mixed integer programming - stochastic programming

We consider a two-stage stochastic program with integer recourse where integer requirements may appear in both first and second stage. We assume the underlying distribution of the random parameter is finite and the problem is then equivalent to a large, block-angular (mixed-) integer program.

We present an algorithm based on a dual decomposition scheme and Lagrangian relaxation for solving the problem. Non-anticipativity constraints are introduced explicitly and then relaxed using Lagrangian multipliers. Due to the integer requirements, this procedure will in general lead to nonzero duality gaps. We show how Lagrangian duality and rounding heuristics can be used in a branch-and-bound procedure to yield good feasible solutions. The algorithm is finite in the pure integer case and various stopping criteria for the mixed-integer case are discussed.

The algorithm has been implemented and promising computational experience is presented for both pure and mixed-integer test problems, showing that the algorithm is capable of solving problems of considerable size.

TU4-N-CO15

Redundacny in Nonlinear Systems

Caron Richard J.

University of Windsor

Boneh Arnon - Antic Mirjana

Keywords: feasibility - nonlinear - redundancy

In this paper we examine the performance of Boneh's probablisitic "Set Covering Equivalence" approach to finding redundancy on systems of nonlinear equations. We will also examine various strategies for improvements in the collection of the sample points. Finally, we will show how the technique can simultaneously determine feasibility. The nonlinear sytems will be specified by quadratic constraints.

TH4-I-CM5

Separation and Lifting of TSP Inequalities

Carr Robert David

CARNEGIE MELLON UNIVERSITY

Keywords: inequalities - lifting - polytope - separation - traveling salesman problem

The problem of *separating* a class of TSP inequalities consists in devising a method that, given a fractional point x^* for a relaxation of the TSP, either finds an inequality in the given class of TSP inequalities that is violated by x^* or determines that there are no such violated inequalities. Both *heuristic* and *exact* efficient separation algorithms are sought after so that we can more easily solve TSP instances when using a cutting plane approach such as *branch-and-cut*.

We present efficient methods for exactly separating very large and generally defined classes of TSP inequalities. These inequality classes arise from a naturally defined procedure for *lifting* familiar TSP inequalities. These ideas came from analyzing the *cycle-shrink linear program*, which is a compact description of the *subtour relaxation* for the TSP.

TH1-I-CM5

Location of Semi-Undesirable Facilities. A DEA Approach

Carrizosa Emilio

UNIVERSITY OF SEVILLE

Conde Eduardo - Pascual Antonio

Keywords: DEA - location

Semiobnoxious facility location models are in essence bicriterion problems, since their aim is the simultaneous minimization of two types of costs, namely, environmental and operation costs.

Although such bicriterion problems have traditionally been scalarized by means of a linear utility function, we propose in this talk the use of the ratio (environmental impact utility / transportation costs), to be maximized in order to find an optimal location for p facilitites in a network, where location on edges is allowed.

Under some assumptions, (e.g. linear (dis)utilities in numerator and denominator), a node-optimality result is given, which reduces the resolution of the problem to a discrete one (e.g. the well-known plant location problem).

This result has strong implications when the weights used in the scalarization are not fixed in advance, since then a (standard) Data Envelopment Analysis can be used.

TH4-C-CO2

Locating un Undesirable Facility by Generalized Cutting Planes

Carrizosa Emilio

UNIVERSITY OF SEVILLE

Plastria Frank

Keywords: location - lower subdifferentiability

In this talk we address the problem of locating an undesirable facility within a compact set by minimizing a strictly decreasing boundedly lower subdifferentiable function of the squared Euclidean distances to a set of fixed points.

Using (generalized) cutting planes, the resolution of this problem is reduced to solving a sequence of maxmin problems. These maxmin problems have a clear geometrical interpretation, which enables to solve them sequentially by means of an on-line enumeration of the vertices of polyhedra in higher dimensions.

TH1-C-CO122

Dominators for Multiple-Objective Quasiconvex Maximization Problems

Carrizosa Emilio

UNIVERSITY OF SEVILLE

Plastria Frank

Keywords: global optimization - quasiconvexity - vector optimization

Given a nonempty compact subset S of $\Re^n$ and a function $F : S \subset \Re^n \longrightarrow \Re^k$, define the *multiple-objective* problem (MP),

$$\max_{x \in S} F(x) \qquad (MP)$$

which seeks those alternatives "maximizing" the components of F.

The most popular solution set associated with (MP), namely, the set of *Pareto-optimal* solutions to (MP), lacks of desirable properties such as being closed, and its exact determination may be a hard task. For this reason a number of solution concepts associated with (MP), to be used as a manageable surrogate of it have been proposed in the literature.

In this talk we consider one of these surrogates, the concept of *dominator*, and show how to construct it in multiple-objective quasiconvex maximization problems by means of Branch-and-Bound schemes.

TU1-C-CO3

On the Asymptotic Behavior of some Hard Assignment Problems

Çela Eranda

TECHNICAL UNIVERSITY GRAZ

Burkard Rainer E.

Keywords: assignment problems - asymptotic behavior - communication tree

Some years ago it was shown that the quadratic assignmemt problem exhibits the following interesting asymptotic behavior: Under natural probabilistic constraints on the problem data, the ratio between the best and the worst value of the objective function approaches almost surely 1, as the size of the problem tends to infinity. We show that another hard assignment problem, the communication assignment problem on trees (CAP-T), exhibits the same asymptotic behavior and hence, becomes in a certain sense trivial as its size approaches infinity.

In the CAP-T we are given a tree and a number of communicating centers together with their matrix of communication rates. The communicating centres are to be located at the nodes of the tree, and the communication between each two centers is to happen along the path joining the corresponding nodes in the tree. Our goal is to find an assignment of the centers to the nodes of the tree which minimizes the maximum of the overall intermediate traffic going through the communicating centers. Computational results on test problems suggest that even "small" instances of CAP-T, say with 50 centers, tend to become trivial in the sense that the ratio between the optimal and the worst value of the objective function gets close to 1.

WE3-A-IN2

OCTANE: A New Heuristic for Pure 0-1 Programs

Ceria Sebastián

Columbia University

Balas Egon - Dawande Milind Wasudeo - Margot François - Pataki Gábor

Keywords: heuristics - integer programming - local search

OCTANE, which stands for OCTAhedroN Enumeration, is a new heuristic for pure 0–1 programs, which finds feasible integer points by enumerating extended facets of the octahedron, the dual of the unit hypercube. We give efficient algorithms to carry out the enumeration, and explain how our heuristic can be embedded in a branch-and-cut framework. Finally, we present computational results on a set of pure 0–1 programs from MIPLIB.

TH3-A-IN1

MIPO: A Mixed Integer Programming Optimizer

Ceria Sebastián

Columbia University

Pataki Gábor

Keywords: disjunctive programming - integer programming - mixed integer models - software - valid inequalities

MIPO is a Mixed Integer Programming Optimizer that implements a branch-and-cut method for solving mixed-integer programs. It allows for the incorporation state-of-the-art tools for cutting plane generation. MIPO uses a flexible interface to allow testing of the different alternatives that are available in a branch-and-cut solver. The code is designed to solve general problems, with no particular combinatorial structure. In MIPO, the user has the choice of using different classes of state-of-the-art cutting plane generators, including disjunctive cuts, lifted-cover inequalities, and valid inequalities for simple mixed-integer sets. Computational results with pubicly available test problems will be reported. Many researchers are part of this project. In particular, Pasquale Avella, Egon Balas, Gérard Cornuéjols, Hugues Marchand, Fabrizio Rossi, Joao Soares and Laurence Wolsey, play an important role in the development of MIPO and its components.

TU1-N-CO15

Sensitivity Analysis in Discrete Optimization: a Survey

Chakravarti Nilotpal

Indian Institute of Management Calcutta

The talk will provide a summary of known results on sensitivity analysis in discrete optimization, as well a survey of ongoing research and future research directions.

WE2-I-CM120

Efficient Vertex-Generation for a Class of Generalized Network Polyhedra

Chang Yaw

UNC-Wilmington, Dept of Mathematical Sciences

Keywords: generalized network - vertex enumeration

A *generalized network* is a network with arc flow subject to multiplicative factors. The characterization of a vertex for a generalized network polyhedron is known as a *one-tree* (a tree with an additional arc forming one cycle). In this paper, we will present a "forbidden configuration" characterization for the vertices of a class generalized network arising in ecosystem development. We will also present a general algorithmic approach to exploiting this property in vertex-generation together with computational experience.

TU3-U-IN10

Simplex and Interior Point Specialized Algorithms For Solving Non-Oriented Multicommodity Flow Problems

Chardaire Pierre

University of East Anglia - School of Information Systems

Lisser Abdel

Keywords: decomposition - interior point methods - multicommodity network flow models - simplex

Multicommodity network flow models arise in a wide variety of contexts typical amongst which is the dimensioning of telecommunication networks. We present various approaches based on specialization of the simplex algorithm and interior-point methods to solve non-oriented multicommodity flow problems. Algorithms are tested with data from the France-Telecom Paris district transmission network.

First, we focus on specialization for the node-arc formulation of the problem. Primal simplex and Dual Affine Scaling algorithms exploiting the particular structure of the constraint matrix are presented and compared. Numerical results are provided for problems up to more than 800,000 constraints and more than 4,000,000 variables.

However, much more powerful approaches based on specialized decomposition methods can be implemented for solving the problem. A Dantzig-Wolfe decomposition method is designed and compared with a specialized implementation of the Analytic Center Cutting Plane Method (ACCPM). Partitioning techniques are used to exploit the structure of the master programs involved in those methods.

WE3-F-IN203

Optimal Control of a Deep Tow Vehicle by an Interior-Point Method

Chauvier Laurent

INRIA

Gilbert Jean Charles

Keywords: BDF formula - algebraic partial differential equations - discretization - interior point methods - optimal control - sea exploration

We consider the problem of controlling an immersed vehicle that is tethered to a cable towed by a vessel. This kind of system is used to explore the bottom of the ocean, so that the cable may be several thousand meters long.

When the speed of the vessel is given, one can integrate the algebraic partial differential equations governing the evolution of the cable-vehicle system, using discretization schemes in space (based on a variational formulation of the problem) and time (BDF formula).

An optimization problem arises when one tries to find the speed of the vessel in order to bring the towed vehicle from one state (position, velocity, and acceleration) to another in a minimum time. In this problem the final time is minimized subject to the equality constraints coming from the discretization of the model equations. Constraints on the position of the vehicle must also be taken into account, because of the presence of natural obstacles, such as the relief of the sea bed. These inequality constraints act on the state variables.

A nonlinear interior point algorithm is used to solve this inequality constrained problem.

WE2-P-IN201

Optimal Periodic Replacement Strategy for Non Self-Announcing Failure Systems

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Université Laval

Ait-Kadi Daoud

Keywords: maintenance - reliability - stochastic process

This work is motivated by the study of randomly failing systems whose failure is not self-announcing. Such systems should be inspected to determine if they are still operating or present some form of failure. In many situations, due to a lack of technological and human resources, it is impossible to perform the inspection. A periodic replacement strategy is then appropriate for such situations. We propose a periodic replacement model which suggests to replace the system at specified times T, 2T, 3T, ... regardless of its state. The corresponding mathematical model is presented and conditions for existence of an optimal replacement period T are established. The model considers replacement costs as well as the inactivity cost associated to the elapsed time between failure and replacement. For a given set of these costs and for a given equipment life time distribution, a numerical algorithm which generates the optimal replacement period is also presented.

MO4-E-CO21

A Global and Local Superlinear Continuation-Smoothing Method for $\mathbf{P}_0 + \mathbf{R}_0$ and Monotone NCP

Chen Bintong

Washington State University

Chen Xiaojun

Keywords: continuation method - nonlinear complementarity problems - smoothing

We propose a continuation method for a class of nonlinear complementarity problems (NCPs), including the NCP with a P_0 and R_0 function and the monotone NCP with a feasible interior point. The continuation method is based on a class of Chen-Mangasarian smooth functions. Unlike many existing continuation methods, the method follows the non-interior smoothing paths, and as a result, an initial point can be easily constructed. In addition, we introduce a procedure to dynamically update the neighborhoods associated with the smoothing paths, so that the algorithm is both globally convergent and locally superlinearly convergent under suitable assumptions. Finally, a hybrid continuation smoothing method is proposed and is shown to have the same convergence properties under weaker conditions.

TU2-B-CO11

On Newton's Method for Huber's M-Estimation Problems in Robust Linear Regression

Chen Bintong

Washington State University

Pınar Mustafa Celebi

Keywords: Huber M-estimation - Newton method - finiteness - overdetermined linear systems

The Newton method of Madsen and Nielsen [BIT 30, pp. 682–699, 1990] for computing Huber's robust M-estimate in linear regression is considered. The original method was proved to converge finitely for full rank problems under some additional restrictions on the choice of the search direction and the step length in some degenerate cases. It was later observed that these requirements can be relaxed in a practical implementation while preserving the effectiveness and even improving the efficiency of the method. In the present paper these enhancements to the original algorithm are studied and the finite termination property of the algorithm is proved without any assumptions on the M-estimation problems.

MO3-P-IN201

Scheduling of Multiprocessor Tasks

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Keywords: approximation algorithms - multiprocessor tasks

- polynomial algorithm - scheduling

We consider the following problem: Given a set of identical parallel processors, we face a number of independent requests for processing tasks. Each request is characterized by a multiprocessor task with (a) its required processing period, (b) required number of processors for the whole period, and (c) the corresponding profit of processing the task. The objective is to decide which requests to accept so as to maximize the total profit subject to the constraint that the total number of available processors is fixed.

The problem of scheduling multiprocessor tasks is equivalent to providing a channel reservation service and a rental service. The problem is also closely related to that of cutting rectangles and of switching tools. While the scheduling problem is generally NP-hard, in this paper, we provide polynomial algorithms for solving various special cases, identify their relations to maximizing a submodular function. We also provide a polynomial time approximation scheme for an interesting restricted version of the problem.

WE2-E-CO21

On Homotopy-Smoothing Methods for Variational Inequalities

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Ye Yinyu

Keywords: homotopy - smoothing approximation - variational inequalities

A variational inequality problem with a mapping $g : \Re^n \to \Re^n$ and lower and upper bounds on variables can be reformulated as a system of nonsmooth equations $F(x) = 0$ in $\Re^n$. Recently, several homotopy methods, such as interior-point and smoothing methods, have been employed to solve the problem. All of these methods use parametric functions and construct perturbed equations to approximate the problem. The solution to the perturbed system constitutes a smooth trajectory leading to the solution of the original variational inequality problem. The methods generate iterates to follow the trajectory. Among these methods Chen-Mangasarian and Gabriel-Moré proposed a class of smooth functions to approximate F. In this paper, we study several properties of the trajectory defined by solutions of these smooth systems. We propose a homotopy-smoothing method for solving the variational inequality problem, and show that the method converges globally and superlinearly under mild conditions. Furthermore, if the involved function g is an affine function, the method finds a solution of the problem in finite steps. Preliminary numerical results indicate that the method is promising.

TU2-N-CO15

Computer Tools for Analyzing Infeasible Mathematical Programs

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Keywords: formulation assistance - infeasibility

Mathematical programs have grown larger and more complex as computing power has grown cheaper and solution algorithms have improved. Unfortunately, it can be extremely difficult to diagnose the causes of model faults in such large and complex models. Infeasibility is an especially serious model fault. The paper covers algorithmic approaches to isolating the causes of infeasibility in mathematical programs, including LPs, NLPs, and MILPs. Variations of these techniques now appear commercially in the LP solvers CPLEX, LINDO, and OSL

TU3-N-CO15

New Software: a Requirements Analysis

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Keywords: formulation - mathematical programming - software

Recently developed software which assists in the process of formulating and understanding mathematical programs is a good start towards the goal of an intelligent mathematical programming system, but there is a long way to go. The paper briefly summarizes the state of the art in software for such purposes, then analyzes the requirements for new software.

WE4-A-IN2

Minimum Cost Multi Level Network Design

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J.L. Kellogg Graduate School of Management

Tsai Chih Yang

We consider the problem of designing networks where facilities of multiple types are available and higher grade interconnections are required for certain critical nodes. The problem is modeled on an undirected graph whose nodes are partitioned into L levels. Each edge of the network is allowed one of L different facility types, with higher grade facilities requiring higher non-negative fixed costs. We transform the problem to a Steiner tree problem on a directed graph and show this formulation to be stronger than those previously considered. We use a branch and cut approach to solve fairly large problems on a PC. Computational results are reported.

WE3-P-IN201

Maximum Value Job Shop Scheduling

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Hall Nicholas G. - Guignard Monique

Keywords: Lagrangean relaxation - branch and bound - job shop - scheduling - time-indexed formulation - valid inequalities

Consider a job shop where sufficient resources to complete all jobs may not be available. We maximize the value of jobs accepted and scheduled in this environment, where each job has its own value, ready time and due date. We show that this problem is unary *NP*-hard. The problem is modeled using time-indexed variables. Good value solutions are found by a greedy heuristic. The solution of Lagrangean relaxation subproblems by dynamic programming provides upper bounds. We introduce a class of valid inequalities, called makespan inequalities, derived from bounds on the makespan for subsets of jobs and machines, and include these inequalities with the relaxed constraints. Our computational results indicate that the introduction of these inequalities generates significantly improved upper bounds. For a class of these inequalities, we provide conditions which are both necessary and sufficient to define a facet of the convex hull of integer solutions. These inequalities are used in a branch and bound algorithm, which can solve to optimality problem instances with up to 10 machines and 10 jobs. The results demonstrate that time-indexed formulations with the addition of makespan inequalities can be effective in a job shop environment.

WE3-E-CO21

Frictional Contact Algorithms Based on Semismooth Newton Methods

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Pang Jong-Shi

Keywords: Newton method - complementarity problems - frictional contact - interior point methods - semismooth equation

In this work, we establish that the discrete, three-dimensional, quasistatic, small-displacement, elastic-body frictional contact problem can be formulated as a system of semismooth equations. We give two such formulations, one unconstrained (i.e., no additional restriction on the variables of the equation) and the other constrained (that is, with additional nonnegativity constraints on some variables). A potential reduction Newton method for solving a constrained semismooth equation is developed and its convergence is established. This method is applied to the two formulations of the frictional contact problem and experimentally tested on several realistic contact problems with over 400 contact nodes. The numerical results demonstrate that the unconstrained formulation yields far superior performance than the constrained formulation.

TH4-U-IN10

A Column Generation Approach for an Inventory Pickup and Delivery Problem with Time Windows

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Nygreen Bjørn

Keywords: branch and bound - column generation - integer programming - inventory management - routing

We are focusing the solution approach of an Inventory Pickup and Delivery Problem with Time Windows (IPDPTW). The problem involves the design of a set of minimum cost routes for a fleet of bulk ships which service a set of harbours one or more times during the planning period. At each harbour we are faced with an inventory management problem.

The resulting MIP-problem decomposes into a subproblem for each ship and a subproblem for each harbour. We use column generation to solve the continuous problem, where new ship route- and harbour columns are generated by DP. The overall problem is solved by branch-and-bound, where new columns are generated in each node in the search tree.

The system is successfully used to solve real instances of the ship planning problem.

WE3-G-IN11

Bilevel Stochastic Optimization in Truss Topology Design

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PRISM, Université de Versailles, and Ecole Polytechnique

Patriksson Michael - Wynter Laura

Keywords: bilevel programming - robust truss topology design - stochastic programming

We consider the problem of calculating a robust truss design while optimizing an additional objective, such as cost minimization. The problem is formulated as a nonlinear stochastic bilevel optimization problem. We present a descent algorithm with very favourable parallellization capabilities for the generation of a design fulfilling the first-order optimality conditions of the problem. Numerical results and analyses are presented.

WE2-S-IN202

Solving Weighted Betweenness Problems in Physical Mapping by Branch-and-Cut

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Universität Heidelberg

Jünger Michael A. - Kececioglu John - Mutzel Petra - Oswald Marcus - Reinelt Gerhard

Keywords: betweenness problem - branch and cut - computational biology - linear ordering problem - physical mapping of chromosomes

A fundamental problem in computational biology is the construction of physical maps of chromosomes from hybridization experiments between unique probes and clones of chromosome fragments in the presence of error. A maximum-likelihood model yields the objective to find an ordering of the probes that minimizes a weighted sum of errors. This model can be formulated as a weighted betweenness problem.

In this talk two IP formulations of the weighted betweenness problem are presented. In one approach an ordering is constructed by making use of the PQ-tree algorithm for testing for the consecutive ones property.

Low-dimensional polytopes associated with the problems are discussed. Their facet defining inequalities are (partially) identified in a separation procedure that is based on a heuristic for the quadratic assignment problem. Computational results show that our approach of identifying optimum rather than approximate solutions in the maximum-likelihood model via branch and cut is superior to a transformation to a Hamming Distance TSP, which is widely done in biological practice.

FR4-F-IN203

Dynamic Programming Techniques to

Solve Real Life Cutting Stock Problems
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Université de Technologie de Troyes

Keywords: cutting stock problem - dynamic programming - heuristics

In this paper, real life cutting stock problems arising in steal companies are considered. These problems involve new concepts not yet studied in the literature such as tolerance and packet. Cutting stock problems are among the first combinatorial problems studied in operations research. However, no methods are available to solve our problems in hand which involve one dimensional rod cutting and two dimensional coil cutting problems. One dimensional rod cutting problems can be optimally solved by dynamic programming approach which leads to combinatorial algorithms which are not appropriate in real life environments. By slightly modifying the definition of states, the problem can be approximately solved using a modified dynamic programming approach. In this approach, the initial problem is decomposed into several subproblems involving a cutting problem in a given rod. It has been shown in traditional trim loss minimization problem without additional constraints, the subproblems can be optimally solved in pseudo-polynomial time. This paper shows that it is also the case even with real life concepts such as tolerance. Computational results on real life data show that the algorithms yield effective solutions. This idea is expected to be able to be adapted to two dimensional coil cutting problems in which not only the trim loss should be minimized but also the changeover of cutting tools. The general idea will be presented.

TU1-P-IN201

Minimizing Total Tardiness: Analysis of a Heuristic
Chu Chengbin

Université de Technologie de Troyes

Keywords: equivalence - heuristics - scheduling

This talk addresses the single machine scheduling problem to minimize total tardiness. This problem has received much attention from researchers, not only because of its theoretical interest but also because of the importance of this criterion in many real life environments, in manufacturing systems, for instance. For this problem, Wilkerson and Irwin propose an algorithm using pairwise exchange idea. This algorithm (called WI) has been considered to be effective. We show that the computational complexity of this heuristic is exponential. Furthermore, it gives the same schedule as a polynomially bounded heuristic (called algorithm S) which dynamically applies the rule proposed by Smith. This result significantly simplifies the description and the implementation of the algorithm. Computational results show important savings in computation time and thus confirm the theoretical analysis. By slightly changing the tie-breaking policy without increasing the computational complexity, we can further improve the performance of algorithm S. However, there is a counter-example which shows that the performance can not always be improved, despite the fact that computational results suggest it.

FR2-F-IN203

Comparing Different Boundary-Value Problems for Solving a Complicated Trajectory Optimization Problem
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Techn. Univ. München

Keywords: trajectory optimization

State constrained optimal control problems play an important role in aerospace engineering as well as in other applications. There exist a number of efficient and competitive direct and indirect solution algorithms. Advantages of the indirect method are the computation of precise numerical solutions and the availability of a large set of a posteriori inequality tests to discard nonoptimal solutions. Long standing disadvantages of the indirect method are moreover today eliminated: The cumbersome task of generating the costate equations can be performed by symbolic computation. The costates can be estimated by applying a suitable direct collocation method. A hybrid approach, a combination of a direct and an indirect method, combines the advantages of both methods.

For state constrained optimal control problems exist a family of related necessary optimality conditions. They yield different boundary-value problems (bvp) which can be solved by multiple shooting. Up to now, usually one formulation was used, due to advantages in deriving the needed formulas by hand. But from a numerical point of view, one should use the set of necessary optimality conditions which yield the best conditioned boundary-value problem. In order to get a feeling of the conditioning of these different boundary-value problems, we compare them for the first time for a complicated trajectory optimization problem. We use a range maximization of a supersonic aircraft subject to a dynamic pressure limit.

We will discuss the numerical results of this complicated example in detail (e.g. there exist some well-conditioned bvps which can be solved very easily as well as severly ill-conditioned bvps which cannot be solved) and derive some general observations and suggestions: If some crucial handling in the formulation of the boundary-value problem is performed, then the indirect solution method (as well as the hybrid method) is a competitive solution method for real-life problems.

TU3-I-CM120

A Mathematical Model for Finding the k Most Vital Arcs in the Shortest Path Problem
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Ahn Jaegeun - Park Soondal

Keywords: 0-1 programming - k-mva(k most vital arcs) - shortest path

This paper deals with a mathematical model and an algorithm for the problem of determining the k most vital arcs in the shortest path problem.

First, we propose a 0-1 integer programming model for finding the k most vital arcs in the shortest path problem given the ordered set of paths with cardinality q. Next, we also propose an algorithm for finding the k most vital arcs in the shortest path problem which uses the above 0-1 integer programming model and shortest path algorithm and maximum flow algorithms repeatedly.

Malik et al. proposed a nonpolynomial algorithm to solve the problem, but that algorithm was contradicted by Bar-Noy et al. with a counter example to the algorithm in 1995. But using our algorithm, the exact solution can be found differently from the algorithm of Malik et al..

WE2-I-CM5

A New Paradigm for Finding Cutting Planes in the TSP

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Rutgers University

Applegate David - Bixby Robert Eugene - Cook William J.

Keywords: traveling salesman problem

A traditional paradigm for finding cutting planes in the TSP is this: having identified classes of linear inequalities (such as comb inequalities or clique-tree inequalities) that are satisfied by all tours, one designs "separation algorithms" for each individual class and finally applies these algorithms to an optimal solution of the current LP relaxation of the TSP instance. We shall present another way of finding cutting planes, which does not fit this paradigm; preliminary computational experience with its implementation is encouraging.

WE2-K-CM106

Artificial Ants to Find Bounded Length Cycle in a Network

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DEI - Politecnico di Milano

Triozzi Marco

In this paper, we consider the problem of finding a network connecting n nodes (users, cities, ...) such that the overall cost, given by the sum of the connection costs, is minimum and the network is reliable enough. We describe here some heuristics descending from a new computational paradigm called Ant System, a "naturalistic" approach simulating the behaviour of an ant colony. In analogy with real ants, we built an artificial system, using it as an optimization tool to find reliable networks. One of these heuristics get the best known results with strong constraint when applied to a real case (the Belgium network): the heuristic seems to be an effective way to solve the given problem. In our problem, we splitted the reliability condition in two constraints: 1) between every pair of nodes there must be at least two paths without common nodes (or common edges); 2) every edge of the solution must belong to an elementary cycle whose length is constrained, so to decrease the probability a second breakdown happens in the same area of the first one.

MO3-B-CO10

Block-Iterative Outer Approximation Methods for Convex Programming in Banach Spaces

Combettes Patrick L.

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Keywords: block-iterative - constrained minimization - convex programming - cutting plane methods - outer approximation - projection - reflexive Banach space - subgradient - surrogate constarints - uniformly convex function

Problem Statement. The goal of this paper is to unify and extend a wide class of outer approximation methods for constrained minimization problems and to propose numerically efficient block-iterative implementations of these methods. The problem under consideration is to minimize a proper lower semicontinuous convex function J over the nonempty intersection S of an arbitrary family of closed and convex sets $(S_i)_{i\in I}$ in a real reflexive Banach space B. It is assumed that, for some $u \in S$, $C = \{x \in B \mid J(x) \leq J(u)\}$ is bounded and that J is uniformly convex over C.

Algorithm. Let K denote the class of all closed and convex subsets of B. The nth iteration is as follows: Given $x_n \in B$ and $D_n \in K$ such that $S \subset D_n$ and x_n minimizes J over D_n, take a finite block of indices $I_n \subset I$ and a set $H_n \in K$ such that $\bigcap_{i\in I_n} S_i \subset H_n$; Let x_{n+1} be the minimizer of J over $D_n \cap H_n$ and take $D_{n+1} \in K$ such that $S \subset D_{n+1}$ and x_{n+1} minimizes J over D_{n+1}.

Results. Under mild assumptions on the control sequence $(I_n)_{n\geq 0}$ and the cuts $(H_n)_{n\geq 0}$, we show that every orbit $(x_n)_{n\geq 0}$ of the above algorithm converges strongly to the minimizer x^* of J over S. By judiciously choosing the sets $(D_n)_{n\geq 0}$ and $(H_n)_{n\geq 0}$, we derive from this result the convergence of various well-known schemes (e.g., cutoff algorithms, cutting-plane algorithms with nonbinding cuts dropping strategies, Haugazeau's constraints disintegration algorithm and its extensions) and of their parallel block-iterative generalizations. We also obtain an efficient and flexible algorithm by constructing, on the one hand, D_n as a Haugazeau-like half-space defined via a subgradient of J at x_n and, on the other hand, H_n as a surrogate half-space based on approximate (linearized) projections onto the sets $(S_i)_{i\in I_n}$. Numerical results are provided to illustrate the benefits of this algorithm in large-scale signal recovery problems.

MO4-B-CO10

Coupling of the Proximal Point Algorithm with Approximation Methods

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Keywords: convex optimization - penalty and viscosity methods - proximal point algorithm - steepest descent

We present recent results on the convergence of a diagonal process for solving a convex minimization problem of the form

$$(P) \qquad \min\{f(x) : x \in \mathbf{R}^n\}$$

where $f(\cdot)$ is a closed proper convex function.

The method combines a proximal point iteration with an approximation scheme in which problem (P) is replaced by a sequence of better behaved approximating problems

$$(P_r) \qquad \min\{f(x,r) : x \in \mathrm{R}^n\}$$

where $r > 0$ is a parameter controlling the degree of approximation of $f(\cdot, r)$ with respect to $f(\cdot)$.

For conveniently chosen sequences of approximation parameters $r_k \to 0$ and Prox penalty parameters λ_k, the method

recursively computes the sequence $\{x_k\}$ by solving

$$(Prox) \qquad \frac{x_k - x_{k-1}}{\lambda_k} \in -\partial f(x_k).$$

An implementable version allowing an inexact solution of this inclusion will also be considered.

Convergence of the whole sequence $\{x_k\}$ towards a particular optimal solution of (P) is established under two complementary sets of assumptions, depending on the speed at which $f(\cdot, r_k)$ approaches $f(\cdot)$: either r_k is assumed to go to 0 sufficiently *fast* or this convergence is supposed to be sufficiently *slow*.

We give a precise mathematical meaning to the terms *fast* and *slow*, and we illustrate the applicability of these conditions by considering some specific approximation schemes coming from penalty methods in linear and nonlinear programming, as well as regularization methods for nonsmooth minimax problems.

TU3-D-CO124

Central Trajectories for a Class of Penalty Methods in Convex Programming

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Auslender Alfred - Haddou Mounir

Keywords: hierarchical optimization - penalty methods - viscosity solution

The central path associated with the logarithmic barrier function has become a central theme in mathematical programming, particularly in connection with interior point methods and their polynomial complexity. This central path enjoys very nice geometric and analytic properties which have been extensively studied in recent years.

On the other side, a host of barrier and penalty methods for mathematical programming have been proposed in the literature, covering specially structured as well as general convex programs. These include inverse barriers, inverse and log shifted barriers, entropic barriers, exponential penalties, hyperbolic penalties, and other very appealing methods.

With the aim of obtaining a better understanding of their geometric aspects, and to shed some light on the specificities of the log-barrier, we present a unifying theory for studying the existence, uniqueness and asymptotic behavior of central paths associated with these barrier/penalty methods. More precisely, given a convex program

$$(P) \qquad \min\{f_0(x) : f_i(x) \leq 0, i = 1 \ldots m\}$$

we consider a one parameter barrier/penalty scheme of the form

$$(P_r) \qquad \min \ f_0(x) + r\sum_{i=1}^{m} \theta(f_i(x)/r)$$

where $\theta(\cdot)$ is a strictly convex and increasing *penalty function* and $r > 0$ is a *penalty parameter* controlling the degree of approximation.

Under extremely weak conditions,we prove that (P_r) gives rise to a unique optimal trajectory $x(r)$, which converges towards a particular optimal solution x^θ of the original problem (P) as $r \to 0$. Moreover, we show that x^θ may be characterized as the unique solution of a natural hierarchy of minimization problems associated with (P) and $\theta(\cdot)$.

The results are valid for linear and (convex) quadratic programs, and more generally for problems involving convex analytic functions. In particular, the asymptotic properties of the log-barrier remain valid for analytic programs.

We illustrate the general results through several penalty methods, paying special attention to the exponential penalty trajectory.

TH1-I-CM121

A Class of Weakly Bipartite Graphs

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Universita di Padova

Gerards Bert

A signed graph (G, Σ) consists of an undirected graph G together with a collection Σ of its edges. We consider the binary clutter of circuits of G that meet Σ an odd number of times. A conjecture of Seymour that characterizes the binary clutters that are ideal, implies that this clutter is ideal if and only if (G, Σ) does not contain $(K_5, E(K_5))$ as a "minor". We show that if (G, Σ) does not contain $(K_5, E(K_5))$ and three other configuratons, each containing a $K_{3,3}$, then the clutter of odd circuits of (G, Σ) is ideal.

TH2-C-CO2

An ℓ_1 Penalty Function Approach to the Nonlinear Bilevel Programming Problem

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Keywords: nonlinear bilevel programming - penalty function

The nonlinear bilevel programming problem is a constrained optimization problem defined over two vectors of unknowns, x and y. Feasibility constraints on (x, y) include the requirement that y is a solution of an inner optimization problem, which is parameterized by x. The bilevel problem is very difficult to solve, and few algorithms have been published for the nonlinear problem. Therefore, instead of solving the bilevel problem directly, a "simpler", related problem is solved. This problem is defined by replacing the solution constraint in the bilevel problem with a set of conditions which must be satisfied at a minimum point of the inner problem.

The resulting one level mathematical program is solved using an exact penalty function technique. The penalty function subproblems are solved within a trust region framework, and specialized techniques are developed to overcome difficulties due to the nondifferentiabilities. The algorithm has been proven to converge to a minimum point of the penalty function. Numerical results will be presented.

FR4-V-CM106

Sequantial Importance Sampling of Dynamic Stochastic Programmes Using EVPI Criteria

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Dempster Michael A. H.

Keywords: dynamic stochastic programs - expected value of perfect information - sequential sampling

The talk will outline progress in developing a sequential sampling procedure for sampling large scale dynamic recourse problems based on expected value of perfect information importance criteria. Software providing a serial implementation of both full and marginal EVPI criteria will be described and numerical experiments with large scale strategic portfolio management problems presented.

FR1-L-CM201

A General Quadratic Penalty Lagrangean Decomposition Algorithm in Non-Convex Optimization

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Keywords: large scale optimization - nonlinear programming

In this paper we propose a quadratic penalty lagrangean decomposition algorithm for solving general non-convex differentiable constrained optimization problems. This algorithm combines an extension-projection decomposition strategy with a partial quadratic augmented penalty relaxation strategy, in order to solve large scale optimization problems. The resulting strategy takes advantage of any separable structure present in the original optimization problem. In particular, in the presence of linear structured constraints, this general technique may be combined with the classical barycentric or tangential linearization techniques for solving structured convex problems. The convergence of the resulting general algorithm is assured under quite mild local optimality conditions. Also, different asymtotically optimal rules for the exterior Method of Multipliers are considered. These rules are crucial for assuring the convergence of this same algorithm in practical situation.

WE1-A-IN2

A Framework for the TSP

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Keywords: TSP - integer programming

We describe the implementation of a linear-programming based, branch-and-bound algorithm for solving the traveling salesman problem and discuss some implications for the solution of general integer-programming problems. This talk is based on joint work with David Applegate, Robert Bixby, and Vašek Chvátal.

WE3-A-IN2

BC-OPT, a Branch & Cut Code For Mixed Integer Programs

Cordier Cécile

C.O.R.E. - U.C.L.

Marchand Hugues - Laundy Richard - Wolsey Laurence Alexander

Keywords: MIPLIB3.0 - branch and bound - branch and cut - computational results - cutting plane methods

We present *bc-opt*, a Branch & Cut code for Mixed Integer Programs based on Xpress' Optimisation Subroutine Library, XOSL. It includes several cut routines (lifted cover inequalities for knapsack constraints and for surrogate constraints, flow cover inequalities, Gomory cuts, etc.) as well as improved branching features (specific node selection, reduced cost fixing, use of local or global cuts in tree, etc.).

We give an overview of the code together with some computational results on both the MIPLIB 3.0 test set and some real world instances.

FR2-C-CO123

Smooth Normal Approximation of Epi-Lipschitzian Subsets of $\Re^n$

Cornet Bernard

UNIVERSITÉ DE PARIS 1

Czarnecki Marco

Keywords: approximation algorithms - epi-Lipschitzian - homeomorphism - lipeomorphism - normal convergence - smooth

The paper studies the "normal convergence" of subsets of $\Re^n$. A sequence (M_k) of closed subsets of $\Re^n$ converges "normally" to $M \subset \Re^n$ if (i) $M = \limsup M_k = \liminf M_k$ in the sense of Painlevé-Kuratowski and (ii) $\limsup \mathrm{G}(N_{M_k}) \subset \mathrm{G}(N_M)$, where $\mathrm{G}(N_M)$ [resp. $\mathrm{G}(N_{M_k})$] denotes the graph of Clarke's normal cone N_M [resp. N_{M_k}].

We mainly show two results. The first one states that every compact epi-Lipschitzian subset M of $\Re^n$ can be approximated by a sequence of "smooth" sets (M_k), which among other properties converges normally to M. The second result shows that, if a sequence (M_k) of closed subsets of $\Re^n$ converges "normally" to an epi-Lipschitzian set M, and if we additionally assume that the boundary of M_k remains in a fixed compact set, then, for k large enough, the sets M_k and M are lipeomorphic (i.e., the homeomorphism between M and M_k and its inverse are both Lipschitzian).

In Cornet-Czarnecki [6], direct applications of these results are given to the study (existence, stability...) of the "generalized" equation $0 \in f(x^*) + N_M(x^*)$ when M is a compact epi-Lipschitzian subset of $\Re^n$, et $f : M \to \Re^n$ is a continuous map (or more generally a correspondence).

WE3-B-CO10

On the Stability of General Convex Programs and Variational Inequalities

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Auslender Alfred

Keywords: nonsmooth optimization - stability

We extend for nondifferentiable data and variational inequalities the Gauvin's theorem that gives necessary and sufficient

conditions to have bounded multipliers. We show the equivalence between the stability of the primal problem and a regularity notion. We also study the closedness and uniform boundedness of the primal and dual solutions sets under perturbations.

FR4-U-IN10

Solving the Shortest Edge Disjoint or Capacited Undirected Paths Problems

Costa Marie-Christine

Cedric, CNAM, Paris

Salmon Genevieve

The edge disjoint paths problem is, given an undirected graph G=(V,A) and K pairs of vertices of G, to decide if there are K mutually edge disjoint paths of G linking the pairs. The problem is known to be NP-complete. Let us consider lengths associated with each edge of A. The problem of finding K edge disjoint paths with a minimum total length is at least as difficult as the edge disjoint paths problem so it is a NP-hard problem. Now let us add capacities uij imposed on any edge [i,j] of A. The shortest capacited paths problem (SCPP) is to find K paths linking K given pairs of vertices of G with a minimum total length and such as an edge [i,j] of A belongs to no more than uij paths. If we put all the uij to 1, the SCP problem becomes a shortest disjoint paths problem; so (SCPP) is NP-hard too.

SCP problems may arise in a wide variety of application contexts. Our study has been made at EDF demand to optimize the laying of cables in a power plant.

We modelize the SCP problem as a 0-1 linear program including capacity constraints and paths constraints. We propose a heuristic method based on a penalty system to solve it. Then we study Lagrangean relaxations of one or the other set of constraints to get lower bounds. We prove that the first Lagrangean relaxation is equivalent to the continuous relaxation and that the second relaxation is at least as good as the first one (it proved to be much better in practice). Finally, we present experimental results: the small size of the duality gaps proves the efficiency of both the heuristic and the bound. We solve instances, heuristic and bound, until 100 vertices, 5,000 edges, 300 pairs to link and a low maximal capacity on the edges.

WE2-A-IN1

On Dodging Degeneracy in Linear Programming

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Stanford University

The oldest techniques for addressing the theoretical problem posed by degeneracy in linear programming have been with us nearly as long as the simples algorithm itself. Alternative devices for handling degeneracy have also cropped up from time to time.

This expository talk combines LP duality theory and quadratic programming methodology to show that if one is willing to deal with a large enough system and tolerate the phenomenon called "stalling";, then a simplex-like (pivoting) algorithm can handle degenerate linear programs using absolutely no special precautions to prevent cycling. The ideas involved are not entirely original, and the algorithm can hardly be recommended in practice; nevertheless, the approach integrates a set of valuable concepts and has a quaint, academic charm to boot.

WE4-K-CM106

Parallel Tabu Search for Network Design

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Gendreau Michel - Toulouse Michel

Keywords: multi-threads cooperative strategies - network design - parallel computing - tabu search

We study parallel tabu search procedures for fixed cost, capacitated, multicommodity network design formulations. We focus on cooperative multi-thread strategies that asynchronously communicate improving solutions. These pool of solutions thus obtained may be viewed as an elite solution set from which good elements may be returned to individual search processes. Moreover, various operations may be performed on the pool set to determine improved solutions. We describe the parallel method and examine its behaviour under several parameter settings, number of processors, communication structures and pool management policies. We also briefly describe hybrid approach where an evolutionary method is applied to the pool population and asynchronously exchanges with the parallel tabu method. Experimental results indicate that cooperative parallel tabu search obtains very good solutions to design problems after a relativelly small computation effort.

WE2-I-CM121

Shellable Hypergraphs, Boolean Functions and Reliability Computations

Crama Yves

Université de Liège

Boros Endre - Ekin O. - Hammer Peter L. - Kogan Alex - Ibaraki Toshihide

A hypergraph $\mathcal{H} = (\mathcal{V}, \mathcal{E})$ is called *shellable* if there is a linear ordering $E_1, E_2, \ldots, E_m$ of its edges with the property that, for all $1 \leq i < k \leq m$, there exists $j < k$ such that $\{x\} = E_j \setminus E_k \subseteq E_i \setminus E_k$. Shellability is a well-established concept in the theory of simplicial complexes and matroids. In reliability theory, it has also been shown to play an interesting algorithmic role: indeed, if $\mathcal{H}$ is shellable, then the probability that a random subset of vertices of $\mathcal{H}$ contain at least one edge can be efficiently computed (whereas the same problem is NP-hard for arbitrary hypergraphs). The complexity of recognizing shellable hypergraphs, however, remains unknown. In this talk, we present some new results about shellability. First, we clarify the relationship between shellable hypergraphs and certain orthogonal expressions of Boolean functions. Next, we show that all minimal transversals of a shellable! hypergraph can be listed in polynomial time. Finally, we prove that recognizing whether $\mathcal{H}$ satisfies the so-called *lexico-exchange property* (a strengthening of shellability) is NP-complete.

WE1-C-CO2

Invexity and Optimal Control

Craven Bruce D.

University of Melbourne

Keywords: invex

For a constrained minimization problem in infinite dimensions, in particular an optimal control problem, the attainment of a minimum follows if necessary Lagrangian conditions - Karush-Kuhn-Tucker or equivalently Pontryagin - are solvable, provided that a suitable invex hypothesis holds. Conditions when this holds are analysed. Duality results are also obtained, where part of the constraint system describes a curved (hyper-) surface, and the invex property is assumed on that surface.

TU1-T-CO22

Mail Stream Optimization: Mathematical Programming in Direct Marketing

Crowder Harlan P.

IBM Consulting Group

Mail stream optimization (MSO) involves selecting sales promotions over time forcustomers with purchasing histories in order to maximize total profit for directmarketing organizations. In this talk we address the MSO problem description, the suite of linear and integer optimization models that solve MSO, and the MSO implementation on a parallel supercomputer.

WE4-C-CO122

Multisection in Interval Methods for Global Optimization

Csendes Tibor

Jozsef Attila University

Markot Mihaly Csaba - Csallner Andras Erik

We investigated the algorithmic and theoretical effects and consequences of multisection in both the Moore-Skelboe and the Hansen algorithms, i.e. the algorithm variants that subdivide the actual interval into many (3, 4 or more) parts instead of the traditional bisection. According to the theoretical results studying the worst case behaviour, the convergence speed is the lower the larger the multisection we apply. An extensive numerical test has been made to study the changes in efficiency. This shows in contrast to the theoretical results that multisection can improve the efficiency of interval global optimization algorithms by as much as 15% in terms of CPU time needed and objective function evaluations. This could be achieved at the cost of slightly larger memory complexity. According to the present results, the most promising is to use multisection into 3 subintervals applying it together with the direction selection rules C, B or E.

FR2-L-CM201

Constrained Two-Dimensional Cutting Stock Problems and the BOB library

Cung Van-Dat

Lab. PRISM, Univ. Versailles Saint-Quentin en Yvelines

Hifi Mhand - Le cun Bertrand

In this talk, we propose a parallel version of the improved Viswanathan and Bagchi algorithm for Constrained Two-Dimensional Cutting Stock problems (CTDC). The BOB library which is easily applied to other combinatorial optimization problems has been used for the implementation.

Viswanathan and Bagchi have proposed a bottom-up algorithm which combines in the nice tree-search procedure Gilmore and Gomory's algorithm, called at each node of the tree, for solving exactly the CTDC problem. The improved version of this algorithm is one of the better known exact algorithms today. We propose to greatly enhance the improved algorithm by introducing: (1) one-dimensional bounded knapsacks in the original algorithm and dynamic programming properties to obtain good lower and upper bounds, (2) three different types of duplicate detection and (3) an efficient data structure for the main list of the algorithm, namely the CLOSE list. These modifications lead to significant prunings in the search tree.

In the parallel implementation, as the algorithm uses a CLOSE list for generating and storing best subproblems which is unsual in Branch-and-Bound algorithms, we propose to distribute this list and broadcast each generated node over the set of processors used.

The presented algorithm is tested on a number of hard problem instances of the literature.

FR3-I-CM121

The Optimal Path-Matching Problem

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University of Waterloo, Dept. of C & O

Geelen James Ferdinand

Keywords: matchings - matroid - polyhedra

We present a common generalization of weighted matching and weighted matroid intersection, and give results that imply most of the important results (polynomial-time algorithms, totally dual integral polyhedral descriptions, min-max theorems) for the two special cases. We also give some new applications.

Here is the framework for the generalization. Let T_1 and T_2 be disjoint stable subsets of vertices of a graph $G = (V, E)$, let R denote $V \backslash (T_1 \cup T_2)$, and let M_1, M_2 be matroids on T_1, T_2 respectively. A *basic path-matching* is a set of vertex-disjoint paths of G joining a basis of M_1 to a basis of M_2, together with a perfect matching of the vertices of R not in any path. (In the case where the T_i are empty, it is just a perfect matching of G, and in the case where R is empty and G consists of nothing but a perfect matching, it amounts to a common basis of M_1 and M_2.)

WE3-E-CO21

Generalized Newton Method for Nonsmooth Nonsymmetric Operators

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Ecole polytechnique fédérale de Lausanne

Alart Pierre

Keywords: augmented Lagrangian - friction - nonsmooth

analysis - unilateral contact

Unilateral contacts with friction between elastic and/or plastic solids undergoing large transformations occur in many branches of applied mechanics such as material forming, vehicle crash or biomechanics. The corresponding problems can be concisely formulated as finding the minimum of the incremental energy of the system subject to coupled contact and friction inequality constraints. Such problems can be reformulated as finding the unconstrained minimax of a differentiable quasi-augmented Lagrangian (the prefix "quasi" emphasizes the lack of a genuine functional due to the nonsymmetric coupling between contact and friction). The stationarity conditions for a saddle point of this Lagrangian form a set of nonsmooth and nonsymmetric equations involving primal solid displacements and dual contact forces. The solution of these equations may not be unique for large coefficients of friction. A generalized Newton method for nonsmooth equations introduced ten years ago has proved one of the most efficient and robust algorithm for solving this set of equations. Although no general proof of global convergence has been established so far, a collection of partial results has been gathered over the last decade in the small displacement case: convergence in at most 2 to the power (c-1) iterations (in contrast with 2 to the power c for Lemke's LCP algorithm), where c is the number of contact constraints, in the frictionless case; convergence for the single contact frictional case . A selection of these convergence results will be discussed together with a new convergence proof of a nonlinear Gauss-Seidel variant of Newton's method which opens similar perspectives for other variants.

TU3-C-CO3

Smooth Representation of Epi-Lipschitzian Subsets of $\Re^n$

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CERMSEM, Université de Paris 1

Cornet Bernard

Keywords: approximation algorithms - epi-Lipschitzian - generalized equation - normal cone - normal convergence - representation - smooth sets

Closed epi-Lipschitzian subsets M of $\Re^n$ are characterized as sets defined by a Lipschitzian inequality constraint $\{x \in \Re^n | f(x) \leq 0\}$ for some function $f : \Re^n \to \Re$ which is Lipschitzian on $\Re^n$ and smooth on the complementary of ∂M (the boundary of M), which satisfies, for every $x \in \partial M$, both the "nondegeneracy" condition $0 \notin \partial f(x)$ (Clarke's subdifferential), and the "normal representation" condition that $N_M(x)$ (Clarke's normal cone) is the cone spanned by $\partial f(x)$.

This characterization result allows us to deduce directly that the sequence of smooth sets: $M_k = \{x \in \Re^n | f(x) \leq -1/k\}$ [resp. $M^k = \{x \in \Re^n | f(x) \leq 1/k\}$], defines an internal [resp. external] "normal" approximation of the compact epi-Lipschitzian set M in the sense that (i) $M = \limsup M_k = \liminf M_k$ in the sense of Painlevé-Kuratowski and (ii) $\limsup \mathrm{G}(N_{M_k}) \subset \mathrm{G}(N_M)$, where $\mathrm{G}(N_M)$ [resp. $\mathrm{G}(N_{M_k})$] denotes the graph of the normal cone N_M [resp. N_{M_k}] (See Cornet-Czarnecki for more properties of normal approximation and convergence).

In Cornet-Czarnecki, applications of these results are given to the study (existence, stability...) of the "generalized" equation $0 \in f(x^*) + N_M(x^*)$ when M is a compact epi-Lipschitzian subset of $\Re^n$, and $f : M \to \Re^n$ is a continuous map (or more generally a correspondence).

FR1-I-CM120

The 2-Hop Spanning Tree Problem and Associated Polytopes

Dahl Geir

University of Oslo

Consider a graph G with a specified root node r. A spanning tree in G where each node has distance at most 2 from r is called a "2-hop spanning tree" (with root r). For given nonnegative edge weights the "2-hop spanning tree" problem is to find a minimum weight 2-hop spanning tree. The problem is NP-hard and has some interesting applications. We present two different integer linear programming problems, associated polytopes and their relations. Some classes of facets are introduced and a complete linear description is obtained for a class of graphs. This is done by developing some results for a class of stable set polytopes.

TH4-I-CM120

Approximation of Piecewise Linear Functions and Constrained Shortest Paths

Dahl Geir

University of Oslo

Realfsen Bjornar

Piecewise linear functions (of one variable) are often used to approximate complex functions or geometrical objects in e.g. computer aided geometric design, cartography and computer graphics. An important problem is to approximate such a function by a simpler one with few breakpoints. This problem may be viewed as a cardinality constrained shortest path problem in a certain acyclic directed graph. We study some properties of polytopes associated with this constrained path problem: vertices, adjacency and integrality for an interesting class of graphs. Based on the results a combinatorial algorithm for solving the problem is developed. Computational results on realistic approximation problems are presented and comparison to e.g. Lagrangian relaxation and dynamic programming based algorithms is given.

WE3-C-CO122

Further Insight Into the Convergence of the Fletcher-Reeves Method

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Institute of Computational Mathematics and Scientific/Engineering Computing

Yuan Ya-xiang

Keywords: conjugate gradient - generalized linesearch - global convergence - unconstrained optimization

Assume that the generalized Wolfe or the generalized Armijo line search is used. Then two conditions are given, which can ensure the convergence of the Fletcher-Reeves Method under a general assumption on the function. An example is constructed to show that the two conditions are also tight in certain senses. Since our anayses is very original, and as a result those already-existing results are included by our results, this paper can be regarded as an overview on the convergence properties of the Fletcher-Reeves Method.

WE1-C-CO2

On the Connectedness of the Efficient Set for set-valued maps

Daniilidis Aris

University of the Aegean

Keywords: connectedness - efficient sets - multivalued maps - vector optimization

We deal with the topological properties of the efficient set in a multivalued vector optimization problem. We consider set-valued maps with values in a normed space ordered by a closed, convex, pointed cone. Using convexity and continuity properties of the multivalued function, we prove a general theorem concerning the connectedness of the efficient set. Our final statements strengthen similar results of the area.

WE2-A-IN1

Some Memories of the Golden Years at RAND

Dantzig George B.

Stanford University

The Golden Years at RAND took place during the 1950's. These were exciting times when many of the fundamental ideas of Operations Research were first proposed and developed by members of the Mathematics, Computer Science, and Economics Divisions of RAND and its coterie of distinguished visitors. Dick Bellman developed Dynamic Programming; Ray Fulkerson developed Network-Flow Theory; LLoyd Shapley developed Game Theory; Harry Markowitz developed Portfolio Theory (that later led to his receiving the Nobel Prize in Economics); Bill Orchard-Hays developed the first practical codes for solving Linear Programs; Alan Manne and Harry Markowitz developed Process Analysis type models for the petroleum and metal working industries, and Philip Wolfe developed his famous Algorithm for solving Quadratic Programs.

Opening Session, Monday 25, 9:30, Metropole

How Linear Programming First Began

Dantzig George B.

Stanford University

Not only is this the 50th anniversary of the Simplex Algorithm, it is also the 50th anniversary of the discovery of the Linear Program. Of the two, the Linear Program is the more important because it provides a general framework for formulating many planning and scheduling problems in mathematical terms and because it is the first-order approximation of the more general class of problem, the Mathematical Program. I will recall some tales about some of the early pioneers of our field.

WE3-W-CO15

An Algorithm for Estimating the Degree of Dependence between Two Random Vectors

Darbellay Georges A.

Academy of Sciences

Estimating statistical dependencece from data is not easy, except if one restricts one's attention to linear dependences. In this work, we describe a new algorithm for estimating linear and nonlinear dependences from a set of N data points in $\mathcal{R}^d$. Both conditional and unconditional dependences can be measured. We derive the algorithm from Dobrushin's information theorem. Essentially, the algorithm looks for and finds a supremum over partitions of $\mathcal{R}^d$. We show, through simulations, that this algorithmic estimator is nearly as accurate and precise as the usual coefficient of linear correlation (or the coefficient of multi-linear correlation for $d \geq 3$). It appears that this estimator is asymptotically unbiased, and that it is, for a large class of probability densities, $\sqrt{N}$-consistent. Our experiments further suggest that Gaussian densities are optimal in the sense that they describe the most linear statistical relationship. In other words, we are lead to surmise that, under the constraints of fixed variances and covariances, Gaussian densities achieve the lowest possible degree of statistical dependence.

FR3-B-CO10

Prox-Regularized Primal-Dual Method with Constraint Aggregation

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Moscow State University, Faculty of Numerical Math. & Cybernetics

Keywords: constraint aggregation - convex programming - primal-dual methods - proximal methods - regularization

In the talk a prox-regularized, primal-dual, constraint-aggregated method for convex programming problems is presented. The purpose of constraint aggregation is to relax the original constraint set thus simplifying the problem. Convergence of the constraint aggregation method is ensured by adding the prox-regularizing term and either making the multiplier at this term tend to infinity or making the stepsize tend to zero. However, this poses a problem since the number of iterations needed to obtain an accurate solution may be very big even though each iteration is very simple. Nevertheless, this difficulty is overcome by incorporating the regularized constraint aggregation in the primal-dual iteration process. This is the subject of the present talk. The idea of the approach is to compromise between simplicity of solution of the auxiliary subproblem and preserving good convergence properties of the classical Lagrange multipliers techniques. The resulting method allows an explicit solution of the subproblem in many special cases. which makes it applicable to large scale optimization. On the other hand, one does not have to make the parameters tend to zero or infinity. Moreover, with the standard assumptions of Lagrange regularity, it is proved that the distance function to any primal-dual solution is decreasing. This implies that the method is convergent to an optimal point. Another attractive feature of the method is a convinient measure of the closeness of current solution approximation to a solution. This measure may serve as an aposteriori stopping criterion for the method. Results about rate of convergence will also be discussed.

TU2-A-IN2

Inference-based sensitivity analysis for mixed integer/linear programming

Dawande Milind Wasudeo

Carnegie Mellon University

Hooker John N.

There is no widely used method of sensitivity analysis for mixed integer/linear programming MILP. We propose a method that appears to be practical and useful for at least moderately sized problems. It is derived from the idea of inference duality. The inference dual of an optimization problem asks how the optimal value can be deduced from the constraints. In MILP, a deduction based on the resolution method of theorem proving can be obtained from the branch-and-cut tree that solves the primal problem. One can then investigate which perturbations of the problem leave this proof intact. On this basis it is shown that, in a minimization problem, any perturbation that satisfies a certain system of linear inequalities will reduce the optimal value no more than a prespecified amount. One can also give an upper bound on the increase in the optimal value that results from a given perturbation. The method is illustrated on two realistic problems. This is joint work with John Hooker.

WE1-P-IN201

A Scheduling Problem with Special Ordered Sets: A Polyhedral Approach

de Farias Ismael Regis

IBM Corporation

Johnson Ellis - Nemhauser George

Keywords: branch and cut - integer programming - scheduling - special ordered sets

We study a scheduling problem that arises in manufacturing for which the concept of Special Ordered Sets of type II appears naturally in its formulation. We derive three non-trivial families of facet-defining valid inequalities, and show that they cut off all infeasible vertices of the set of feasible solutions of its LP relaxation. We also give the complete facetial description for a particular case, and show that the separation problems for these families of inequalities are NP-complete. We then use one of these families of inequalities as cuts in a branch-and-cut scheme, and report computational results

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TH3-D-CO124

Primal-Dual Affine-Scaling Methods for Semidefinite Programming

de Klerk Etienne

Delft University of Technology, Department SSOR

Roos Cornelis - Terlaky Tamás

Keywords: affine scaling - primal-dual methods - semidefinite programming

Two primal-dual affine-scaling algorithms for linear programming (LP) are extended to semidefinite programming (SDP). The first algorithm is the Dikin-type affine-scaling method of Jansen et al., and the second the classical primal-dual affine-scaling method of Monteiro et al. The extensions of the respective algorithms have the same polynomial worst-case complexity bounds as their LP counterparts. Both SDP algorithms use the symmetric primal-dual scaling of Nesterov and Todd (the classical primal-dual affine-scaling method fails for some other choices of symmetrix primal-dual scaling). We also show how the analysis presented here may be used to formulate implementable versions of the algorithms.

WE1-T-CO22

A new model for ranking efficient units in DEA

De Leone Renato

Università di Camerino, Dipartimento di Matematica e Fisica

Merelli Emanuela

We present a variation of the classical DEA model that allows to discriminate among efficient units. The new model takes into account all the input and output values and allows to determine whether a unit is marginally efficient. This newly proposed formulation can be interpreted as a Lagrangian relaxation of the classical DEA problem. Computational results obtained using AMPL will be presented.

TH2-I-CM200

Exact solutions for the Maximum Edge-Weighted Clique Problem

de Souza Cid Carvalho

Universidade Esttadual de Campinas - Instituto de Computacao

Macambira Elder

Keywords: branch and cut - clique - edge-weighted - polyhedron

Given a complete graph G on n nodes with weights on the edges and an integer $k \leq n$, we look for a clique C in G whose sum of edge weights is maximum and such that $|C| \leq k$. We discuss on different integer programming formulations for the problem and investigate the facial structure of the polyhedron introducing new families of facet defining inequalities. Finally we describe our computational experiments with a branch-and-cut algorithm and compare our results with those appearing in the literature.

TU4-R-IN203

Minimizing the Length of Retangular Partitions: an Integer Programming Approach

de Souza Cid Carvalho

Universidade Esttadual de Campinas - Instituto de Computacao

Nogueira Claudio

Keywords: branch and cut - branch and price - computational geometry - restricted retangular partitions

Given a rectangle R in the plane and a set P of points in the interior of R, we want to partition R into smaller rectangles such that no point in P is interior to any rectangle of the partition. The goal is to minimize the sum of the lengths of the straight line segments defining the partition. Two different integer programming models are considered. In the first one the variables are associated to line segments and we investigate the polyhedron associated to this model. Facet defining inequalities are presented and computational results obtained by a Branch-and-Cut algorithm based on these inequalities are reported . The second model is based on a Set Partitioning formulation. A Branch-and-Prize algorithm for this model has been implemented and the results are compared with those obtained by the Branch-and-Cut algorithm.

TU4-R-IN203

Integer Programming Models for Minimum-Weight Triagulations

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Universidade Esttadual de Campinas - Instituto de Computacao

Nunes Aminadab

Keywords: branch and cut - column generation - computational geometry - minimum-weight traigulations

We consider the problem of finding a triangulation of a set of points P in the plane such that the sum of the lengths of the straight line segments in the triangulation is minimized. The computational complexity of this problem, denoted by MWTP, is still unknown for the general case. Our goal is to solve the problem to optimality and for this we make use of Integer Programming techniques. Two formulations are discussed. The first model explores the equivalence between the MWTP and a restricted version of the Minimum Weight Independent Set Problem. The variables are associated to the straight line segments between points in P. We propose to solve the problem with a Branch-and-Cut algorithm in which we use facet defining and strong valid inequalities of the Independent Set Polytope. In the second model we increase the number of variables which are now associated to triangles with vertices in P. We implement this model computationally via column generation techniques. For euclidean distances, the optimal solution of LP relaxation is quite often integer and no branching is necessary. The last algorithm outperforms the Branch-and-Cut one and allows us to solve instances for $|P| = 500$.

FR4-A-IN2

Cutting Plane Techniques for the Capacitated Vehicle Routing Problem

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Istituto di Analisi dei Sistemi ed Informatica - CNR

Rinaldi G.

Keywords: cutting plane methods - polyhedral combinatorics - vehicle routing

In the capacitated vehicle routing problem, a commodity has to be delivered to a set of clients according to their demands using a fleet of k trucks of equal capacity. The goal is to minimize of the total distance travelled by the trucks. Although the problem is pretty much like a minimum length k-TSP, the introduction of the capacity constraints makes it remarkably more difficult to solve to optimality. Actually, problem instances with 75 clients described in the literature have resisted to several attacks and, to the best of our knowledge, are still unsolved. We discuss separation techniques for some classes of inequalities of the linear system describing the polytope associated with the problem and give preliminary computational results.

TU2-I-CM200

Polyhedral Methods for Discrete Tomography

de Vries Sven

Graduiertenkolleg Mathematische Optimierung der Uni Trier

Gritzmann Peter

Keywords: discrete tomography - high resolution transmission electron microscopy - independence systems - polyhedral combinatorics

We focus on the algorithmic problem of recovering discrete lattice sets from their discrete X-rays. This problem is of fundamental importance in many practical applications. In particular, improvements in the interpretation and generation of high resolution transmission microscopy images lead to the problem of recovering crystalline structures with the knowledge of X-ray information for certain directions.

While the problem is known to be NP-complete if more than 2 X-rays are given, the algorithmic question, how to solve it in reasonable time, remains to be studied.

We introduce two linear programs to describe reconstruction-problems in discrete tomography:

$$\begin{aligned} &Ax = b,\\ &0 \le x \le 1,\\ &x \text{ binary;} \end{aligned}$$

and the (equivalent) maximization problem on its submissive:

$$\begin{aligned} \max &\sum x_i,\\ s.t. \quad & Ax \le b,\\ & 0 \le x \le 1,\\ & x \text{ binary.} \end{aligned}$$

The feasible region P of the second formulation turns out to be fulldimensional, while the decision problem, whether the first polytope is 0- or larger-dimensional given a single solution, is already NP-complete. We describe various families of facets of the *tomography polytopes P*.

To reduce the problem-size we propose an interior-point based strategy to fix variables.

For approximate results we use matroid based methods and a rounding strategy.

WE1-I-CM120

Polynomially Solvable Cases of the Quadratic Assignment Problems for Exponential Neighbourhoods

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Institute of Mathematics, Technical University Graz

Reva Vladimir Nikolaevich

Keywords: polynomially solvable cases - quadratic assignment problem - traveling salesman problem

Let $A = (a_{ij})$ and $B = (b_{ij})$ be the n x n matrices and let S_n is the set of all permutations of N=1,2,...,n. Consider the quadratic assignment problem (QAP):

$$\min_{P \subseteq S_n} \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} b_{s(i)s(j)}$$

We present a class of matrices A , B and set $P \subseteq S_n$ for which the QAP can be solved in polinomial time. The set $P \subseteq S_n$, so-called exponential neightbourhoods, have cardinality k!, where $k < n$. The travelling salesman problem as special cases of the QAP can be solved for the neigtbourhoods of cardinality more than $2[n/2]! + 3[n/3]! - 6[n/6]!$ and for any distance matrices.

FR3-I-CM120

Polynomially Solvable Cases, Exponential Neighborhoods and Heuristics for NP-hard Combinatorial Problems

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Institute of Mathematics, Technical University Graz

Keywords: combinatorial optimization - neighborhood - polynomially solvable cases - traveling salesman problem

For many years we have been investigating polynomially solvable cases of NP-hard combinatorial problems. The concept of exponential neighborhoods is a nice byproduct of these investigations. An *exponential neighborhood* is a large set of feasible solutions whose size grows exponentially with the input length. We are especially interested in exponential neighborhoods over which a given combinatorial optimization problem can be solved in polynomial time. Particularly, exponential neighborhoods for the traveling salesman problem (TSP) have been investigated. For some of them special conditions on a distance matrix have been formulated such that an optimal solution of the TSP belongs to these neighborhoods.

Some of exponential neighborhoods have a nice relationship with well-known algorithms. As an example we consider a double tree (minimum spanning tree) algorithm for the TSP. It was shown that the set of all tours that can be constructed by the double tree algorithm is nothing but an exponential neighborhood described by a special PQ-tree. An optimal tour in this neighborhood can be found in some cases in polynomial time. Particularly, for the Euclidean TSP the complexity of the algorithm is $O(n^3)$. Computational experiments showed that such a realization of the double tree algorithm is the best tour constructing heuristic among all ones investigated by G. Reinelt.

TU1-T-CO22

Managing the Environmental Costs of Closing US Army Bases

Dell Robert F.

Naval Postgraduate School

The United States Army is realigning or closing more than 100 installations, which contain more than 1900 sites needing some form of environmental clean-up. The Army will spend over \$1 billion in the next five years to clean up these sites. This talk describes an integer program developed to help the Army budgetfor the environmental clean-up of these sites.

WE3-C-CO2

Generalized PC^1-Functions and their Application to Bilevel Programming Problems

Dempe Stephan

Universität Leipzig

Unger Thomas

Keywords: bilevel programming - optimality conditions - parametric optimization

Bilevel programming problems are optimization problems where a part of the variables is restricted to be an optimal solution of a second, parametric optimization problem. If this second problem is not assumed to have a uniquely determined optimal solution for all values of the parameter, the bilevel problem is usually replaced by an auxiliary problem of minimizing a generally discontinuous function. Under certain assumptions, this function is a so-called generalized PC^1-function, i.e. it is composed by a finite number of continuously differentiable functions. For this class of functions, radial directional derivatives as well as radial subdifferentials can be defined. By use of these notions we are able to describe necessary and sufficient optimality conditions for minimizing a generalized PC^1-function. This theory is then applied to the original problem.

WE2-G-IN11

Sequantial Importance Sampling of Dynamic Stochastic Programmes Using EVPI Criteria

Dempster Michael A. H.

University of Cambridge, Judge Institute of Managament

Consigli Giorgio

Keywords: dynamic stochastic programs - expected value of perfect information - sequential sampling

The talk will outline progress in developing a sequential sampling procedure for sampling large scale dynamic recourse problems based on expected value of perfect information importance criteria. Software providing a serial implementation of both full and marginal EVPI criteria will be described and numerical experiments with large scale strategic portfolio management problems presented.

FR3-L-CM201

Parallel Solution of Large Scale Dynamic Stochastic Programmes

Dempster Michael A. H.

University of Cambridge, Judge Institute of Managament

This paper describes a master/slave parallel implementation of the nested Benders solution algorithm for the large scale certainty equivalent LP of a dynamic stochastic linear programme. In the context of financial asset/liability management, results are presented for multicomputer machines including workstation networks under PVM and IBM SP2 and Fujitsu AP3000 and VX/4 under MPI. These include wall clock time and speedup performance for both nodal and time period aggregated problems up to 3000 scenarios, as well as parallel performance on tasks associated with sequential sampling algorithms under development for financial planning problems.

WE4-E-CO11

A Primal-Dual Infeasible Newton Analytic Center Cutting Plane Method for Variational Inequalities

Denault Michel

Université McGill

Goffin Jean-Louis

Keywords: cutting plane methods - primal-dual interior point methods - variational inequalities

We will describe an interior-point analytic center cutting plane algorithm for monotone or pseudo-monotone variational inequalities with linear equality constraints.

The pseudo-monotone variational inequality problem translates naturally into a a feasibility problem given by a separation oracle, and thus can be solved by a cutting plane approach. The algorithm used is an infeasible primal-dual analytic center algorithm.

Extensions to correct or possibly incorrect quadratic cuts (using the diagonal of the Jacobian or the symmetrized Jacobian) will be described in the strongly monotone case. Encouraging numerical results about the use of quadratic cuts in the algorithm will be presented.

Convergence and complexity proofs will be discussed.

FR2-W-CO15

The CWP Object-Oriented Optimization Library: A Tool for Studying Optimization Problems

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Mobil Technology Company

Scales John

Keywords: object oriented software - optimization

A wide variety of problems in science can be thought of as solutions to optimization problems: the maximizing or minimizing of a function, possibly subject to constraints or penalties. We have developed the CWP Object-Oriented Optimization Library (COOOL) as a tool for studying problems related to optimization.

COOOL consists of a collection of C++ algebraic classes, a variety of optimization algorithms implemented using these classes, and a collection of analytical objective-functions, which can be used to test new algorithms. The object-oriented design of COOOL provides the flexibility of accessing any algorithm or objective function in the collection easily, as well as the easy extensibility by adding new components to the library. A user can also code a customized objective-function according to a simple input/output model — in any programming language. COOOL is able to communicate with such a user-provided objective function for obtaining function values as well as gradient information if this information is available to the user. In addition, COOOL facilitates the development of new optimization and linear-algebra algorithms because of the reusability of the codes inherited in the object-oriented philosophy.

The current version of COOOL can handle the user-specified ranges in model parameters and inequality constraints in optimization. The “soft” constraints can be coded into the penalty terms of the user-specified objective-function evaluation. Applications of COOOL to seismic inverse problems will be presented.

TU3-I-CM200

Algorithms and Complexity Issues for Combinatorial Optimization Games

Deng Xiaotie

City U of Hong Kong

Ibaraki Toshihide - Nagamochi Hiroshi

Keywords: algorithms - combinatorial optimization - complexity - cooperative games - core

We consider an integer programming formulation for a class of combinatorial optimization games, which includes many interesting problems on graphs. We present a theorem that the core is nonempty for this class of games if and only if a related linear program has an integer optimal solution. We completely study the relationship between related prime/dual linear programs for the corresponding games to be totally balanced, that is, the core is nonempty for the game of any subset of players. This also leads to an interesting connection with balanced matrices, those that guarantee integer solutions for a certain class of similar linear programs.

These theorem open the door to use techniques developped in combinatorial optimization for a large class of cooperative games. For example, it immediately allows us to extend the algorithmic result for finding imputations in the core of the network flow game on unit networks by Kalai and Zemel We further study the properties for conditions of these mathematical theorems to hold for several fundamental games on graphs, and apply these theorems to resolve algorithmic and complexity issues for their cores.

Opening Session, Monday 25, 9:30, Metropole

Optimization: An Essential Tool for Decision Support

Dennis John

Rice University

High performance computing in the early 90’s meant supercomputing. Now it means a workstation, and it soon will mean a PC. Consequently, there has been a huge increase in the amount of computing capability available and in the number of people with access to significant computing resources. However, this is just the most visible part of the revolution. Just as important, but less often mentioned, is the equally rapid pace of algorithm and software development.

Both these aspects of the computer revolution have meant that in an increasingly number of arenas a decision maker is able rapidly to simulate the implications of a decision by running sophisticated computer models. Spreadsheet software is a common rudimentary example of this process of obtaining rapid responses to "what-if?" questions, but so are simulations of the behavior of fluids in underground reservoirs, simultions of metal forming processes, aircraft and automobile driving simulators, etc.

The thesis of this talk is that optimization is poised to enter a golden age if mathematical programming researchers take up the challenge to design and implement tools to help the decision maker iteratively search for the most informative "what-if?" questions to ask until a sufficiently good outcome is predicted by the simulation. In a real sense, this is what optimization research has always been about. However, real world examples will be used to argue that there are significant non-traditional research questions to consider in this context.

MO4-T-CO22

Optimization using Surrogate Objectives
Dennis John

Rice University

Serafini David - Torczon Virginia J.

Keywords: novel applications

This talk is about some problems the speaker is working on during a sabbatical year at Boeing Information Support Services. This sabbatical has led to two PhD dissertations in preparations at Rice, and we gratefully acknowledge the sabbatical support of DOE and AFOSR. Although this will be a research talk, the speaker would be happy to discuss the sabbatical experience during the meeting.

We will give example problems from design, both for maintainability and for performance as well as an example from manufacturing process control. The Boeing team who collected these diverse examples and made the abstraction to a single problem class did what mathematicians do better than anyone else. We will outline the solution approach of a Boeing/IBM/Rice collaboration.

MO4-G-IN11

Differentiable Selections of Multifunctions and Asymptotic Behaviour of Random Sets
Dentcheva Darinka

Humboldt-University Berlin

Keywords: Castaing representation - Steiner center - delta-theorems - selection

Multifunctions defined on a linear normed spaces with closed convex images in a Banach space are considered. The aim is to construct selections, which are Hadamard-directionaly differentiable up to the second order using certain tangential approximation of the multifunction. The constructions preserve measurability and lead to a directionally differentiable Castaing representation of multifunctions admitting the required tangential approximation. A generalized set-valued delta-theorem for random sets in infinite dimensional spaces is presented. The results yield asymptotic distributions of measurable selections forming the Castaing representation of the multifunction. If the image space is finite-dimensional, Castaing representations by Steiner selections are constructed. In particular, random sets of this kind represent the solutions of two-stage stochastic programs with random right hand-sides subjected to perturbations.

FR4-I-CM5

Crew Pairing for a Regional Carrier
Desaulniers Guy

École Polytechnique and GERAD

Desrosiers Jacques - Lasry Arielle - Solomon Marius M.

Keywords: column generation - crew scheduling - regional carrier

We consider a set of five crew pairing problems for a regional carrier. These are solved by using an IP column generation process. Two network structures are compared for the generation of the feasible pairings and various parameter scenarios are examined. By grouping all the data, a 986-leg problem is created: we show that perturbation strategies allow for an accelerated solution process that is 60 times faster.

TH3-I-CM200

Solitaire Cones
Deza Antoine

Technion

Avis David

The classical game of Peg Solitaire has uncertain origins, but was certainly popular by the time of Louis XIV, and was described by Leibniz in 1710. The modern mathematical study of the game dates to the 1960s, when the solitaire cone was first described by Boardman and Conway. Valid inequalities over this cone, known as pagoda functions, were used to show the infeasibility of various peg games. In this paper we study the extremal structure of solitaire cones for a variety of boards, and relate their structure to the well studied metric cone. In particular we give:

1. an equivalence between the multicommodity flow problem with associated dual metric cone and a generalized peg game with associated solitaire cone;
2. a related NP-completeness result;
3. a method of generating large classes of facets;
4. a complete characterization of 0-1 facets;
5. exponential upper and lower bounds (in the dimension) on the number of facets;
6. results on the number of facets, incidence, adjacency and diameter for small rectangular, toric and triangular boards;
7. a complete characterization of the adjacency of extreme rays, diameter, number of 2-faces and edge connectivity for rectangular toric boards;
8. results on the boolean relaxation of solitaire cones.

MO3-C-CO3

An Approach to the Solution of NLP Problems Using an Exact Augmented Lagrangian Function

Di Pillo Gianni

Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza"

Lucidi Stefano - Palagi Laura

Keywords: augmented Lagrangian function - general constrained problems

We consider an approach to the solution of the (NLP) problem $\{\min f(x) : x \in \mathcal{F}\}$, where $\mathcal{F} = \{x \in \mathbb{R}^n : g_i(x) \leq 0, i = 1, \ldots, m\}$, with f and g twice continuously differentiable functions. The approach is based on the unconstrained minimization of a new exact augmented Lagrangian function $L_a(x, \lambda; \varepsilon)$, where $\lambda \in \mathbb{R}^m$ and ε is a penalty parameter. The function L_a is continuously differentiable, and has compact level sets; for sufficiently small values of ϵ, every minimum point (KKT point) of the original problem is a minimum point (stationary point) of L_a on $\mathcal{P} \times \mathbb{R}^m$ and conversely, where $\mathcal{P}$ is a given open subset containing $\mathcal{F}$; these strong exactness results hold even if $\mathcal{F}$ is unbounded, provided that f is coercive on $\mathcal{F}$. Due to the properties of L_a we are able to propose a descent algorithm globally convergent towards KKT pairs of the constrained problem. If the problem functions are three times continuously differentiable, the algorithm can be endowed with a superlinear rate of convergence by employing search directions obtained as the solution of simple linear systems not including third order derivatives. Numerical results are reported.

TH4-D-CO124

Acceleration of the Affine Scaling Method Convergence for Optimisation Problems of Thermodynamics

Dikin Ilya I.

Siberian Energy Institute

The paper presents and studies algorithms of searching for optimal and feasible solutions. Consideration is given to classical extremal problems of thermodynamics: minimization of the free Gibbs energy function and maximization of entropy. These interesting problems can be solved by the suggested algorithms of the affine scaling method. Here the vector of dual variables, that have an informal interpretation in both problems under investigation, is assigned to each interior feasible point. The authors have revealed reliable convergence of a sequence of dual variables to the dual problem solution. This experimental fact forms the base for devising and realization of effective ways to speed up convergence. The suggested simple formulas to improve an approximate solution allow the feasible solution and dual variables satisfying optimality conditions within a high range of accuracy to be obtained in a small number of iterations. The affine scaling method efficiency is demonstrated on the examples.

FR4-D-CO124

Determination of Interior Point of Linear System

Dikin Ilya I.

Siberian Energy Institute

Keywords: convergence - dual estimate - ellipsoid of the affine scaling method - interior point methods - potential function - two-sided inequalities

In order to determine a relatively interior point of a linear sistem in the form of equalities and two-sided inequalities an iterative algorithm is suggested. Here the next approximation belongs to an ellipsoid of the affine scaling method. Convergence of the sequences of primal variables and dual estimates is studied, a local potential function is applied. Besides, substantiation of the affine scaling method is achieved based on the results of convergence of the algorithm for searching the feasible vector.

TU2-E-CO21

A Comparison of MPEC Solvers Using New Interface Libraries

Dirkse Steven P.

GAMS Development Corporation

Ferris Michael C.

Keywords: GAMS - MATLAB - MPEC - bundle methods - interfaces - modeling

Although MPEC algorithms have received much attention in recent years, the algorithms have not matured to the point where they can all be compared on a well-known set of test problems. To enable such comparisons and foster the development of realistic MPEC models, we have added an MPEC model type to the GAMS language, constructed an interface library between so formulated models and MPEC solvers written in C or Fortran, and extended this interface library so that prototype solvers written in Matlab can access the model data. We will describe the interfaces and give computational results exhibiting how several existing MPEC codes solve problems from a growing model library.

TH2-C-CO3

Reverse Differentiation and Nonlinear Programming

Dixon Laurence Charles Ward

NOC, University of Hertfordshire

Christianson Bruce

Keywords: constraints - least squares - nonlinear programming - reverse differentiation

In Griewank (1989) it was shown that the gradient g of any scalar function f of a vector x can be obtained automatically in less than 3 times the number of arithmetic operations needed to calculate f independent of the dimension n of x. The automatic implementation of this result involves computational overheads that introduce multiplicative factors in the CPU times. Reverse differentiation can be implemented by skilful coding for any particular function without such overheads. In contrast the bound on the operations needed to calculate the Jacobian of a m dimensional vector function $s(x)$ will in general depend on m or n. Also if the calculation of the objective function, or the merit function in NLP. contains the solution of a set of linear equations in m dimensions requiring $O(m^3)$ operations then the equivalent calculation in the calculation of its gradient only needs $O(m^2)$ operations. In this lecture the implication of these 3 results will be explored for NLP and LS

optimisation. Very changed algorithms result.

TU4-C-CO3

Third Order Necessary and Sufficient Conditions in the Finite-Dimensional Extremal Problem with Constraints

Dmitruk Andrei Venediktovich

CEMI Russian Academy of Sciences

Keywords: Lagrange multipliers - critical variations - inequality constraints - necessary and sufficient conditions - second and third variations

In a finite-dimensional space we consider the general problem of nonlinear programming, with a finite number of equality and inequality constraints:

$$J = f_0(x) \to \min$$

$$f_i(x) \le 0, \quad i = 1, ..., s$$

$$g_k(x) = 0, \quad k = 1, ..., m$$

where all the functions are three times smooth in a neighbourhood of a point x_0, which is investigated to be a point of a local minimum in this problem. The collection of Lagrange multipliers is assumed to be unique, up to normalization. In the case when the second order condition holds in the nonstrict form (i.e. only the necessary condition is fulfilled, but not the sufficient one), we give necessary and sufficient conditions of the third order for a local minimum. These conditions, like those already known of the second order, constitute an adjoining pair with a minimal gap between them: the necessary condition transforms into sufficient one only by strengthening a third order homogeneous inequality. Due to the presence of inequality constraints in the problem, it is possible for the sufficient condition of the third order to be fulfilled (which is obviously impossible in case without inequality constraints).

WE3-F-IN203

Quadratic Order Conditions of a Weak, Pontryagin, and Strong Minima for Singular Extremals

Dmitruk Andrei Venediktovich

CEMI Russian Academy of Sciences

Keywords: Pontryagin minimum - necessary and sufficient conditions - quadratic order of estimation - strong minimum - weak minimum

For the control system linear in the control, a general optimal control problem is considered, involving terminal equality and inequality constraints, a terminal functional to be minimized, and the pointwise constraint on the control. The admissible control set U is convex, closed and solid. We examine a totally singular trajectory, assuming that the control lies in the relative interior of one and the same face U_0 of U. A difficulty in this case is that one cannot take two-side variations of the control, which are of crucial importance in obtaining higher-order optimality conditions for an interior control. The case $U_0 = U$ means that the reference control belongs to $intU$. We consider three types of minimum - the classical weak, strong, and an intermediate Pontryagin minimum, the last being an L_1-minimum with respect to control on any uniformly bounded control set. It allows one to take so-called needle-type variations of the control. We choose a special quadratic functional - the order of estimation - and give necessary and close to them sufficient conditions (adjoint pairs of conditions) of this order for a weak minimum, and separately for a Pontryagin minimum. The latter pair of conditions differs from the former pair only by an additional pointwise condition including coefficients of the third variation of Lagrange function and taking into account the admissible control set U (a new condition of Legendre type). In particular case, when U_0 is a singleton (e.g. when U_0 is a proper face of a strictly convex U), the quadratic-order sufficient condition for a weak minimum guarantees actually a strong minimum at the examined extremal. This theorem proved to be helpful in the problem of minimality of abnormal sub-Riemannian geodesics.

FR3-U-IN10

Optimal Scheduling of Cogeneration Plants

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Holmstroem Kenneth H.

Keywords: cogeneration - economic dispatch - heat water storage - nonlinear programming - unit commitment

A cogeneration plant, feeding its output water into a district heating grid, may include several types of energy producing units. The most important being the cogeneration unit, which produces both heat and electricity. Most plants also have a heat water storage. Finding the optimal production of both heat and electricity and the optimal use of the storage is a difficult optimization problem.

This paper formulates a general approach for the mathematical modelling of a cogeneration plant. The model objective function is non-linear, with non-linear constraints. Internal plant temperatures, mass flows, storage losses, minimal up and down times and time depending start-up costs are considered.

The unit commitment, i.e. the units on and off modes, is found with an algorithm based on Lagrangian relaxation. The dual search direction is given by the subgradient method and the step length by the Polyak rule II.

The economic dispatch problem, i.e. the problem of determining the units production given the on and off modes, is solved using a combination of dynamic programming and general purpose solvers. The model and algorithms are implemented in MATLAB.

TU2-A-IN1

On the Convergence of the Affine Scaling Algotiyhm in the Presence of Degeneracy

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Keywords: affine scaling - degeneracy - linear programming

The Affine Scaling algorithm, which was introduced by Dikin in 1967, is known to converge to the optimal solution subject to the conditions that the problem and its dual are both nondegenerate. Without any assumptions concerning degeneracy, Tsuchiya has since shown that the algorithm produces a sequence converging to an optimal solution provided the step lengths do not exceed two thirds of the distance to the boundary. More recently, Mascarenhas has produced an example showing that the sequence can converge to non-optimal solutions if the step lengths are too large. In this paper, we show that Mascarenhas's example cannot apply to a wide class of linear programming problems.

TH3-W-CO15

Modeling by Construction — an Example-Based Introduction

Dresbach Stefan

Ministry for Science and Research NRW

Keywords: modeling methodology - structured modeling

Models can be very helpful for solving economic problems. Especially quantitative models can support the process of decision-making. However, two questions arise: first, how can you construct a model that corresponds to reality and second, how can you solve the model?

Modeling by Construction answers the first question which is purely supported in a conceptual as well as in a technical way. In this abstract we focus on the conceptual dimension of such models that are not created for a special solving method like e.g. linear programmming.

Two main ideas are important to understand. First, model building is the art of describing problems. Therefore it is viewed as a creative act which needs constructive achievement and which is not only a mapping or snapshot of reality. Thus, model construction is a very complex task. Second, the complexity of this task is managed by the well known method of abstraction. It is based on the recently new developed "concept of independence".

Modeling by Construction consists of eight modeling levels which correspond directly to the concept of independence and can function as components of the modeling process. The role of these levels is demonstrated and explained by the help of examples. A graphical modeling language is proposed that is carefully suited to the levels.

Modeling by Construction is a methodology which is easy to use, problem-driven and management-orientated. It is a framework for a step-by-step conception. We do not consider it as a replacement of the way of Geoffrions's "Structured Modeling", but as a complementary approach to the difficult task of general decision model construction.

TH-am-SPO

Two Applications of the Divide and Conquer Principle in the Molecular Sciences

Dress Andreas W.M.

U. Bielefeld

Brinkmann G. - Perrey S.W. - Stoye Jens

In this note, two problems from the molecular sciences are addressed: the enumeration of fullerene-type isomers and the alignment of biosequences. We report on two algorithms dealing with these problems both of which are based on the well-known and widely used Divide&Conquer principle. In other words, our algorithms attack the original problems by associating with them an appropriate number of much simpler problems whose solutions can be "glued together" to yield solutions of the original, rather complex tasks. The considerable improvements achieved this way exemplify that the present day molecular sciences offer many worthwhile opportunities for the effective use of fundamental algorithmic principles and architectures.

FR4-H-CO22

Evolution with a Varying Stage Game: An Economic Approach to Mutational Models

Droste Edward

Tilburg University, Department of Econometrics

Tieman Xander

Keywords: Markov process - evolutionary game theory - mutation - replicator dynamics - simulation

We analyze an evolutionary model with both deterministic and stochastic mutation rates. We focus on changes in the underlying stage game, which is a coordination game, to generate short- or medium-run results. The model explores the implications of letting the payoff matrix and the stochastic mutations vary over time. It is shown that this speeds up convergence to the stationary state near the Pareto efficient equilibrium. Furthermore, the model is extended to allow for the endogenous expansion and contraction of the strategy space. To value the results properly we incorporate the well-known economic business cycle into the model.

TH1-P-IN201

Review of Linear Programming Models for Multiprocessor Task Scheduling

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Blazewicz Jacek

Keywords: linear programming - multiprocessor tasks - parallel tasks - scheduling

The classical scheduling theory assumed that a task requires for its processing one processor at a time. This postulate is recently rejected, especially in the context of modern multicomputer and multiprocessor systems. We call tasks requiring more than one processor at a time multiprocessor. In this work we review linear programming formulations for preemptive scheduling of multiprocessor tasks.

For scheduling on parallel processors we first consider the case of fixed number of processors to be used by a task. Schedule length and maximum lateness criteria are analyzed. A solution based on the concept of processor feasible set of tasks and linear programming is presented. A processor feasible set of tasks is a set of tasks that can be feasibly executed on the given processors. The algorithm is polynomial provided the number of processors is fixed.

When the number of processors used by a task can be changed during the run-time we consider tasks with sequential (i.e. executed by a single processor) starting and finishing parts, and unboundedly parallelizable central part. For this problem a method based on linear programming is presented. The procedure is polynomial-time provided we now the order of the starting times and completion times of different tasks' central parts.

For dedicated processors the set of simultaneously required processors is important rather than the number. We present linear programming formulations solving the problem of preemptive scheduling multiprocessor tasks on dedicated processors subject to maximum lateness also in the presence of time windows of the processor availability. This approach can be extended to the case of multiprocessor tasks which can be processed in multiple modes, i.e. by several alternative sets of processors. Again, this method is based on processor feasible sets and linear programming.

Results of some computational experiments on the proposed methods are presented.

FR1-W-CO15

A General Pre-processor for Nonlinear GAMS Models

Drud Arne Stolbjerg

ARKI Consulting & Development A/S

Keywords: modeling system - nonlinear programming - preprocessing

We describe a general purpose pre- and post-processor for nonlinear GAMS models, independent of and usable with most GAMS solvers. The pre-processor removes variables, changes constraints into bounds, aggregates or disaggregates constraints based on user options, adds domain bounds for nonlinear models, checks scaling, etc. It will also convert the models into a form that allows the interface to compute bounds on function values and derivatives. We report experiments with several large GAMS models.

WE-pm-CO2+3

Interactions between Nonlinear Programming and Modeling Systems

Drud Arne Stolbjerg

ARKI Consulting & Development A/S

Keywords: model definition - modeling system - nonlinear programming - preprocessing

Modeling systems are very important for bringing mathematical programming software to non-expert users, but few nonlinear programming algorithms are today linked to a modeling system. The paper discussed the advantages of linking modeling systems with nonlinear programming. Traditional algorithms can be linked using black-box function and derivatives evaluation routines for local optimization. Methods for generating this information are discussed. More sophisticated algorithms can get access to almost any type of information: interval evaluations and constraint restructuring for detailed preprocessing, second order information for sequential quadratic programming and interior point methods, and monotonicity and convex relaxations for global optimization. Some of the sophisticated information is available today; the rest can be generated on demand.

TH4-D-CO124

An Interior Point Algorithm For Minimum Sum-of-Squares Clustering

du Merle Olivier

GERAD, École des HEC

Hansen Pierre - Jaumard Brigitte - Mladenovic Nenad

Keywords: analytic center cutting plane method - column generation - minimun sum-of-squares clustering

An exact algorithm is proposed for partitioning a set of N entities into M clusters in order to minimize the sum of squared distances between entities and the centroids of the clusters to which they belong. It uses the column generation approach together with an interior point algorithm: the analytical center cutting plane method (ACCPM). The auxiliairy problem of finding a column is shown to be reductible, in view of Huyghens' theorem, to a hyperbolic program in 0-1 variables. This problem can in turn be solved through a sequence of quadratic problems in 0-1 variables. Finally variable neighborhood search heuristic are used to built an initial solution and to reduce the time spent in the hyperbolic auxiliairy problem.

Problems with up to N=150, e.g. Fisher's Iris, are solved exactly for the first time.

TU1-C-CO122

On Global Optimization of Sums of Ratios and the Corresponding Multiple-Criteria Decision Problem

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University of Trier, Department of Mathematics

Horst Reiner - Thoai Nguyen van

Keywords: branch and bound - fractional programming - multiobjective optimization - sums of ratios

Constrained maximization of a sum of $p > 1$ ratios is a difficult nonconvex optimization problem, even if all functions involved are linear. The corresponding multiple-criteria decision making problem consists of maximizing each ratio simultaneously. We discuss a parametric approach to the first problem and show its connection to efficient solutions of the multi-objective program. Then we present a general branch-and-bound algorithm which uses rectangular partitions only in the Euclidean space of dimension p. For affine fractions this algorithm requires only linear programming techniques. The bounding procedures use efficient point calculation and dual constructions.

TU4-I-CM120

A Repetitive Strategy for Combinatorial Optimization with Application to the Steiner Tree Problem

Duin Cees

Operations Research Dept Faculty of Economics and Econometrics

Voss Stefan

As a metaheuristic to obtain solutions of enhanced quality we formulate the so-called pilot method. The method is to avoid the greedy trap by looking ahead for each possible choice (memorizing the best result). Repeatedly, a so-called master solution is modified; each time in a minimal fashion to accountfor the 'best' choice, where all choices have been judged by means of a separate heuristic result, the 'pilot' solution. We illustrate the method on the TSP and on the almost equally well-known Steiner tree problem in a weighted graph.

TU4-T-CO22

Precedence Constrained Traveling Salesman Problem and Automated Production of Printed Circuit Boards

Duman Ekrem

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Or Ilhan

Keywords: component damages - sequence optimization - traveling salesman problem

The use of computer or numerically controlled component placement machines have become major production factors in the automated production of printed circuit boards due to their fast, reliable and error free component placement capabilities. However, the productivity of these machines is highly affected by the sequence of placement operations. In this study, the component placement sequence determination problem was taken up and modeled as a traveling salesman problem (TSP). However, for some placement machines, the placement head may damage previously placed components due to its physical structure. In such cases, the sequence generated by the TSP model is not suitable to production since some precedence constraints due to component damages are not respected. Our main focus was to develop and apply damage prevention routines to the TSP result to generate a producible and minimum cost placement sequence. The solution developed was applied in a real printed circuit board production facility and very successful results were obtained.

FR4-V-CM106

Bond Portfolio Management – Sensitivity with respect to the Model Input

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Bertocchi Marida

Keywords: bond portfolio management - estimated parameters - interest rate scenarios - sensitivity - stochastic programming

The bond portfolio management problem is formulated as a stochastic program based on interest rate scenarios. These scenarios are sampled from the binomial lattice obtained according to Black - Derman - Toy model. The aim of the contribution is to analyze sensitivity of the solution of the resulting large scale mathematical program with respect to the model input, i.e., to analyze the impact of the term structure estimated from the available market data on the values of parameters of the fitted binomial lattice, on the coefficients of the mathematical program and on its solution.

TU4-G-IN11

Solving Recourse Problems with Binary First Stage using Branch and Bound

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Norwegian University of Science and Technology

Tomasgard Asgeir - Wallace Stein W.

Keywords: mixed integer programming - stochastic programming with recourse

We consider 2-stage stochastic programming problems with recourse and binary first stage decisions. Laporte and Louveaux (1993) applied branch and bound to such problems employing the L-shaped decomposition. Their method added cuts only at integer branch and bound nodes. This potentially gives loose lower bounds (at least initially). We propose methods to tighten the lower bounds at non-integer nodes.

The method is illustrated using an application from intelligent telecommunication networks. The problem may be modelled as a stochastic version of a transportation network with supply eating arcs. The first stage decision is which arcs, of a transportation network, to allow flow on. These arcs “eat” a discrete quantity from their supply node. The remaining supply is available to meet the uncertain demand.

TH4-D-CO123

Computing on the Grassmannian Manifold

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Stanford University

The Grassmannian manifold has played a critical role in the proof of existence and computation of equilibria for the economic model with incomplete asset markets. Features of the manifold in this context are developed. In particular, the number of times the local coordinates must be changed is shown to be finite and a partition of the manifold into "convex" components is described.

TH1-C-CO2

Towards a Rank One Convex Analysis

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Ralph Danny - Nyblom Michael

Keywords: generalized convexity - rank one representers - second order derivatives

A rank one representer is a subset $\mathcal{A}$ of matrices Q which is constructed by intersecting a family of half spaces of the form $\{Q \mid \langle Q, uv^t \rangle \leq \alpha\}$ where u and $v \in \Re^n$. Even though these sets are convex sets in the space of matrices, with the usual linear structure, convex analysis is not always the best tool to use for their description. This is due to the fact that convex analysis is often based on interiority conditions and for many rank one representers the important support directions occur on the boundary of the barrier cone. In particular this is true for the interesting and important special case of Q real symmetric and $\mathcal{A}$ containing the negative semi-definite matrices in its recession cone. Such rank one representers arise naturally as Subhessians or Subjets when investigating these as generalised second order derivatives. For this special class of rank one representers one may elegantly characterise the

symmetric rank one support $S(u) := \sup\{\langle Q, uu^t\rangle \mid Q \in \mathcal{A}\}$, even in some infinite dimensional spaces. We present some results which move towards analysing such sets using only rank one information based on mappings such as $u \mapsto S(u)$ rather than in the underlying matrix or operator space.

FR2-L-CM201

An Adaptable Parallel Toolbox for Branching Algorithms

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Hart William E. - Phillips Cynthia A.

Keywords: combinatorial optimization - object oriented programming - parallel computing

We describe work in progress on a portable C++ class library for portable, modular, parallel implementation of branch-and-bound and related algorithms. The basic serial layer of the library allows for low-level specification and debugging of the search, borrowing some of its ideas from Thienel's ABACUS system. We argue that acceptable parallel performance requires each processor to asynchronously time-share between a variety of different tasks, including bounding subproblems and maintaining global information such as the incumbent value and the task pool. To this end, the parallel layer of the library employs a specialized scheduler incorporating a technique sometimes called "stride scheduling". Our approach should promote the blending of implicit enumeration and parallel heuristic search within a single computer code. Processors communicate using the portable MPI message-passing interface. We hope to present computational results for a few applications of the library, including massively parallel mixed integer programming on an Intel supercomputer.

WE2-E-CO11

Smooth Methods of Multipliers for Complementarity Problems

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Rutgers University, MSIS Department, School of Business

Ferris Michael C.

Keywords: complementarity problems - proximal methods

We describe two new classes of augmented-Lagrangian-like methods for solving mixed complementarity problems involving an arbitrary monotone nonlinear function F. The methods reduce the complementarity problem to a series of subproblems, each consisting of the approximate solution of a monotone system of nonlinear equations. With the proper choice of a certain auxiliary function used by the algorithm, this system can inherit the smoothness and domain of definition of F. The analysis of the methods combines an approximate Bregman-based proximal algorithm with a Fenchel duality framework for monotone operators. The Bregman proximal algorithm involves an approximation condition that is much easier to check in practice than previously proposed criteria. The duality framework includes a dual of the type proposed by Mosco and Gabay, but also a new, primal-dual formulation. A prototype implementation of one version of the algorithm, corresponding to a cubic augmented Lagrangian method with a quadratic proximal term, yields promising computational results on the MCPLIB test set, even though most of its members are not monotone.

TU2-B-CO11

A Sparse Implementation of a Finite Continuation Algorithm for Linear Programming

Edlund Ove

Department of Mathematics

Keywords: linear programming - multifrontal QR-factorization - piecewise quadratic functions - sparse matrices

The subject of this talk is to describe an implementation of the continuation algorithm for linear programming by Madsen, Nielsen and Pınar. The basic idea behind that algorithm is that a linear programming problem with unit upper and lower bounds has a dual that is a linear ℓ_1-optimization problem. This dual problem is solved by approximating the solution to the ℓ_1 problem with Huber's M-estimator. The new thing is that the implementation is made for sparse problems. A software package for sparse LQ-factorization, that has been developed for this purpose, will be described. Some modifications of the overall algorithm will also be discussed, e.g. a simple generalization to efficiently solve problems where some variables have one-sided bounds by using "one sided Huber functions". Finally some test results will be presented.

WE1-A-IN1

With Love To George, Modest Tries To Improve On 50-Year-Old Stuff Which Is Already Too Good: The Pivot-Choice Challenge.

Edmonds Jack

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I don't know if there have been any recent efforts
to compare experimentally the times and numbers
of pivots used by various pivot-choice rules
on LP-FEASIBILITY test problems.
That is the present proposed challenge.

Please do what you can to help, for
ISMP 97, Lausanne, EPFL, August 24-29.
Please share what you can toward
an experimental pivot project.

E-mail me what you have for the purpose,
what you know, or would like to discuss,
at `jedmonds@math.uwaterloo.ca`.
If possible we'll point to it before the meeting
on the ISMP website:
http://dmawww.epfl.ch/roso.mosaic/ismp97/topics.html#1
under Topic A210
and/or ask for your comments at the Session A210,
which is intended as an open forum
to celebrate the golden anniversary of
the Simplex Method.

With object-oriented tools, the InterNet,
the golden anniversary, and so forth,

the time seems overdue to gather resources
for cooperative experiment and use.

When I was a kid we sent observations of variable stars to Harvard. Pivot sequences are variable stars for which we need telescopes. The telescopes include a numerical "pivoter", and a RANDOM chooser of row or column from a specified subset.

For simplicity we propose restricting the first challenge to LP-FEASIBILITY, in view of various ways of adapting feasibility to optimization.
Of course any comparison of methods should include at least one version of good old Phase One Simplex, since it is the acclaimed champ, and there is a good chance it is still the most practical.

My best credential for making this appeal is that I know nothing about real computing, in particular, with regard to pivoting.
My impetus to suggest the session is having tried unsuccessfully for several years to get tests of a particular approach to pivot-choice which I love. Due to embarrassment at displaying my incompetence, I'd rather not talk more about it until I know something about how badly it works.

The approach for which I would especially like to see experiments is called RAH, which stands for "Redundancy And Helly."

RAH is the following pivot algorithm which, for a system of linear equations, always stops with an equivalent tableau which has either a non-negative basic solution or else an equation which cannot have a non-negative solution:

At any stage of the algorithm, along with specification of a tableau, there is specified a "weak ordering sequence":
[N(0),r(1),N(1),r(2),...,r(q),N(q)], such that {r(1),...,r(q)} is a subset of the basic columns, and {N(0),N(1),...,N(q)} is a partition of all the non-basic columns.
To start, the sequence is [N(0)].

Choose (RANDOMLY) a basic variable x(i) such that its basic-solution value is negative and such that i is not an r-term of the sequence.
If there is no such i, STOP, because each r-term of the sequence is "redundant" in the sense that if every basic variable which is not an r-term is non-negative then every basic variable which is an r-term will automatically also be non-negative, and hence we have feasibility.

If a basic variable x(i) is chosen, it will leave the basis if there is a pivot. That is, row i is the pivot row.
Choose a term N(t) of the sequence, such that where W is the set of all columns in N(t),N(t+1),..., or N(q), which are negative in row i,
W is at least of size 1 and at most the size of N(t).
If there is no such N(t), STOP, because equation i has no negative coefficients and hence is infeasible.

If there is an N(t), and the corresponding set W of non-basic columns, as described above, then pivot a (RANDOM) member j of W into the basis, and pivot i out of the basis.

To get the new "weak ordering sequence" do not change any of the terms earlier than N(t) of the old sequence; let the new N(t) be W-j
(or more generally let the new N(t) contain W-j and any other non-basic columns of the old N(t),N(t+1),..., or N(q), so long as the new N(t) is smaller than the old N(t)); let the new r(t+1) be j; and let the new final term N(t+1) = N(q) consist of all non-basics not in earlier terms.
(Any r-terms after N(t) in the old sequence are no longer r-terms in the new sequence though they are still basic.)
That's it.

In one specialization, the pivot choice at each step can be made by randomly computing values of basic variables which are not r-terms until one negative value, x(i), is found; then for N(q), and then for N(q-1), ... , randomly computing values in row i until one negative, in the column to be designated as j, is found.
This numerics is enough to update the weak ordering sequence as well as to specify the new tableau.

It is obvious that RAH terminates.
The only other thing to be proved is that the r-term basic variables are "redundant" in the sense described. This follows immediately from the following easy-to-prove

Lemma: If, for a tableau T of equations, the basic value of basic variable i is negative, and coefficient-entry (i,j) is negative for a non-basic j, then, for any equivalent tableau T' such that j is basic and j' remains non-basic for every other negative (i,j') of T, the basic value of basic variable j in T' is non-negative (in fact, positive) if the basic values of the other basic variables of T' are non-negative.

Notice that, unlike Phase One Simplex, and the least index method, RAH does not impose extra structure to predetermine pivot choices.
Choosing pivots as randomly as possible, subject to pertinent discoveries by prior tableaus (remembered by the weak ordering), might be worthwhile.

For these reasons, and less numerics to do, it is plausible that some version of RAH is competitive with Phase One Simplex.
If so, it is simpler, and easily adapted to LP optimization.
I would really appreciate some help on it.
Don't hesitate to tell me the bad news.
Happy Anniversary.

MO3-I-CM5

The General Routing Problem Polyhedron: A Unifying Framework

Eglese Richard W.

University of Lancaster

Letchford Adam

Keywords: routing

The General Routing Problem (GRP) is the NP-Hard problem of routing a single vehicle, so as to minimise cost, subject to the condition that certain vertices and edges are visited at least once.

New polyhedral results are given for the GRP, providing a unifying framework for known results and yielding new classes of valid inequalities and facets. Some comments are made concerning separation algorithms and some computational results are presented.

TH2-I-CM121

A Frequency Assignment Problem in Cellular Phone Networks

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ZIB Berlin

Borndörfer Ralf - Grötschel Martin - Martin Alexander

Keywords: cellular phone network - frequency assignment - heuristics

We present a graph-theoretic model of the *Frequency Assignment Problem* as it is encountered when operating a Cellular Phone Network: Frequencies have to be assigned to base stations so that as little interference as possible is induced while obeying several technical and legal restrictions.

This optimization problem is NP-hard. Good approximation cannot be guaranteed, unless P = NP. We describe several start and improvement heuristics. Computational results on real-world instances with up to 4240 base stations and 75 frequencies are presented.

WE2-D-CO123

Asymtotic Analysis of Barrier Trajectories without Constraint Qualifications

El Afia Abdellatif

Sherbrooke University

Dussault Jean-Pierre

We consider interior penalty (barrier) methods applied to nonlinear programs whose feasible set possess an interior; we make no constraint qualification assumption. Usually, a constraint qualification assumption together with the second order sufficient optimality and the strict complementarity conditions are used to prove the differenciability of the trajectories defined by the algorithm at its limit point, a stationary point of the program. For special problems (linear programming), only the boundedness of the solution set is required to obtain the differenciability property. We obtain differenciability results for the trajectories under weak hypotheses; in particular, we do not require the existence of Lagrange multipliers. When the constraint qualifications are satisfied, we do not require the strict complementarity assumption.

TU1-B-CO10

Robust Semidefinite Programming

El Ghaoui Laurent M.

École Nationale Supérieure de Techniques Avancées

Keywords: robustness - semidefinite programming - sensitivity

In this talk we consider semidefinite programs (SDPs) whose data depends on some unknown-but-bounded perturbation parameters. We seek "robust" solutions to such programs, that is, solutions which minimize the (worst-case) objective while satisfying the constraints for every possible values of parameters within the given bounds. Assuming the data matrices are rational functions of the perturbation parameters, we show how to formulate sufficient conditions for a robust solution to exist, as SDPs. When the perturbation is "full", our conditions are necessary and sufficient. In this case, we provide sufficient conditions which guarantee that the robust solution is unique, and continuous (Hölder-stable) with respect to the unperturbed problems' data. The approach can thus be used to regularize ill-conditioned SDPs. We illustrate our results with examples taken from linear programming, maximum norm minimization, polynomial interpolation and integer programming.

WE4-D-CO123

Semidefinite Programming in Control

El Ghaoui Laurent M.

École Nationale Supérieure de Techniques Avancées

Keywords: semidefinite programming

The talk will present results based on a recent book, entitled "linear matrix inequalities in system and control theory", by Boyd, El Ghaoui, Féron and Balakrishnan (SIAM, 1994).

A large number of problems in systems and control theory can be cast as semidefinite programming (SDP) problems. Although most of these problems have no known "analytical" solution (eg, via the solution of a standard Riccati equation), the LMI formulation allows for a reliable (polynomial-time) numerical solution.

We illustrate this point with three examples from control theory. The first deals with a special class of stochastic systems, useful to model linear systems subject to random (Markovian) failures. The second concerns linear systems subject to deterministic (norm-bounded) perturbations. In the last example, we extend the approach to a class of non linear systems.

TU3-D-CO124

A Primal-Dual Polynomial Interior-Exterior Algorithm for Linear Programming

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Université de Sherbrooke, Département de mathématiques-informatique

Benchakroun Abdelhamid

Keywords: interior-exterior method - linear programming - path following - polynomial time algorithm

We propose a primal-dual polynomial interior-exterior algorithm for linear programming problem. The algorithm is based on path following idea and uses a two parameter mixed penalty function. Each iteration updates the penalty parameters and finds an approximate solution of Karush-Kuhn-Tucker system of equations which characterizes a solution of the mixed penalty function. The approximate solution obtained gives a dual and a λ-feasible primal points. Since the primal solution is non feasible, a new pseudo-gap definition is introduced to characterize primal and dual solutions. The total number of arithmetic operations is shown to be of the order of $\mathcal{O}(\beta n^2 L)$.

WE3-D-CO124

Identifying Groups of Variables in Interior-Point Methods

El-Bakry Amr Saad

RICE UNIVERSITY, CENTER FOR RESEARCH ON PARALLEL COMPUTATION

Gonzalez-Lima Maria - Tapia Richard Alfred - Zhang Yin

Keywords: centrality measures - interior point methods - linear and nonlinear programming

The identification of certain groups of variables in linear programming is an important ingredient in many applications. Two new indicator functions are introduced to identify several groups of variables in the context of primal-dual interior-point methods. Computational utilization of this information is discussed.

TH4-E-CO21

Pseudo-Monotone Variational Inequalities Convergence of the Auxiliary Problem Method

El-Farouq Naima

LIMOS-UNIVERSITÉ BLAISE PASCAL

Keywords: convergence of algorithms - decomposition - generalized monotonicity - optimization - pseudomonotonicity - variational inequalities

In this paper, we examine the convergence of the algorithm built on the Auxiliary Problem Principle for solving pseudo-monotone variational inequalities.

TU1-T-CO22

Linear Programming Models for Disentangling a Stock Market Crash

Elimam Abdelghani A.

COLLEGE OF BUSINESS - SAN FRANCISCO STATE UNIVERSITY

Girgis M. - Kotob S.

A highly speculative and heavily leveraged stock market, called Souk al-Manakh, emerged in Kuwait in 1979 as a result of a ban on the establishment of new companies. Due to the absence of checks and balances normally practiced in mature equity markets, one trader's default led to a stock market crash and anational financial crisis, with debts rising to more than four times Kuwait's GDP. In trying to resolve the crisis, neither the government nor the courts were able to untangle the web of debts involving traders. We designed linear programming models that were adopted by the Finance Minister and the courts as an effective, equitable and robust way to resolve the crisis.

FR4-C-CO2

Convexity and Quasi-Convexity of Marginal Functions for Problems with Bounded or Unbounded Feasible Region

Ellero Andrea

UNIVERSITÀ CA'FOSCARI DI VENEZIA

Andramonov Michael

Keywords: generalized convexity - marginal functions

The investigation of the properties of marginal functions, or value functions, allows to know how the optimal value of an objective function on a feasible set changes, when this set and/or the objective function changes depending on a scalar or vector parameter. Marginal functions play an important role also in many methods of minimizing non-linear functions.

Continuity and directional differentiability of marginal functions were studied by many authors and there is a lot of work done on this subject. The generalized convexity of these functions, however, became topic of interest more recently.

Our approach allows to study generalized convexity properties of optimal value functions from a general point of view, without strong preliminary assumptions on the objective function, such as differentiability: the analysis is performed directly through the study of the level sets or epigraphs.

Given an arbitrary function f from $\Re^n$ to $\Re$, a convex subset U of $\Re^m$ and a point-to-set map $a : U \to 2^{\Re^n}$, we consider the marginal function

$$\varphi(u) = \inf_{x \in \ a(u)} f(x) \quad \forall u \in U \quad .$$

Let be $Im(a) = \bigcup_{u \in U} a(u)$ and $L_f(\alpha)$, $L_\varphi(\alpha)$ the lower level sets of f and φ respectively. Defined as usual the inverse map a^{-1} of a, i.e. $u \in a^{-1}(x)$ iff $x \in a(u)$, we prove relationships like

$$L_\varphi(\alpha) \supseteq \ a^{-1}(L_f(\alpha) \cap Im(a))$$

and

$$L_\varphi(\alpha) = \bigcap_{\varepsilon > 0} a^{-1}(L_f(\alpha + \varepsilon) \cap Im(a)) \quad .$$

Indeed, we establish relationships between level sets of the objective function, feasible set and level sets or epigraph of the marginal function. We put attention in particular to the case in which the feasible set is not necessarily bounded or closed and the objective function is not necessarily lower semicontinuous.

The results obtained are then used to study quasi-convexity of marginal functions for some classes of non-linear programming problems.

WE3-I-CM3

Constructing Periodic Timetables for Local Railway Systems

Enders Reinhard

SIEMENS AG, ZT AN1

When planning new local railway systems or modifications of existing ones, the simulation tool **TRANSIT** is used to evaluate cost and robustness of different alternatives. For simulating train movements, one needs to construct time tables. The input of the tool currently consists of track layout, train properties, lines, periods and additional user defined constraints. The tool tries to create conflict free time tables that obey additional constraints like minimum buffer times at conflict points and to minimize the number of trains needed. A constraint programming library is used to implement conflicts and user defined constraints and an incremental minimal cost flow algorithm is integrated to minimize the number of trains. The search is done by branch & bound.

TU2-R-IN203

Exact Volume Computation for Polytopes: A Practical Study

Enge Andreas

Eidg. Technische Hochschule Zurich (ETH)

Bueler Benno - Fukuda Komei

Keywords: convex polytope - exact computation - experiments - triangulations - volume

Although the notion of the volume of a polytope is very basic and intuitive its computation raises a lot of problems. We attempt to answer some fundamental and practical questions on volume computation for higher dimensional convex polytopes given by their vertices and/or facets. In particular, we study through extensive computational experiments typical behaviours of the known exact algorithms, including Delaunay and boundary triangulation, the triangulation scheme described by Cohen and Hickey and the algorithms presented by Lasserre and Lawrence. Our studies point out that all tested algorithms have their own weaknesses and no algorithm runs competitively for all classes of polytopes. We propose various modifications of the existing algorithms and some new computational techniques to overcome their weaknesses. As byproducts, we have efficient codes for volume computation which are publicly available.

TH4-W-CO15

A Java-Based Programming Interface for Optimization Modeling

Entriken Robert

Stanford University

Infanger Gerd - Saunders Michael A.

Keywords: client-server - internet - modeling language - optimization - web

We introduce a Java-based API that specifies a standard for communication between optimization models and solvers. Such a standard offers the following features:

- mix and match systems,
- more-readily integrate and put to use new systems,
- create new software for the niches between the two building blocks, and
- construct high-order solution algorithms from standardized solvers.

These features will greatly enhance the productivity of the many areas of science and industry that utilize optimization software.

WE4-G-IN11

Language Constructs for Modeling Stochastic Linear Programs

Entriken Robert

Stanford University

This paper introduces two tokens of syntax for algebraic modeling languages that are sufficient to model a wide variety of stochastic optimization problems. The tokens are used to declare random parameters and to define a precedence relationship between different random events. It is necessary to make a number of assumptions in order to use this syntax, and it is through these assumptions, which cover the areas of model structure, time, replication, and stages, that we can attain a deeper understanding of this class of problem.

TU2-I-CM5

Fleet Assignment with Respect to Itineraries

Erdmann Andreas

University of Cologne

Schrader Rainer - Kiahaschemi Mehran

Keywords: Lagrangean relaxation - column generation - fleet assignment

The optimal assignment of a specific type of aircraft (equipment) out of a given fleet to each of the scheduled flights (called legs) is called *fleet assignment problem*. Restrictions are given not only by the subfleet sizes but also by seat capacities and passenger demands. The objective is to maximize the overall gain: Profits per passenger are given for every itinerary, while fixed costs depend on the flight leg and the assigned equipment. The novelty of our approach is that passenger demands and profits given per itinerary are taken into account. We give a mixed integer formulation of this *extended fleet assignment problem* and use relaxation methods to get upper bounds. Results from our heuristical approaches are compared with exact solutions obtained by column generation on small generated and real instances. We give lower and upper bounds on large real world data using heuristics and Lagrangian relaxations, respectively.

TH2-I-CM3

Applying Graph Models and Algorithms for the Train Scheduling Problem

Erhard Karl-Heinz

Siemens AG, ZT AN 1

Keywords: interval graphs - train scheduling

We present a program for automated train dispatching. Our tool continuously compares the actual behaviour of trains with the pre-established schedule and adjusts the timetable in case of deviations, e.g. due to disturbances. A main objective of this rescheduling is the minimization of train delays subject to several technical restrictions.

To solve the train scheduling problem, we introduce interval graphs for representing free time intervals within a timetable and apply shortest path algorithms to these graphs. The resulting paths represent both the topological route and the time scheduling of trains. Our heuristic provides real-time capability in spite of the large number of possible solutions. Furthermore, the proposed approach is independent of the track topology, i.e. it can be used for railway lines as well as general railway networks.

We tested our program on realistic scenarios of a main line with high traffic density. As compared to manual dispatching, significant reductions of train delays could be achieved.

FR3-L-CM201

A Parallel Computing Approach for Water Resources Utilization Planning under Uncertainty

Escudero Laureano F.

IBERINCO

Keywords: augmented Lagrangian - full recourse - non-anticipativity - parallelization - scenario analysis - stochastic - water resources

In this paper we present a general modelling framework and a parallel computing optimization approach for the efficient solution of a multi-stage water resource system planning. The aim is to obtain the optimal policy for water resources utilization under uncertainty. The reservoirs and water transportation topology is given. The target levels to achieve are related to the following parameters: reservoirs capacity, hydroelectric demand and other demand uses for urban, industrial, irrigation, ecological and other purposes. The approach allows for conjunctive use of surface systems and groundwater systems. The hydrological exogenous inflow and demand for different using types are considered via a scenario analysis scheme due to the uncertainty of the parameters. So a multi-stage based scenario tree is generated and, through the use of full recourse techniques, an implementable solution is obtained for each scenario group at each stage along the planning horizon. Novel schemes are presented for modelling the multi-stage linking constraints related to the water demand cummulated deficit for given consecutive time periods, and the constraints to preserve the reserve stored water in (directly and non-directly) upstream reservoirs to satisfy potential future needs in selected demand centers at given time periods; both types of constraints must be satisfied through the scenario tree. The non-anticipativity constraints are modelled by using a splitting variable scheme, via a redundant circular link representation of the stored water variables from one period to the next one. Both types of constraints are particularly well-suited for augmented Lagrangian decomposition schemes. A scheme of this type has been implemented on a distributed computational environment, and a static load balancing approach has been chosen for the parallelization scheme, given the subproblem structure of the model. An extensive set of computational experiments is reported; the numerical results and running times obtained for our real-life test set confirm the efficiency of the procedure.

TH4-L-CM201

Parallel Branch-and-Cut for Set Partitioning

Eso Marta

Cornell University, School of OR&IE

Ladanyi Laszlo - Trotter Leslie Earl

Keywords: branch and cut - graphical user interface - parallel computation - set partitioning

We discuss the use of the COMPSys framework applied to large set partitioning problems. Efficient solution methods for this model are vital for various applications, including airline crew scheduling, where the problem matrix very often has hundreds of thousands of columns. In addition to this difficulty, set partitioning problems are hard to approximate (MAX-SNP hard), and feasible solutions may be difficult to find. Also, only a handful of separation procedures have been implemented to date, and these are not sufficiently effective for some of the problems we have encountered.

Due to the typically large size of these problems and the difficulty of finding feasible solutions, our initialization routines comprise a considerable part of the user-written functions required by COMPSys. The backbone of our initialization is a problem-size reduction routine which iteratively deletes columns and rows from the problem matrix based on logical implications. We have shown that the order of these standard reduction operations is irrelevant for the quality (although obviously not the execution time) of the final reduced matrix. Our heuristic for finding a feasible solution combines solving the LP relaxation of the current problem, fixing variables, and invoking the reduction routine.

We also describe cut generation, the other major part of the user-implemented routines for COMPSys. We will discuss the use of a graphical interface that enables interactive cut generation. We have used it, for example, in the detection of violated wheel and even K_4 inequalities for the set partitioning model. This graphical user interface is sufficiently general to be used in any applications with underlying graphical structure.

Computational results will be presented.

WE2-P-IN201

An Exact Algorithm for the 0-1 Nonlinear Constraint Satisfaction Problems: Application to Task Allocation in Distributed Computing System

Ettaouil Mohamed

Univ. Sidi Mohammed Ben Abdellah, Dpt Math. et Inf., Fac Sci. et Tech. Fes-Saiss

This paper deals with the resolution of the 0-1 nonlinear constraint satisfaction problem. This problem is well known to be NP-complete. It has many applications in technology, economy and computer science. In the linear case, the problem was studied by Wallace, Plateau and Bennaceur. In the mixed-integer nonlinear programming case, for computing a feasible solution Duran and Grossmann proposed an algorithm which makes use of an outer-approximation procedure based on characterizations of convex sets through intersection of supporting half-spaces. For solving the 0-1 nonlinear constraint satisfaction problem we propose an exact method, called FANLIST (Fast Algorithm for NonLInear constraint Satisfaction problem Testing), our method does not use the linearization principle. Given a mxn 0-1 system of nonlinear constraints (S), this method generates a finite sequence of nonlinear 0-1 minimization problems until a solution of the system is found, or the domain is proved to be empty. The Lagrangean dual of each generic problem is solved not only to prove that the do-

main is empty but also to satisfy new constraints currently violated or to reach a solution for the system. If none of these goals is reached, a binary tree search is used. The enumeration tree is developed using a depth-first search strategy with tools exploiting flexible Lagrangean relaxations, heuristics and reduction scheme. In the process of solving a generic problem a Tabu search is performed to improve a new Lagrangean heuristics (lower bound) and the initial upper bound is produced by using the best solution of the generic problem in the previous iteration. Finaly, we propose a concrete application example in the computer science field (Task allocation in distributed computing system). This method has been implemented for instances with 0-1 quadratic constraints. Computational experiments are reported.

TU3-T-CO22

On a Stochastic Cutting Stock Problem

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Eötvös Loránd University

Keywords: cutting stock problem - stochastic programming

Fiberglass is produced from solid rods of glass. During the process, fiber can break accidentally. From the random lengths of fiber produced that way, a certain demand must be satisfied. That is, requested lengths must be cut out of the random lengths.

The speed by which fiber is drawn from a rod is constant. When taking an order, we should be able to decide whether it can be safely filled before a given deadline. In the talk we will formulate the problem, and describe diverse solution methods. We will also show how to determine optimal cutting procedures.

WE1-E-CO21

Structural and Stability Properties of P_0 Nonlinear Complementarity Problems

Facchinei Francisco

Università di Roma 'La Sapienza' - Dipartimento di Informatica e Sistemistica

Keywords: P_0 functions - complementarity problems - connectedness - stability

We consider P_0 nonlinear complementarity problems and study the connectedness and stability of the solutions by applying degree theory and the Mountain Pass theorem to a smooth reformulation of the complementarity problem. We prove that the solution set is connected if a bounded isolated component of the solution set exists and that a solution is locally unique if and only if it is globally unique. Furthermore we prove that a solution is stable in Ha's sense if and only if it is globally unique, while the complementarity problem itself is stable if and only if the solution set is bounded.

MO3-C-CO3

Convergence to Second Order Stationary Points in Inequality Constrained Optimization

Facchinei Francisco

Università di Roma 'La Sapienza' - Dipartimento di Informatica e Sistemistica

We propose a new algorithm for the nonlinear inequality constrained minimization problem and prove that it generates a sequence converging to points satisfying the KKT second order necessary conditions for optimality. The algorithm is a line search algorithm using directions of negative curvature and it can be viewed as a nontrivial extension of corresponding known techniques from unconstrained to constrained problems. The main tools employed in the definition and in the analysis of the algorithm are a differentiable exact penalty function and results from the theory of LC1 functions.

TU2-L-CM201

A Nonlinear Conjugate Reduced-Gradient Method for Solving Bounded Nonlinear Optimal Control Problems on Parallel Computers

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Universidade Federal do Rio de Janeiro, Instituto de Matematica

Keywords: conjugate gradient - generalized reduced gradient - linear systems - nonlinear optimal control - parallel computers

Nonlinear dynamical control systems are considered as discrete-time nonlinear optimal control problems with bounds on the state and the control variables. In general these problems are large-scale, and numerical solutions are obtained by constrained nonlinear programming (NLP) methods.

The method proposed here is a special version of an optimal control generalized reduced-gradient method (GRG) for parallel computers.

The dynamic equations are used to reduce the equality constrained and bounded NLP problem to an unconstrained one, in the space of the superbasic variables submitted only to the bounds, where an efficient conjugate gradient method can find the improving feasible search directions.

The staircase structure of the jacobian matrix of the dynamic equations is exploited by some priority principles to choose the basic variables at each basic matrix reinversion, and to choose a superbasic variable candidate when changes of basis occur. A factorized representation of the GRG basic matrix make easier the solution of the linear systems of equations in different parts of the algorithm. LU decompositions of submatrices of the diagonal blocks of the main factor in the basic matrix representation improve the numerical stability of the processes.

The conjugate gradient procedure and the solution of the linear systems procedure are carefully designed to exibit efficient parallel implementations on an IBM SP-2 parallel computer with 8 processors.

TU2-I-CM121

Ordered Submodular Structures and the Greedy Algorithm

Faigle Ulrich

Department of Applied Mathematics, University of Twente

Keywords: Monge - greedy algorithm - ordered set - polymatroid - submodular linear program

A combinatorial model is presented that extends Edmonds' approach to polymatroids to a general model involving modular functions on lattices, where we view a lattice as a closure operator relative to a (partially) ordered set E.

We show that a primal-dual greedy algorithm optimizes linear functionals under generalized submodular constraints in this setting. (We remark that our generalized model does not require the submodular functions to be 0-normalized.)

We characterize the type of submodularity relative to which the modular functions can be identified with vectors in $\Re^E$. This special model includes the models of, *e.g.*, Edmonds, Fujishige, Queyranne, Spieksma and Tardella for primal or dual (*i.e.*, "Monge-type") greedy algorithms. We also prove that the analogue of Edmonds' intersection theorem holds for this special model if the order on E is a rooted forest.

TU3-D-CO124

Convergence Rate, Implementation Issues and Numerical Results of a Long-Step Path Following Algorithm for Semidefinite Programming

Fampa Marcia Costa

LNCC

Anstreicher Kurt M.

Keywords: interior point methods - long-step path following algorithm - semidefinite programming

We consider a primal long–step path following algorithm for semidefinite programming. Our main result is that Roos and Vial's elegant analysis of quadratic convergence, for the linear programming case, extends in a very natural way to semidefinite programming. For problems with a semidefiniteness constraint on an $m \times m$ matrix we obtain algorithms with complexities of $O(m \ln(t))$ or $O(\sqrt{m} \ln(t))$ iterations to reduce the initial primal–dual gap by a factor of t, depending on how the barrier parameter is reduced. We consider a primal long–step path following algorithm for semidefinite programming. Our main result is that Roos and Vial's elegant analysis of quadratic convergence, for the linear programming case, extends in a very natural way to semidefinite programming. For problems with a semidefiniteness constraint on an $m \times m$ matrix we obtain algorithms with complexities of $O(m \ln(t))$ or $O(\sqrt{m} \ln(t))$ iterations to reduce the initial primal–dual gap by a factor of t, depending on how the barrier parameter is reduced. The algorithm has been successfully employed to solve real-world problems involving the diagonal approximation of positive definite matrices. We show the computational results obtained and consider interesting aspects of implementation related to stability.

TU3-M-IN202

On the Solution Methode "Optimization With Minimal Information"

Farkas Zoltan

Statistical Institute

Keywords: decision making - heuristics - invariance of solutions

Let us assume that in some cases any reasonable objective function cannot be given for modelling and solving a compound optimization problem. In such a case let us utilize only the available (minimal) information for decision making, without the effort to construct any concrete objective function.

This way of optimization can be based on exact modelling of certain heuristic assumptions, as principles, for characterization of properties of the optimization objectives. On certain conditions we can define and solve a certain type of decision (optimization) problem, and its solution will be invariant for a whole class of problems ("Optimization with Minimal Information" - OMI).

These considerations can give some basis of various types of decision problems, as for example modelling a consensus-type synthesis of certain number of independent decisions. Some of the Author's new results will be presented.

WE1-I-CM200

Combinatorial Optimization Games

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Faigle Ulrich - Hochstättler Winfried - Kent Kathryn - Kern Walter

Keywords: computational complexity - cooperative games - core - distance monotonic - matchings - minimum spanning trees - nucleon - population monotonic - traveling salesman problem

We consider the problem of fair cost allocations for combinatorial optimization games. In particular, we consider MST games, TSP games, and Matching games. We develop an LP-based allocation rule for TSP games guaranteeing that no coalition pays more than α times its own cost, where α is the ratio between the optimal TSP-tour and the optimal value of its Held-Karp relaxation, which is also known as the solution over the "subtour poytope". A well-known conjecture states that $\alpha \leq \frac{4}{3}$. We also exhibit examples showing that this ratio cannot be improved below $\frac{4}{3}$. This idea of a relative deficit motivates the concept of the "nucleon".

For MST games, it is known that there always is a fair cost allocation. We show that it is coNP-complete to decide whether a given allocation is fair. This result has important consequences for finding "best" fair allocations, since it implies that optimizing a linear function over the core of this simple game is computationally intractable. We also discuss the concects of population and distance monotonicity for MST games.

Finally, we discuss Matching games. In general, the profit of a Matching game cannot be allocated fairly; however, we can compute the nucleon for Matching games in polynomial time, guaranteeing best possible relative satisfaction of all players.

MO4-I-CM121

Approximation Algorithms for Lawn Mowing and Milling

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Arkin Esther M. - Mitchell Joseph S.B.

Keywords: NC machining - NP-completeness - approximation algorithms - computational geometry - geometric programming - lawn mowing - milling - shortest path - traveling salesman problem - watchman routes

We study the problem of finding shortest tours/paths for "lawn mowing" and "milling" problems: Given a region in the plane, and given the shape of a "cutter" (typically, a circle or a square), find a shortest tour/path for the cutter such that every point within the region is covered by the cutter at some position along the tour/path. In the milling version of the problem, the cutter is constrained to stay within the region. The milling problem arises naturally in the area of automatic tool path generation for NC pocket machining. The lawn mowing problem arises in optical inspection, spray painting, and optimal search planning.

Both problems are NP-hard in general. We give efficient constant-factor approximation algorithms for both problems. In particular, we give a $(3+\epsilon)$-approximation algorithm for the lawn mowing problem and a 2.5-approximation algorithm for the milling problem. Furthermore, we give a simple $\frac{6}{5}$-approximation algorithm for the TSP problem in simple grid graphs, which leads to an $\frac{11}{5}$-approximation algorithm for milling simple rectilinear polygons.

WE4-F-IN203

Discretization Based Optimality Conditions and Solution Regularity

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Keywords: Lipschitz result - discretization - optimal control - optimality conditions

We consider a Ritz type discretization technique for optimal control problems with mixed state-control constraints. Based on a primal-dual approach, optimality conditions are obtained in continuous and in discrete versions.
Stable formulations of coercivity conditions are discussed for the auxiliary problems where we distinguish the cases that the control functions are continuous or discontinuous.

Concerning a class of problems with convex, time-independent control constraints, it is known that strong coercivity is related to certain solution regularity. Particularly we will present a result on Lipschitz continuity of the optimal control function.

FR3-U-IN10

Logic Programs for Urban Traffic Control

Felici Giovanni

CSST; CNR - IASI

We present a new decentralized system for controlling the traffic lights in a urban network. The basic component of the system is a control unit that governs the traffic lights at a single intersection. Traffic control over a network is achieved by connecting different control units, each one operating at the same hierarchical level without supervisor.

Each control unit consists of several logic programs that are composed of statements in first order logic with finite quantification. The control decisions are produced solving the instances of certain minimum cost satisfiability problems associated to the logic programs. We use the *Leibniz* System for logic programming. The *Leibniz* System analyzes the structure of the minimum cost satisfiability problems using several decomposition techniques. Based on that analysis, it assembles solution algorithms that solve all instances arising from the given minimum cost satisfiability problems, and computes an upper time bound for the run time of each solution algorithm. These bounds guarantee reliable and timely decision making by each control unit.

A visual traffic simulator performs the graphic animation of the network, interacts with the control decisions, and collects traffic statistics. The system can visually represent any type of regular grid network. It has been used to develop several decentralized control strategies and compare their performances with fixed-time control systems, using real-life traffic data as well as simulated data. Significant improvements are obtained using the decentralized control based on logic programming.

WE4-S-IN202

A Polyhedral Approach for DNA Fragments Rearrangement

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University of Sao Paulo

de Souza Cid Carvalho - Wakabayashi Yoshiko

Keywords: computational biology - integer programming - polyhedral combinatorics

We consider a problem that arises in the process of rearrangement of DNA fragments. A graph theoretical formulation of the problem is presented and some extensions mentioned. We show this problem to be NP-hard. A 0/1-integer linear programming formulation of the problem is given and some results of a branch-and-cut algorithm based on this formulation are discussed.

MO4-I-CM4

Comparing E-task-Graphs by Identifying their Differences

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INRIA Rhône-Alpes

Keywords: graph re-writing - graph similarity

An E-task-graph is an oriented graph which has exactly one entry vertex and one exit vertex, and only the edges are labelled. In fact, it is a graphic representation of a set of linked programs, chosen in a library program, whose objective is to solve a given problem. This is what is called here "problem resolution strategy". Notice, however, that a problem resolution strategy can be constructed based on another known strategy for a similar problem. Further, it is also possible that a problem can be solved by using different strategies. Therefore, the purpose of this work is both to verify how similar two E-task-graphs are and which transformations must be carried out for converting an E-task-graph G1 into another G2. Thus, both construction operations defined over them and two relations between E-task-graphs were studied. These operations and relations allow us to identify the "difference" between two E-task-graphs. The difference aims at indicating the needful transformations for converting an E-task-graph into another. A similarity measure between two E-task-graphs, which can be determined as a function of their difference, aims at indicating their degree of resemblance.

MO3-L-CM201

Parallel Implementation of Graph Diameter Algorithms

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Keywords: all pairs distance - graph diameter - parallelism - shortest path

The diameter of a graph is the length of the longest among all shortest path between any pair of vertices, also known as the "all pairs distance" (APD). Exact methods to calculate the diameter include solving n instances of a shortest path problem or manipulating the distance matrix.

We have implemented some of these methods on the different parallel architectures available here at EPFL. We will discuss their efficiency for various categories of large graphs.

TU2-G-IN11

Robust Path Choice and Vehicle Guidance in Networks with Failures

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University of Wisconsin

Ruszczyński Andrzej

Keywords: robust path choices - stochastic linear programming - vehicle guidance

The problem of vehicle guidance in a network with failures is considered. The network may be in one of finitely many states characterized by different travel times along the arcs, and transitions between the states occur according to a continuos-time Markov chain. The objective is to guide the vehicles in a manner minimizing the total expected travel time. Dynamic programming models and flow-oriented models are developed and analyzed in the uncapacitated and the capacitated case. It is shown that the robust plan can be found from a special two-stage stochastic programming problem in which the second stage problem describes the re-routing of vehicles that experienced state transition during their travel. The models are illustrated on an example of the Sioux Falls transportation network. The computational results reveal striking properties of different guidance policies and show that substantial improvements in both duration and size of traffic jams can be achieved by employing robust guidance strategies.

WE1-E-CO11

NLP2MCP: Formulating and Solving Large Scale Nonlinear Programs as Complementarity Problems

Ferris Michael C.

University of Wisconsin

Horn Jeffrey

Keywords: automatic differentiation - complementarity problems - nonlinear programming

We show how to reformulate a nonlinear program as a mixed complementarity problem. We demonstrate how this is carried out automatically from a specification of the nonlinear program in a modeling language such as GAMS, or a programming language such as C. A procedure to carry out this conversion automatically is described using various automatic differentiation tools. Some numerical results obtained using PATH that display the efficiency of such an approach on a class of large nonlinear programs is given.

TU1-E-CO21

Inverse Problems, MPEC Models and Solution via Nonlinear Programming

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Tin-Loi Francis - Toint Philippe L.M.

Keywords: MPEC - inverse problems - nonlinear programming

Inverse problems are prevalent in many applications, including structural engineering and transportation modeling. Many of these problems are most easily cast as a mathematical program with equilibrium constraints (MPEC), which include bilevel programs as a special case. In two different applications, we show how to reformulate the MPEC in a nonlinear programming format and give concrete examples of solving inverse problems of both small and large dimension, even with imperfect observations.

TU3-I-CM120

An efficient Auction Algorithm for the Shortest Path Problem using Virtual Source Concept

Festa Paola

DIA R. M. Capocelli, Università di Salerno

Raiconi Giancarlo - Cerulli Raffaele

Keywords: auction - shortest path

We present a new version of the auction algorithm for solving the shortest path problem. Auction algorithms, which were first proposed by Bertsekas, follow a primal-dual approach and consist of tree basic operations: *path extension*, *path contraction*, *variables updating*. More precisely, at each iteration any auction algorithm mantains a candidate path P and a prices vector π of n elements, if n is the cardinality of the set of nodes. The price associated to a node i is the value of the corresponding dual variable and estimates the shortest distance from the node i self to the sink. At each iteration the candidate path P is either extended by adding a new node at the end of the path or contracted by deleting from P the last node inserted, said terminal node. If no extensions or contractions are possible, the value of the dual variable corresponding to the terminal node of P is raised. The computation termines when the candidate path P is extended by the target node.

In our new approach we completely eliminate the contraction steps: when a contraction step on a node i should be necessary, we simply store such current node in a special list L, ordered by the value of a function of the variables π_j, begin a new iteration starting from the node corresponding to the first element of L (said *virtual source*) and update L.

We showed that this technique drives to an optimal solution,

if the values of the dual variables are updated in a correct way and that, once chosen an efficient data structure, the management costs of the list L are smaller than those relatively to the eliminated contraction steps.

TU3-I-CM120

Graph Collapsing in Auction Algorithms for the Shortest Path Problem

Festa Paola

DIA R. M. Capocelli, Università di Salerno

Keywords: auction - shortest path

We present a strongly polynomial version of the auction algorithm for solving the shortest path problem.Auction algorithms were first proposed by Bertsekas for the assignment problem and later extended to the trasportation and to the shortest path problems. We propose an efficient criterion to drastically reduce the dimension of the original graph; this criterion works to reduce both the number of the arcs and the number of the nodes.
The basic idea of our technique consists in the following observation: let i and j be two nodes of a graph G, if there exists one path P between them, then we can substitute such path with only one arc (i, j) having as lenght the "distance" from i to j through P. We proved that the way in which we implement such reduction enable us to not lose any information regarding the solution of the shortest path problem. The major effect of this technique is the drammatic reduction of the number of both contractions and extentions operations required to find the optimal solution.
The standard auction algorithm follows a primal-dual approach and consists of tree basic operations: *path extension*, *path contraction*, *variables updating*. We showed the effectiveness of our approach, analysing the extension and contraction operations. We found out that some of them are redundant and can be eliminate, withoutcompromise the convergence of the algorithm.

FR2-H-CO22

A Posteriori Studies in Multicriteria Network Flow Interactive Procedures

Figueira Jose Rui

LAMSADE, Université Paris-Dauphine

In this paper, we introduce a complement to interactive procedures called a posteriori study (or analyse). This kind of studies occurs when some satisfactory nondominated point has been already found. A posteriori analysis consists of the following steps: (1) find some points in the neighbourhood of the satisfactory point, and (2) investigate the uality of the solutions associated with these points in the decision avariables space. The purpose of this test is to analyse the adequacy of the model, in particular if all dimensions (or criteria) and constraints has been included in the initial formulation. In network flow problems, users are frequently interested in checking the values of the flow in some arcs of network and adjusting them to desirable (reference) values. So, we conclude that the user's preferences can depend non only on the criteria performances but also on some arc flows. Consequently in many real cases we need to "add or delete" some constraints and/or criteria to the model during the interactive protocol.

TH1-P-IN201

New Theoretical Results on Robotic Flowshops

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Laboratoire LEIBNIZ - IMAG

Brauner Nadia

Keywords: flow shop - material handling system - scheduling

We consider a robotic cell, consisting of a flowshop in which the machines are served by a single central robot. We concentrate on the case where only one part type is produced and want to analyze the conjecture of Sethi, Sriskandarajah, Sorger, Blazewicz and Kubiak. This well-known conjecture claims that the repetition of the best one-unit production cycle will yield the maximum throughput rate in the set of all possible robot moves.

We shall present the following results. The conjecture is valid for a robotic flowshop with unitary buffer capacity at each machine. For this case, we are able to describe the optimal cycle and the maximal improvement of the production rate if compared to the corresponding bufferless configuration. The conjecture is false for the more general hoist scheduling problem and also for the classical robotic flowshop where the travel distances of the idle robot are of a more general nature. It remains the intriguing case of the bufferless robotic flowshop with the usual additive distances. For this problem, the conjecture is still open but has been established for two and three machines. We shall present new elements for the proof of the three-machine flowshop.

WE4-A-IN1

Randomized Pivot Algorithms in Linear Programming

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Keywords: bounding techniques - linear programming - lp-type problems - pivoting algorithm - randomization

We discuss randomized algorithms for linear programming, in particular an algorithm due to Matoušek, Sharir, and Welzl with subexponential expected run time. This recursive algorithm (denoted by MSW) was used for linear programming under certain strong assumptions, so all LP problems to be recursively solved are bounded and have a unique optimal solution. Consequently it is not clear how one can transform the MSW algorithm to a true LP algorithm without losing its subexponential behaviour and without introducing large numbers (as e.g. when a numerical bounding box is used). In this paper we present a simple pivot algorithm based on MSW using a new notion of lexicographic bounding box. It is a sort of the dual simplex method with the same time complexity as MSW. The pivoting algorithm has been implemented and we report some computational experiences.

MO4-E-CO21

Merit Functions and Stability

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Klatte Diethard

Keywords: merit function - parametric complementarity problem - stability

Merit functions are frequently used for reformulating complementarity, variational inequality and related problems as (possibly constrained) nonlinear programs. We show how merit functions can be exploited to obtain stability results for the former problems. The approach basically relies on lower bounds for the distance of a given point to the solution set of the problem at hand. Particular results will be presented for complementarity problems. On the other hand, the reverse approach will be dealt with, that is the derivation of such lower bounds from stability results. Corresponding applications will be included, in particular the design and analysis of superlinearly convergent Newton-type methods for problems with nonunique solution sets.

FR-am-CO2+3

Algorithms for Railway Crew Management

Fischetti Matteo

DMI - University of Udine

Caprara Alberto - Toth Paolo - Vigo Daniele - Guida Pier Luigi

Crew management is concerned with building the work schedules of crews needed to cover a planned timetable. This is a well-known problem in Operations Research and has been historically associated with airlines and mass-transit companies. More recently, railway applications have also come on the scene, especially in Europe. In practice, the overall crew management problem is decomposed into two subproblems, called crew scheduling and crew rostering. In this paper, we give an outline of different ways of modeling the two subproblems and possible solution methods. Two main solution approaches are illustrated for real-world applications. In particular we discuss in some detail the solution techniques currently adopted at the Italian railway company, Ferrovie dello Stato SpA, for solving crew scheduling and rostering problems.

FR2-A-IN2

0-1/2 Chvátal-Gomory Cuts for Integer Programming: A Preliminary Computational Study

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Caprara Alberto - Toth Paolo

Keywords: Chvátal-Gomory cuts - binary clutters - branch and cut - integer programming - odd cycles

We report a preliminary computational experience with the use of 0-1/2 Chvátal-Gomory cuts in a branch-and-cut approach to general ILPs. Our separation procedures are based on the computation of min-cost odd cycles in a suitably-defined separation graph, and on tabu search. Our results show that the use of 0-1/2 cuts can significantly tighten the LP bounds when part of the ILP constraints have a strong combinatorial structure.

TU1-I-CM121

Detachment of Vertices of Graphs Preserving Edge-Connectivity

Fleiner Balázs

Eötvös Loránd University

Keywords: detachment - edge-connectivity - graph

The detachment of vertex s of an undirected graph G is the following operation: we delete the vertex s and we connect the edges incident with s to one of the new vertices $s_1, \dots, s_t$. We speak about $\{d_1, \dots, d_t\}$-detachment if for the resulting graph G' $d_{G'}(s_1) = d_1, \dots, d_{G'}(s_t) = d_t$. We call a detachment feasible (according to k) if $d_{G'}(X) \geq k$ whenever X separates two vertices of $V(G) - s$. In our main theorem, we give necessary and sufficient condition for the existence of a feasible $\{d_1, \dots, d_t\}$-detachment of vertex s. This theorem also holds for graphs containing 3-vertex hyperedges not incident with s. From special cases of the theorem we get a characterization for those graphs whose edge-connectivity can be augmented to k by adding γ new edges and p new 3-vertex hyperedges. We give a new proof for the theorem of Nash-Williams which gives necessary and sufficient condition for the existence of such a simultaneous detachment of the vertices of a given graph such that the resulting graph is k-edge-connected.

FR4-I-CM4

Covering a Symmetric Poset by Symmetric Chains

Fleiner Tamás

CWI

Keywords: matchings - poset

We prove a min-max result on special partially ordered sets, a conjecture of András Frank. As a corollary we deduce Dilworth's theorem and the well-known min-max formula for the minumum size edge cover of a graph.

MO4-I-IN202

Faster Algorithms for the Quickest Transshipment Problem

Fleischer Lisa

Cornell University

Keywords: dynamic network flows - parametric network flows

The field of network flows blossomed in the 1940s and 50s with interest in transportation planning, and has developed rapidly since then. However, it has largely ignored a crucial aspect of transportation: transportation occurs over time. In the 1960's, Ford and Fulkerson introduced dynamic network flows to include time in the network model. Now, dynamic network flows are used to model not only vehicular transportation, but also electronic communication and job scheduling.

A dynamic network consists of a graph with capacities and transit times on the edges. Flow moves through a dynamic network over time. Edge capacities restrict the rate of flow and edge transit times determine how long each unit of flow spends traversing the network.

This talk focusses on a special case of dynamic networks when all transit times are zero. I look at the transshipment problem with demands that exceed network capacity and answer the question: How can flow be sent to satisfy all demands in the least amount of time? This is the quickest transshipment problem.

FR3-I-CM5

Lower Bounds for the VRP with Time Windows

Fleischmann Bernhard

UNIVERSITY OF AUGSBURG

Keywords: Lagrangean relaxation - time windows - vehicle scheduling

We present a new relaxation of the vehicle routing problem with time windows (VRPTW) into an assignment problem, based on variable splitting and Lagrangean relaxation. It can be used to compute lower bounds to the VRPTW by means of subgradient optimization. The procedure can be applied in the cases of a homogenous as well as a heterogenous fleet of vehicles and with or without waiting times allowed at early arrivals. Computational tests using problems from literature with up to 100 customers and known optimal solutions, show that the procedure leads to very sharp lower bounds in most cases.

TU3-A-IN1

Block Triangular Orderings and Factors in LP

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Keywords: Tarjan's algorithm - implicit LU factors - transversal

Tarjan's algorithm together with depth-first transversal search is an efficient method for finding an irreducible block triangular ordering of a nonsingular sparse matrix A. However, when used in conjunction with $PA = LU$ factors within the blocks, there are difficulties in finding a simple data structure which permits linear systems involving A or A^T to be solved efficiently. Thus many sparse matrix codes ignore the possibility of using block orderings. The possibility of using the less well known technique of Implicit LU factors is considered and it is shown that a much more simple data structure is available. For certain irreducible sparse matrix patterns the fill-in with this technique is no worse than that incurred by LU factors.

In Linear Programming the invertible representation of the basis matrix must also be updated when one column in A is replaced by another, and this causes more problems for an algorithm based on block factors. It is shown how the block ordering can be updated efficiently when the basis is changed. Some information in the Implicit LU factors is unaffected by the update. How best to deal with the part that is affected is currently under review.

This work is ongoing and current progress will be reported at the symposium.

FR3-V-CM106

Portfolio Management in the Electricity Industry

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Wallace Stein W. - Ziemba William T.

Keywords: electricity market - hydro scheduling - risk management - stochastic programming

We present a portfolio management model for a hydropower producer operating in a deregulated electricity market. The focus in this modeling effort is on the coordination of physical generation resources in the form of multiple hydropower reservoirs, with "paper" resources in the form of financial instruments on electricity. These portfolio management instruments are available in functioning forward and futures markets. The model presented is a stochstic programming model, and represents a synthesis of a traditional power scheduling model and an asset and liability management model.

WE2-C-CO2

An Attempt to Define the Conjugate of Set-Valued Maps

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UNIVERSIDAD DE CONCEPCIÓN, DPTO. INGENIERIA MATEMATICA

Keywords: contingent cone - critical value - duality theory - set-valued maps

It is known that the classical convex duality theory as well as some nonconvex duality schemes as that of Ekeland or Toland are based on the notion of convex conjugate function. Given a locally convex topological vector real space X, with dual X^*, and a function $f : X \to \Re \cup \{+\infty\}$ such that $f \not\equiv +\infty$, the convex conjugate of f is $f^* : X^* \to \Re \cup \{+\infty\}$, given by

$$f^*(x^*) = \sup_{x \in X} \left\{ \langle x^*, x\rangle - f(x) \right\} \quad (x^* \in X^*).$$

Here $\langle \cdot, \cdot \rangle$ denotes the duality pairing between X and X^*. This notion was introduced by Fenchel for the finite dimensional case and further developed by Rockafellar. Some other nonconvex duality theories but based on an extension due to Moreau of the above notion of conjugacy, were developed by Balder, Dolecki and Kurcyusz, among others.

Purpose of this talk is to introduce a notion of conjugacy for set-valued maps defined in spaces of finite dimension and to derive its main properties useful in conjugation theory. Several examples showing its geometric interpretation will be presented, as well as a relationship with its contingent derivative. As a consequence, the subdifferential of set-valued maps is also defined. It seems (to this author's knowledge) that no attempt was done elsewhere.

FR1-U-IN1

Methods for Analysing the Demand for Toll Highways

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UNIVERSITÉ DE MONTRÉAL, CENTRE DE RECH. SUR LES TRANSPORTS

Keywords: multiclass assignment - network equilibrium - stated preference models

Various methods for anlysing the demand and network flows for toll highways have been developed and used over the past few years. This presentation reviews the main methods used and their implementation by using multiclass network equilibrium assignments with fixed and variable demand. The propensity to use toll roads is given by probabilistic stated preference models

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WE3-C-CO3

A Bilevel Programming Application in Transportation Planning

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Université de Montréal, Centre de rech. sur les transports

Chen Yang

Keywords: adjusting O-D matrices - bilevel programming - large scale optimization - transportation planning

We present several large scale applications of bilevel programming problems which originate in transporttaion planning methods. One application is the adjusting of origin-destination matrices from observed link counts. The problem formulation as a bilevel programming problem is presented as well as necessary conditions for an optinal solution. Several large scale applications on networks which originate from the practice of transportation planning are presented. These applications involve origin-destination matrices of up to 1000 zones and networks up to 20,000 links. The results obtained are very good and demonstrtae why this method was used in many applications.

TU1-C-CO122

A Global Optimization Method aBB for General Twice-Differentiable Constrained NLPs

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Princeton University

Adjiman Claire - Dallwig Stefan - Neumaier Arnold

Keywords: constrained nlps - global optimization - twice-differentiable

The deterministic global optimization algorithm, αBB, (α–based Branch and Bound) is presented. This algorithm offers mathematical guarantees for convergence to a point arbitrarily close to the global minimum for the large class of twice–differentiable NLPs. A convex relaxation of the original nonconvex problem is obtained by (i) replacing all nonconvex terms of special structure (i.e., bilinear, univariate concave) with customized tight convex lower bounding functions and (ii) by utilizing some α parameters to generate valid convex underestimators for nonconvex terms of generic structure. In most cases, the calculation of appropriate values for the α parameters in order to construct valid convex underestimators is a challenging task. A number of approaches are proposed, which rigorously generate a set of α parameters for general twice–differentiable functions. A crucial phase in the design of such procedures is the use of interval arithmetic on the Hessian matrix or the characteristic polynomial of the function being investigated.

TH3-C-CO3

Global Optimization In Batch Process Design Under Uncertainty

Floudas Christodoulos A.

Princeton University

Harding Steve

Keywords: batch process design - global optimization - uncertainty

This paper addresses the design of multiproduct and multipurpose batch plants with uncertainty in both product demands and in processing parameters. The uncertain demands may be described by any continuous/discrete probability distribution. Uncertain processing parameters are handled in a scenario-based approach. Through the relaxation of the feasibility requirement, the design problem with a fixed number of pieces of equipment per stage is formulated as a single large-scale nonconvex optimization problem. This problem is solved using a branch and bound technique in which a convex relaxation of the original nonconvex problem is solved to provide a lower bound on the global solution. Several different expressions for the tight convex lower bounding functions are proposed. Using these expressions, a tight lower bound on the global optimum solution can be obtained at each iteration. The αBB algorithm is subsequently employed to refine the upper and lower bounds and converge to the global solution. The tight lower bounds and the efficiency of the proposed approach is demonstrated in several example problems. These case studies correspond to large-scale global optimization problems with nonconvex constraints ranging in number from 25 to 3,750, variables ranging from 30 to 15,636 and nonconvex terms ranging from 50 to 15,000. It is shown that such large-scale multiproduct and multipurpose batch design problems can be solved to global optimality with reasonable computational effort.

WE3-I-CM200

Critical Extreme Points of the 2-Edge Connected Spanning Subgraph Polytope

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Équipe Combinatoire, Université Pierre & Marie Curie

Mahjoub Ali Ridha

Keywords: 2-edge connected graph - cut - minimal extreme point - polytope

We study the extreme points of the polytope $P(G)$, the linear relaxation of the 2-edge connected spanning subgraph polytope of a graph G. We introduce an ordering among the extreme points of $P(G)$ and we show that, if $\bar{x}$ is an extreme point which is minimal for this order, G and $\bar{x}$ can be reduced by means of some operations to a graph G' and an extreme point $\bar{x}'$ of $P(G')$ which satisfy some simple properties. As a consequence we obtain a charaterization of perfectly 2-edge connected graphs.

MO4-L-CM201

Progress in the Parallel Interior Point Al-

gorithm in OSL and Successor

Forrest John J.

IBM

Gupta Anshul

Keywords: OSL - interior point methods - parallel

IBM's OSL (Optimization Subroutine Library) has included a parallel interior point algorithm since before the last Mathematical Programming Symposium. While effective on many problems, results showed that in order to obtain a truly scaleable code, it would be necessary to completely re-design the code. The current state of progress in OSL and a possible successor code OSL++ will be described, with especial reference to the ordering and Cholesky factorization phases of the algorithm.

TU3-C-CO2

Inertia-Controlling Primal-Dual Interior Methods for Nonlinear Programming

Forsgren Anders

Royal Institute of Technology (KTH)

Gill Philip E.

Keywords: barrier methods - constrained minimization - interior methods - modified Newton methods - nonlinear programming - penalty methods - primal-dual methods

This talk concerns the solution of large-scale general (nonconvex) nonlinear programming problems when first and second derivatives of the objective and constraint functions are available.

The solution method discussed is based on solving the primal-dual penalty-barrier equations for a sequence of decreasing values of the scalar penalty-barrier parameter. An augmented penalty-barrier function is used as a merit function for both the primal and dual variables. An inertia-controlling symmetric indefinite factorization is used to provide descent directions and directions of negative curvature for the merit function.

We describe our recent research in this area, including extensions to semidefinite programming. Some preliminary computational results will be presented.

MO3-E-CO21

Homotopy Algorithms and Properties of Systems of Polynomial Equations

Forster Walter

University of Southampton

Keywords: simplicial algorithm

Homotopy algorithms combine beautiful mathematics with the capability to solve complicated nonlinear systems. Developed over the last 30 years, these algorithms have shown to be capable of solving problems where other algorithms fail. The algorithm given by Kuhn for a polynomial in one variable finds all the roots of a polynomial of degree n . A problem encountered in the convergence proof for the case of multiple roots was resolved by W.Forster in 1992 by using material from Nielsen fixed point theory. This then opened the way for the determinination of the number of solution classes for systems of polynomial equations in more than one variable. In the talk the number of solution classes for systems of polynomial equations will be discussed. We will also discuss the influence this has on the solution of the Kuhn-Tucker equations by homotopy methods.

TH1-E-CO11

Implementation of Homotopy Algorithms

Forster Walter

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Keywords: homotopy method

Herbert Scarf's constructive proof of the Brouwer fixed point theorem in 1967 started the new field of homotopy algorithms. Many such algorithms have now been published and many examples of complex nonlinear problems which have been solved by homotopy algorithms have been given in the literature. Nevertheless, the dissemination of knowledge about homotopy algorithms into the wider research community is progressing only slowly. The discussion in this session will try to highlight problems in computer-implementations, difficulties in applications, and why despite superior capabilities of homotopy algorithms we have not seen a faster and wider spread of these techniques.

TH4-I-CM120

Designing Reliable Networks with Bounded Ring

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Labbé Martine

The minimum-weight two-connected spanning network problem consists in finding a network with minimal total weight for which there exist two node-disjoint paths between every pair of nodes. This problem, arising from the need to obtain survivable communication and transportation networks, has been widely studied.

In our model, the following constraint is added in order to increase the reliability of the network : each edge must belong to a cycle using at most K edges (a bounded ring). This condition ensures that when traffic between two nodes has to be re-directed (e.g. in case of failure of an edge), we can limit the increase of the distance between these nodes.

We provide here a polyhedral study of the two-connected network with bounded ring problem. More precisely, we show it is strongly NP-hard for any fixed K and we describe valid inequalities for this problem. Among those, some classes are shown to be facet-inducing. We conclude by the description of a branch-and-cut algorithm and by numerical results obtained with real and randomly generated instances.

WE4-G-IN11

Stochastic Programming Using AMPL

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Gay David M.

Keywords: AMPL - stochastic programming

The AMPL modeling language was originally designed for expressing deterministic mathematical programming problems. Thus it can express explicit deterministic equivalents of some stochastic programming problems, but this is only practical for problems involving a relatively small or simple scenario structure, and even then the expression can be somewhat clumsy.

We are working on several ways to make at least some stochastic programming problems more convenient to express in AMPL. One is the introduction of named scenarios, a facility that should also be convenient in other contexts. Another is a "stochastic" declaration for expressing the time/stage structure of recourse problems. A third way extends the existing mechanism for handling nonlinearities to permit expressing both dependent and independent random variables.

TU2-N-CO15

Analysis Support in a Modeling Language for Mathematical Programming

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Keywords: AMPL - analysis - modeling language

Modeling languages let people describe optimization problems in a natural form that is nonetheless readable by a computer system. Most such languages provide expressions for a variety of values generated by the optimization process, such as variables' reduced costs and bounds, and constraints' shadow prices and slacks. These expressions are built into the languages, however, and as a result they often prove to be insufficient — both in number and in flexibility — to report all of the useful information that solvers generate as a result of optimization.

We describe an approach to this situation that allows the user or solver to define any number of new entities associated with each variable, constraint or other model component. We refer to these new entities as "suffixes" since they are typically represented by appending a short tag to a component's name. Each suffix permits reference to a different piece of information about the solution, such as might be produced by sensitivity or infeasibility analysis; different solvers are free to employ different collections of suffixes as appropriate to the analyses they perform. The suffix mechanism also proves useful for conveying information such as integer variable priorities to solvers, and for exchanging information such as basis statuses.

We illustrate these ideas with examples from their implementation in the AMPL modeling language.

FR3-W-CO15

General-Purpose Modeling Languages for Combinatorial Optimization

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Keywords: combinatorial - discrete - logic programming - modeling language

General-purpose modeling languages are widely used to formulate and solve broad classes of optimization problems, particularly linear programs and smooth nonlinear programs. These languages could be made much more useful for combinatorial optimization, however, through a variety of extensions such as conditional and counting operators, variables in subscripts, and object-valued or set-valued variables.

One major obstacle to such extensions has been a lack of general- purpose solvers to deal with them. In some cases, established branch-and-bound codes can find solutions efficiently by relying on conversion to an integer program. But often the most appropriate solvers are ones that operate more directly on the combinatorial formulation, employing methods that have their roots in logic programming.

These observations and related research topics are illustrated using the AMPL modeling language and ILOG's C++ solver class library.

TU2-D-CO124

Hooking an Interior Point-based Decomposition with the Mathematical Programming Modeling Languages

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Chang Dave

Keywords: algebraic modeling language - decomposition methods - interior point methods - parallel implementation

A general approach is proposed to include automated decomposition techniques in the mathematical programming modeling language. The motivation for such an approach has emerged from the following statement. On one side, modelers often choose to formulate their problems in well tested general purpose modeling languages such as GAMS and AMPL since the syntax of writing a model in this environment closely resembles the mathematical notation when written on paper. A number of such obtained models (e.g. dynamic or stochastic ones) reveal particular structure that makes them eligible to the use of decomposition-based optimizaton techniques. On the other side, there exist a number of cutting edge mathematical programming solvers that are able to exploit particular structure of the model. The lack of a well developed link between these algorithms and the modeling languages prevents many modelers from accessing a rich source of algorithmic techniques.

A modeling language is always linked with a solver through a set of functions that facilitate the communication between them. We propose to implement the automated decomposition at the level of these functions. Our approach has been implemented with two subroutines (SPLITDAT and DECOMP) added in the GAMS I/O library. The aim of both of these subroutines is to provide the GAMS user with the possibility of using Benders decomposition (i.e. a decomposition technique which is particularely well adapted to solve stochastic programming problems) within the GAMS modeling language. Recently, we have extended this approach hooking an interior point-based decomposition solver with the GAMS modeling language.

WE3-I-CM121

Relative Size of Certain Polynomial Time Solvable Subclasses of Satisfiability

Franco John

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We determine, according to a certain measure, the relative sizes of several well-known polynomially solvable subclasses of SAT. The measure we adopt is the probability that randomly selected k-SAT formulas belong to the subclass of formulas in question. This probability is a function of the ratio r of clauses to variables and we determine those ranges of this ratio that result in membership with high probability.

We show, for any fixed $r > 4/(k(k-1))$, the probability that a random formula is SLUR, q-Horn, extended Horn, CC-balanced, or renamable Horn tends to 0 as $n \to \infty$. We also show that most random unsatisfiable formulas are not members of one of these subclasses.

TU1-I-CM121

Covering Symmetric Supermodular Functions by Graphs

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Benczur Andras

Keywords: connectivity augmentations - hypergraphs - supermodular function

T. Watanabe and A. Nakamura proved a min-max formula for the minimum number of new edges whose addition to a given undirected graph results in a k-edge-connected graph. E. Cheng considered the problem of increasing the connectivity of hypergraphs by adding a minimum number of graph edges, and provided a solution for the special case where the starting hypergraph is $(k-1)$-connected. Extending further the results of Cheng, J. Bang-Jensen and B. Jackson solved the general hypergraph connectivity augmentation problem. The purpose of the present work is to exhibit a generalization of these results by deriving a formula (and algorithm) for the minimum number of edges of an undirected graph covering a symmetric, supermodular set-function. The main result, when specialized to hypergraphs, tells how many new graph-edges are needed to make a hypergraph k-connected inside a specified terminal set.

MO4-T-CO22

Optimization and Analysis via Surrogate Modeling

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Keywords: computer experiments - optimization - response modeling

An emerging optimization technique is the use of inexpensive global models that serve as "surrogates" for expensive analysis codes. Surrogate models are used as stand-ins for analysis codes in both single and multidisciplinary optimization. Motivated by industrial problems, this talk emphasizes two aspects of surrogate modeling that usually get litle attention in related presentations. These are, refinement of inaccurate models, and the problem insight to be gained via surrogate model analysis. This talk will describe some of the motivating industrial problems and discuss sequential modeling and model analysis methods. A proposed system of surrogate model-based tools will also be described.

WE3-L-CM201

Exploitation of Embedded Multistage Structure by a Large-Scale SQP Solver

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Arnold Eckhard

Keywords: interior point methods - large scale optimization - multistage problems - nonlinear programming - optimal control - quasi-Newton methods - sequential quadratic programming

Multistage problems constitute an important class of large-scale nonlinear programming problems. They arise typically from optimal control and design problems that are discretized in time or space. We discuss how their special structure is exploited in the large-scale nonlinear optimization solver HQP. The optimization solver is based on a sequential quadratic programming (SQP) method and treats convex quadratic subproblems with an interior point algorithm. The efficiency of this sparse implementation of general-purpose optimization algorithms strongly depends on the problem structure. It can often be improved considerably by introducing additional linearly constrained variables, even though the problem size increases. Additional variables help to improve the sparse structure of the directly solved equation systems. Furthermore, they allow the partitioning of the Hessian of the related Lagrangian function into diagonal blocks, which can be updated separately by the dense BFGS quasi-Newton formula for constrained problems. Finally, the presence of state variables in mathematical programming problems resulting from optimal control applications can be advantageous for the treatment of constraints. The high-level front-end Omuses has been implemented to support the appropriate formulation of multistage problems. Connections to parallel computing are motivated. Examples are taken from the CUTE test set and from an application to a solar heating plant.

TU1-G-IN11

On the Role of Weak Convergence in Stochastic Programming

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The numerical solvability of stochastic programs depends essentially on how the nested optimization and multidimensional integration of implicitely given value function is carried out. One common way to overcome these difficulties is discretize the probabilistic data and solve the deterministic equivalent. Clearly, the discretization is a simplification of the real dynamics, which may have severe impact on the goodness of the surrogate problem. In theory, weak convergence of the probability measures is sufficient for the epi-convergence of the value functions, and hence for the convergence of the minimizers. In this talk we discuss the role of weak convergence with respect to solvability of the underlying stochastic program and its numerical effort.

FR4-I-CM4

A Network Flow Based Theory for Generalized Matching Problems

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Keywords: matching problems - network flow

A network flow model is presented which simplifies the description and analysis of general matching problems, sometimes called degree constrained subgraph problems. The cardinality matching problem, the f-factor problem, and the (f, g)-factor problem are within the scope of this network flow model.

The reduction of bipartite matching problems to network flow problems is known since the early 70'ies. However, the equivalence of not-necessary bipartite matching problems and the *balanced network flow problem* has first been studied by Kocay and Stone in 1993!

We have established a theory for balanced network flows which is really exhaustive. Nearly all cardinality matching algorithms and theorems can be derived and extended to the new problem without much effort. Our theory is very intuitive, and includes an augmenting path theorem, a max-flow min-cut theorem, the Gallai-Edmonds decomposition, and the factor theorems of Tutte and Lovasz for example.

We will sketch two kinds of algorithms for the balanced network flow problem. The first approach solves the corresponding max-flow problem first, and is due to Anstee. The second approach depends on the theory of Vazirani proving the correctness of his famous cardinality matching algorithm. We have refined Vazirani's ideas to come to more intuitive intermediate results.

Only minor changes take place when the theory is generalized from 1-factors (respectively 0-1 flows) to degree constrained subgraphs (respectively capacitated flows). We will point out such differences.

TU2-J-IN202

Condition Number Complexity of an "Elementary" Algorithm for Resolving a Conic Linear System

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Epelman Marina

Keywords: complexity - conditioning - convex programming - error analysis

We develop and analyze an algorithm for resolving a conic linear system (FP_d), which is a system of the form

$$(\mathrm{FP}_d): \quad \begin{array}{l} b - Ax \in C_Y \\ x \in C_X, \end{array}$$

where C_X and C_Y are closed convex cones, and the data for the system is $d = (A, b)$. The algorithm "resolves" the system in that it either finds an ϵ-solution of (FP_d) for a pre-specified tolerance ϵ, or demonstrates that (FP_d) has no solution by solving an alternative dual system. The algorithm is based on a generalization of von Neumann's algorithm for linear inequalities. The algorithm is "elementary" in the sense that it performs only a few relatively simple mathematical operations at each iteration (in the spirit of a reflection algorithm for linear inequality systems). The number of iterations of the algorithm is essentially bounded by $O\left(\mathcal{C}(d)^2 \ln(\mathcal{C}(d)) \ln\left(\frac{\|b\|}{\epsilon}\right)\right)$ when (FP_d) has a solution, and is bounded by $O\left(\mathcal{C}(d)^2\right)$ when (FP_d) has no solution, and so depends only on two numbers, namely the feasibility tolerance ϵ and the condition number $\mathcal{C}(d)$ of the data $d = (A, b)$ (in addition to the norm of the vector b), and is independent of the dimensions of the problem. The quantity $\mathcal{C}(d)$ is the condition number of (FP_d), originally defined by Renegar as $\mathcal{C}(d) := \|d\|/\rho(d)$, where $\rho(d)$ is smallest change in the data $\Delta d = (\Delta A, \Delta b)$ needed to create a data instance $d + \Delta d = (A + \Delta A, b + \Delta b)$ that is ill-posed, i.e., $\rho(d)$ is the "distance to ill-posedness". Each iteration of the algorithm performs a small number of matrix-vector and vector-vector multiplications (that take full advantage of the sparsity of the original data) plus a small number of other operations involving the cones C_X and C_Y that are typically easy to compute (and which are easy to compute when these cones are the nonnegative orthant R^n_+, the semi-definite cone $S^{k\times k}_+$, and/or the origin $\{0\}$).

WE4-B-CO10

Augmented Lagrangians with Adaptive Precision Control for Quadratic Programming with Simple Bounds and Equality Constraints (II.Applications)

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Dostal Zdenek - Santos Sandra Augusta

Keywords: adaptive precision control - augmented Lagrangian - equality constraints and simple bounds - quadratic programming

The problem of identification of the contact interface and evaluation of contact stresses of systems of elastic bodies in contact arises in Mechanical Engineering. Starting from the variational formulation of the equilibrium conditions, the problem is reduced to a definite or semidefinite quadratic programming problem. Both finite element discretization and boundary element discretization approaches are considered. We present numerical results including 3D semicoercive problems.

FR2-C-CO122

Combinatorial Analysis of Process Network Synthesis

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Imreh Balazs - Fülöp János

Keywords: branch and bound - combinatorial analysis - process network synthesis

In a process network, materials are consumed through various chemical and physical transformations to yield desired products where these transformations are carried out in the operating units of the network. Since the cost of the production strongly depends on the selection of the process network

among the usually large number of alternatives, process network synthesis (PNS) has big practical and economical impact.

PNS can be formulated as mixed integer programming (MIP) where a binary variable expresses the existence or absence of an operating unit in a selected network. The size of this MIP problem in terms of the number of binary variables renders the model difficult to solve by any available method that does not exploit the structural features of feasible process structures. Combinatorial analysis of the MIP models of PNS and that of feasible process networks have yielded mathematical tools for exploiting the unique characteristics of PNS. These tools serve as a basis for effective techniques in solving PNS.

TU4-D-CO123

SDPA (Semidefinite Programming Algorithm)

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Kojima Masakazu - Nakata Kazuhide

Keywords: interior point methods - numerical experiments - semidefinite programming - sparsity

The SDPA is an implementation of a primal-dual interior-point method for semidefinite programming. The code is written in C++. The SDPA incorporates the Mehrotra-type predictor-corrector step and an efficient method for computing the Helmberg-Rendl-Vanderbei-Wolkowicz/Kojima-Shindoh-Hara/Monteiro and Nesterov-Todd directions when the SDP is sparse. We discuss some implementation issues and report numerical results on the SDPA for large scale problems.

TU4-E-CO21

A New Merit function and a Descent Method for Semidefinite Complementarity Problems

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Yamashita Nobuo

Keywords: bounded level sets - error bounds - merit function - semidefinite complementarity problem

Recently, Tseng extended some merit functions for the nonlinear complementarity problem to the semidefinite complementarity problem (SDCP) and investigated various properties of those functions. We propose a new merit function for the SDCP based on the squared Fischer-Burmeister function and show that it has some favorable properties. Particularly, we give conditions under which the function provides a global error bound for the SDCP and conditions under which its level sets are bounded.

FR2-C-CO122

A Global Optimization Approach for Solving Process Network Synthesis Problems

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COMPUTER AND AUTOMATION INSTITUTE OF HAS

Friedler Ferenc - Nagy Adam

Keywords: branch and bound - global optimization - process network synthesis - separable concave minimization

Process network synthesis problems with concave cost, including fixed charge, of the operating units are considered in the lecture. We present a global optimization approach that combines the benefits of the accelerated branch-and-bound technique based on combinatoral techniques and those of the branch-and-reduce method for solving separable concave minimization problems. Computational experience is also presented.

FR4-H-CO22

The Tragedy of the Commons and the Core: A Partition Function Form Approach

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Yamato Takehiko

Keywords: cooperative games - core - partition function - the tragedy of the commons

This paper considers a model of the tragedy of the commons, which is analyzed by Roemer(1989), Roemer and Silvestre(1993), Ito, Saijo and Une(1995). Under decreasing returns to scale, it is known that the Nash equilibrium does not attain the Pareto optimum. We show the possibility to obtain the efficiency if people behave cooperatively. For that purpose, the concept of so-called partition function form game is used and the core of the game is considered.If people have pessimistic views, then the core always exists, but if they have optimistic views, the core might be empty. In addition, when we consider an approach of bargaining by two coalitions, we show the pessimistic situation corresponds to maximin value approach and the optimistic situation corresponds to Nash equilibrium approach.

TU2-I-CM200

An Approach to the Feedback Vertex Set Problem with Branch and Cut

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Keywords: branch and cut - combinatorial optimization - feedback vertex set

The feedback vertex set problem (FVSP) on an undirected or directed graph consists of finding a set of nodes with minimum cardinality and the property that this set contains at least one node from every cycle of the graph. In other words all cycles have to be broken by deleting as few nodes as possible. Variations are possible if node weights and/or arc weights are given. It is known, that the feedback vertex set problem is NP-complete.

There exist several applications and approximative algorithms, polynomial exact algorithms for special cases and exact algorithms with exponential time complexity. In our talk we discuss the possible variants of feedback problems and our branch–and–cut approach to one of them. This discussion in-

cludes an integer programming formulation, facets and additional valid inequalities. The separation of these inequalities, various strategies of selecting branching variables and computational results with the new branch–and–cut framework ABACUS will be presented as well.

TH4-U-IN10

Order Batching in a Parallel-Aisle Warehouse

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van de Velde Steef L. - van den Berg Jeroen

Keywords: branch and bound - column generation - order batching - warehousing

In many warehouses the number of items per pick is less than that of a storage module such as a pallet. In particular if individual orders consist of relatively few items, efficient order picking can often only be achieved by grouping orders into batches. Then a batch of orders can be picked in one tour through the warehouse and the mean travel time per order will be reduced. The order batching problem is the problem of distributing the orders among batches to enable efficient order picking, and of determining a batch picking tour for every batch.

We consider the problem of batching orders in a parallel-aisle warehouse. We consider two objective functions, namely to minimize the maximum pick time of any of the batches and to minimize the sum of the pick times for all batches respectively. We present exact algorithms for these problems. As a subroutine of our algorithms we use a polynomial time algorithm by Ratliff and Rosenthal to find an optimal tour through the warehouse for a single batch.

TH4-G-IN11

No Arbitrage Conditions in Multiperiod Pricing Models

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Arbitrage theory is based on a single fundamental assumption corresponding to an intuitively straightforward principle: 'There is no free lunch!'. Basically, market participants are all assumed to be greedy, i.e. they prefer more to less. This reasoning results in the existence of equilibrium prices. Depending on the economic context, prices refer to assets, states, interest rates, etc.

A basic model of the no arbitrage approach applies to the one-period setting with different outcome states as well as to the multiperiod deterministic context. A generalization can be formulated applicable to the multiperiod stochastic situation. It allows pricing within the framework of discrete models obtained for instance by scenario tree analysis.

TU3-D-CO123

Long-Step Surface-Following Interior-Point Method for Semidefinite Programming: Implementation and Numerical Results

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The Mathworks Inc.

Nemirovskii Arkadi

Keywords: interior point methods - semidefinite programming

We describe the scheme and implementation of a theoretically efficient long-step surface-following algorithm for Semidefinite Programming, with emphasis on (1) Flexible policies to simultaneously enforce feasibility and optimality (2) Efficient implementation of the Linear Algebra routines for the problem structures typically encountered in Control Analysis and Design applications (3) Numerical issues in large-scale problems (4) Preliminary numerical results for a sample of control-oriented applications.

TH3-U-IN10

Optimal design of backbone ATM network with dynamic capacity reallocation using stochastic programming

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Francesco Fantauzzi

Keywords: broadband networks - stochastic programming - telecommunications

We consider the problem of design of broadband ATM (Asynchronous Transfer Mode) which should accomodate uncertain demand. For our purposes such networks can be considered as consisting of two layers: physical and logical. Design of physical network consists in selection of link capacities between nodes which can be switches or crossconnects. The logical network is imposed on the top of physical network and consists of virtual paths between different nodes. Connections (virtual circuits) are established over logical network. The logical network can be reconfigured within restrictions imposed by capacities of physical links in order to reflect changes in demand patterns. The possibility to adapt the logical network to actual demand is important feature which is not present in traditional telecommunication networks and which can lead to improved network capability to provide required grade of service.

The design problem which we treat here consists in selection of optimal link capacities of physical network taking into account reconfiguration capabilities. Due to stochastic nature of demand it is natural to treat this problem as stochastic programming problem. We formulate this problem as stochastic programming problem with recourse where the first stage variables are the capacities of links in the physical network while the second stage variables are the capacities of links in logical network, i.e. amount of physical capacity allocated to each virtual path between nodes.

This problem can easily reach limits of computational capabilities of modern methods. We present here numerical experiments where we combine stochastic Benders decomposition with stochastic quasigradient approach.

FR1-G-IN11

Nonstationary Stochastic Optimization with Applications to Optimal Portfolio Selection

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Keywords: nonstationary optimization - portfolio management - stochastic programming

We consider the problem of tracking the optimal solution of the sequence of optimization problems which depend on changing parameter. Unlike in parametric optimization, the optimizer does not have neither knowledge nor control on evolution of problem in question. Moreover, the values of objective functions are observed with errors which puts this problem in the domain of stochastic programming. It is often necessary to react quickly to changing environment and provide approximate solutions in real time.

One example of such situation is provided by evolving stock markets where prices of stocks are changing rapidly and the objective function of portfolio selection problem depends on past observations which are updated in real time.

In this paper we develop algorithms for nonstationary stochastic optimization and study their properties. Financial applications with numerical experiments on data from New York stock exchange are presented in accompanying paper in session V020

TH2-C-CO2

The Bilevel Linear/Linear Fractional Programming Problem: An enumerative algorithm for finding a global optimum

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Keywords: bilevel programming - enumeration - linear-fractional - nonconvex optimization

Bilevel programming involves two optimization problems where the constraint region of the first level problem is implicitly determined by another optimization problem. We consider the bilevel linear/linear fractional programming problem in which the objective function of the first level is linear, the objective function of the second level is linear fractional and the feasible region is a polyhedron. For this problem an optimal solution can be found which is an extreme point of the polyhedron. Taking into account the relationship between feasible solutions to the problem and bases of the technological coefficient submatrix associated to variables of the second level, an enumerative algorithm is proposed that finds the global optimum to the problem.

TH4-I-CM4

Hypergraph Models in Production Scheduling

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Keywords: hypergraphs - production scheduling

Directed hypergraphs find interesting applications in many areas. Here we consider the use of hypergraph concepts to model and to solve some problems arising in manufacturing systems. In particular two problems will be addressed: the One-Dimensional Cutting Stock problem and the optimal Assembly Plan problem. The former, which is a problem well known and widely studied in the O.R. literature, can be modelled in terms of hyperflows on a suitably structured layered hypergraph. We show how hyperflow computations allow to solve efficiently its continuous relaxation and lead to improvements with respect to the classical Gilmore&Gomory's method. The results of a wide experimentation are presented. The latter is a problem arising in robotic assembly systems, where one or more types of items are produced by assembling together several parts given in input, according to a properly defined assembly plan. By assembly plan we mean a sequence of feasible assembly operations which allow to derive the desired product from the given parts, where a feasible assembly operation is an operation which connects together two sub-assemblies in order to obtain a new sub-assembly or the final product. Systems of this type should be characterised by a high degree of flexibility in order to allow for quick switches from one type of product to another, or to recover easily from errors or unexpected events which may require changes in the assembly plan. Crucial to this point is the capability of generating and updating assembly plans in an efficient way. We show how hyperpath and hyperflow models and algorithms can be used to model and solve the problem of finding an optimal plan, under a certain set of assumption, that is the problem of finding an assembly plan which can be realised with minimum makespan on a given set of machines.

WE2-R-IN203

Numerical Implementations of Mixed Volume Computation

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Li Tien-Yien

In this paper, we will discuss effective numerical implementations of mixed volume computation by applying appropriate linear programming algorithms and other techniques, then apply them to solving polynomial systems by homotopy continuation methods.

MO3-B-CO11

Minimal Forecast Horizons and Monotonicity of Optimal Solutions

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Keywords: dynamic programming - infinite horizon - monotonicity of optimal solutions - rolling horizon procedures

We make use of monotonicity properties of finite horizon solutions to nonstationary dynamic programs, to prove existence of forecast horizons and provide a stopping rule that ensures that the minimal forecast horizon is detected. The monotonicity of optimal plans is a pervasive feature of many applications. We briefly discuss infinite horizon production planning and exploitation of a renewable natural resource. A stopping rule that is ensured to detect the minimal forecast horizon is presented for production planning with convex costs. Finally, future extensions of this work are discussed.

TU1-B-CO11

Relaxation Factor in Projection Methods

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Keywords: convex feasibility - linear systems

Sequential Iterative Methods, given by

$$x[i+1] = x[i] + w(P(x[i]) - x[i])$$

, where w is a real value in the interval (0, 2), and P(.) is a projection on a suitable nonempty closed convex set are useful methods for solving the Convex Feasibility Problem. It has been argued that Conjugate Gradient Like Methods are preferable to projection methods [1], although it is easy to show that the former is a special case of the latter. It has as well been argued that good results are obtained if the relaxation factor (w) equals one; nonetheless, in solving PDEs a value greater than one often leads to a faster convergence, whereas in image restoration small values of (w) yield better numerical results.

Advanced acceleration techniques show that the relaxation factor (w) can be corrected and values not in the (0, 2) interval can improve the results [2]. In this paper we report numerical experiments to show the effect that the w-correction step has on the overall performance of projection methods. We found a beneficial effect in solving linear systems.

WE4-A-IN1

Tail Estimates for Clarkson's Randomized LP Algorithm

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Welzl Emo

We review Clarkson's expected linear-time algorithm for LPs with a fixed number of constraints, and the main sampling lemma underlying its analysis. In combiniation with combinatorial identities that exactly describe the probabilities of certain events handled by the algorithm, we obtain good tail estimates for the runtime of Clarkson's algorithm.

WE4-G-IN11

An Input Format and Object Library for Stochastic Programming Problems

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Keywords: input format - model management - stochastic programming

Linear programming problems have been freely distributed among researchers and shared between different programs, using a widely accepted input format (MPS). The same cannot be said of other types of mathematical program, such as network problems, nonlinear problems or stochastic problems. In stochastic programming especially, this is a serious shortcoming, since even slight problem variations may require completely different solution techniques and software packages. Commonly accepted input routines are therefore imperative to the success of stochastic programming. This paper describes an attempt at describing a standard for stochastic programs, relying on the MPS format as a point of departure, and addressing shortcomings that were identified in previous efforts. In addition to the work on the standard problem formulation we will describe a number of utility functions to be included in an object library for stochastic programming problems.

TH4-W-CO15

The Evolving AMPL/Solver Interface

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Keywords: AMPL - interfaces - solver

AMPL started out as a declarative algebraic modeling language for expressing mathematical programming problems. With the addition of various imperative commands, it has slowly grown to a modeling environment that makes it easy to solve sequences of problems and to evaluate arbitrary algebraic expressions involving the problem data and computed solutions. AMPL does not solve problems itself, but invokes separate solvers to do this chore. Originally AMPL communicated with solvers just via files and the environment; for example, it wrote a file of expression graphs for constraints and objectives, which solvers could use with the help of routines in the AMPL/solver interface library. Solvers would then write a file with the solution they found, and AMPL would read that file to obtain solution values.

It has long been clear that conveying more information to and from solvers could be helpful. For example, to solve a modified problem, it might save considerable time if the solver would stay active after reporting a solution, so that AMPL could simply send it a list of modifications rather than a whole new problem description. For solvers that use an active-set method, specifying an initial basis and being able to examine the final one could be helpful.

We are working to permit AMPL and solvers to exchange more detailed problem information and, where appropriate, to carry on two-way conversations, both to solve sequences of problems more efficiently and to provide better diagnostic information. We have also recently restructured the AMPL/solver interface library to make Hessian information available to nonlinear solvers, and to scratch a variety of other itches.

FR1-W-CO15

Making Use of Hessians Easy and Efficient with Automatic Detection of Partially Separable Structure

Gay David M.

Bell Labs

Keywords: Hessian - automatic differentiation - partial separability

Many nonlinear optimization problems are partially separable: the objective is the sum of terms, each of which, perhaps after a suitable linear change of variables, depends on only a few variables. Knowing this structure permits one to efficiently evaluate or operate with the Hessian of the Lagrangian, using backwards automatic differentiation to compute Hessian-vector products of each of the terms. With a suitable algebraic representation of the objective, such as the one made available by AMPL modeling language, we can find partially separable structure automatically. This makes it easy for people to use some sophisticated nonlinear solvers that require Hessians or partially separable structure – without having to express or even know about these details.

We have recently extended the AMPL/solver interface library to make Hessian information (including sparsity details) conveniently available to solvers. Source for the interface library is available from netlib, as are sample drivers for several popular nonlinear solvers, and a MATLAB interface.

FR3-I-CM121

An Algebraic Matching Algorithm

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Keywords: Tutte matrix - matchings

The Tutte matrix of a simple graph G=(V,E) is a certain skew-symmetric matrix, with indeterminate entries, whose rank is twice the size of a maximum cardinality matching of G. Fifty years ago, Tutte used this algebraic formulation of the matching problem to prove his famous matching theorem. We describe an efficient deterministic algorithm that replaces the indeterminates in the Tutte matrix with constants without decreasing its rank. Consequently, one can efficiently determine the size of the largest matching in G by determining the rank of the resulting matrix. The algorithm is purely algebraic, though conceptually it relies on the Gallai-Edmonds structure theorem.

TU3-U-IN10

On the Minimum Capacity Multicommodity Multiperiod Flow Network Problem

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Centre National d'Étude des Télécommunications France Télécom

Martin Vincent - Lutton Jean-Luc

Keywords: Benders - Dantzig-Wolfe - linear programming - multi-period - multicommodity flow routing

A big issue in the telecommunication industry is how to manage efficiently the routing of the leased line over different time periods in a network. More explicitly, for a given topology, the question is how to minimize the capacity requirements which allow to meet the demands. We consider leased lines which start and finish at different time. Then the difficulties come from the routing of a leased line. Indeed it must remain the same through the different periods of time over which the leased line runs. Then when a leased line last a long time it prevents any other leased line to use the same capacity.

From this problem arises a linear program whose size grows tremendously as the number of periods and demands increases. Let consider n as the number of periods. Basically it breeds to a model consisting of n " minimum capacity multicommodity flow network problem " which are dependent from each other. Obviously this linear problem cannot be explicitly computed. By adding variables, we design a model which can be work out with decomposition methods. A Benders decomposition is followed by a Dantzig-Wolfe algorithm applied on the satellites produced by the first

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TU1-I-CM5

A Tabu Search Heuristic for the Capacitated Arc Routing Problem (CARP)

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Gopalakrishnan Srimathy - Rousseau Jean-Marc

Keywords: arc routing - heuristics - tabu search

The Capacitated Arc Routing Problem (CARP) is one of the most important problems in arc routing with numerous applications. In this paper, we propose a tabu search heuristic for the CARP. The heuristic is based on balancing demands on routes by moving capacity excesses or deficits among neighbouring routes. The tabu search also exploits an adaptive memory that contains the routes of the best previously visited solutions. The adaptive memory helps to generate new starting solutions for the tabu search by combining routes from different solutions, as well as intensify the search in the neighbourhood of particularly good solutions. We present the various aspects of the tabu search algorithm and computational results.

MO3-I-CM5

The Mixed Rural Postman Problem on Trees and Circles

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Anily Shoshana - Laporte Gilbert

Keywords: arc routing - circles - mixed graph - rural postman problem - trees

We consider Rural Postman Problems defined on mixed graphs with an underlying tree or circular structure. These special RPP instances are shown to be polynomially solvable under suitable assumptions. These assumptions correspond to situations which are likely to be encountered in many practical settings. A new characterization of circular Eulerian graphs is also presented; it plays a key role in the design of the algorithm for RPPs on these graphs.

WE4-K-CM106

A General Tabu Search Approach for Two-Stage Stochastic Programming with Recourse

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Louveaux Francois

Keywords: recourse - stochastic programming - tabu search

Two-stage stochastic programming with recourse is an extremely useful modelling framework for addressing planning situations where optimal decisions must be made in an uncertain environment. Stochastic programs with integer first-stage variables are typically encountered in stochastic vehicle routing and stochastic facility location; they are, however, quite difficult to solve exactly, since they combine combinatorial and stochastic features. This situation has prompted some authors to develop heuristics to tackle these problems, but these attempts have been limited to instances in which the possible number of realizations for the random variables is fairly small. In this talk, we present a tabu search heuristic capable of handling two-stage stochastic programs with a large or infinite number of possible realizations. The method is based on a limited sampling scheme, reminescent of stochastic quasi-gradient techniques: at each iteration, only a small number of random scenarios (realizations) are generated and used for the evaluation of potential solutions. Robust solutions are obtained by maintaining throughout the search a list of several elite solutions which are evaluated at each iteration on the scenarios just sampled. The method will be illustrated in the context of a stochastic capacitated plant location problem with Poisson-distributed demands and computational results on fairly large instances will be reported and discussed.

MO3-L-CM201

Parallel Branch-and-Bound for Multicommodity Capacitated Network Design

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DIRO-CRT, Université de Montréal

Bourbeau Benoit - Crainic Teodor Gabriel - Frangioni Antonio

Keywords: Lagrangean relaxation - branch and bound - network design - parallel computing

We present parallel branch-and-bound algorithms for multicommodity capacitated network design problems. The bounding procedures are based on Lagrangean relaxation and state-of-the-art nondifferentiable optimization techniques. Several variants of parallelizations are introduced and compared, based on experimental results on clusters of workstations.

FR2-I-CM121

The Matroids Representable over the 4-Element Field

Gerards Bert

CWI

Geelen James Ferdinand - Kapoor Ajai

In 1991, Rota conjectured that for each finite field there exist a finite list of matroids such that a matroid is not representable over the field if and only if it has a minor on the list. At that time, this was only confirmed for the 2- and 3-element fields, respectively by Tutte in 1948 and Reid in 1971. Now we can also prove it for the field with 4 elements. It turned out that the list of "forbidden minors" in that case has 7 members. That it took so long to make the step from 2 and 3 to 4 is with no doubt caused by the fact that representations over the two smallest fields are unique (up to the obvious) but over the 4-element field not. As we shall explain uniqueness of representations is very useful in inductive proofs. Fortunately, it has been proven by Kahn in 1988 that representations over the 4-element field are unique under certain connectivity assumptions. Although these assumptions complicate the issue a lot, it turned out that they where not too strong to make an inductive proof work.

MO3-C-CO122

A Bundle Method for Nonlinear Programs with Noisy Functions

Gfrerer Helmut

Universität Linz

Hintermüller Michael

We consider the following mathematical program

$$\begin{aligned} &f(x) = \min ! \\ &c_i(x) \leq 0, \qquad i = 1, 2, \ldots, m \end{aligned}$$

where $f, c_i : \Re^n \to \Re$ are twice continuously differentiable. However, we assume that the values and first derivatives of the problem functions can only be obtained within some (possibly low) precision. In this situation, standard methods often break down with linesearch difficulties due to the fact that the available information does not reflect the local behaviour of the functions but that of the noise. To master this lack of information we propose a bundle concept. Doing this we obtain an algorithm which converges in theory and seems to be fast and robust in practice.

MO3-C-CO3

Some Remarks on Lagrange Multipliers and Separation of Sets

Giannessi Franco

University of Pisa

Recent investigations have shown that separation of sets can be usefully considered as a general framework for developing the theory of constrained extrema and, in particular, the Lagrange multiplier approach. The related results are briefly reviewed as concerns both finite and infinite dimensional problems. Remarks are made for some extensions to the variational Inequality field.

WE1-D-CO124

A BFGS Interior Point Algorithm for Minimizing a Convex Function Subject to Linear Constraints

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INRIA Rocquencourt

Armand Paul - Jégou Sophie

Keywords: BFGS - convex function - interior point methods - large scale optimization - linear inequality constraints - quasi-Newton algorithms

We consider the problem of minimizing a convex function subject to linear inequality constraints. In many large-scale optimization problems the Hessian of the function to minimize is not available. We consider algorithms that generate BFGS approximations of the Hessian and that use interior point techniques for handling the inequality constraints. We give some extensions of the convergence theory of the unconstrained BFGS algorithm to this class of problems.

FR1-F-IN203

An SQP Method for the Optimization of Dynamical Systems

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Jay Laurent O. - Petzold Linda R.

Keywords: DAE methods - SQP - large scale optimization - multiple shooting methods - optimal control

When used in conjunction with multiple shooting, SQP methods provide a powerful technique for optimizing systems in which the nonlinear equality and inequality constraints include a large-scale system of differential-algebraic equations (DAEs). In this situation, most of the work goes into the $O[Nn(n+m)]$ sensitivity calculations associated with each constraint Jacobian, where N is the number of shooting intervals, n is the number of interior spatial grid points, and m $(m \ll n)$ is the number of basis functions used to represent the control function.

We describe an SQP method that is specially designed for problems with DAE constraints. The idea is to transform the constraints of the QP subproblem so that the Jacobian has only $O[n(n+m)]$ nontrivial entries. These entries involve matrix products that can be computed in a time that is independent of the spatial grid size. An advantage of our approach is that DAE structure is exploited without radically changing the optimizer.

WE2-L-CM201

MINOS and SNOPT - A Status Report

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University of California, San Diego

Murray Walter - Saunders Michael A.

Keywords: SLC methods - SQP - inequality constraints - large scale optimization - nonlinear programming

The large-scale nonlinear programming codes MINOS and SNOPT have some features in common but otherwise complement each other. We discuss some recent algorithmic developments, including the treatment of infeasible problems (and LC or QP subproblems) and the exploitation of second derivatives. The CUTE test collection is used for extensive numerical comparisons.

TU4-I-CM5

On Some Polynomial Solvable Cases of the Simple Plant Location Problem

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Keywords: connected matrices - plant location - polynomial algorithm

This paper focuses on some authors's results concerned special cases of the Simple Plant Location Problem (SPLP) when effective algorithms for solving the problem can be constructed. The number of cases we obtain imposing restrictions on the class of transportation cost's matrices (c_{ij}).

We proposed exact polynomial algorithms in case of matrices (c_{ij}), which are named connected, quasiconvex, quasiconcave, quasiconvex to the right and to the left and generally quasiconvex.

In case of so-called central-connected matrices (c_{ij}) for the network SPLP it was shown that optimal decision with connected servicing areas exists. In this case we constructed $O(mn)$-time exact algorithm solving the SPLP on a tree. As an example of the central-connected matrix (c_{ij}) is the matrix with $c_{ij} = c_i + d_{ij}$ where $c_i \geq 0$ and d_{ij} to be the sum of edge lengths in a shortest path connecting the vertices i and j. Polynomial exact algorithms for some classes of cyclic networks are constructed too.

It seems reasonable to say that most of proposed results are widely unknown for west researchers.

FR4-P-IN201

Solution Algorithms for the Multimode Scheduling Problem with Dedicated Resources

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University of Rome "Tor Vergata"

Bianco Lucio - Dell Olmo Paolo - Speranza Maria Grazia

Keywords: heuristics - lower bounds - multimode taks - project scheduling

Let us consider a set $\mathcal{P} = \{P_1, \ldots, P_m\}$ of m dedicated processor, and a set of n tasks $\mathcal{T} = \{T_1, \ldots, T_n\}$ to be carried out using these processors. Each task $T_i \in \mathcal{T}$ can be undertaken in m_i different modes, each mode requiring a set of dedicated processors for a given processing time. Let $\mathcal{G} = (\mathcal{T}, A)$ be the digraph representing general precedence constraints among tasks. A task can start its execution only if all tasks preceding it in $\mathcal{G}$ have been completed. A single mode has to be assigned to each task and a starting time has to be defined for each task in such a way that each processor is used by a single task at a time and precedence constraints are satisfied. Moreover, the processing of a task cannot be interrupted and restarted later. The objective of the problem is the minimization of the time required to complete all tasks (i.e., the makespan). In previous works, we studied procedures in which a solution was obtained by means of an iterative procedure that combines mode assignment and sequencing phases separately. In this paper, we present some new composite heuristics where the decision on the mode assignment is taken on the basis of a partial schedule. Then for each task, the mode selection and the starting time are chosen simultaneously considering the current resource usage. Different lower bounds on the optimal value of the objective function are derived from the mathematical formulation of the problem. Heuristics and lower bounds are evaluated on randomly generated test problems.

TH1-C-CO2

Nonsmooth Vector-Valued Invex Functions and Applications

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Guerraggio Angelo

Keywords: Lipschitz functions - invexity - multiobjective optimization

Various types of locally Lipschitz vector-valued invex (and generalized invex) functions are examined. Then the said classes of nonsmooth invex functions are used in order to formulate sufficient generalized Kuhn-Tucker results for a multiobjective programming problem, both with a conical ordering and in the Paretian case. Weakly efficient and properly efficient points are obtained

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FR2-P-IN201

Shop Scheduling with Batching to Minimize the Makespan

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Potts Chris N. - Strusevich Vitaly A.

Keywords: approximation algorithms - batching - complexity - flow shop - heuristics - open shop - scheduling

This paper examines machine scheduling problems in which the batching of operations of a job is a key issue. Jobs proceed from one machine to another as a batch. Both the flow shop and open shop systems are analysed. The objective in each situation is to minimize makespan, and the processing time of a batch on a machine is the sum of the processing times of the operations in that batch. For a flow shop system, we prove that the problem of finding an optimal schedule is $NP-$hard in the strong sense, even for two machines. For the case of a two-machine flow shop, we develop a heuristic with a worst-case performance ratio of 3/2. The heuristic crucially relies on the observation that there is an optimal solution with consistent batches, so that batches on both machines contain the same jobs. For the two-machine open shop system, we prove that the problem of finding an optimal schedule is $NP-$hard in the ordinary sense and is pseudopolynomially solvable. We show that we may restrict our attention to consistent batches, as for the flow shop, and, moreover, that there need be at most three batches. We also provide a heuristic which runs in $O(n \log n)$ time, where n is the number of jobs, with a worst-case performance guarentee of 11/9.

TH3-E-CO21

Variational Methods in Nonsmooth Dynamics

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Keywords: nonsmooth dynamics

In classical mechanics the concept of virtual work is used in order to classify displacement-dependent forces. Forces are called “active” if they produce virtual work, otherwise they are called ”passive”. Both types are treated completely different with respect to formulation and evaluation of the equations of motion: Active forces are continuous functions of the displacements and can therefore be directly evaluated when the displacements are known. Passive forces originate from bilateral constraints and can not be represented by functions. Usually certain displacements are prescribed but the forces are arbitrary. The evaluation of the passive forces is thus done either by inverting the corresponding force characteristics which yields additional equations depending on the displacements known as constraints, or by choosing appropriate reduced sets of new coordinates, called “minimal coordinates”, such that the constraints are automatically satisfied and thus eliminated from the equations of motion. This approach makes sense as long as the above mentioned classification applies to all forces within a multibody system. However, there are forces of intermediate type acting in some regions as applied forces, in other regions as constraints. Usually one becomes aware of them when dealing with dry friction, unilateral constraints, or impact effects. This type of forces leads to hemivariational inequalities which are variational expressions for multivalued differential equations obtained by generalized differentiation of certain non-convex superpotential functions. The paper treats the evaluation of the accelerations in rigid multibody systems which are subjected to set-valued force interactions resulting from non-smooth potential functions via generalized differentiation. A generalization of the classical principles of d’Alembert, Jourdain, and Gauss in terms of variational inequalities will be given. A strictly convex minimization problem depending on the unknown accelerations of the system will be stated, known in classical mechanics as the Principle of Least Constraints.

WE2-B-CO10

Linear Semi-Infinite Systems and Optimization

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University of Alicante. Faculty of Sciences

Jornet Valentin

Keywords: linear inequality systems - optimization theory - semi-infinite programming

Linear inequality systems with an arbitrary number of constraints and finitely many unknowns arise, in a natural way, in separation and optimization problems (linear semi-infinite programming). In general, such kind of systems perform poorly from the geometrical, optimality and duality perspectives and, so, different classes of systems have been introduced in the literature, in order to get better properties. This paper is intended to survey and compare different families of well-known (Farkas-Minkowski, canonically closed) and recently introduced (analytical, p-systems, locally polyhedral and locally Farkas-Minkowski) systems.

TH3-P-IN201

One Machine Scheduling with Release Dates

Goemans Michel X.

MIT

Keywords: approximation algorithms - polyhedral combinatorics - relaxation - scheduling

I will consider the problem of scheduling jobs on one machine subject to release dates and with the goal of minimizing a weighted sum of completion times. I will describe several relaxations for the problem, and discuss their relationship and their quality in the worst-case.

TU-am-CO1

Semidefinite Programming in Combinatorial Optimization

Goemans Michel X.

MIT

Keywords: combinatorial optimization - eigenvalues - maximum cut - semidefinite programming - stable set

Recently, there has been increasing interest in the use of convex optimization techniques and more specifically semidefinite programming in solving combinatorial optimization problems. In this talk, I will try to highlight the power (as well as the limitations) of semidefinite programming in the area of combinatorial optimization. I will describe some of the most important developments, starting from the seminal work of Lovász on the theta function. The topics that I will touch upon also include the automatic generation of strong valid inequalities, the maximum cut problem, and the embedding of finite metric spaces and its relationship to the sparsest cut problem. Several intriguing open questions will be mentioned.

TU1-D-CO124

A Nonlinear Analytic Center Cutting Plane Method for a Class of Convex Programming Problems

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Sharifi Mokhtarian Faranak

Keywords: analytic centers - convex programming - cutting plane methods - interior point methods - potential function - self-concordance

A cutting plane algorithm for minimizing a convex function subject to constraints defined by a separation oracle is presented. The algorithm is based on approximate analytic centers. The nonlinearity of the objective function is taken into account, yet the feasible region is approximated by a containing polytope. This containing polytope is regularly updated either by adding a new cut at or by shifting an existing cut to the test point. In the first phase of the algorithm, the test point is an approximate analytic center of a containing polytope. In the second phase, it becomes an approximate analytic center of the intersection of a containing polytope and a level set of the nonlinear objective function. We prove that the algorithm converges and establish its complexity. In the case where the oracle generates a finite number of cuts, the algorithm is polynomial in this number, while it is a polynomial approximation scheme (in the dimension of the space) in the case where the oracle can generate an infinite number of cuts.

WE4-I-CM4

Negative-Cycle Detection Algorithms

Goldberg Andrew V.

NEC Research Institute

Cherkassky Boris

We study the classical problem of finding a negative-length cycle in a network. This problem comes up directly and as a subproblem in algorithms for other important problems. An algorithm for the negative cycle problem combines a shortest path algorithm and a cycle detection strategy. We study various combinations of shortest path algorithms and cycle detection strategies and find the best combinations.

All shortest path algorithms in our study are based on the labeling method of Ford. We prove the following result about this method: If the input graph contains a negative cycle, then, after a finite number of labeling operations, the distance label of some vertex is less then the length of a shortest simple path in the graph and the graph of parent pointers always contains a cycle. This result is fundamental for many cycle detection strategies, yet it was unknown prior to our paper.

Tarjan proposed a cycle detection strategy that allows immediate detection of cycles in the graph of parent pointers, without asymptotic increase in complexity of underlying shortest path algorithms. Surprisingly, this strategy improves practical performance of shortest path algorithms.

Our previous study showed that an algorithm of Goldberg and Radzik is the best for shortest path problems with negative length arcs. Tarjan's algorithm is competitive with the Goldberg–Radzik algorithm on a wide range of negative cycle and shortest path problems.

WE4-I-CM4

Beyond Flow Decomposition Barrier

Goldberg Andrew V.

NEC Research Institute

Rao Satish

Keywords: algorithms - combinatorial optimization - maximum flow

The maximum flow problem is a classical optimization problem that has been intensely studied because of its numerous applications. For a network with n vertices and m arcs, $O(nm)$ is a natural bound for a maximum flow algorithm: The size of an explicit flow decomposition gives a matching lower bound. This lower bound does not apply if the decomposition is not needed. No previous maximum flow algorithm, however, runs in $O(nm)$ time. In the unit capacity case, the decomposition size is $O(m)$ and the problem can be solved in $O(min(n^2/3, m^1/2)m)$ time [Karzanov, Even & Tarjan].

We present an algorithm that significantly improves upon the flow decomposition bound unless the input capacities are huge. Our algorithm runs in $O(min(n^2/3, m^1/2)m \log(n^2/m) \log U))$ time, assuming the capacities are integers between 1 and U. This bound bridges the gap between the unit capacity case and the case of arbitrary integral capacities. The algorithm is based on a new approach to the maximum flow problem.

TU4-I-CM121

The Data-Correcting Algorithm for De-

termining Global Minima if Supermodular Functions with Applications to NP-Hard Problems

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Sierksma Gerard - Tijssen Gert - Tso Michael Kia-Sho

Keywords: algorithms - general case - global minima - supermodular function

The problem of minimizing a supermodular set function defined on the unit hypercube underlies a lot of NP-hard discrete optimization problems. The Data-Correcting (D-C) Algorithm is an enumerative algorithm that constructs a sequence of subproblems by 'correcting' the input data for a given (NP-hard) problem such as to obtain data corresponding to polynomially solvable instances of the problem. One of the main advantages of this approach is that at each iteration an upper bound for the difference between the optimal and current solution is at hand. In the paper it is shown how the D-C Algorithm can be used for minimizing supermodular functions in case of the simple plant location problem and the Boolean expression simplification problem. We report the results of tests on randomly generated instances of the quadratic cost partition problem, and compare the results with those in Lee et al.(1996). It turns out that for problems with density more than 20% the D-C Algorithm is at least 10 times faster, and for problems with density at most 20% our algorithm has a comparable performance.

MO4-D-CO123

A Product-form Cholesky factorization for Handling Dense Columns in Interior Point Methods for LP

Goldfarb Donald

IEOR Department, Columbia University

Scheinberg Katya

Keywords: Cholesky factorization - interior point methods - linear programming

In this talk we describe a product-form Cholesky factorization method for solving the least squares problem that arises at each iteration of an interior point method for linear programming. Our approach is based on removing dense columns of the constraint matrix A and handling them separately by means of a product-form Cholesky factorization of ADA^T. We analyze the method's computational requirements and present preliminary computational results.

TH1-I-CM120

Polynomial-Time Highest-Gain Augmenting Path Algorithms for the Generalized Circulation Problem

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IEOR Department, Columbia University

Jin Zhiying - Orlin James B.

Keywords: generalized circulation - generalized maximum flows - network flow

This paper presents two new combinatorial algorithms for the generalized circulation problem. After an initial step in which all flow-generating cycles are canceled and excesses are created, both algorithms bring these excesses to the sink via highest-gain augmenting paths. Scaling is applied to the fixed amount of flow that the algorithms attempt to send to the sink, and both node and arc excesses are used. The algorithms have worst-case complexities of $O(m^2(m+nlogn)logB)$, where n is the number of nodes, m is the number of arcs, and B is the largest integer used to represent the gain factors and capacities in the network. This bound is better than the previous best bound for a combinatorial algorithm for the generalized circulation problem, and for sparse graph, it is better than the previous best bound for any algorithm for this problem.

MO3-D-CO123

Interior Point Trajectories in Semidefinite Programming

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IEOR Department, Columbia University

Scheinberg Katya

We discuss interior point trajectories in semidefinite programming (SDP) including the central path of an SDP. Under an assumption of primal and dual strict feasibility, we show that the primal and dual central paths exist and converge to the analytic centers of the optimal faces of, respectively, the primal and dual problems. We consider a class of trajectories similar to the central path that can be constructed to pass through any given interior infeasible point and study their convergence. Finally, we study the derivatives of these trajectories and their convergence.

TH4-B-CO10

A Primal-Dual Decomposition Method for Solving Linear Programming Problems

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Central Economics & Mathematics Institute, Russian Academy of Sciences

We consider the linear programming problem P

$$c_1^T x + c_2^T u \to \max,$$

under conditions

$$A_{i1}x + A_{i2}u = b_i, \quad i = 1,2, \quad x \geq 0, \quad u \in G,$$

where A_{ij} is a $m_i \times n_j$-matrix, $c_1, x \in E^{n_1}$, $c_2, u \in E^{n_2}$, $b_i \in E^{m_i}$, $G \subset E^{n_2}$ is a polytope, E^k stands for k-dimensional Euclidean space. Problem P has two vector variables (x and u) and two groups of the constraints ($A_{i1}x + A_{i2}u = b_i$, $i = 1,2$) connecting x and u.

Let us suppose that if we fix u and use only the first group of the constraints then the resulting linear programming problem has a simple structure, that is for any $\overline{c_1}$ and $\overline{b_1}$ problem $P(\overline{c_1}, \overline{b_1})$

$$\overline{c_1}^T x \to \max, \quad A_{11}x = b_1, \quad x \geq 0,$$

may be solved much more effectively than a general linear programming problem of the same dimensions.

In this paper we propose a decompopsition method for solving problem P, analysing an auxiliary problem $P(\overline{c_1}, \overline{b_1})$ on each iteration, where both $\overline{c_1}$ and $\overline{b_1}$ are determined by the previous steps. The method transforms problem P to the saddle-point problem of a convex-concave function and uses a saddle-point variant of the level-method.

Numerous testings of the method for multicommodity production-and-transportation problems confirm its high computational efficiency.

TU3-G-IN11

Regularizing the Aquifer Parameter Estimation Problem using Multi-Scale Optimization

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IIMAS UNAM

Alvarez Rosa M. - Perez Angel

Keywords: aquifer model - ill-posed problems - inverse problems - multi-scale grids - parameter estimation - regularization

To predict an aquifer behaviour, it is necessary to solve the two-dimensional partial differential equation which governs unsteady groundwater flow, and to identify the functional coefficients which are not directly measurable from a physical point of view. Rather, these parameters are identified by observing the dependent variable collected (with noise) in the spatial domain of the aquifer under study. The coefficients we study here are the transmissivities which vary spatially.

It is necessary then to solve an ill-posed inverse least-squares optimization problem. In this work, we propose the use of multiscale grids to perform the optimization in a stable way, and present numerical results on a synthetic and on a real aquifer.

TU4-K-CM106

New Structures for Lennard-Jones Atomic Clusters

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IIMAS UNAM

Barron Carlos - Romero David - Saavedra Armando

Keywords: Lennard-Jones potential - atomic clusters - genetic algorithms - global optimization - twisted-icosahedron

In regard to the difficult problem of determining optimal configurations for clusters of n atoms ($13 < n < 147$), we present here solutions for $n = 75, 76$, and 77, found with the peeling algorithm previously proposed by the authors, and with lower Lennard-Jones potential energy than the minimum reported in the literature.

Remarkably, the solutions obtained do not display the commonly accepted icosahedral geometry, but rather that of a *twisted icosahedron*.

We also present a new genetic algorithm tailored for this problem, which enabled us to reproduce all the best results known for clusters of $13 < n < 147$ atoms, including our three new structures.

TH2-D-CO124

Warm Start of the Primal-dual Method in the Cutting Plane Scheme

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Keywords: cutting plane methods - interior point methods - warmstart

A practical warm start procedure is described for the infeasible primal-dual interior point method employed to solve the restricted master problem within the cutting plane method. In contrast to the theoretical developments in this field, the approach presented in this paper does not make the unrealistic assumption that the new cuts are shallow. Moreover, it treats systematically the case when a large number of cuts is added at the time. The technique proposed in this paper has been implemented in the context of HOPDM, the state of the art, yet public domain, interior point code. Numerical results confirm a high efficiency of the approach: regardless the number of cuts added at the time (that grows to thousands in the largest examples) and regardless the depth of the new cuts, reoptimizations are usually done in several iterations.

WE3-S-IN202

Using Paralogous/Orthologous Information for the Reconstruction of Phylogenetic Trees

Gonnet Gaston H.

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The reconstruction of accurate phylogenetic trees from sequence data is a very important and timely topic. Better phylogenetic trees usually imply better multiple sequence alignments, which is one of the main tools for secondary/tertionary structure prediction.

Two sequences are said to be orthologous if they have separated because of speciation. That is, in principle the sequences serveidentical purposes, but are found in different species.

Two sequences are paralogous if they arose by geneduplication. If two such sequences are found in a single species, this is an unequivocal indication that they were generated by geneduplication and hence are paralogous.

With the sequencing of complete genes, the decision of paralogous/orthologous can be completely determined. This is indeed rather accurate information, compared to other sources.

We investigate how to improve our methods of tree construction, based on distances and/or based on probability of evolution, by including this bit of information.

WE1-D-CO124

Computational Experience with Several Centrality Measures in Locating Analytic Centers

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Keywords: analytic centers - centrality measures - interior point methods

Locating the analytic center in linear programming problems is crucial in some applications, e.g. Data Envelopment Analysis. One of the main ingredients of interior-point methods that converges to the analytic center is to generates iterates in the neighborhood of the central path. Measuring how close the iterates are to the central path is an important aspect of such methods. In this talk, we present a computational experience with several centrality measures and demonstrate the effect of centrality measures on the behavior of the algorithm.

TH4-P-IN201

Due Date Assignment for Single Machine Scheduling Problems

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Keywords: due dates - earliness - scheduling - single machine - tardiness

In the early years, most scheduling researchers restricted themselves to considering problems with preassigned due dates. Of obvious practical importance, an optimal assignment of due dates became the subject of growing interest over the last years. We consider due date assignment and preemptive scheduling of n jobs on a single machine under precedence constraints. Along with a processing time p_i, the job i has release date r_i. A due date d_i is assigned depending on p_i. Several rules for assigning due dates with a slack allowance common among all the jobs are considered: $d_i = p_i + k, d_i = r_i + p_i + k, d_i = k_1 p_i + k_2$, where due date parameters k, k_1 and k_2 denote due date multiple factor (k_1) and slack allowance (k or k_2). The problems are to minimize objective functions depending on the assigned due date parameters and maximum tardiness penalties or weighted earliness penalties. Polynomially solvable cases of the problems are considered.

WE3-S-IN202

Concurrent Construction of Multiple Sequence Alignment and Phylogenetic Tree

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Keywords: iterative optimization - multiple sequence alignment - phylogenetic tree

The problem of phylogenetic reconstruction from biomolecular sequence information is tightly related to the multiple sequence alignment problem. First, most methods for phylogenetic inference use a given multiple sequence alignment as an input. Second, efficient multiple alignment procedures often take advantage of a phylogenetic relationship of the members to be aligned. Third, correction for biased representations (or weighting) of sampled sequences is possible only with a knowledge about interrelationship among the sequences. This talk presents a heuristic method that concurrently refines the alignment, tree, and weights in an iterative manner. Assessment of the quality of resulting alignments will be discussed.

MO3-D-CO123

Primal-Dual Methods for Nonconvex, Linearly Constrained Minimization

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Conn Andrew Roger - Toint Philippe L.M.

Keywords: linearly constrained minimization - nonconvex minimization - primal-dual methods

In this talk we consider a method for minimizing a (possibly) nonconvex function of a large number of variables subject to a set of linear constraints and simple bounds on the variables. The search direction at each iteration is either the primal-dual direction or a Newton-like direction for the given merit function. A well-defined sequence of iterates is shown to converge to a first-order stationary point. We examine how the basic method may be modified to ensure convergence to a second-order point. Numerical results will be given.

WE3-C-CO122

A Convergent Generalized Benders Decomposition Algorithm for Solving Bilinear and Quadratic Programming Problems

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Hansen Pierre - Jaumard Brigitte

Keywords: convergence - decomposition methods - global optimization

The problem we adress are special instances of quadratic problems involving only mixed terms. These problems are called bilinear since they become linear as soon as either one of two groups of variables are fixed. The bilinear problem we consider are bilinear in the objective and in the constraints. These problems are hence difficult global optimization problems. A recent algorithm due to C.A. Floudas and V. Viseweswaran uses the generalized Benders decomposition method to solve the bilinear problems. Unfortunatelly, their algorithm, as it is described in their paper, experiences some convergence problems, although it indeed solves many small to medium size problems. We propose a variant of their algorithm for which we established the theoretical convergence. Both algorithms are illustrated on some small examples and preliminary computational results are presented.

TU1-I-IN202

The Assymetric Travelling Salesman Problem: Aggregating a Multicommodity Flow into a Node Oriented Formulation

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Pires Jose Manuel

Abstract: In a previous work the authors presented an Improved Miller-Tucker Zemlin (IMTZ) model for the Assymetric Travelling Salesman Problem (ATSP) which includes an improved and disaggregated version of the well known Miller-Tucker-Zemlin constraints. The linear programming (LP) relaxation of a new model is characterized by a set of circuit inequalities given in Grotschel and Padberg (1985) which are

weaker than the well known subtour elimination constraints given in Dantzig, Fulkerson and Johnson (1954). This shows that the multicommodity flow (MCF) model for the ATSP is stronger than the new IMTZ model. We show that the IMTZ model can be seen as a node oriented aggregation of the MCF model and in particular show that the aggregation process suggests generalizations of the Miller-Tucker-Zemlin constraints for sets of arcs. Liftings of the generalized constraints which are not dominated by the subtour elimination constraints are also presented.

TH4-I-CM120

Using Variable Redefinition For Computing Minimum Spanning and Steiner Trees With Hop Constraints

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Requejo Cristina

We use variable redefinition to strengthen a multicommodity flow (MCF)¿model for minimum spanning and Steiner trees with hop constraints between a root node and any other node. The lagrangean dual value associated to one lagrangean relaxation derived from the MCF formulation dominates the corresponding LP value. To find alternative and possibly more efficient lower bounding schemes for this problem we use variable redefinition to obtain a generalization of the MCF formulation whose LP bound is equal to the previously mentioned dual lagrangean bound. The main step in obtaining the new model consists of deriving a compact and exact formulation ("exact" in the sense that the corresponding LP optimal solution is always integer valued) for a hop constrained shortest path problem. A new lagrangean based scheme based on the new models is also proposed. We use a set of instances with up to 100 nodes, 50 basic nodes and 350 edges for comparing three lower bounding methods: a LP approach based on solving the LP relaxation of the new model, the new lagrangean scheme and the old lagrangean scheme derived from MCF.

FR1-I-CM120

A Comparative Study of Flow Based models for the Capacitated Minimum Spanning Tree Problem

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Hall Leslie

In this talk we consider network-flow formulations for the capacitated spanning tree problem. As in many network design problems, what is particularly attractive about these flow-based models is that by using a small number of constraints it is possible to enforce an exponential number of combinatorial connectivity constraints on the design variables. In particular, we focus on the relationship between the linear programming (LP) relaxation of a model using undirected edge design variables and the LP relaxation of a model using directed arc design variables. Experience dictates that better formulations (i.e., more compact formulations and/or those that provide a better LP bound empirically) can be obtained by formulating the problem in a directed graph. We shall give several examples of formulations where a polynomial number of constraints in the directed flow formulation imply an exponential number of constraints in the undirected flow model. Moreover, an important outcome of our study suggests that a nice projection result (into the space of design variables) obtained with a directed flow formulation seems very unlikely to be obtainable with the analogous undirected flow model.

TU3-E-CO21

On the Connectedness of Solutions Sets of Continuous Functions

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Keywords: locally unique - univalence

In this talk we present a result concerning the connectedness of the solution set of the equation $f(x) = q$ where f is continuous and weakly univalent on a subset X of R^n. The univalence results of Radulescu-Radulescu, Moré-Rheinboldt, and Gale-Nikaido follow from our result. For a nonlinear complementarity problem corresponding to a P_0-function, we show that the solution set is connected if it contains a nonempty bounded clopen subset; in particular, the problem will have a unique solution if it has a locally unique solution. For the linear complementarity problem corresponding to an R_0-matrix M, we show that every solution set of LCP(M, q) is connected if and only if the matrix is P_0.

MO4-P-IN201

Algorithms of Optimal Choosing a Set of Machines for Job-Shop Problem with Parallel Machines

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Pempera Jaroslaw - Werwinski Pawel

Keywords: heuristics - job shop - parallel machines - scheduling

This paper deals with the job-shop problem with parallel machines. The problemcan be formulated as follows. There is the set of jobs $J_1, ..., J_n$ whichshould be carried out by using the set of various type machines $M_1, ..., M_n$ and q is the number of these types. Each job consist of a sequence of operations $J_i = < O_{i1}, O_{i2}, ..., O_{in_i} >$. We shall assume that processing times of operations are fixed and different for different machines. The problem arises to determine the allocation of machines to the individual operation and to determine a sequence of operations on machines, taking into account technological requirements, that the total costs of allocated machines are minimal, subject to the completion time of processing of all operations is not greater then a given due date C. The mathematical model and some properties are presented. The heuristic algorithms for solving this problem are given. The developed algorithms have been tested on a set of problems with up 50 jobs, 20 machines and 10 machine types, and the computational resutls are presented.

MO3-B-CO10

Infeasible Primal-Dual Methods for the General Cone

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Keywords: convex programming - interior point methods - primal-dual algorithms

Much of the recent work in primal-dual methods for convex programming is directed towards the set of *homogeneous self-dual* (HSD) cones (also known as *self-scaled* cones). There are a number of practical convex programs, however, which do not benefit from these methods. Many constraints simply cannot be mapped onto the set of HSD cones; still others can be so mapped only at a cost of efficiency.

In this paper, we present an infeasible primal-dual method which can applied to convex programming problems expressed in conic form. We make no restrictions on the cone, except for the existence of a corresponding self-concordant, logarithmically homogeneous barrier.

TH3-I-CM4

A Sequential Algorithm for Coloring some Perfect Graphs

Gravier Sylvain

Laboratoire Leibniz (Grenoble)

We give a sequential algorithm to color a new class of perfect graphs. Our algorithm is based on a 3-chromatic exchange using the Tucker algorithm of 3-coloring of perfect graphs which does not contained a clique of size four.

TU1-R-IN203

Construction, Realization, and Drawing of Configurations

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Keywords: configurations - graph drawing - hypergraphs - matroid realization

A configuration (v_r, b_k) is an incidence structure with v points and b lines such that there are k points on each line, k lines through each point, and through 2 different points there is at most one line.

Configurations are just linear r-regular k- uniform hypergraphs, however, they have been investigated already since 1876. During their first years they were considered to consist of points and lines in the real Euclidean plane, but soon they were seen as purely combinatorial structures where point only means element and line means subset of elements. The *construction* problem of configurations discusses whether for given parameters v, r, b, k a configuration exists or not. A short survey on the already known results will be given.

The *realization* problem discusses whether a (combinatorially) constructed configuration can be realized over a given field in the sense of matroid realization. This is achieved by constructing a matrix with entries in the field such that certain determinants of submatrices are 0 if and only if the corresponding points form a line in the configuration.

The *drawing* problem discussing whether there is a mapping of the points of the configuration into the 2-dimensional plane such that all lines of the configuration are drawn as straight lines. There is also the concept of a schematic and an approximate drawing where nearly all lines are very close to lines.

This problem should be considered in the context of graph drawing and can be extended to all linear hypergraphs. In this sense configurations are quite suitable prototypes for investigations in the fields of matroid realization and hypergraph drawing.

FR1-I-CM3

On-Line Optimization of a System of Automated Guided Vehicles

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Konrad-Zuse-Zentrum

Kamin Nicola

Keywords: integer programming - online optimization - simulation - vehicle scheduling

Jointly with the Herlitz AG, Berlin, we investigated the optimization of a system of automated guided vehicles under on-line conditions. In their main distribution center a fleet of automated guoided vehicles picks up orders from several automated storage systems while following a circular course. The orders have to be processed in a predetermined sequence. While respecting these precedence constraints, we aim at minimizing the time in which the daily orders are processed. Therfore, we seek to minimize the total number of stops the vehicles make to pick up orders. We have proven that this optimization problem is NP-hard. We present an integer programming model and based on this model derive lower bounds for the optimal solution. We describe several primal heuristics that can be applied to the on-line situation. We have developed and implemented a simulation model and compare the behaviour of the heuristics within this model. First results show that significant improvements can be achieved with respect to minimizing the lap time of the vehicles.

WE4-I-CM5

Implementing Ejection Chains for the TSP: Neighbourhoods and Evaluations

Gruenert Tore

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Keywords: computational testing - heuristics - traveling salesman problem

Recently, progress in the area of heuristics and meta-heuristics has led to a growing number of papers dealing with new heuristic algorithms for the well-known Traveling Salesman Problem (TSP). The objective is to find a shortest Hamiltonian cycle (tour) through all nodes of a graph (here, we assume a symmetric graph). Most of the new techniques are based on some generalization of the concept of a neighborhood. In the context of the TSP, a neighborhood consists of all the tours that can be reached by a transformation of the current tour. Ejection chain algorithms belong to this important class of algorithms. However, other concepts which are commonly used in meta-heuristics have not been studied as thoroughly in the TSP-context. These concepts include strategic oscillation, critical event handling, and biased move evaluation. The talk will report on the computational aspects and results which have been obtained by implementing the ideas described above.

MO3-I-CM5

Transformation of Capacitated Arc Routing Problems with Time Windows and Split Deliveries to a Node Routing Formulation. Resolution by a Column Generation Approach

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Dejax Pierre - Dror Moshe - Gendreau Michel

Keywords: arc routing - column generation - graph transformations - split deliveries - time windows

We examine capacitated arc routing problems with time windows on directed, undirected and mixed graphs and transformations of these arc routing problems into a node routing setting. Problems with split deliveries are solved using a column generation methodology applied to the node routing images of the transformed arc routing problems. Those solutions are compared with a direct integer solution methodology applied on the node routing settings of the problems. The focus is on solving arc routing problems with time windows for which a direct formulation is impossible.

FR2-I-CM121

Weakly Bipartite Graphs: A Proof of a Conjecture by Seymour

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Keywords: binary clutters - ideal clutter - minors - weakly bipartite graphs

A *signed graph* is a pair (G, Σ) where G is an undirected graph and Σ is a subset of the edges of G. An *odd circuit* of (G, Σ) is a connected subgraph of G with all degrees equal to two, that has an odd number of edges in Σ. A signed graph (G, Σ) with edge set E is said to be *weakly bipartite* if the polyhedron:

$$\{x \in \Re_+^{|E|} : \sum_{i \in C} x_i \geq 1, \text{ for all odd circuits } C \text{ of } (G, \Sigma)\}$$

is integral.

Seymour conjectured that a signed graph is weakly bipartite if and only if it does not contain, as a minor, the complete graph on five nodes with all edges in Σ. A proof of this conjecture is given in this paper.

WE4-C-CO2

A Prox–Regularization Method for Generalized Fractional Programming

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Keywords: Dinkelbach's algorithm - generalized fractional program - ill-posed problems - linear convergence - prox-regularization

If a fractional program does not have a unique solution or the feasible set is unbounded, numerical difficulties can occur.

By using a prox–regularization method that generates a sequence of auxiliary problems with unique solutions, these difficulties are avoided. The regularization method introduced here is based on Dinkelbach's method.

TH1-D-CO123

Search Directions in Semidefinite Programming

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WE4-L-CM201

Computational Solution of Large Scale Linear Programs Exploiting Embedded Network Structures

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Mitra Gautam - Maros Istvan

Many large scale LP models drawn from the domains of planning, scheduling and supply chain material flow applications display an embedded network structure. The authors describe an algorithmic approach which first solves a network problem with side constraints. The feasible and near optimal solutions of subproblems are then used to create advanced starting points for the LP problem. Computational results of applying this technique to Netlib as well as the other industrial models are presented.

TU-am-CO2+3

Financial Risk Management - A Business Between Regulation and Research

Gumerlock Robert

Swiss Bank Corporation

The profound changes that the financial markets have experienced were accompanied by a reviewed understanding of risk and attitude towards risk in the financial industry. The derivative financial instruments provided a major impact on this development, once the theoretical background for their valuation was developed and accepted by the markets.

Derivatives are powerful instruments to adjust the risk profile of a portfolio, but they make it virtually impossible to intuitively assess the (market-) risks inherent in the portfolio due to their non-linear behaviour. Thus risk measurement becomes a priority, not only for a bank's management but also for regulators, as they have to ensure systemic stability in financial markets. Although initially developed for market risks, the measurement concepts and principles may be implemented for other risk categories as well. Research that applies scientific rigour to these issues of practical relevance is extremely valuable: it complements the pragmatic solutions by practitioners, and it provides know-how on industry practice to the academic researchers.

Although quantitative skills have become a desirable condition for a career in an investment bank, they are not sufficient. A successful conception to manage risks in a bank goes beyond pure measurement techniques to include organisational aspects (e.g. independent control functions), procedural issues (e.g. risk identification, risk limits) as well as personnel incentives schemes.

Risk is recognised to be integral to a bank's business, and - as in the insurance industry - its management is based on increasingly advanced methodologies, it has become highly professional.

FR1-U-IN10

Parallel Branch-and-cut: A Comparative Study

Günlük Oktay

Cornell University, Dept of ORIE

Keywords: branch and cut - integer programming - network design - parallel computing

We present a branch-and-cut algorithm to solve capacitated network design problems and discuss alternative ways to parallelize it. We compare different tree management schemes (centralized vs. distributed) and study the effect of different load balancing procedures for the distributed case. We also compare different computing platforms and present computational results.

FR2-A-IN2

A Branch-and-cut Algorithm for Capacitated Network Design Problems

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Cornell University, Dept of ORIE

Keywords: branch and cut - computing - integer programming - network design

We present a branch-and-cut algorithm to solve capacitated network design problems. Given a capacitated network and point-to-point traffic demands, the objective is to install more capacity on the edges of the network and route traffic simultaneously, so that the overall cost is minimized.

We identify some new facet defining inequalities for the problem, and use them as cutting planes together with other known inequalities. To choose the branching variable, we use a new rule called "knapsack branching". We address computational issues and present computational results using real-life data.

Finally, we briefly discuss issues related with a parallel version of the algorithm.

TU1-D-CO124

An Infeasible-Interior-Point Algorithm for Convex Quadratic Programming Problems

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Computer Science & Electronics Inst. Devi Ahilya University

Chaudhari Narendra Shivaji

Keywords: convex quadratic programming - global convergence - infeasible interior point methods

An infeasible-interior-point algorithm for convex quadratic programming (CQP) problem is proposed. There are several interior point algorithms for CQP problems which have to be initiated by strictly feasible interior points, which is very difficult to obtain in practice. Such points are obtained by creating artificial problem with artificial variables of M coefficients. Such variables create numerical instability and numerical inefficiency. The proposed infeasible-interior-point algorithm for CQP problems can be initiated by points which satisfy the positivity restrictions but not necessarily the equality constraints. The step length has been controlled in such a way that the algorithm is globally convergent.

TH3-G-IN11

Sample-Path Solution of Stochastic Variational Inequalities and Equilibrium Models

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Özge A. Yonca - Robinson Stephen M.

Keywords: simulation optimization - stochastic optimization - stochastic variational inequalities

Sample-path optimization is an effective simulation-based method for optimizing limit functions, such as expectations or steady-state functions, that arise in the study of complex stochastic systems. Recently, the sample-path optimization approach has been extended to provide a simple algorithm for the solution of stochastic variational inequalities, including as a special case the first order necessary optimality conditions for simulation optimization problems. Variational inequalities are used to model a large number of equilibrium phenomena in mathematical economics, energy planning, engineering, and operations research. This new approach makes it possible to solve stochastic equilibrium models involving expectations or steady-state functions; in such cases, by using simulation together with gradient-estimation techniques, the sample-path method could provide an effective alternative to discrete scenario representations of uncertainty, with their associated data-management problems.

In this talk, we first show how to apply the sample-path approach to solve stochastic variational inequalities. We then present a new set of sufficient conditions under which we can show that the method will converge almost surely; we also exhibit bounds on the error of the resulting approximate solutions. Finally, we present numerical results for an application of the method to a stochastic equilibrium model of the European natural gas market. These preliminary results indicate that the method, when applicable, can be very effective.

TH1-B-CO10

Computing Bounds for Functions, Defined by Power Series

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Stavanger College

Keywords: infinite series - quadrature rules - semi-infinite programming

We consider the problem of estimating the value of a function F which is defined for complex arguments z by an infinite series of the form

$$F(z) = a(0) + za(1) + z^2a(2) + \dots$$

Here the function $a(t)$ is real-valued and defined for nonnegative real arguments t. We also assume that a table of n values $a(0), a(1), \ldots, a(n-1)$ is given numerically. We will study the problem of finding the maximum and minimum values of the real and imaginary parts of $F(z)$ when $a(t)$ is allowed to vary over all functions in a certain class K which reproduce the given numerical values. A simple example could be when $n = 4$ and K is the class of polynomials of degree less than 10. A more important case is when K is the class of functions which are completely monotonic over the positive real line. Then $F(z)$ assumes its extremal values when $a(t)$ is approximated by a linear combination with nonnegative coefficients of decaying exponentials and the optimal values correspond to the results delivered by quadrature rules with positive weights. It is noteworthy that one my construct bounds for $F(z)$ even for such values of z when the defining series is divergent. We will discuss various generalisations of this problem, applying the theory and algorithms of semi-infinite programming.

TU4-I-CM4

Intersection Graphs and Clique Application

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Keywords: DV - RDV - UV - chordal - clique application - dually chordal - helly - interval - proper interval

We call Σ_P the class of families of finite sets satisfying a certain property P, $\Omega\Sigma_P$ the class of intersection graphs of any family belonging to Σ_P and $Clique\Sigma_P$ the class of those graphs whose family of cliques is in Σ_P.

We prove that a graph $G \in \Omega\Sigma_P$ if and only if there is a family of completes of G which covers all edges of G and whose dual family is in Σ_P. This result generalizes those of Fulkerson-Gross, Gavril and Monma-Wei for interval graphs, chordal graphs, UV, DV and RDV graphs. Moreover, it leads to the characterization of Helly-graphs and dually chordal graphs as classes of intersection graphs.

We prove that if P the implies conformal property and Σ_P is closed under reductions, then $Clique\Sigma_P = \Omega\Sigma_P^*$ ($\Sigma_P^* =$ Class of dual families of families in Σ_P). We find sufficient conditions for the Clique-application, K, to map $\Omega\Sigma_P$ into $\Omega\Sigma_P^*$. These results generalize several known results for particular classes of intersection graphs. Furthermore, they lead to the Robert-Spencer characterization for the image of K and the Bandelt-Prisner result on K-fixed classes.

WE4-C-CO2

A New Axiomatic Approach to Lagrangian Conditions

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Keywords: Lagrangian conditions - polarity - quasiconvex optimization

The quasiconvex minimization problem is included in a problem defined by sets (instead of functions) in a l.c.s. Lagrangian conditions for both problems are then studied and related. Lagrangian conditions for the standard convex minimization problem are usually defined in terms of subdifferentials. Lagrangian conditions are defined here instead in terms of functionals which satisfy certain axioms.

Farkas-Minkowsky conditions are considered. Constraint qualifications valid at all points in the feasible set are also considered, in connection with questions of redundancy.

TH1-I-CM200

Exponential Neighbourhood Local Search for the TSP and the VRP

Gutin Z. Gregory

Brunel University of West London

In almost all prevoius approaches of local search for combinatorial optimization, only small, polynomial, neighbourhoods were used. This is because at least constant time is spent per every solution (tour in the TSP, for example). In exponential neighbourhood local search (ENLS), we find the best among exponential number of solutions. To achieve that we use various transformations of hard optimization problems, restricted to special exponential size subsets of solutions, into easy optimization problems. In the talk, we discuss ENLS with respect to the TSP and the VRP.

FR4-F-IN203

Lot-Sizing Problem with Interrupted Geometric Yiled, Rigid Demand, and General Cost Stuctures

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Keywords: applications - dynamic programming - imperfect production process - lot sizing

We study the multiple lot sizing problem with interrupted geomeric yield distribution. In the literature, the prevailing production cost is assumed to be linear. We shall relax this assumption to see the impacts of a general cost structure to this lot-sizing problems.

FR2-G-IN11

Solving a Sequence of Deterministic Equivalent Problems

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Keywords: approximation algorithms - discretization - refinement scheme

In Stochastic Multistage Linear Programming the major challenges are the nested minimization and multidimensional integration of implicitly given value functions. The barycentric approximation technique helps carry out the nested minimization and provides information on how accurate the real dynamics are mapped. The goodness of the barycentric approximation depends strongly on the discretization of conditional probability measures, which is applied successively within an iterative cycle. This way, a sequence of scenario trees and associated path probabilities are derived, whose corresponding deterministic equivalent problems provide a sequence of lower and upper bounds of the original problem. Weak convergence of the discrete probability measures implies epiconvergence of the value functions and, hence, convergence of the minimizers. Due to the curse of dimensionality, the scenario trees and their associated mathematical programs grow exponentially in size. In order to solve the sequence of the underlying surrogate problems efficiently, we investigate accelerating techniques which exploit the structure and the convergence behaviour of the deterministic equivalent problems.

TH2-I-CM200

Composition Operations for the Stable Set Polytope

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Fonlupt Jean

Keywords: composition of graphs - perfect graph - stable set polytope

Let G_1 and G_2 be graphs. Suppose that H_1 and H_2 are isomorphic induced subgraphs of G_1 and G_2 respectively. Let G be the graph obtained from G_1 and G_2 by the identification of H_1 and H_2. Let H denote the subgraph of G corresponding to H_1 and H_2.

We show that the stable set polytope of G, $P(G)$, is completely described by the union of the two systems defining $P(G_1)$ and $P(G_2)$ if any of the following conditions holds :

(1) all the chordless paths in G_1 and G_2 linking two vertices of H have the same parity;

(2) the composition operation does not induce an odd chordless cycle, H is a stable set and G_2 is in one of some special classes of graphs;

(3) the composition operation does not induce an odd chordless cycle and H is a stable set with less than five vertices. In these cases, perfection and h-perfection of the graphs are preserved.

TU1-C-CO2

Generalized Monotonicity in Equilibrium Problems II (vector case)

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Schaible Siegfried - Daniilidis Aris - Bianchi Monica

Keywords: equilibrium problems - pseudomonotonicity - quasimonotonicity - variational inequality problems

Vector Variational Inequality Problems (VVIP) and Vector Equilibrium Problems (VEP) were extensively studied in recent years. In our talk we first present a brief survey of these topics, especially regarding results obtained by Daniilidis/Hadjisavvas (1996) for quasimonotone, multivalued operators and by Bianchi/Hadjisavvas/Schaible (1997) for quasimonotone bifunctions. (This part will use some background from the lecture of S. Schaible "Generalized Monotonicity in Equilibrium Problems II (scalar case)").

We then present an approach which extends and unifies these results, based on an extension of a work by Oettli (1997): we show an existence theorem which involves a quasimonotone pair of real-valued bifunctions, rather than one bifunction, and then apply it to obtain existence results for the VVIP and VEP.

TH3-L-CM201

PARSMI, a Parallel Revised Simplex Algorithm incorporating Minor Iterations and Devex Pricing

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When solving linear programming problems using the revised simplex method, two common variants are the incorporation of minor iterations of the standard simplex method applied to a small subset of the variables and the use of Devex pricing. Although the extra work per iteration which is required when updating Devex weights removes the advantage of using minor iterations in a serial implementation, the extra work parallelises readily. An asynchronous parallel algorithm PARSMI is presented in which computational components of the revised simplex method with Devex pricing are either overlapped or parallelism is exploited within them. Minor iterations are used to achieve good load balance and tackle problems caused by limited candidate persistence. Initial computational results for a six-processor implementation on a Cray T3D indicate that the algorithm has a significantly higher iteration rate than an efficient sequential implementation.

TH1-I-CM5

Combinatorial Solution Algorithms for Max Ordering Location Problems

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Keywords: combinatorial optimization - location problems - max ordering - multicriteria optimization

A max ordering optimization problem is a multi-criteria problem where the maximum of Q given objective functions is minimzed. (In the literature these problems are also often referred to as max-min problems.) In this talk combinatorial algorithms for solving continuous and network location problems with max ordering objectives are discussed.

TU3-I-CM200

On some Balanced, Totally Balanced and Submodular Delivery Games

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Tilburg University

Granot Daniel - Tijs Stef

This paper studies a class of delivery problems associated with the Chinese postman problem and a corresponding class of delivery games. A delivery problem in this class is determined by a connected graph, a cost function defined on its edges and a special chosen vertex in that graph which will be referred to as the post office. It is assumed that the edges in the graph are owned by different individuals and the delivery game is concerned with the allocation of the traveling costs incurred by the server, who starts at the post office and is expected to traverse all edges in the graph before returning to the post office. A graph G is called Chinese postman-submodular, or, for short, CP-submodular (CP-totally balanced, CP-balanced, respectively) if for each delivery problem in which G is the underlying graph the associated delivery game is submodular (totally balanced, balanced, respectively).

For undirected graphs we prove that CP-submodular graphs as well CP-totally balanced graphs are weakly cyclic graphs and conversely. An undirected graph is shown to be CP-balanced if and only if it is a weakly Euler graph. For directed graphs, CP-submodular graphs can be characterized by directed weakly cyclic graphs. Further, it is proven that any directed connected graph is CP-balanced. For mixed graphs it is shown that a graph is CP-submodular if and only if it is a mixed weakly cyclic graph.

Finally, we note that undirected, directed and mixed weakly cyclic graphs can be recognized in linear time.

WE-pm-CO1

Logical Analysis of Numerical Data

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Boros Endre - Ibaraki Toshihide - Kogan Alex

In its original conception, the methodology of "Logical Analysis of Data (LAD) was designed for the discovery and utilization of "patterns" distinguishing the "true" and the "false" binary n-vectors ("observations") in a given dataset. The methodology of LAD was then extended (by using a "binarization" process) to datasets of "true" and "false" n-vectors of real numbers. Work currently in progress is aimed at further extending this methodology to the study of datasets of n-vectors of real numbers, with real-valued "outcomes" associated to the observations. The methods of LAD are based on combinatorial optimization and the theory of partially defined Boolean functions. This survey will:

1. describe the essential features of LAD and its extensions to the case of numerical data;

2. examine some mathematical problems related to LAD, including the study and the use of well-known and of new structured classes of Boolean functions;

3. discuss some algorithmic issues concerning LAD, including complexity questions involved in the binarization process;

4. present comparative results about the classification power of LAD, using datasets from the Depository of the University of California at Irvine;

5. outline uses of LAD in classification, data compression, construction of decision support systems, error detection, etc., based on case studies from medicine, economics, seismology, oil exploration, sociology, etc.

WE-am-CO2+3

Cluster Analysis and Mathematical Programming

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GERAD, MEC

Jaumard Brigitte

Given a set of entities, Cluster Analysis aims at finding subsets, called clusters, which are homogeneous and/or well separated. As many types of clustering and criteria for homogeneity or separation are of interest, this is a vast field. A survey is given from a mathematical programming viewpoint. Steps of a clustering study, types of clustering and criteria are discussed. Then algorithms for hierarchical, partitioning, sequential, and additive clustering are studied. Emphasis is on solution methods, i.e., dynamic programming, graph theoretical algorithms, branch-and-bound, cutting planes, column generation and heuristics.

TH4-I-CM121

Maximizing the Product of Two Linear Functions in 0-1 Variables

Hansen Pierre

GERAD, MEC

Hammer Peter L. - Pardalos Panos M. - Rader David J.

We study both the continuous and discrete problems of maximizing the product of two linear functions subject to all variables being between 0 and 1. We first give linear and low-order polynomial algorithms for the solution of the continuous problem. In addition, we describe penalties that help to fix variables in the discrete problem. Extensive computational tests demonstrate the effectiveness of these results.

FR2-W-CO15

SGOPT: A C++ Library of Global Optimization Algorithms

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Keywords: genetic algorithms - global optimization - heuristics

SGOPT is a library of general global optimization algorithms that is being developed at Sandia National Laboratories. This library utilizes an object-oriented design which allows the flexible construction of algorithmic hybrids between global and local search methods. A main focus of the initial algorithmic development for this library was genetic algorithms and Monte Carlo sampling, including parallel versions of these methods. This library is being expanded to include a variety of other general global optimization methods like simulated annealing and tabu search. This talk will describe the basic design and capabilities of SGOPT and discuss its relationship with the DAKOTA and OPT++ optimization toolkits being developed at Sandia.

TH3-I-CM5

On Wire Length Minimization in VLSI Design

Hartmann Stephan

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Keywords: VLSI - interval graph coloring - wire length minimization

gn of integrated circuits has achieved a great deal of attention in the last decade. We consider the following VLSI design problem: an instance consists of a rectangular grid, the *routing region* and a set of *nets*. The set of nets consists of k nets $N_1, .., N_k$, where each net is a set of so–called *terminals* which here are intersection points at the lower boundary of the grid. A solution of this single–line routing problem, called a *layout*, is given by pairwise edge–disjoint Steiner trees $T_1, ..., T_k$ embedded in the grid such that T_i connects the terminals of net N_i, $i = 1, \ldots, k$. The first question under consideration is to find solutions which are routed within the minimum number of horizontal lines. This problem can be solved in linear time in the Manhattan as well as in the knock–knee model. The second question is to find solutions with a minimum total wire length, i.e. solutions which occupy the minimum number of vertical and horizontal segments of the grid. For the Manhattan model, the minimization of the total wire length is known to be NP–complete. This problem is closely connected to special weighted colorings of interval graphs, also refered to as the *optimal cost chromatic partition problem* [Sen et al. '92]. We report on algorithms and computational experiences attacking this problem with linear programming techniques. The high quality of the achieved results for this hard problem seems to be surprising at first glance. For the knock–knee model, we present an linear time combinatorial algorithm for the total wire length minimization problem if the number of terminals per net is bounded.

MO3-I-CM120

Compact Representations of Cuts

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Keywords: min cuts - multiterminal cuts

The well-known flow equivalent tree (due to Gomory and Hu) is a compact representation of the min cuts in an undirected graph. We generalize this notion to the multitermal cut problem and other problems. This work extends the related work of Hassin.

TU2-B-CO10

On a Splitting Method for Finding a Zero of the Sum of Two Maximal Monotone Operators

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Keywords: convex programming - maximal monotone operator - parallel optimization - splitting method - variational inequalities

Many problems of convex programming can be reduced to that of finding a zero of the sum of two maximal monotone operators.

To solve this problem, a large variety of splitting methods has been proposed, the three most famous of these methods being the Forward-Backward scheme, the Peaceman-Rachford scheme and the Douglas-Rachford scheme, which have been extensively studied in the literature. More recently, Glowinski and Le Tallec have proposed a new splitting algorithm, called the $\theta-$scheme, to solve this problem. They mentioned that this scheme seemed to give good numerical results but, from a theoretical point of view, there was no general convergence analysis.

In the first part of the talk, after having briefly described the splitting methods above, we will see that if the inverse of one of the operators is strongly monotone, then the sequence generated by the $\theta-$scheme of Glowinski and Le Tallec converges to a solution of the problem. Moreover the rate of convergence will be at least linear if, in addition, the same operator itself is strongly monotone.

The second part of the talk will be devoted to the applications. We will apply the $\theta-$scheme to the dual of some well-known problems in order to derive new splitting algorithms for solving them. The first problem to be considered is a variational inequality problem with some separable structure. Finally we discuss some separable convex programming problem which is a particular case of the previous problem.

TH1-U-IN10

Congestion Toll Pricing Models and Methods

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Ramana Motakuri

Keywords: taffic assignment - toll pricing

Congestion toll pricing models address the problem of determining tolls for the traffic assignment problem such that the solution of the tolled user equilibrium problem will be system optimal. In recent research we have shown that there are a variety of models which can be formulated to determine a toll vector from set of all possible tolls. This talk will summarize the mathematical properties of toll sets and report computational experience with the proposed toll pricing models.

TH2-H-CO22

Constraint Proposals Method for Computing Pareto Solutions in n-Party Negotiations

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Ehtamo Harri - Hämäläinen Raimo P.

Keywords: Pareto optimum - decomposition - hierarchical optimization - negotiations - optimization

A constraint proposals method for computing Pareto-optimal solutions in n-party negotiations is developed. In the method the problem of computing Pareto-optimal solutions is decomposed. The decomposition leads to a hierarchical optimization problem and it involves finding the affine set orthogonal to the gradients of the decision makers' value functions at a Pareto-optimal point. At every iteration n individual subproblems are solved: each party maximizes his own value function on an affine set, i.e, under a set of linear constraints. On the upper level a new affine set going through a fixed reference point is formed. A candidate for Pareto-optimal solution is found when the optimal solutions of the subproblems coincide. Conditions under which the solution is Pareto-optimal are given.

The solution is shown to always dominate the reference point and two ways for selecting reference points for generating several Pareto-optimal points are considered. An algorithm for solving the upper level problem is given and its behavior is studied by numerical examples.

WE4-D-CO123

Fixing Variables in Semidefinite Relaxations

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Keywords: quadratic 0-1 programming - reduced cost fixing - semidefinite programming - semidefinite relaxations

The standard technique of reduced cost fixing from linear programming is not trivially extensible to semidefinite relaxations as the corresponding Lagrange multipliers are usually not available. We propose a general technique for computing reasonable Lagrange multipliers to constraints which are not part of the problem description. Its specialization to the semidefinite $\{-1, 1\}$ relaxation of quadratic 0-1 programming yields an efficient routine for fixing variables. The routine offers the possibility to exploit problem structure. We extend the traditional bijective map between $\{0, 1\}$ and $\{-1, 1\}$ formulations to the constraints such that the dual variables remain the same and structural properties are preserved. In consequence the fixing routine can efficiently be applied to optimal solutions of the semidefinite $\{0, 1\}$ relaxation of constrained quadratic 0-1 programming, as well. We provide numerical results showing the efficacy of the approach.

WE2-C-CO122

On the Relation between Global Optimization and Integer Programming

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Keywords: global optimization - integer programming

There are several aspects in the relation between global optimization at one side and combinatorial optimization at the other. In literature on global optimization usually only the complexity aspect is emphasized. In this paper some other aspects are added namely, the ability to solve multiextremal problems by integer programming techniques, the similarity in algorithms and the applicability of the analysis in a global optimization way on integer programming problems. Examples derived from applications in Agricultu- ral and Environmental research are used to illustrate these aspects.

MO4-A-IN2

On Hilbert Bases of Simplicial Cones

Henk Martin

ZIB

Weismantel Robert

The geometrical structure of (minimal) Hilbert bases is not well understood yet. Even for simplicial cones it is more unknown than known although bases of such cones occur in many different fields of mathematics. In this talk we discuss geometrical properties of those bases and show some of their applications, e.g. w.r.t. simultaneous Diophantine approximation problems and linear Diophantine equations.

MO4-U-IN10

A Capacitated Bus Grid Network Design Problem

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Keywords: heuristics - network design

We present a capacitated network design problem, where optical fiber buses are to be connected in a grid-like manner. Fibers are categorized as either horizontal or vertical, where fiber connections are only allowed between one horizontal and one vertical fiber. Demand points are connected to fibers via access nodes, and fibers are connected to each other via switching nodes. Fibers are physically grouped into cables, and a cable can contain different numbers of fibers. Fibers and nodes have limited capacities. As a redundancy requirement, all pairs of demand points with nonzero demand must be connected with at least two paths. In addition there are limitations on the number of “hops” (switching nodes) that the flow between two demand points may pass. A heuristic solution method for the problem is presented. The method starts by connecting all access nodes to horizontal fibers in a geographical manner, and then connects the end nodes of these fibers with vertical ones in order to satisfy the redundancy requirements. At this stage a cable network is created by associating each fiber with one cable. A TSP heuristic is used to decrease the length of the cables. Another heuristic technique is used to group the fibers into cables, so that the number of cables can be reduced. Then we try to satisfy the demand by sequentially sending flow through the fiber network, taking capacities and hop constraints into account. When necessary, new fibers are added and placed within the existing cable network, and more flow is sent. This is repeated until the demand is satisfied.

TU4-C-CO3

Nonsmooth Constraint Mappings with Cone Increasing Behavior

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Keywords: nonsmooth optimization

We discuss Lipschitzian stability of cone constraints $F(x) \in K_y$ where $F : X \to Y$ is a (nonsmoooth) mapping between Banach spaces and $K_y \subseteq Y$ is a closed cone. It is assumed that F has some cone-increasing behavior, i.e. there exists a cone $K_x \subseteq X$ such that $x_1 - x_2 \in K_x \Longrightarrow F(x_1) - F(x_2) \in K_y$. Such additional information on F - which is given for instance for distribution functions of probability measures in the context of chance constrained programming - may be exploited in order to obtain sharper characterizations of stability. As a main tool we apply Mordukhovich's coedrivative criterion. In a finite-dimensional setting the property of constraint mappings being metrically regular at all feasible points is shown to be generic in case they are locally Lipschitzian and nondecreasing w.r.t. the partial orders of R^n, R^m, respectively.

WE1-D-CO124

Feasible Arc Interior Point Algorithms For Nonlinear Optimization

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Santos Gines

Keywords: interior point methods - nonlinear constrained optimization

We consider nonlinear constrained optimization problems and propose a quasi - Newton algorithm that at each iteration makes a line search along a feasible arc. The present method is based on a general technique for feasible direction interior point algorithms that solves Karush - Kuhn -Tucker conditions by Newton - like primal - dual iterations. At each iteration, these algorithms compute first a descent direction by solving a linear system. By perturbing the system, a feasible descent direction d is then obtained. A line search is finally performed to get a new interior point with a lower objective. Newton, quasi - Newton or first order algorithms can be obtained in this way. For the quasi - Newton algorithm, the convergence is superlinear if the line search step length becomes unitary near the solution. However for some problems with strongly nonlinear constraints the unitary step length is not obtained and the rate of convergence is worst than superlinear. This effect, that is similar to Maratos' effect for SQP algorithms, occurs when the feasible segment on d is not long enough.

The present method avoids Maratos effect. Given an interior point x^k, to define the feasible arc we obtain first a descent and feasible direction d^k. Then, the constraints are evaluated at $x+d$ and we compute estimates of their second derivatives along d^k. With this estimates, $\tilde{d} \in R^n$ is obtained solving a new system with the same matrix. The feasible arc is $x(t) = x^k + td^k + t^2\tilde{d}^k$.

We prove global convergence with two - steps superlinear rate and show the results with several test problems and applications in structural optimization.

TH2-C-CO2

A New Method for Bilevel Programming Based on a Smooth Optimization Technique

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Leontiev Anatoli

Keywords: bilevel programming

We prove that the set of local solutions of the convex bilevel programming problem (BLPP) is equivalent to a particular subset of the local minima of a smooth regular nonlinear classical optmization problem. To find this subset, we propose an algorithm based on an interior point technique for nonlinear optimization.

Let be x and y the decision vectors associated with the upper and lower levels respectively. The BLPP is defined as:

$$\begin{aligned}&\min_{x,y} F(x,y)\\&\text{subject to } g(x,y) \le 0\\&\ \text{where } y \text{ solves}\\&\min_{y} f(x,y)\\&\text{subject to } h(x,y) \le 0.\end{aligned}$$

We consider a finite dimensional problem with $x \in R^n$ and $y \in R^q$. We suppose that $F, f:\ R^n \times R^q \to R^1$, $F(x,y)$ is once and $f(x,y)$ is twice continuously differentiable in (x,y); f is convex in y for all value of x; $g:\ R^n \times R^q \to R^l$; $h: R^n \times R^q \to R^m$ is twice differentiable and convex in y for all value of x and continuous in x for all y.

Replacing, under an appropriate constraint qualification, the lower level problem by its Karush-Kuhn-Tacker conditions, we obtain a standard one-level mathematical program. However, since this problem is nonregular, it is not posible to solve it by standard nonlinear programming methods.

We prove that the BLPP problem admits the following equivalent formulation: find $\overset{*}{x}$, $\overset{*}{y}$ and $\overset{*}{\lambda}$:$h(\overset{*}{x},\overset{*}{y}) \le 0, \overset{*}{\lambda} \le 0$ a solution of the mathematical program, which is regular now:

$$\begin{aligned}&\min_{x,y,\lambda} F(x,y)\\&\text{subject to } g(x,y) \le 0,\\&\nabla_y f(x,y) + \lambda \cdot \nabla_y h(x,y) = 0,\\&\lambda \cdot h(x,y) = 0.\end{aligned}$$

TU1-I-CM5

A Tabu Search Heuristic for the Capacitated Arc Routing Problem

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Keywords: capacitated arc routing problem - tabu search

The Capacitated Arc Routing Problem arises in several contexts where streets or roads must be traversed for maintenance purposes of for the delivery of services. A tabu search is proposed for this difficult problem. On benchmark instances, it outperforms all known heuristics and often produces a proven optimum

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MO3-R-IN203

A Distance-Preserving Subgrid for VLSI-Routing

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Shortest-path-search on large grid graphs is a central issue in VLSI-routing. Though well-known for a long time, the increasing complexity of the problem instances drives the development of new approaches. Basically there are two possibilities for improvement: The design of faster algorithms for the search itself or reduction techniques for the problem instance. The latter is promising because memory consumption and runtime may be optimized simultaneously.

For repeated path searches on a threedimensional grid, a new algorithm for the computation of a distance preserving subgrid will be presented. It preserves the length of shortest paths between dedicated nodes. Its size depends on the size of a suitable description of the original grid as a collection of intervals. It theoretically and practically improves about existing methods based on visibility graphs.

TH3-U-IN10

Stochastic Network Optimization for Control of Nested Demands

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Sen Suvrajeet

Keywords: admission control - stochastic programming - yield management

There are numerous applications in which a network of resources serves multiple classes of demand, each unit of which requires the allocation of resources on a sequence of links. Such demand is usually classified by the origin, destination (O-D) pair and by the class. One of the main sources of uncertainty in such operations arises from the uncertainty in total demand. For such systems, the admission policy has a direct impact on the revenues generated by the operation. In this paper, we develop a stochastic programming model that can be used to develop a set of prices and/or allocations which can be used for admission control. The modeling framework allows certain standard features that are common in applications. For example, a demand class that generates higher revenues is given preference over one that produces lower revenues. Similarly, O-D demand representations are also included in this framework. The applications that motivate our work arise in telecommunications, transportation and manufacturing. Computational experiments and simulation results will be presented.

FR2-F-IN203

Optimal Control of Large Scale DAE Systems in Chemical Engineering by a Direct Multiple Shooting Method

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Keywords: direct multiple shooting - large scale optimization - optimal control

In chemical engineering, optimal control problems subject to high dimensional systems of differential algebraic equations yield a great challenge for numerical software. These problems are often characterized by a low number of control variables, a moderate number of differential state variables, but a high number of algebraic state variables. Additionally, several equality and inequality constraints are to be taken into account. In order to reduce the number of variables in the constrained nonlinear programming problem obtained after discretization, a method of choice among direct methods seems to be direct multiple shooting. Direct multiple shooting works with two grids, a first fine grid on which the control variables are discretized, e. g. by piecewise linear functions, and a second coarser grid, the socalled multiple shooting grid, on which the the numerical integrations of initial value problems are carried through intervalwisely. If the algebraic state variables are chosen to be consistent at each multiple shooting grid point, they do not contribute to the number of variables involved in the resulting nonlinear programming problem. Hence, only the control variables contribute considerably to the number of variables of the nonlinear programming problem. If the control process exhibts a structure that can be described by a multistage process, this structure can also be exploited by multiple shooting to reduce the number of variables of the nonlinear programming problems. Finally, the parallel structure of the dirct multistage multiple shooting method can be exploited by parallel computing to reduce the large amount of computation due to the numerical integrations of the differential algebraic equations.

TU3-I-CM5

Routability Checking for Planar Layouts

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Keywords: CAD - layout - routability

In VLSI and printed wiring board design, routing process usually consists of two stages: the global routing and the detailed routing. The routability checking is to decide whether the given global wires can be transformed into the detailed ones or not. We propose two graphs, the capacity checking graph and the initial flow graph, for the efficient routability checking for planar layouts. Comparing with Cole and Siegel's algorithm, our method is simple and easy to implement. It is also efficient in comparison with Leiserson and Maley's algorithm.

FR2-B-CO10

First and Second Order Sensitivity of all Eigenvalues of a Symmetric Operator

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Keywords: directional derivatives - eigenvalues - generalized subdifferentials - second order expansions - symmetric operators

The sensitivity analysis of eigenvalues of matrices (or, more generally, of linear operators) is a classical research subject in Numerical analysis and Optimization. The symmetric case is well-adapted to a variational approach and, moreover, important from the applications viewpoint. The eigenvalue functions are "naturally" nonsmooth and nonconvex, so that they offer an appropriate experimentation ground for techniques and results from nonsmooth and/or convex Analysis. In this communication we will present some results on the following points : -"Usual" first-order directional derivatives and (generalized) subdifferentials of all eigenvalue functions ; -(Main point) Second order directional derivatives of all eigenvalue functions ; -(Secondary point) Possible extensions to self-adjoint operators on a Hilbert space.

FR4-P-IN11

Column Generation with a Rule System

for Crew Scheduling Problems

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Keywords: airline - column generation - k-shortest path - pairing

For many years large airlines have used operations research techniques, along with increasingly powerful computer systems, to help schedule their operating crew. This has resulted in significant cost savings, and is vital in today's competitive environment.

One important problem in the planning process is the construction of pairings, or legal lines of work, for anonymous crew members. A number of solution techniques have been proposed for this problem, for example, heuristic procedures, partial enumeration of possible pairings along with a set partitioning/covering optimizer, and column generation approaches. The technology has advanced sufficiently that airlines now demand very high quality solutions.

Experimentation has shown that column generation can produce high quality solutions (sometimes guaranteed optimal solutions), but there are difficulties in implementing a column generation method in a production environment. The rules that define legal lines of work are often complex, and in the past have been hard coded into the column generator, albeit with some parameters. European carriers often wish to modify rules, and these modifications sometimes require more than just a parameter change. It is not practical to expect the carriers to edit column generation source files, and requiring the developer to continuously update source files is problematical.

One solution to the problem of changing rules is to write a rule system that allows the airline carriers to easily write and maintain their own rules. These rule systems often present a black box interface, i.e. we can only ask the rule system if a partial/complete pairing is legal, and the system only returns a simple yes/no. This limited interface causes problems with a column generation approach. In this paper we show how these difficulties can be overcome with a pricing subproblem based on a k-shortest path algorithm, and give results based on production problems.

TH2-I-CM4

On Graphs with Bounded Chromatic Number

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Keywords: chromatic number - perfect graph

A family $\mathcal{C}$ of graphs is said to be a family of graphs with bounded chromatic number if there is a function f such that for every graph G of $\mathcal{C}$, we have $\chi(H) \leq f(\omega(H))$ for any induced subgraph H of G. Here $\chi(G)$ denotes the chromatic number of G and $\omega(G)$ denotes the number of vertices in a largest clique of G. The class of perfect graphs is a well known class of graphs with bounded chromatic number. In this paper, we propose several conjectures on graphs with bounded chromatic number. One of these conjectures implies the Strong Perfect Graph Theorem.

TH1-K-CM106

A Framework for Half Integrality and 2-Approximations

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Keywords: approximation algorithms - minimum cuts - relaxation

We define a class of integer programs for which half integral superoptimal solutions are obtained in polynomial time. For some of these problems it is possible to round the half integral solution to a 2-approximate solution. This extends the class of integer programs with at most two variables per constraint that were analyzed in Hochbaum, Meggido, Naor and Tamir, 1993. Interesting problems for which we can get superoptimal half integral solutions include the sparsest cut problem, and minimum weight edge deletion to obtain a bipartite graph. Problems for which we can get 2-approximations include minimum satisfiability, scheduling with precedence constraints, optimization of boolean functions in two variables (generalized 2SAT) and the feasible cut problem. Certain constraint satisfaction problem are included in this framework as well.

The approximation algorithms here work by solving a minimum cut on a certain network associated with the formulation. These algorithms provide an improvement in running time and range of applicability compared to existing 2-approximations, if any. Furthermore, we conclude that problems in the framework are MAX SNP-hard and at least as hard to approximate as vertex cover.

Problems that are amenable to the analysis provided are easily recognized. The analysis itself is entirely technical and only involves manipulation of the constraints, transforming them to a totally unimodular system while losing no more than a factor of 2 in the integrality.

MO4-I-IN202

The Pseudoflow Algorithm: A New Algorithm and a New Simplex Algorithm for the Maximum Flow Problem

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Keywords: maximum flow - parametric analysis - pseudoflow - simplex

We introduce a new algorithm that solves the maximum flow problem using pseudoflows. The algorithm solves directly a problem we call the maximum s-excess problem. That problem is equivalent to the minimum cut problem, and is a direct extension of the maximum closure problem. The new ideas in this algorithm are based on our extension of Lerchs and Grossman's algorithm [LG64] for maximum closure described in Hochbaum, 1996.

The new algorithm works for general graphs, and employs the lowest label selection rule of a merger arc introduced by Hochbaum [Hoc96]. The insights derived from the analysis of the new algorithm lead to a new simplex algorithm for the maximum flow problem. We show that the new simplex algorithm (as well as other simplex algorithms for maximum flow) can perform a parametric analysis in the same amount of time as a single run. This is the first known simplex algorithm for maximum flow that generates all possible breakpoints of parameter values in the same complexity as required to solve a single maximum flow instance.

The complexity of our new pseudoflow algorithm, the new simplex algorithm, and the parametric analysis is $O(mn \log n)$. We compare the simplex to the non-simplex approach and elaborate on the practical advantages of the non-simplex algorithm.

FR4-F-IN203

Tree Partitioning under Constraints

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Keywords: clustering - complexity - dynamic programming - tree partitioning

We consider the problem of *tree partitioning under constraints*:

Given a tree $T = (V, E)$, $w : V -> N^q$ a set of q non-negative, integer weight functions and an integer threshhold R, the objective is to find a set of edges $F \subseteq E$ of minimal cardinality such that

$$\sum_{v \in T_i} w(v) \leq R$$

for all connected components T_i of $T \setminus F$.

We briefly discuss the complexity of several variants of this problem and present a dynamic programming algorithm which has polynomial running time for instances with bounded degree and bounded number of weight functions. The algorithm and key ideas of the analysis of the running time are illustrated at the special case of binary trees with two weight functions.

Finally we report on numerical results and an application to vehicle routing problems.

TU2-I-CM121

Linear Programming over a Totally Ordered Abelian Group

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Let G be a totally ordered abelian group. Expanding on ideas of Burkard and Zimmerman, we consider linear programs where either the right-hand side or the objective vector (but not both) are elements of G. Some theorems of combinatorial optimization hold in this context, but not all, and some proofs are different. We also contemplate a definition of convexity in n-dimensional space over G, and examine whether some classica theorems (Caratheodory, Helly) hold in this context.

TH3-A-IN2

A Comparison of Alternate Formulations for the Single Airport Ground Holding Problem with Banking Constraints

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Ball Michael O.

Keywords: facets - formulation - integer programming - projection

The single airport ground-holding problem (SAGHP) is a problem faced by air traffic management authorities when they must limit the number of arrivals at an airport whose acceptance rate has been diminished due to bad weather. Airlines with hub-and-spoke route structure have a desire to land certain groups of flights, called banks, within fixed time windows; this prevents the propagation of delays throughout their entire operation. The SAGHP can be formulated as a transportation problem. In the presence of banking constraints, the SAGHP becomes a difficult integer programming problem which can be viewed as a transportation problem with side constraints. In this paper, we construct several different models of the single-airport ground holding problem with banking constraints. These formulations differ in terms of number of variables, number of constraints and strength of linear programming relaxation. The models are evaluated both computationally and analytically. Using the best model considered the most difficult real-world problem instances can be directly solved by commercial integer programming solvers.

TH4-U-IN1

Parametric Programming, Analytic Centers, and Radiotherapy

Holder Allen

University of Colorado at Denver

Newman Francis

Keywords: analytic centers - interior point methods - parametric programming - radiotherapy

A linear model is proposed to decide the angle and intensity of beams used to treat benign and malignant tumors. The right hand side values are user input and are viewed as targets rather than hard limits. From this perspective, we propose to solve the problem using parametric techniques. Furthermore, the concept of the analytic center is used for the following two reasons: there are efficient algorithms for large problems, and it produces a plan that is attractive because it strictly satisfies all the targets. However, technological limitations inherent to some facilities renders the plan produced by the analytic center solution unusable. Methods to collapse the feasible polyhedron, thereby restricting the number of beams and rendering a usable plan, are proposed. Results for two and three dimensional problems are presented.

TU1-N-CO15

Sensitivity of the Central Path

Holder Allen

University of Colorado at Denver

Keywords: central path - linear programming - sensitivity analysis

The central path and its connection to the polynomality of the class of linear programs has been investigated for over ten years. Much is known about the analytic properties of the central path with respect various parameterizations. However, the central path and its limiting value have interesting analytic properties with respect to the problem data. In particular, a complete marginal analysis of the primal analytic center solution is developed with respect to right hand side changes. Furthermore, parametric convergence results for the entire central path are presented for changes in either the right hand sides or cost coefficients.

TU2-N-CO15

Overview of ANALYZE

Holder Allen

University of Colorado at Denver

Greenberg Harvey J.

Keywords: computational economics - linear programming - sensitivity analysis

This is a software system to provide computer-assisted analysis support for mixed-integer linear programs. It was developed in the late 1970's and has evolved over the past 20 years. This talk will present the basic concepts and applications of its functions. Further information about the software and how to obtain it is in the software section of the author's web site, http://www-math.cudenver/edu/ hgreenbe/consortium/software.html

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MO4-U-IN10

Lagrangean Heuristic Based Solution Methods for Capacitated Network Design Problems with Different Characteristics.

Holmberg Kaj

Linköping University

Yuan Di

Keywords: Lagrangean heuristics - network design - telecommunications

The interest in network design problems has increased with the advent of optical fiber technology and the increased need for bandwidth in telecommunication networks. The basic model contains multicommodity flow satisfying certain demands (for pairs of nodes) and fixed charges for the edges. We consider both the directed and the undirected cases. The capacities of the fibers are very large, but they are limited. Therefore we must consider the capacitated version of the problem. In addition, survivability has become an important issue. In long term planning the design of the network must be such that there are, for example, at least two different paths between each pair of demand points. On the other hand, short term planning is more a question of capacity expansion, i.e. to decide the number of additional fibers to be installed in the existing cables. The costs for increasing the capacity is then staircase formed. An additional requirement could be integral valued flow, or to keep the flow together in even larger units.

Solution approaches for the different versions of the network design problem based on Lagrangean heuristics are discussed. Lagrangean heuristics, containing Lagrangean relaxation, subgradient optimization and primal heuristics, can be applied in similar ways to all of these problems, and in general produce fairly good solutions. A branch-and-bound framework, with special penalty tests and cutting criteria, could be added in order to get the exact optimal solution. Computational comparisons to a state-of-the-art mixed-integer code are presented.

TU1-A-IN2

Mean Value Cross Decomposition Based Branch-and-Bound for Mixed Integer Programming Problems

Holmberg Kaj

Linköping University

Keywords: branch and bound - mixed integer programming - primal-dual decomposition

Mean value cross decomposition is a primal-dual decomposition method developed for linear programming problems. It is a generalization of the Kornai-Liptak method and of the Brown-Robinson method for finite two-person matrix games. This work deals with the usage of mean value cross decomposition in a branch-and-bound method for mixed integer programming problems. Special issues discussed are heuristics for obtaining feasible integral solutions, information available to base the branching decisions and tree search strategies on, and reoptimization after branching or adding valid inequalities. The availability of reduced costs, to be used for variable fixation tests and branching decisions is investigated. Variations of the basic mean value cross decomposition method are also treated. The effects of different kinds of separability are investigated. Finally application to problems of typical structures, facility location and network design problems, are discussed, and computational results are presented for one of the problem types.

MO3-N-CO15

TOMLAB - A General Purpose, Open MATLAB Environment for Research and Teaching in Optimization

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Keywords: MATLAB - algorithms - mathematical software - nonlinear least squares - optimization

TOMLAB is a general purpose, open and integrated MATLAB environment for research and teaching in optimization on UNIX and PC systems. The motivation for TOMLAB is to simplify research on practical optimization problems, giving easy access to all types of solvers; at the same time having full access to the power of MATLAB.

By using a simple, but general input format, combined with the ability in MATLAB to evaluate string expressions, there is direct possibility to run internal TOMLAB solvers, MathWorks Optimization Toolbox and commercial solvers written in FORTRAN and C using MEX interfaces. Currently MEX interfaces have been developed for *MINOS*, *NPSOL*, *NPOPT*, *NLSSOL*, *LPOPT*, *QPOPT* and *LSSOL*.

TOMLAB may either be used totally parameter driven or menu driven. The basic principles will be discussed. The menu system makes it suitable for teaching. Many standard test examples are included and further more are easily added. There are many example and demonstration files. Iteration steps including line search may be graphically displayed together with contour plots when running unconstrained optimization.

TOMLAB is based on NLPLIB, a MATLAB toolbox for nonlinear programming and parameter estimation and OPERA,

a MATLAB toolbox for operational research, with emphasis on linear and discrete optimization. About 40 different algorithms are implemented. Of special interest are the algorithms for general and separable nonlinear least squares. Our new implementation of the Fletcher-Xu hybrid method, the Al-Baali-Fletcher hybrid method and Huschens totally structured secant method (TSSM) give fast and robust convergence on ill conditioned parameter estimation problems. Some results will be presented.

TOMLAB is free for academic purposes. Contribution from others are welcome, like more solvers, interfaces to other software packages, utilities and MEX interfaces.

TU1-I-CM200

Many Polytopes Meeting the Conjectured Hirsch Bound

Holt Fred B.

Boeing ISS

Klee Vic

Let P be a simple d-polytope with n facets; if the diameter of P is at least $n-d$, then P is called H-sharp. We have identified conditions on H-sharp P under which repeated truncation and wedging of P produces other H-sharp polytopes, of higher dimension and with more facets. Moreover, a variation on a construction used by Barnette and Adler, which we call fast-slow blending, can produce from two H-sharp d-polytopes another H-sharp d-polytope with more facets; a fast-slow blend of an H-sharp (d, m)-polytope with an H-sharp (d, n)-polytope produces an H-sharp $(d, m + n - d)$-polytope. Applying these results to the unique H-sharp $(4, 9)$-polytope, we have constructed polytopes which meet the Hirsch bound for many more pairs (d, n) than previously known, including all (d, n) with $14 \leq d < n$. Consequently the Hirsch bound $n-d$ cannot be lowered for $d \geq 14$.

WE3-P-IN201

Parallel Machine Scheduling by Column Generation

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Dpt of Mathematics and Computing Science, Eindhoven University of Technology

van den Akker Marjan - van de Velde Steef L.

Keywords: column generation - parallel machines - scheduling - total weighted completion time

Parallel machine scheduling problems concern the scheduling of n jobs on m machines to minimize some function of the job completion times. If preemption is not allowed, then most problems are not only *NP*-hard, but also very hard from a practical point of view. In this paper, we show that strong and fast linear programming lower bounds can be computed for an important class of objective functions. First, we point out that any parallel machine scheduling problem can be formulated as a set covering problem with a single type of side constraint and an exponential number of variables. What is more, we show that for an important class of objective functions the linear programming relaxation can efficiently be solved by column generation, since the pricing problem is solvable in pseudo-polynomial time. We provide extensive computational results for the problem of minimizing total weighted completion time. The linear programming lower bound is used in a branch-and-bound algorithm, which uses a new type of branching strategy, but is usually so strong that no branching is required.

FR1-C-CO122

Lagrange-Duality and Partitioning Techniques in Nonconvex Global Optimization

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Universität Trier, Fachbereich IV, Mathematik

Duer Mirjam

Keywords: branch and bound - duality gap - nonconvex quadratic constraints - partly convex programs

The Lagrange-duals of astonishingly large classes of nonconvex multiextremal optimization problems can be formulated as linear programs. These classes include, among others, in particular several important problems with nonconvex quadratic constraints such as the pooling problem, the sphere packing problem and a reformulation of the sum-of-ratios problem. This fact has motivated the investigation of convergence properties of general branch-and-bound methods combined with dual bounds. It is shown that, for very general classes of nonconvex global optimization problems, the duality gap obtained by solving a corresponding Lagrangian dual is reduced to zero in the limit when combined with suitably refined partitioning of the feasible set. A similar result holds for partly convex problems where exhaustive partitioning is applied only in the space of nonconvex variables.

MO3-A-IN2

Degrees of Groebner Bases of Integer Programs

Hosten Serkan

Cornell University, School of Operations Research

Groebner bases provide minimal test sets to solve integer programs. Giving meaningful bounds on the size of these Groebner bases elements leads to improved complexity results in integer programming. For instance, estimates on the distance between feasible points of an integer program could be imporved. This talk reports progress in the direction of such improved bounds following two general techniques. One of these boils down to improving the bounds on the size of Hilbert basis elements of certain polyhedral cones.

FR2-D-CO124

The Design and Implementation of an Interior Point Method for Nonlinear Programming

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Rice University

Nocedal Jorge - Byrd Richard H.

Keywords: constrained optimization - interior point methods - large scale optimization - nonlinear programming - primal-dual methods - successive quadratic programming - trust region method

We present an interior point algorithm for solving nonlinear programming problems and demonstrate that it is robust and efficient for solving large problems. This algorithm is a barrier method which employs a sequential quadratic programming strategy within a trust region framework. We will give the details of the design issues for this method: formulations for the subproblems, the definition of the trust region, and the scaling of variables, concentrating on how each affects the behavior of the algorithm. Finally, we will present numerical results, comparing the performance of our method to that of other algorithms for large scale optimization.

WE4-L-CM201

Identification of Embedded Network Structure in Linear Programming Models

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Fourer Robert

Keywords: linear programming - networks

Linear programming models that contain a substantial network structure frequently arise in many applications. We present a heuristical method for identifying pure or generalized network structure in network linear programs with side constraints. Constraints and variables may be in arbitrary order and may be scaled arbitrarily, and no special structure in the side constraints is assumed.

We show that this method is very efficient both theoretically and computationally, with a worst-case complexity almost linear in the number of nonzeroes in the LP's constraint matrix. Unlike other fast heuristics, the method is guaranteed to find the complete network in the case when it is possible to transform the entire LP into a network by scaling rows and columns. In other cases it reliably finds large network subsets, as demonstrated by computational results on a wide range of LP test problems. Additionally, the method identifies the block-diagonal structure within the network, which can be exploited subsequently in optimizing over the network constraints.

TU1-E-CO21

Linear Complementarity Approach to Pricing American Options

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Department of Mathematical Sciences, The Johns Hopkins University

Pang Jong-Shi

Keywords: american options - linear complementarity - option pricing

The simplest financial option, also known as a European option, is a contract such that at a specified time in the future (the maturity date), the owner of the option may purchase (or sell) an underlying asset at a prescribed price from (to) the issuer of the option. An American option differs from the standard European option in that the former may be exercised at any time prior to the maturity date. The pricing of American options is a central problem in finance. Unlike European options which often admit explicit solutions to certain partial differential equations, no such convenient computational formulas exist for American options. Instead, free-boundary obstacle problems in the form of variational inequalities provide a viable mathematical formulation and promising computational approach for the pricing of American options. In this talk, we discuss how the complementarity methodology in conjunction with numerical approximation techniques for partial differential operators can be applied to solve various American option pricing models.

TU1-D-CO123

Homotopy Methods for Effective Schubert Calculus

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Department of Mathematics, Texas A+M University

Sottile Frank - Sturmfels Bernd

Keywords: Grassmannian - Groebner bases - homotopy continuation - overdetermined system

The Schubert calculus deals with the problem of counting the number of m-planes H which non-trivially meet a given set of linear subspaces in general position. In this talk, representing recent work with Frank Sottile and Bernd Sturmfels, we present algorithms based on homotopy continuation for finding these m-planes. We will present two algorithms based on extrinsic deformations of the Grassmannian and, time permitting, will describe a more generally applicable algorithm based on intrinsic deformations. The methods we describe are optimal in the sense that they only require following a number of paths equal to the actual number of solutions for the given enumerative problem. Computational results will also be discussed.

TU2-R-IN203

Applications of the Cayley Trick for Convex Polytopes

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Department of Mathematics, Texas A+M University

Keywords: Minkowski sum - mixed volume - polytope

In this talk I will describe the Cayley trick and some applications, including finding all mixed volumes of a set of polytopes and calculating the facets or vertices of their weighted Minkowski sums.

TU4-A-IN1

A Lower Bound on the Average Number of Pivot Steps in the Simplex Method - Valid for all Variants

Huhn Petra

University of Augsburg

Keywords: linear programming - probabilistic analysis - simplex

We consider the linear programming problem: $\max v^T x$ s.t. $a_i^T x \leq 1$, $i = 1, \ldots, m$, and the following stochastic model: $a_1, \ldots, a_m$ and v are distributed independently, identically and symmetrically under rotations.
In phase II all variants of the Simplex-Method generate a sequence of successively adjacent vertices of the corresponding polyhedron, beginning at a start-vertex and improving the ob-

jective function step by step. To derive a lower bound on the average number of pivot steps we consider the angles between adjacent vertices. If ϕ is the angle between the starting and the optimal vertex, then the sum of the angles between two adjacent vertices of the generated sequence is even greater than ϕ, because the edges do not take a rectilinear course from the starting to the optimal vertex. The approximation idea works as follows: We select all angles being greater than a specified bound s. This bound s is chosen in a way such that the sum of the angles greater than s does not exceed $\phi/2$. To cover the rest of ϕ we need some more angles. But the remaining ones are smaller than s, so we need at least $\phi/2s$ of these.
Now in our stochastic model the following holds true: If the starting vertex is generated by a phase I, which does not take the objective function into account, then the expectation value of ϕ is $E(\phi) = \pi/2$. Furthermore we can find a bound s for the size of the angles such that the average sum of the angles exceeding s is less than $E(\phi/2)$. Therefore on the average at least $O(\pi/4s)$ steps must be carried out to reach the optimal vertex. A suitable bound in that sense is $s \approx const.\cdot c(n)^{-1} \cdot m^{-1/(n-1)}$. Therefore in phase II any variant of the Simplex-Method requires at least $const.\cdot c(n) \cdot m^{1/(n-1)}$ pivot steps on the average. For $m >> n$ we can improve this result to $const. \cdot m^{1/(n-1)}$. These lower bounds on the average number of pivot steps in the Simplex-Method are valid for all variants.

TU4-A-IN1

An Upper Bound for the Average Number of Iterations Required in Phase II of an Interior-Point-Method

Huhn Petra

University of Augsburg

Keywords: interior point methods - linear programming - probabilistic analysis

We consider the linear programming problem: $\max v^T x$ s.t. $a_i^T x \leq 1$, $i = 1, \ldots, m$, and the following probabilistic model: $a_1, \ldots, a_m$ and v are distributed independently, identically, uniformly on the unit sphere of $\mathbf{R}^n$.
We employ an interior-point-method to solve the optimization problem, and we assume that a proper starting point is given (as a result of a phase I). At least in the asymptotic case ($m \to \infty$, n fixed) the remaining solution process (phase II) leads to the optimal solution. The complexity of phase II is dominated by the number of iterations which have to be carried out until termination. We apply a finite "'projection-and-check"' procedure for termination, which guarantees to yield the optimal vertex if the current iterate is better than the second best vertex. Otherwise the reduction process of the interior-point-method will be continued.
If U denotes the difference between the objective value of the best and the second best vertex, then from worst-case-analysis it is known that the number of iterations is at most $O(R \cdot |\ln U|)$, where R depends on the reduction in each iteration of the interior-point-method. Moreover, in the worst case a lower bound for U is 2^{-L} (where L is the bit size of the input) and an upper bound for the number of iterations is $O(R \cdot L)$.
On the average this difference U may be much greater and termination is possible much earlier. So if we know the distribution of U, we can calculate the average number of iterations, which is $O(R \cdot E(|\ln U|))$, where $E(\cdot)$ denotes the expectation value. Under our probabilistic model we can derive a proper approximation of the distribution of U and give an upper bound for $E(|\ln U|)$. We conclude that for $m >> n$ in phase II the average number of iterations of an interior-point-method is at most $O(R \cdot \ln m)$, which means strong polynomiality in the average case.

WE3-K-CM106

Efficient Calculation of a Best Neighbor for a One Machine Batching Problem

Hurink Johann

Universität Osnabrück

Keywords: batching - local search - neighborhood - shortest path

We will consider a one machine batching problem which is a combination of a sequencing and a partitioning problem. Since for a fixed sequence an efficient method for calculating the best partition of this sequence into batches is known, local search may be applied by considering as solutions sequences and as objective value of a sequence the value of the best partition of this sequence into batches.

It will be shown that for a special neighborhood the process of finding the best sequence in the neighborhood of a solution can be speeded up by considering the calculation of the objective values of all neighbored sequences simultaneously. Furthermore, a new neighborhood will be develloped, where one step may correspond to a sequence of steps in the original neighborhood. The number of neighbors of a given solution is exponential for this new neighborhood structure and the best neighbor concerning this neighborhood can be found in quadratic time using shortest path calculations.

TH2-I-CM121

Upper and Lower Bounding Techniques for Frequency Assignment Problems

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Tiourine Sergey R.

Keywords: bounding - frequency assignment

We consider two variants of the radio link frequency assignment problem. These problems arise in practice when a network of radio links has to be established. Each radio link has to be assigned an operating frequency. The interference level between frequencies assigned to different links has to be small, since otherwise communication will be distorted. The frequency assignments have to comply with certain regulations and physical characteristics of the transmitters. Moreover, the use of the frequency spectrum is to be minimized.

We discuss several approximation algorithms for the problems, based on local search, and we compare their performance on some practical instances. A lower bounding technique based on nonlinear programming is used to estimate the quality of the approximate solutions for some of these instances.

TH1-W-CO15

Algorithms for Set Covering Problems in

Statistical Disclosure Control
Hurkens Cor A.J.

EINDHOVEN UNIVERSITY OF TECHNOLOGY, DEPT. OF MATHEMATICS AND COMPUTING SCIENCE

Tiourine Sergey R.

Microdata sets, i.e. sets of records containing information on individual respondents, are relatively new products released by statistical offices. The problem of protecting confidentiality of such a data is called statistical disclosure control (SDC). One way to tackle this problem is to protect potentially unsafe combinations of entries in a microdata set by certain data operations such as aggregations or suppressions. Each unsafe combination has to be protected by at least one of the data operations at minimum cost. This suggests a set covering formulation of the problem with additional classes of side constraints that limit the set of possible combinations of data operations. We propose an exact algorithm, based on polyhedral techniques, and a couple of heuristics for this problem. The algorithms were tested on a set of real-life instances. In the conclusions we discuss the applicability of these algorithms in the SDC-package mu-ARGUS.

TH2-W-CO15

Why do we need Modeling Languages?
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Keywords: modeling - modeling language

There exist many programming languages that allow us to formulate 'algorithmic knowledge', that is a notation to express algorithms and data structures in order to execute a sequence of tasks - a way on 'how to solve a problem'. Only few languages, most of them in a prototypical stage, exist to represent 'declarative knowledge' (a model) which allow us to write down 'what the problem is'. Mathematical and logical notation is a compact way to state a problem in a 'declarative' manner. However, this notation cannot be processed easily on a computer. A systematic way is shown in this paper on how a modern, high level programming language has to be extended in order to integrate declarative knowledge as well. Such a language will be called modeling language.

WE1-C-CO3

Global Optimization by Multilevel Coordinate Search
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Neumaier Arnold

Keywords: bound constraints - coordinate search - global optimization - local optimization

Inspired by a method by Jones et al., we present a global optimization algorithm based on multilevel coordinate search. It is guaranteed to converge in the long run if the function is continuous in the neighborhood of the global minimizer. By subjecting certain good points to local search, an improved convergence result is obtained. We discuss implementation details and give some numerical results.

TU2-I-CM4

Augmenting Edge-Connectivity in O (nm) Time
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Keywords: edge-connectivity - graph augmentation - minimum cuts

For a given undirected graph $G = (V, E, c_G)$ with edges weighted by nonnegative reals $c_G : E \to R^+$, let $\Lambda_G(k)$ stand for the minimum amount of weights to be added to make G k-edge-connected, and $G^*(k)$ be the resulting graph obtained from G. This paper first shows that function Λ_G over the entire range $k \in [0, +\infty]$ can be computed in $O(nm + n^2 \log n)$ time, and then shows that all $G^*(k)$ in the entire range can be obtained from $O(n \log n)$ weighted cycles, and such cycles can be computed in $O(nm + n^2 \log n)$ time, where n and m are the numbers of vertices and edges, respectively.

FR3-P-IN201

Scheduling RMG (rail mounted gantry crane) shift operations in a container terminal
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Keywords: container terminal - maximum weight matching on a graph - scheduling - shortest Hamiltonian path

In a modern system of container terminal, its yard is divided into a set of pairs of buffer area and stack area in order to separate ship loading/unloading and yard operations. Such a system then necessitates the shift operations between buffer areas and stack areas; import containers in a buffer area are moved to its stack area, and export containers in a stack area are moved to the buffer area, by using two RMGs (rail mounted gantry cranes) installed at each pair of stack and buffer areas.

As a result of analyzing the movement of two RMGs, which may interfere each other, we reduce the scheduling of shift operations into two graph theoretical problems: the pairing problem which is formulated as the maximum weight matching with degree constraints in a general graph, and the sequencing problem which is a shortest path problem to visit specified number of nodes in a weighted graph. We solve the former by an exact algorithm and the latter by a heuristic algorithm. Furthermore, to deal with multilayer stacks of containers, the scheduling period is decomposed into everlapping subperiods, to which the above scheduling algorithm is applied.

The resulting algorithm shows good performance in both quality of solutions and computational speed, and will be in operation in a real container terminal system.

TU3-I-CM5

Reliable and Secure Communications in Distributed Systems
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Gunma University

Bao Feng - Funyu Yutaka

Keywords: broadcasting - distributed systems - fault tolerance - independent spanning trees - secure message distribution

Let $T_1, \cdots, T_n$ be n spanning trees rooted at node r of graph G. If for any node v of G, n paths from r to v, each path in each spanning tree of $T_1, \cdots, T_n$, are internally disjoint, then $T_1, \cdots, T_n$ are called independent spanning trees rooted at r of G. A graph G is called an n-channel graph if G has n independent spanning trees rooted at each node of G. We generalize the definition of n-channel graphs. If for any node v of G, among the n paths from r to v, each path in each spanning tree of $T_1, \cdots, T_n$, there are k $(k \leq n)$ internally disjoint paths, then $T_1, \cdots, T_n$ are said to be (n,k)-independent spanning trees rooted at r of G. G is called an (n,k)-channel graph if G has (n,k)-independent spanning trees rooted at each node of G.

We study two fault-tolerant communication tasks in (n,k)-channel graphs. Broadcasting in a distributed system is the message dissemination from a source node to every other node. The first one is reliable broadcasting. High reliability can be achieved by sacrificing efficiency. We analyze the trade-off between the reliability and the efficiency of broadcasting in (n,k)-channel graphs. The second one is secure message distribution (i.e., one node attempts to send different messages safely to different nodes). It is required that each message should be received by only its destination node and that we should keep the message secret from other nodes. We give two secure message distribution schemes in (n,k)-channel graphs. The first scheme can tolerate $t+k-n$ listening adversaries for any $t < n$ if G is an (n,k)-channel graph. The second scheme can tolerate $t+k-n$ disrupting adversaries for any $t < n/3$ if G is an (n,k)-channel graph.

MO4-A-IN1

The Finite Criss-Cross Method for Hyperbolic Programming

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Eötvös Loránd University

Szirmai Ákos - Terlaky Tamás

Keywords: criss-cross method - fractional linear programming - hyperbolic programming - pivoting

In this paper the finite criss-cross method is generalized to solve hyperbolic programming problems. Just as in the case of linear or quadratic programming the criss-cross method can be initialized with any, not necessarily feasible basic solution.

It is known that if the feasible region of the problem is unbounded then some of the known algorithms fail to find the solution. Our criss-cross algorithm does not have such drawback.

Finiteness of the procedure is proved under the usual mild assumptions. Some small numerical examples illustrate the main features of the algorithm and show that our method generates different iterates then methods published earlier.

WE1-R-IN203

Geometric Clustering and its Application

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Imai Hiroshi

Keywords: clustering - color quantization

Clustering is the grouping of similar objects and a clustering of a set is a partition of its elements that is chosen to minimize some measure of dissimilarity. It is very fundamental and used in various fields such as statistics, image understanding, learning theory, computer graphics, etc. There are two types of clustering problem, one is clustering on a weighted graph (or a (dis)similarity matrix), and the other is a geometric one. Geometric clustering has nicer structures than the graph version due to constraints induced by geometry.

This talk first points out combinatorial optimization aspects of the geometric clustering problem, and summarizes recent results by our group on the k-clustering problem for a set S of n points $p_i = (x_i)$ $(i = 1, \ldots, n)$ in the d-dimensional space with variance-based errors as clustering criteria. A main problem is to find a k-clustering of S into S_j $(j = 1, \ldots, k)$ minimizing

$$\sum_{j=1}^{k} \sum_{p_i \in S_j} \|x_i - \bar{x}(S_j)\|^2$$

where $\|\cdot\|$ is the L_2 norm and $\bar{x}(S_j)$ is the centroid of points in S_j, i.e., $\frac{1}{|S_j|}\sum_{p_i \in S_j} x_i$.

Next, relations of those results with the existing local improvement technique, called k-means, are described, together with an application to the color quantization problem for pseudo-color system, which is to select a set of good representative colors out of huge amout of possible colors, and can be considered as a clustering problem in the RGB (Red Green Blue) 3-dimensional color space where every pixel of images is mapped into.

We also relate this problem to some mathematical programming problem called geographic optimization problem by Iri, Murota, Ohya. We further consider an improvement of the k-means algorithm via overrelaxation, motivated from the viewpoint of mathematical programming, together with results of computational experiments.

WE3-G-IN11

Multi-Stage Stochastic Programming for Funding Uncertain Cash-Flows of Mortgage Pools

Infanger Gerd

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Keywords: computation - stochastic programming

Conduits in the secondary mortgage market decide what fraction of a mortgage pool should be funded through issuing mortgage backed securities and what portion should be funded by issuing bonds of various maturities. Uncertain parameters of the decision are interest rates and mortgage pre-payments over a long planning horizon of 30 years. We show how this problem can be formulated as a multi-stage stochastic program. We determine efficient frontiers of expected returns versus risk and compare them to ones obtained from single-stage optimization. We show that significant profits can be obtained using flexible (multi-stage) versus fixed (single-stage) funding strategies.

MO3-U-IN10

Flexible Lagrangean-Based Heuristics for Dynamic Multi-Level Uncapacitated and Capacitated Lot Sizing

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Gröflin Heinz

Keywords: Lagrangean relaxation - MRP - capacitated multi-level lot sizing - heuristics - production planning

We first present feasible sequential decisions for uncapacitated multi-level lot sizing. As an application, we present a flexible Lagrangean-based heuristic which takes into account constraints on cumulative production and lot sizes and departs from the usual mrp-type processing order of the products, making it very flexible and suited for interactive use. We then extend the approach of feasible sequential decisions to capacitated problems, showing also the limits of applicability. Based on this, we present a Lagrangean-based heuristic for capacitated problems which first constructs a solution for a relaxation of the original problem and then insures feasibility by several types of adjustments to the inital solution. Computational results show improvement over current heuristics for capacitated as well as uncapacitated problems.

TH3-I-CM120

Topics from the Theory of Uncontrollable Flows

Iri Masao

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Keywords: complexity - slimming of a capacitated network - uncontrollable flow

Since the author proposed a new theory of uncontrollable flows at ISMP94 in Ann Arbor, Michigan, there have been some progresses, among which the following topics (i)–(iii) will be reported. Uncontrollable flows in a directed graph are flows which are defined as a convex combination of flows around directed elementary circuits (or flows along directed elementary paths from the source to the sink in a two-terminal network), and only the sum and the multiplication by a positive scalar are admitted as superposition operation among flows. Thus a partial order is naturally defined among uncontrollable flows.

(i) The problem of discerning whether or not a given two-terminal flow in a two-terminal network is uncontrollable was proved to be NP-complete by M. Matsui.

(ii) The concept of slimming a capacitated network was introduced, where slimming is an operation of reducing the edge capacities of a network to the minimum in such a way that the feasibility/infeasibility of (uncontrollable) flows is preserved. Slimming of a two-terminal network is proved to be NP-hard, since the two-path problem for a directed graph (a famous NP-complete problem) is polynomially transformable to slimming a related two-terminal capacitated network.

(iii) The homomorphic relation between uncontrollable flows and the congestion patterns of a capacitated network, which was vaguely suggested three years ago, is more clearly defined and illustrated.

TH4-E-CO11

Zero-Epi Mappings and Complementarity Theory

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Keywords: complementarity problems - exceptional families - topological degree

The concept of zero-epi mapping is more refined and simpler than topological degree. Using this concept, we will study the solvability of several kinds of complementarity problems.

Recently we obtained several existence results in $\mathbf{R}^n$, for the complementarity problems, using the concept of *exceptional family of elements* for a continuous function. Now, in this paper, we will show how we can extend these results to the infinite dimensional case applying the concept of zero-epi mapping.

Some multiparameter complementarity problems will also be considered.

TU4-I-CM4

Improvements on Bottleneck Matching and Related Problems Using Geometry

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Efrat Alon - Katz Matthew

Let A and B be two sets of n objects in $\Re^d$, and let M be a (one-to-one) matching between A and B. Let $\min(M)$, $\max(M)$, and $\Sigma(M)$ denote the length of the shortest edge, the length of the longest edge, and the sum of the lengths of the edges of M respectively. *Bottleneck matching*—a matching that minimizes $\max(M)$—is suggested as a convenient way for measuring the resemblance between A and B. Several algorithms for computing, as well as approximating, this resemblance are proposed. The running time of all the algorithms involving planar objects is close to $O(n^{1.5})$. For instance, if the objects are points in the plane, the running time of the exact algorithm is $O(n^{1.5}\log n)$.

Next, the problem of finding a translation of B that maximizes the resemblance to A under the bottleneck matching criterion is considered. When A and B are point-sets in the plane, an $O(n^5 \log n)$ time algorithm for determining whether for some translated copy the resemblance gets below a given ρ is presented, thus improving the previous result of Alt, Mehlhorn, Wagener and Welzl by a factor of almost n.

The *uniform matching* problem (also called the *balanced assignment* problem, or the *fair matching* problem) is to find M_U^*, a matching that minimizes $\max(M) - \min(M)$. A *minimum deviation matching* M_D^* is a matching that minimizes $(1/n)\Sigma(M) - \min(M)$. Algorithms for computing M_U^* and M_D^* in roughly $O(n^{10/3})$ time are presented.

FR1-B-CO10

A Dual Parametrization Method for Convex Semi-Infinite Programming

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The Institute of Statistical Mathematics

Liu Yangun - Teo K.L.

Keywords: KKT conditions - convex programming - duality - semi-infinite programming

We propose in this talk a new computational method for solving a general class of convex semi-infinite programming problems. The method is based on some characterization of the dual variable for the infinite-dimensional inequality constraint. Several numerical examples including linear and convex quadratic cases will be presented.

WE2-E-CO11

Proximal Point Method for Convex Optimization in Banach Spaces

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Instituto de Matematica Pura e Aplicada

Butnariu Dan

Keywords: Banach spaces - convex optimization - proximal methods

The classical Proximal Point Method for optimization, i.e. $x^{k+1} = \text{argmin}\{g(x) + ||x - x^k||^2\}$ for minimizing a convex function g, leads to complicated subproblems in a Banach space due to the nonlinearity of the derivative J of $||\cdot||^2$. The natural extension to a Banach space seems to be the Proximal Method with Bregman distances, i.e. $x^{k+1} = \text{argmin}$ $\{g(x)+D_f(x,x^k)\}$, with $D_f(y,z) = f(x)-f(y)-\langle f'(y), x-y\rangle$ (where f is an appropriately chosen convex function), which produces simpler subproblems. Taking $f(x) = ||x||^2$, we recover the classical method in a Hilbert space, but we obtain a different method in nonhilbertian Banach spaces. In most Banach spaces this f is not the most convenient choice (e.g. in L^p, $f(x) = ||x||_p^p$ leads to simpler subproblems) and so consideration of more general f's is required. This methods has been considered in the literature with the requirement that f be strongly convex, but no strongly convex and smooth functions exists in nonhilbertian Banach spaces. In our analysis we demand that f satisfies a weaker condition, which we call *total convexity*. Totally convex functions exist in any Banach space, and $f(x) = ||x||^s$ with $s > 1$ is totally convex in any reflexive and uniformly convex Banach space. We prove that the method with totally convex f shares most convergence properties of the classical method in a Hilbert space.

TH2-E-CO11

A New Search Startegy for Korpelevich s method

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Instituto de Matematica Pura e Aplicada

Svaiter Benar Fux

Keywords: Armijo search - variational inequalities

We present a variant of Korpelevich's method for variational inequality problems with monotone operators. Instead of a fixed and exogenously given stepsize, possible only when a Lipschitz constant for the operator exists and is known beforehand, we find an appropriate stepsize in each iteration through an Armijo-type search. Differently from other similar schemes, we perform only two projections onto the feasible set in each iteration, rather than one projection for each tentative step during the search, which represents a considerable saving when the projection is computationally expensive. A full convergence analysis is given, without any Lipschitz continuity assumption.

FR3-H-CO22

Ellipsoidal Approximation Technique for Differential Games with Integral-Terminal Payment

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Keywords: ellipsoidal function - guaranteed control strategy

A special class of zero-sum linear differential games (DG) on a fixed time segment is considered. This DG class is a formulation for optimal control problems with unknown but bounded disturbances. We are concerned in optimization of the guaranteed result. In other words we consider the controller and the disturbance as two players with opposite goals. Such well-known DG classes as linear DG with quadratic payment functional and linear DG with ellipsoidal constraints are two limiting cases of games from the class under consideration.

We introduce a special functional class which members we refer to as ellipsoidal functions. A graph of an ellipsoidal function is a part of an ellipsoid. The ellipsoidal functions are strongly convex and are parametrized by a finite set of real numbers. The convexity makes possible to apply convex analysis and to operate in terms of conjugate convex functions. The finite parametrization permits us to construct effective algorithms.

We develop a calculus of ellipsoidal functions, namely we construct upper and lower approximations of sum and difference between two conjugate ellipsoidal functions in the class of conjugate ellipsoidal functions. This calculus is the basis for calculation of upper and lower approximation of the DG value function in the class of conjugate ellipsoidal functions.

Guaranteed control strategies are defined explicitly by means of the DG value function approximations. The strategies are proved to be continuous and stable. This properties show significant advantages of the method under consideration in comparison with the ellipsoidal technique developed by Kurzhanski.

FR4-H-CO22

A Minimax Principle for Differential Games

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Keywords: programmed strategy - saddle points

This paper deals with nonlinear zero-sum differential games on a fixed time segment. Control vectors of two players are subjected to geometrical constraints. The goals of the two players are correspondingly minimization and maximization of a payment functional, which is a sum of terminal and integral terms. Programmed strategies of the players are set to be admissible strategies. It means that the players should choose their controls as functions of time before the begging of the game. It is well-known that a saddle point in the class of the programmed strategies may not exist. This fact implies that

Pontrjagin maximum principle can not be applied for differential games in general. Therefore the basic method to solve differential games is dynamical programming principle, which solves the problem for all initial positions of the state vector. In other words, the dynamical programming principle is a global method; consequently it is more complicated and less efficient than the local Pontrjagin principle. The most important assumption of the paper is that the integrand in the payment functional is strongly convex with respect to a control vector of a player, minimizing the payment and strongly concave with respect to a control vector of a player, which maximize the payment. Moreover the constants of the convexity and the concavity are sufficiently large. The main results of the paper are: 1) a unique saddle point exists in the class of programmed strategies; 2) a minimax principle is a necessary and sufficient condition for player's strategies to form the saddle point (the minimax principle is a direct generalization of Pontrjagin maximum principle in optimal control theory); 3) the value function of the differential game is Lipschitz differentiable; 4) the optimal programmed control strategies are continuous with respect to time.

We consider examples to compare the new class of differential games with well-known classes of games – linear games with a quadratic functional and games with purely geometrical constraints and a terminal payment.

FR1-I-CM200

An Inversion of Beckmann's Plane Assignment Problem

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Tetscuichiro Iki

Keywords: assignment problems - discrete optimization - dynamic programming - inverse theory - stopping time

We focus on the famous "Plane Assignment Problem" in Beckmann's *Dynamic Programming of Economic Decisions* and develop a further theory of the assignment problem. Formulating the problem into an optimal (main) stopping problem, we propose a new inversion of the stopping problem. By exchange of objective function and constraint function together with replacement of optimizer min by Max, we introduce an inverse assignment problem, which is also an optimal stopping problem. We establish several inverse theorems between main and inverse stopping problems. We also analyze the finite-stage (nonstopping) problems and specify the envelopping relation to the stopping problems. Detailed numerical solutions for both problems are specified.

FR3-I-CM121

The Parity Problem for Linear Delta-Matroids

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Geelen James Ferdinand - Murota Kazuo

Keywords: delta-matroid - matroid parity - skew-symmetric matrix

We generalize the Lovász minimax formula on the linear matroid parity problem. The matroid parity problem, which contains the matching and the matroid intersection problem, is intractable in general, but solvable if the matroid in question is linearly represented. There have been developed efficient algorithms for the linear matroid parity problem. In particular, Gabow and Stallmann devised an augmenting path algorithm, which provides an alternative proof of the minimax formula. We address the parity problem in the more general setting of delta-matroids. Even in this general setting, the problem is solvable for linear delta-matroids, which are represented by skew-symmetric matrices. A minimax relation follows from an analysis of an efficient augmenting path algorithm, which extends the Gabow and Stallmann algorithm for the linear matroid parity problem. This resolves open problems of Bouchet on special classes of delta-covering problems concerning a pair of delta-matroids.

TU4-I-CM121

A Faster Cycle-Canceling Algorithm for Minimum Cost Submodular Flows

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McCormick S. Thomas - Shigeno Maiko

Keywords: network flow - polynomial algorithm - submodular function

The submodular flow problem, introduced by Edmonds and Giles, is one of the most important frameworks of efficiently solvable combinatorial optimization problems. There have been proposed a number of combinatorial algorithms, which rely on an oracle for exchange capacities, as generalizations of minimum cost flow algorithms. We review recent algorithms on submodular flows, and then present a new cycle canceling algorithm, which uses an assignment problem whose optimal solution identifies the most negative node-disjoint cycles in the auxiliary network. The cost scaling version of this algorithm runs in $O(n^4 h \log nC)$ time, where n is the number of nodes, h is the time for computing an exchange capacity, and C is the maximum absolute value of arc costs. This improves the best previously known weakly polynomial bound due to Cunningham and Frank.

TU2-C-CO2

Sqp-methods based of Exact-Barrier Cost Function for Nonlinear Programming Problem

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Mary State University

Petropavlovskii Michail - Blinov Alexey

Keywords: SQP - exact cost function - nonlinear programming

This paper is presenting an approach for construction in a unified scheme of methods for solving nonlinear programming problems with inequality restrictions. This approach is based on the idea of linearization of " active " constraints and the notion of " reduced " direction used as search direction in the iteration points. Different cost functions used to calculate the step length along reduced direction. Into the frame of the scheme of reduced direction methods has been parametri-

cally realized the methods of following known groups: the non-differentiable cost functions,the differentiable cost and barrier functions, the modified Lagrangian function, the methods of centers, the feasible directions methods. Special choise of the method parameters gives both known and new methods and the hybrid methods also.Proposed cases of cost parameters calculating in the iteration points as formulas has been used in the new methods. Cost functions determined these parameters become exact-barrier cost function. Criteria formulated for iteration point gives the possibility to halt the iteration sequence in the solution of original problem. The theorems of convergence has been proved for every groups of methods. The first order methods converges with linear rate. The moving along curvlinear trajectory is used in order to accelerate the rate of convergence in the second order methods.The principles of combining of hybrid algorithms are carred out on the base of uniform organization of calculating algorithms of different methods, it is given the proof of their convergence.The construction of methods in the frame of unified scheme gives the possibility to determine the unified calculating algorithm and to realized the dialog optimization system ODiS for IBM PC.

WE2-U-IN10

Applications of Mathematical Programming in Airline Planning

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Sabre Decision Technologies

Smith Barry C.

Mathematical Programming is used in airlines for fleet assignment, yield management and crew scheduling. We discuss these models, solution methods and ongoing research.

TH2-A-IN1

Geometrical solution to the Fermat problem with arbitrary weights

Jalal Galina

DIKU, University of Copenhagen

Krarup Jakob

The prime motivation is a famous problem, allegedly first formulated in the early 1600's by Fermat, and the so-called "Complementary Problem" (CP), proposed but incorrectly solved in 1941 by Courant and Robbins. For a given triangle, Fermat asks for a fourth point such that the sum of its euclidean distances, each weighted by +1, to the three given points is minimized. CP differs from Fermat in that the weight associated with one of these points is -1 instead of +1. We extend the geometrical approach discussed in Krarup and Vajda's "Torricelli paper" to cover any combination of positive and negative weights associated with the vertices of a given triangle. Among the by-products are surprisingly simple correctness proofs of the geometrical constructions of Torricelli (around 1640), Simpson (1750), and Martelli (1997) as well as the correct solution to CP. Furthermore, the strong version of Ptolemy's Theorem (around A.D. 150) and Heinen's Theorem (1834) follow as "corollaries".

FR4-P-IN201

Flow-Shop Scheduling with Resources - Exact and Approximation Algorithms

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Keywords: branch and bound - convex models - genetic algorithms - permutation flow-shop - resource allocation

The paper is an extension of the classical permutation flow-shop scheduling problem to the case where some of the job operation processing times are convex decreasing functions of the amounts of resources (e.g. financial outlay, energy, raw materials) allocated to the operations (or machines on which they are performed). For this problem, the objective is to find a processing order of the jobs (which will be the same on each machine) and an allocation of a considered resources so as to minimize the makespan. An analysis of the structure of the optimal solutions provides some elimination properties, which are exploited in a branch-and-bound solution scheme and genetic algorithms as well. The results of some computational experiment with the mentioned algorithms and some additional approximate ones are also included.

WE3-I-CM120

An Optimal Greedy Algorithm for Wavelength Allocation in Directed Trees

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Universität Trier, FB IV Mathematik

Erlebach Thomas - Kaklamanis Christos - Persiano Pino

Keywords: approximation algorithms - chromatic number - path coloring

The wavelength allocation problem in optical networks with directed tree topology has recently received a substantial amount of attention. Wavelengths must be assigned to connection requests which are represented as directed paths, and it is required that paths receive different wavelengths if they share a directed link. The goal is to minimize the number of different wavelengths used. The best previously known approximation algorithm for this NP-hard problem routes any set of paths with $\frac{7}{4}L$ wavelengths, where L is the maximum load on a directed link. We give an improved algorithm that uses at most $\frac{5}{3}L$ wavelengths. This is provably the best ratio that can be achieved by any greedy algorithm for this problem.

MO3-I-CM4

Approximation Results for the Optimum Cost Chromatic Partition Problem

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Keywords: approximation algorithms - combinatorial optimization

In this talk, we give an overview about the optimum cost chromatic partition (OCCP) problem for several graph classes. The OCCP problem can be formulated as follows: Given a graph $G = (V, E)$ with n vertices and a sequence of coloring costs $(k_1, \ldots, k_n)$, find a partition into independent sets $U_1, \ldots, U_s$ with $s \leq n$ such that the costs $\sum_{c=1}^{s} k_c \cdot |U_c|$ are minimum. We prove that there exists no polynomial approximation algorithm with ratio $O(|V|^{0.5-\epsilon})$ for the OCCP problem restricted to bipartite and interval graphs, unless $P = NP$. Furthermore, we propose approximation algorithms with ratio $O(|V|^{0.5})$ for bipartite, interval and unimodular graphs. Finally, we prove that there exists no polynomial approximation algorithm with ratio $O(|V|^{1-\epsilon})$ for the OCCP problem restricted to split, chordal, permutation and comparability graphs, unless $P = NP$.

WE4-C-CO122

Exact Bounds for Linear Systems with Interval Input Data

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Keywords: global optimization - interval arithmetic - linear systems

A linear system with interval input data is defined as a family of real linear systems where the coefficients of the system matrix and the right hand side vary between given lower and upper bounds. The corresponding solution set is defined as the set of all solutions of this family. This set is generally nonconvex and not connected.

Since the last three decades many peaple are interested in calculating lower and upper bounds of the solution set. This problem can be viewed as a global optimization problem with linear objective function and a nonconvex set of feasible solutions. Many methods that were developed in the last decades work only in special cases and require additional properties of the matrix, like strong regularity and sufficiently small diameter of the input data.

In a recent paper, Rohn provet that the problem of calculating bounds for the solution set is NP-hard. In this talk a method for calculating exact bounds of the solution set is presented. This method needs p calls of a polynomial time algorithm, where p is the number of nonempty intersections of the solution set with the orthants. Frequently, due to physical or economical requirements, many variables do not change the sign. In those cases p is small, and our method works efficiently.

FR2-C-CO2

On Self-Concordant Barrier Functions for Conic Hulls and Fractional Programming

Jarre Florian

Universität Würzburg

Freund Roland W. - Schaible Siegfried

Keywords: conic hull of a convex set - fractional programming - interior point methods - self-concordant barrier function

Minimizing a linear fractional subject to convex feasibility constraints can be reformulated as a convex program. Here we investigate in how far the properties of the convex domain of the fractional program are maintained by this reformulation. In particular, we show how to find the best possible—in a certain sense—barrier function for the reformulation of the fractional program.

MO3-D-CO124

A Primal-Dual Interior-Point Method for Quadratically Constrained Convex Programs

Jarre Florian

Universität Würzburg

Kocvara Michal - Zowe Jochem

Keywords: Mehrotra corrector - primal-dual methods

We present an interior-point method for solving quadratically constrained convex quadratic programs. We discuss the concept of Mehrotra's corrector and give some numerical results that show the practical efficiency of the corrector step. The numerical results are taken from a large scale application that arises in truss topology design problems.

WE4-D-CO123

An Application of Semidefinite Programming in Combinatorial Optimization

Jarre Florian

Universität Würzburg

Lepenis Rouven - Seipel Dietmar

Keywords: combinatorial optimization - semidefinite programming

A combinatorial problem arising in the computation of stable models of databases containing uncertain knowledge is solved by semidefinite programs and by standard combinatorial optimization techniques. Preliminary numerical results indicate that for problems with a simple combinatorial structure like in the above example, combinatorial optimization techniques are very competitive.

TH1-C-CO122

Concave Minimization: Best Simplicial Bounds and a New Convergence Proof

Jaumard Brigitte

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Hansen Pierre - Meyer Christophe

Keywords: concave optimization - cone splitting algorithm

We define two classes of lower bounds using either one or two simplices for the minimization of a concave function over a polytope. For each of them, a procedure is developed to compute the best lower bound of the class. We also present a convergence proof of Tuy's cone splitting algorithm with a pure ω-subdivision strategy. The key idea is to associate with the current hyperplane one that supports the whole polytope instead of only the portion of it contained in the current cone.

TU2-U-IN10

A Stabilized Column Generation Algorithm for the Multi Source Weber Problem

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Hansen Pierre - Krau Stephane - du Merle Olivier

Keywords: column generation - location

The Multisource Weber Problem consists in locating simultaneously p facilities in the Euclidean plane and allocating n users, each to the closest facility in order to minimize the weighted sum of distances between the users'locations and the facilities to which they are assigned. A column generation algorithm is proposed, which uses global optimization to solve the auxiliary problem of finding a column with negative reduced cost. It is combined with a bundle method in the L_1-norm to stabilize the solution process around a good dual solution obtained with a Variable Neighborhood Search heuristic. Problems with $n = 1060$ and $p = 100$, i.e., 20 times larger on both counts than previously done, are solved exactly.

TU4-B-CO10

Duality for a Sum of Fractions

Jefferson Thomas Richard

Sultan Qaboos University

Scott Carlton H.

Keywords: convex programming - fractional programming - geometric programming

Sums of fractional functions are generally nonconvex. Here we give duality results for a special convex case and for a nonconvex case as well. Results are obtained using conjugate duality and geometric programming respectively.

TH4-V-CM106

Automatic Regulatory Compliance using Optimization Techniques

Jensen David

IBM

Keywords: financial optimization - risk management

Financial firms, such as broker-dealers, are regulated to ensure the stability of the financial markets in which they act as intermediaries, for example with respect to amount of capital required to cover open positions. Firms have choices with respect to the satisfaction of the regulations, but the sheer number of regulations and securities on the books make it an arduous task even to prove compliance. This talk will discuss how optimization can automate these tasks, while minimizing capital.

TU3-E-CO21

Solving Nonlinear Complementarity Problems via Fischer-Burmeister Functional

Jiang Houyuan

Department of Mathematics, The University of Melbourne

Keywords: generalized Newton method - global convergence - nonlinear complementarity problems - nonsmooth equations

The nonlinear complementarity problem NCP(F) has been reformulated as a system of semismooth (nonsmooth) equations via the Fischer-Burmeister functional. The local convergence of the generalized Newton methods applied to this semismooth equation has been established before. In this talk, global convergence of the damped generalized Newton method, the modified damped Gauss-Newton method, and the trust region method, are presented. This shows that the elegant traditional global convergence theory of Newton-type methods to the smooth equations is able to be extended to this special system of nonsmooth equations. In partucular, the damped generalized Newton method converges to the unique solution when F is a uniform P-function, and any accumulation point of the iteration sequence generated by the modified damped Gauss-Newton method is a solution of NCP(F) when F is a P-function. Moreover, interior point approaches to the solution of complementarity problems via the Fischer-Burmeister functional are discussed.

FR2-E-CO21

Global Convergence of Numerical Approaches to Mathematical Programs with Equilibrium Constraints (MPEC)

Jiang Houyuan

Department of Mathematics, The University of Melbourne

Ralph Danny

Keywords: convergence analysis - equilibrium constraints - mathematical programming - numerical methods

We discuss global convergence of some numerical approaches to MPEC, mathematical programs with equilibrium constraints, where the equilibrium constraints are nonlinear, for instance parametric nonlinear complementarity problems. Traditional penalty strategies from nonlinear programming appear to be extendable to the MPEC, but the penalty functions used for MPEC appear to have different characteristics. Quasi-Newton methods are also considered.

FR2-C-CO123

A Nonconvex Separation Property in Banach Spaces and its Applications to Economics

Jofré Alejandro Rene

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Keywords: equilibrium price - nonconvex set - subgradient - variational principle

One of the cornestone in Functional Analysis is the Hahn-Banach separation theorem. This result establish that for two convex closed sets Z_1 and Z_2 of a Banach space X one of them with interior nonempty such that $Z_1 \cap Z_2 = \{z\}$ there exists $p^* \neq 0$ belongs to the topological dual X^* such that :

$$< p^*, z_1 - z > \leq 0, \; < p^*, z_2 - z > \geq 0, \;\; \text{for all} \;\; z_1 \in Z_1, z_2 \in Z_2.$$

These conditions can be written in terms of the convex normal cones as follows,

$$p^* \in \; N_{Z_1}(z) \quad \text{and} \quad -p^* \in \; N_{Z_2}(z).$$

Our aim in this paper is to extend this result to closed sets in infinite dimensional spaces by using an abstract notion of subdifferential which requires only properties on lipschitzian functions and replacing the n ormal cone by the subgradient set to the distance function. In finite dimens ion spaces this result was proved by Jofré and Rivera , where we gave som e applications to optimization and economics. As a consequence, we prove an extension of the Second Welfare Theorem for a general nonconvex nontransitive economics with an infinite number of goods and we also give so me formulae to compute pseudo-equilibrium prices.

Finally, we combine our results with some compactness conditions to obtain simpler (limits) calculus rules to compute prices.

FR4-C-CO2

Monotonicity Properties of Subgradients and Well-Behavioured Nonconvex Functions

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Keywords: monotonicity - nonconvex functions - subgradient

One of the interesting topics of convex analysis is to study the link between the convexity of a function and the maximal monotonicity of its subdifferential. Poliquin (1990) proved that the monotonicity of the Clarke subdifferential of a lower semicontinuous function defined on a finite dimensional space is equivalent to its convexity. Recently, Correa, Jofré and Thibault (1992) by using a Moreau-Yosida approximation and the mean value theorem of Zagrodny (Z.M.V.T.) extended this characterization of convexity to reflexive Banach spaces. Later, an extension to any Banach space and any subdifferential (belonging to a certain class) was proved by the same authors using only Z.M.V.T. In parallel, another proof was established by Luc based also on Z.M.V.T. The case of the Lipschitz-smooth subdifferential is proved in Clarke's book (1983). In a recent paper Aussel, Corvelet and Lassonde using the smooth variational principle of Borwein & Preiss established an approximate mean value inequality which permited them to unify some previous results. Finally, Correa, Jofré and Thibault have proved that convexity is equivalent to the monotonicity of a more general notion of subdifferential called *Presubdifferential*. All these works were made in order to characterize lower semicontinuous convex functions.

The purpose of this paper is to prove for some classes of *nonconvex* real-extended valued functions characterizations in terms of local and global monotonicity and maximality properties of their subgradient set. We also show some consequences in Nonsmooth Optimization and Nonlinear Analysis of these characterizations.

FR3-F-IN203

Estimation of Formation Constants in Chemical Equilibrium Analysis

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Holmstroem Kenneth H.

Keywords: approximation algorithms - chemical equilibrium analysis - formation constants - multiphase multimethod data - nonlinear least squares

This paper presents algorithms to find starting values to the nonlinear parameter estimation problem of finding formation constants in inorganic chemical equlibria.

There is a need of robust programs to solve multiphase multimethod chemical equilibrium problems, i.e. to find the complexes formed, their unknown formation constants, and many types of method dependent and other parameters. Our program package LAKE has since many years been a neccessary computational tool for several inorganic research groups.

The problems solved are large, ill-conditioned, constrained nonlinear least squares problems, which can not be solved by standard optimization software. In LAKE we are using a new type of separable nonlinear least squares algorithm. It is also neccessary to use as good starting values as possible and therefore several algorithms for finding starting values have been developed. In this paper we develop new algorithms to find starting values for the formation constants, especially when using combined multimethod data from NMR spectroscopy and potentiometric measurements.

TU2-K-CM106

The Asymmetric Traveling Salesman Problem: Algorithms and Applications

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Keywords: TSP - compilers - no-wait flowshop

A variety of scheduling and other problems can be modeled as asymmetric TSP's, from manufacturing set-up problems to no-wait flowshops. Unfortunately, no heuristics are known which have provably good worst-case behavior, even assuming the triangle inequality, and in practice most tour-construction heuristics perform quite poorly compared to their counterparts for the symmetric TSP. Fortunately, it appears that we can do surprisingly well in practice using the relatively simple local optimization algorithm "Iterated 3-Opt," first proposed (for the symmetric TSP) by Martin, Otto, and Felten. In this talk I'll summarize ongoing experiments to evaluate this heuristic and its main competition in comparison to the assignment problem and Held-Karp lower bounds on optimal tour length. These experiments cover a wide variety of instance families, including ones that arise in an intriguing new compiler application for which detailed results will be given. This research has been performed in collaboration with Lyle A. McGeoch of Amherst College, David R. Karger of MIT, and Cliff Young and Michael D. Smith of Harvard.

TU1-C-CO122

Engineering Optimization Using Statistical Models

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General Motors Research

Welch William - Schonla Matthias

Keywords: bayesian optimization - black-box - global optimization - random function - response surface - stochastic process

The long running times of engineering analysis codes pose a special challenge for global optimization. Because only a few function evaluations can be afforded, a promising strategy is

to run the computer program on a small set of candidate designs and then fit a statistical model to the data. The statistical model can then be used as a fast surrogate for the analysis code, facilitating what-if analyses, visualization, and optimization. This talk will survey the fascinating attempts in the literature to use statistical models in optimization, and discuss some new breakthroughs that promise to make the approach truly practical.

TU2-T-CO22

Black-Box Global Optimization with Nonlinear Inequality Constraints and No Tuning Parameters

Jones Donald R.

General Motors Research

Keywords: Bayesian optimization - DIRECT - Pareto optimum - black-box - global optimization - inequality constraints

Black-box global optimization algorithms often require the user to adjust parameters that determine the balance between local and global search. Because the best settings of these parameters are problem dependent, the user must typically spend considerable time "tuning" the algorithm to get good results. This talk will describe an algorithm called DIRECT that balances local and global search in a way that eliminates the need for tuning parameters. In addition, the talk will explain how the original DIRECT algorithm (published in the Journal of Optimization Theory and Applications) was extended to handle nonlinear inequality constraints.

WE1-G-IN11

A Class of Stochastic Programs with Decision Dependent Random Elements

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Woodruff David L. - Wets Roger J.-B.

Keywords: integer stochastic programming - modeling - stochastic programming with recourse

In the 'standard' formulation of a stochastic program with recourse, the distribution of the random parameters is independent of the decisions. When this is not the case, the problem is significantly more difficult to solve. This paper identifies a class of problems that are 'manageable' and proposes an algorithmic procedure for solving problems of this type. We give bounds and algorithms for the case where the distributions and the variables controlling information discovery are discrete. Computational experience is reported.

TH2-E-CO11

On the Solution of the Linear MPEC

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Dept. Mathematics, University of Coimbra

The Linear MPEC (LMPEC) is defined as

$$\begin{array}{ll} \text{Minimize} & c^T x + d^T y \\ (x,y) \in K & \end{array}$$

where K is a nonconvex set consisting of the solutions of the following General Linear Complementarity Problem (GLCP):

$$\begin{gathered} q + Mx + Ny \geq 0 \\ x \geq 0, y \in K_y \\ x^T\left(q + Mx + Ny\right) = 0 \end{gathered}$$

with M a Q_0 matrix and K_y a convex polyhedron. The LMPEC includes as special cases Linear and Linear-Quadratic Bilevel Programs, Bilinear and Nonconvex Quadratic Programming Problems, 0-1 Integer Programs and the usual Linear Complementarity Problem.

In this talk we address the problems of finding a feasible solution (that is, a point $(x, y) \in K$), a stationary point, a local minimum and a global minimum for the LMPEC. We discuss some existence and complexity properties and a number of Descent and Sequential algorithms to deal with each one of these issues. Some computational experience is included to highlight the efficiency of these procedures.

FR1-I-CM4

Solution of Large Max-Cut Instances Arising from Statistical Physics

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Institut für Informatik, Universität zu Köln

Diehl Martin - Rinaldi G.

Keywords: branch and cut - max-cut - spin glasse - statistical physics

We report about an application of the max-cut problem in sparse graphs arising from Statistical Physics, the so-called "spin glass ground state problem". We solve this problem with a branch-and-cut algorithm using mainly the cycle inequalities of the max-cut polytope and some inequalities obtained by a procedure described in a companion talk. The focus of the work lies on the minimization of the running time to get good sample statistics. We implemented the code using the ABACUS C++ framework. We run experiments on 2-dimensional toroidal instances of spin glasses of sizes up to 22 500 spins. The results of these experiments are sometimes in agreement with those that can be found in the Physics literature. Surprising enough, in some cases they disagree with the theoretical predictions.

FR1-I-CM4

Max-Cut on Sparse Graphs

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Reinelt Gerhard - Rinaldi G.

Keywords: branch and cut - max-cut - polyhedral combinatorics - separation

In the past few years many new results have been obtained on the maximum cut problem in complete graphs that make it now possible to find an optimal solution for instances of size up to one hundred nodes in a moderate amount of time. On the other hand, very little work has been done on this problem for arbitrary (sparse) graphs. One of the motivations for studying the maximum cut problem for sparse graph comes from a classical application to Statistical Physics: the exact determination of a minimal energy configuration of a spin glass

under no exterior field and under a continuously varying exterior magnetic field. In the first case, typically one has to solve very large but sparse instances of max-cut to optimality; in the second one has to provide an optimal solution for all members of a family of objective functions.

To solve these kinds of problems, we introduce new separation and lifting procedures for the cut polytope on arbitrary (sparse) graphs. These procedures exploit any algorithmic and structural results known for the cut polytope on complete graphs to generate valid (and sometimes facet defining) inequalities for the cut polytope on arbitrary graphs, which are violated by the current fractional solution of a cutting-plane or of a branch and cut algorithm.

TU3-I-CM121

Delta Matroid and Jump System
Kabadi Santosh Narayan

University of New Brunswick

Sridhar R.

We prove an equivalence between delta matroid and jump system. Using this, we give some new results, as well as simple, alternate proofs of some known results on jump system.

TH4-E-CO11

Integer Solution for Linear Complementarity Problem
Kabadi Santosh Narayan

University of New Brunswick

Chandrasekaran Ramaswamy - Sridhar R.

We consider the problem of finding an integer solution to a linear complementarity problem. We introduce the class I of matrices for which the corresponding linear complementarity problem has an integer complementary solution for every vector, q, for which it has a solution. We provide necessary and sufficient conditions for some well-known classes of matrices in LCP to belong to the class I. some algorithmic results will also be presented.

TU3-L-CM201

Computational Experiences with the QAP
Kaibel Volker

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Keywords: integer programming - quadratic assignment problem

The Quadratic Assignment Problem (QAP) is the task to assign n objects having flows a_{ik} between each other by a permutation π of $\{1, \ldots, n\}$ to n locations with distances b_{jl} such that $\sum_{i,k=1}^{n} a_{ik} b_{\pi(i)\pi(k)}$ is minimized.

In the first part of the talk we give a brief overview on some aspects of the polyhedral structure of the Quadratic Assignment Problem (QAP). In the second part, we report about the exploitation of the polyhedral knowledge for computing lower bounds or even optimal solutions via cutting plane procedures for the QAP.

We discuss properties of polytopes associated with general QAPs as well as with specially structured ones, like, e.g., symmetric QAPs or a generalization, where the number of locations might exceed the number of objects. In particular, we present a first large class of facet defining inequalities for the QAP-Polytopes, the box inequalities. They are coming from a certain class of (facet defining) inequalities for the boolean quadric and the cut polytope, of which the QAP-Polytope is a face.

One issue of the computational part of the talk is a discussion of our computational experiences with these inequalities. Incorporated into cutting plane procedures, they yield very tight bounds for many instances in the QAPLIB. In particular, several instances (including the `esc16` examples) could be solved to optimality for the first time without using branch-and-bound type algorithms by pure cutting plane methods. Another issue is the special treatment of QAPs whith more objects than locations. For this case, exploiting results on projections of certain relaxation polytopes, we can compute linear programming based bounds for large instances (the `esc32` examples) with many "dummy-objects" for the first time.

TU-pm-CO1

Linear Programming, the Simplex Algorithm and Simple Polytopes
Kalai Gil

Hebrew University

In the first part of the paper we survey some far-reaching applications of the basic facts of linear programming to the combinatorial theory of simple polytopes. In the second part we discuss some recent developments concerning the simplex algorithm. We describe subexponential randomized pivot rules and upper bounds on the diameter of graphs of polytopes.

TH4-E-CO11

Application of Topological Degree Theory to Complementarity Problem
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Central Economics and Mathematics Institute (CEMI)

Abdelouahed Hamdi - Isac George

Keywords: complementarity problems - topological degree

Complementarity problems of various types are considered, including the standard, the implicit ones, and the complementarity problem over an arbitrary cone in R^n. In each of these cases, notions of an exceptional family and normed exceptional family of points are introduced, and existence theorems are obtained. The theorems assert that either the complementarity problem has a solution or there exists an exceptional family (normed exceptional family). When proving the theorems, the notion and properties of the topological degree of a continuous mapping, and those of an 0-epi mapping, are used.

TU1-D-CO124

A General Convex Cut - Based Logarithmic Barrier Decomposition Method for Hard Semi-infinite Programming
Kaliski John A.

Mankato State University

Terlaky Tamás - Haglin David

Keywords: cutting plane methods - logarithmic barrier - semi-infinite programming

A computational study of a general convex cut–based logarithmic barrier decomposition algorithms for semi–infinite programming is presented. The conceptual algorithm is a straightforward adaptation of the logarithmic barrier cutting plane algorithm which was presented recently by Kaliski et al. Usually decomposition (cutting plane methods) use cutting planes to improve the localization of the given problem. In this paper we propose an extension which uses general convex cuts to solve large scale, difficult real world problems. This algorithm uses both static and (doubly) dynamic enumeration of the parameter space and allows for multiple cuts to be simultaneously added for larger/difficult problems. The algorithm is implemented both on sequential and parallel computers. Implementation issues and parallelization strategies are discussed.

FR4-L-CM200

Large-Scale Convex Optimization via Saddle Point Computation

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Helsinki School of Economics

Rosa Charles H.

Keywords: large scale convex programming - saddle points

This article proposes large-scale convex optimization problems to be solved via saddle points of the standard Lagrangian. A recent approach for saddle point computation is specialized, by way of a specific perturbation technique and unique scaling method, to convex optimization problems with differentiable objective and constraint functions. In each iteration the update directions for primal and dual variables are determined by gradients of the Lagrangian. These gradients are evaluated at perturbed points which are generated from current points via auxiliary mappings. The resulting algorithm suits massively parallel computing, though in this article we only consider a serial implementation. We test a version of our code embedded within GAMS on 16 nonlinear problems, which are mainly large. These models arise from multi-stage optimization of economic systems. For larger problems with adequate precision requirements, our implementation appears faster than MINOS.

TU4-G-IN11

A note on Exponential Rate Convergence in Stochastic Programming Problems

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Keywords: dependent and independent random samples - estimates - exponential convergence rate - stochastic programming

Solving an optimization problem depending on a probability measure mostly it is necessary to substitute the underlying probability measure by some its statistical estimate. The empirical distribution function is usually employed whenever the theoretical one is fully unknown, while a parameter estimate determines the estimate of the distribution function in the case when it is known that the unknown distribution function belongs to a parametric family. Obviously, the estimates of the optimal value and the optimal solution can be obtained only by this approach.

In the literature, a great attention has been already payed to the relationship between the theoretical optimal characteristics and the corresponding statistical estimates. In particular, there were investigated problems in which the optimal solution is sought with respect to the mathematical expectation (of some continuous random function) over the both a deterministic set and a set determined by the probability measure. Moreover, an exponentional rate convergence has been proven for a relative great class of such stochastic programming problems as well as for the both independent and some types of dependent random samples.

In the talk we shall try to extend the class of the problems for which the corresponding estimates are consistent and, moreover, the convergence rate is at least exponentional (or at least "almost" exponentional). To this end, first, we shall include in our consideration the problems with probability objective, furthermore, we shall consider two–stage stochastic programming problems and chance constrained stochastic programming problems corresponding to the underlying problems in which the decision and the random element are unseparable. We shall consider the both parametric case and an empirical distribution approach. At the end, we shall try to extend "possible" types of dependence in the corresponding random samples.

TU2-E-CO21

A Modified Fischer-Burmeister NCP-Function.

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FR2-E-CO11

On Block Pivoting and Line Search Methods for Linear Complementarity Problems

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Keywords: linear complementarity problem - merit function - pivoting methods

Pivoting methods like Bard's algorithm, Murty's least index method or Kostreva's block pivoting method belong to the classical algorithms for the solution of linear complementarity problems. Some recent investigations show that these methods are also quite successful for, e.g., positive definite linear complementarity problems. The main disadvantage of pivoting methods, however, is the fact that they usually need some strong assumptions in order to be at least well-defined.

In this talk, we combine pivoting methods with line search methods which are based on some recently introduced merit functions for the solution of more general complementarity problems. In this way, we can improve the global convergence properties of the pivoting methods considerably. Moreover, the new methods are well-defined for an arbitrary linear complementarity problem. We demonstrate the benefits of these new algorithms by some numerical examples.

WE1-E-CO11

QP-free Constrained Newton-type Methods for Variational Inequalities

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Qi Hou-Duo

Keywords: Levenberg-Marquardt regularization - active set - global convergence - quadratic convergence - variational inequalities

We consider a simply constrained reformulation of the Karush-Kuhn-Tucker conditions arising from variational inequalities. Based on this reformulation, we present a new Newton-type method for the solution of variational inequalities. The main properties of this method are:

(a) It is well-defined for an arbitrary variational inequality problem,

(b) it is globally convergent at least to a stationary point of the constrained reformulation,

(c) it is locally superlinearly/quadratically convergent under a certain regularity condition,

(d) all iterates remain feasible with respect to the constrained optimization reformulation, and

(e) it has to solve just one linear system of equations (of reduced dimension) at each iteration.

Some numerical results indicate that this method is quite promising.

TH3-D-CO123

Solving Graph Bisection Problems with Semidefinite Programming

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Rendl Franz - Clausen Jens

Keywords: graph bisection - semidefinite programming

An exact solution method for the general graph bisection problem is presented. We consider the problem of partitioning the vertices of an edge-weighted graph into two components of given (and possibly different) size, such that the total weight of edges connecting the two components becomes minimal. We describe a branch-and-bound algorithm which is based on a cutting plane approach combining semidefinite programming and polyhedral relaxations.

We report on extensive numerical experiments which were performed for various classes of graphs. The results indicate that the present approach is very robust and allows to solve problems on general graphs with around 90 vertices in a routine manner and provides tight approximations for larger instances. Our approach is particularly well suited for special classes of graphs such as planar graphs and graphs based on grid structures.

TU1-I-CM4

Minimum Extensions of Graph Distances

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For a connected graph $H = (T, U)$ and a set $V \supseteq T$, a metric m on V is called an *extension* of H if m coincides with the distances of H within T, and a 0-*extension* if, in addition, for each $v \in V$ there is $s \in T$ satisfying $m(v, s) = 0$. In the *minimum extension problem* (1) (resp. *minimum 0-extension problem* (2)), one is given a nonnegative function c on the unordered pairs in V, and is asked for minimizing the inner product cm over all extensions (resp. 0-extensions) of H to V. When $H = K_3$, problem (2) turns into the minimum 3-terminal cut problem, which is known to be NP-hard, due to Dalhaus et al. On the other hand, (2) is polynomially solvable if $H = K_2$ (the minimum cut problem) or $H = K_{2,r}$ (the minimum $(2, r)$-metric problem).

We call H *minimizable* if for any V and c, the minima in (1) and (2) coincide. In metric terms, this means that the distance function of H has a unique primitive extension. For all fixed minimizable graphs problem (2) can be solved in polynomial time. Using combinatorial and topological arguments, we completely characterize the set of minimizable graphs, which turns out to be exactly the set of orientable hereditary modular graphs.

We then generalize the construction from Dalhaus et al. to show that (2) is NP-hard for a large class of (fixed) non-minimizable graphs. For some other non-minimizable graphs, e.g. for the skeleton graphs of hypercubes, (2) is proved to be polynomially solvable. Finally, we characterize the set of graphs H whise distance function has possibly more than one but a finite number of primitive extensions. As a consequence, this gives special duality theorems for certain multicommodity flow problems. Also further results are presented.

TU4-B-CO10

Young Programming, an Analytical Approximation of Linear Programming

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Klafszky Emil - Malyusz Levente

Keywords: analytical approximation of LP - convex programming - row-action methods

The terminology Young programming refers to a convex programming problem that is based on the Young inequality. In this talk the Young programming is introduced as an analytical approximation of linear programming. A perfect dual of the Young programming problem is formulated. An algorithm is presented for the solution which is shown to be a row-action method in terms of the primal problem and a gradient type method, we call it dir-action method, in terms of the dual problem.

FR4-I-CM121

The Cone of Envelopes

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Keywords: extremal ray - polymatroid - set functions - upper envelopes

A set function is a function defined on the power set of a set, which is assumed to be a finite in our study. We study a set function defined on a finite set Ω as an element of the linear space which consists of all set functions. A set function φ defined on Ω is said to be an upper envelope if there exists a set $\{p^i\}$ of nonnegative vectors on Ω such that $\varphi(G) = \max\{p^1(G), \ldots, p^n(G)\}$ where $p(G) = \sum_{x \in G} p_x$. All the upper envelopes form a cone. We give a necessary and sufficient condition in general form for a set function to be an extremal ray in the cone of all upper envelopes in terms of its representation $\{p^i\}$.

The polymatroid rank functions can be looked upon as a special case of upper envelopes. All the extremal points of the base polyhedron of a polymatroid form a representation of the rank function of the polymatroid. We investigate the relation between the two classes. Especially we study the extremality condition of a polymatroid rank function in the cone in terms of its representation.

Moreover, we consider the case that a upper envelope is represented by uniform vectors, which take a constant value on their supports. The class of upper envelopes represented by uniform vectors is to the class of upper envelopes what the class of matroid rank functions is to the class of polymatroid rank functions. We present a necessary and sufficient condition for a upper envelope represented by uniform vectors to be extremal in the cone of upper envelopes. We define the connectedness for a upper envelope represented by uniform vectors. Then we show that a upper envelope represented by uniform vectors is extremal if and only if it is connected.

WE1-C-CO2

Parametric Variational Inequalities with K-Pseudomonotone Operators

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Kolumbán József

Keywords: parametric variational inequalities - pseudomonotone maps

In this paper we prove a stability result for parametric variational inequalities generated by K-pseudomonotone operators. The main tool we use is an existence result for variational inequalities (without parameter) with K-pseudomonotone operators due to J. C. Yao (JOTA, 1994) and an implicit function theorem due to the authors (1989).

Some applications for parametric optimization are given.

TH2-C-CO122

INTOPT_90, A Fortran 90 Package for Rigorous Global Search

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Keywords: interval computations - nonconvex global optimization

INTOPT_90 is a Fortran 90 package for rigorous computation of all solutions to nonlinear systems of equations and for deterministic unconstrained and constrained global optimization. The package INTOPT_90 will be introduced through examples. Certain underlying principles will be explained. Finally, present development of INTOPT_90 into a commercial-quality package will be outlined.

WE3-I-CM120

Packing Connectors

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UNIVERSITEIT VAN AMSTERDAM, FACULTEIT WINS

Schrijver Alexander

Given an undirected graph $G = (V, E)$ and a partition $\{S, T\}$ of V, an S–T *connector* is a set of edges $F \subseteq E$ such that every component of the subgraph (V, F) intersects both S and T.

We show that G has k edge-disjoint S–T connectors if and only if for every collection $\{V_1, \ldots, V_t\}$ of nonempty, pairwise disjoint subsets of S and for every such collection of subsets of T it holds that $|\delta_G(V_1) \cup \ldots \cup \delta_G(V_t)| \geq kt$.

By an easy orientation-argument, this can be derived from theorems of Tutte and Nash-Williams (on disjoint spanning trees) and Schrijver (on disjoint bi-branchings).

If either S or T is a singleton, an S–T connector is just a spanning tree of G, so the above result generalizes the Tutte-Nash-Williams theorem. If G is bipartite with colour classes S and T, an S–T connector is an edge cover of G. Therefore, Königs theorem on the edge-painting number of a bipartite graph is another special case.

TH1-T-CO22

Racing Vehicle Dynamics

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NORTH CAROLINA STATE UNIVERSITY

Choi Tony - David Joseph - Georg Gablonsky

Keywords: implicit filtering - noisy functions - vehicle dynamics

We discuss some noisy optimization problems that arise in parameter identification and optimization of race car vehicle dynamics. A new three-dimensional model of a valve train has been created, tested, and used in optimal design using the implicit filtering, Nelder-Mead, and DIRECT algorithms. We will report on the engineering results and our experiences in comparison of these algorithms and implementation on the CRAY T3-D and E machines.

WE1-I-CM200

Allocation and Fractional Combinatorial Optimization

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University of Twente

Faigle Ulrich

Keywords: TSP - bin packing - cost allocation

Cost allocation problems can be related to certain fractional combinatorial optimization problems by LP-duality in a straightforward way. We consider two specific examples - bin packing and euclidean TSP - and come up with two interesting conjectures concerning the relation between the optimum solution and the corresponding fractional optimum.

TH2-D-CO123

On the complexity of integer and mixed semidefinite programming

Khachiyan Leonid

Department of Computer Science, Rutgers University

Porkolab L.

We extend Lenstra's theorem on the polynomial-time solvability of linear integer programming in fixed dimension to integer and mixed semidefinite programming

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WE1-I-CM121

On the Complexity of Generating all Minimal Implicants and Implicates of Monotone Boolean Functions

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Let $f : 2^N \to \{0,1\}$ be a monotone Boolean function defined on the subsets of a finite set N. Denote by MAX_f (MIN_f) the families of all maximal (minimal) subsets X of N such that $f(X) = 0$ (1). We show that the problem of simultaneously generating all elements of MAX_f and MIN_f can be solved in quasi-polynomial incremental time for any function f given by a quasi-polynomial-time oracle. On the other hand, we show that for some classes of polynomial-time computable functions f, it is coNP-hard to test either of the conditions $\mathcal{F} = MIN_f$ or $\mathcal{F} = MAX_f$, where $\mathcal{F}$ is an explicitly given family of subsets of N. This provides evidence that for each of these classes neither MIN_f nor MAX_f can be generated in total (or incremental) quasi-polynomial time. Such classes of monotone functions naturally arise in convex programming, game theory, networks and relay contact circuits, and include a subset of $\wedge, \vee$-formulae of depth 3.

TH1-C-CO122

Theory and Practice of Global Search with Concave Support Functions

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Keywords: concave support functions - generalized semi-infinite optimization - global optimization

We give a diffinition of functions with a concave minorant or a concave support function. Then we show how concave support functions can be used in global optimization problems. Numerical results connected with the use of concave support functions in global minimization of multiextremal functions over compact sets are given. We also discuss the efficiency of concave support functions in some special problems, maximization of the probability function, bilevel programming, and others.

MO4-I-CM4

Housing Market Short-Term Equilibria and the Sets of Disjoint Cycles of a Maximum Total Length

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Keywords: circuit - housing market - linear programming - oriented graph

Notations: I, H - finite sets of positive integers; D_{ih}, S_i - positive integers ($i \in I$, $h \in H$); $A_h \subseteq I$ ($h \in H$); $V = \{(i,j,h)/i \notin A_h,\ j \in A_h,\ D_{ih} \neq 0\}$; $x = (x_{ijh}/(i,j,h) \in V)$; $T^-_{ih}(x) = \sum_j x_{ijh}$; $T^-_i(x) = \sum_h T^-_{ih}(x)$; $T^+_{jh}(x) = \sum_i x_{ijh}$; $T^+_j(x) = \sum_h T^+_{jh}(x)$; $Q = \{x/x_{ijh} \geq 0,\ \sum_j x_{ijh} \leq D_{ih},\ \sum_h T^+_{ih}(x) - \sum_h T^-_{ih}(x) \leq S_i$ for $(i,j,h) \in V\}$; P - the set of all integer vectors from Q; $E = \{x/x \in P$ and $(y \in P$ & $y \leq x \to y = x)\}$

The problem of searching the short-term equilibria in the local housing market, maximizing the linear utility function, can be expressed in the form $max\{(c,x)/x \in E\}$.

Theorem 1. The matrix of constraints, describing the polyhedron Q, is totally unimodular.

Corollary. All corner points of Q belong to P.

If $c > 0$ then the problem $max\{(c,x)/x \in E\}$ can be reduced to linear programming problem (LPP) by the following theorem.

Theorem 2. If $c > 0$, x^* is a corner point of Q and

$x^* \in Arg\max\{(c,x)/x \in Q\}$, then $x^* \in Arg\max\{(c,x)/x \in E\}$.

Let $S_i = 0$, $\sum_h D_{ih} = 1$ for all i. Then we can set $I = H$, $V = \{(i,j)/i \in A_i,\ j \notin A_i\}$. $G = (I,V)$ is oriented graph without loops. Let S be the collection of all sets of disjoint circuits in G. For $x \in P$ let $L(x) = \{(i,j)/x_{ij} = 1\}$ (obviously, $x_{ij} \in \{0,1\}$).

Lemma 1. $L(x)$ is one-to-one correspondence between P and S.

For $s \in S$ let $I(s)$ be the set of all nodes belonging to circuits from s. Set of disjoint circuits s will be called maximal if subgraph of G, created by the nodes from $I \backslash I(s)$, contains no circuits. Let S_0 be the set of all maximal elements of S.

Lemma 2. $L(x)$ is one-to-one correspondence between E and S_0.

Let's interpret c_{ij} as length of the verge (i,j), $c_{ij} > 0$.

Theorem 3. $L(x)$ is the set of circuits with the maximum total length in G iff x is a corner point of the polyhedron Q and $x \in Arg\max\{(c,x)/x \in Q\}$.

Thus, the problem of searching in a graph the set of circuits with the maximum total length is reduced to the LPP.

TU2-A-IN1

A Method of Sensitivity Analysis for the

Primal-Dual Barrier Method

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Kim Jonghwa - Park Soondal

Keywords: linear programming - primal-dual barrier method - sensitivity analysis

This paper presents a method of the sensitivity analysis on the cost coefficients and the right hand sides which is applicable to the primal-dual barrier method. Since the primal-dual barrier method does not guarantee the optimal solution, we start from the optimality conditions of the final solution obtained by the primal-dual barrier method. Then we propose a method of sensitivity analysis to determine the characteristic region where the final solution satisfies the optimality conditions as a cost coefficient or a right hand side changes. To do so, we first develop new mathematical expressions for the final solution with input data and intermediate data which are maintained in the primal-dual barrier method. Then we extract the characteristic regions on the cost coefficients and the right hand sides based on new mathematical expressions for the final solution. The numerical results show that the characteristic regions obtained by the proposed method are convergent to those obtained by the sensitivity analysis of the simplex method in the nondegenerate case.

TH4-V-CM106

Strategic Risk Management using Stochastic Programming

King Alan J.

IBM Research

Keywords: financial optimization - risk management - stochastic programming

Modeling decisions under uncertainty requires not only an understanding of possible future events but also their impact. But stress-testing does not give information on which to base a decision. Stochastic programming is a branch of linear programming that models the optimization of risk. This talk outlines the methodology and discusses recent developments.

WE3-F-IN203

Optimization Techniques for Stability Margins in Reduced Order Controller Design

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Universität Trier

Sachs Ekkehard W.

Keywords: logarithmic barrier function - reduced order systems - stability

In this talk, we discuss a reduced basis approach to the design of low order feedback controllers for systems described by partial differential equations. The motivation for such designs is to provide practical, computationally efficient controllers for complicated systems, such as those which model fluid flow.

The reduced basis framework involves the use of theory for control of distributed parameter systems to obtain optimal infinite dimensional feedback control laws and approximation theory to design and compute low order finite dimensional compensators. We show how results from semidefinite programming can be used in the approximations to guarantee stability margins for the closed loop systems. We report on numerical results for a nonlinear control problem in structural vibrations.

MO3-G-IN11

On Algorithm of Solution of the Continuous Stochastic Problem of Optimal set Partitioning with Objective Functional Restoration

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Kuznetsov Konstantin A.

Keywords: optimal set partitioning - order risk

The paper deals with continuous stochastic problem of optimal euclidean set partitioning into non-crossed subsets with fixed centroids. Analitical forms of the functions that appears in objective functional are unknown, but independent random realizations of these functions are accessiable to observation. The modification of the order risk minimization is suggested to restoration of the analitical form of these functions. The algorithm of solution of the optimal set partitioning problem with restored functions has been worked up. This algorithm rests on reduction initial infinetly measured optimization problem to the dual finetly measured problem with non-smooth objective functional. We tackled dual problem by applying Shor's r-algorithm. Numerous of computational experiments have been pursued.

TH2-B-CO10

Ballstep Subgradient Level Methods for Convex Optimization

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Larsson Torbjörn - Lindberg P. O.

Keywords: convex optimization - nondifferentiable optimization

The subgradient projection method for convex nondifferentiable optimization is used in many applications, mainly due to its simplicity, although it lacks stopping criteria and popular heuristic stepsize rules do not ensure convergence. We give the following remedies. We study subgradient methods that use projections onto successive approximations of the level sets of the objective corresponding to estimates of the optimal value. We establish, for the first time, convergence and efficiency estimates for simple ballstep level controls without requiring that the feasible set be compact. Further, we introduce stopping criteria based on optimality estimates. Our framework may handle accelerations based on "cheap" projections, surrogate constraints and conjugate subgradient techniques.

WE1-U-IN10

A Combined Daily/Exceptions Crew Pairing Model
Klabjan Diego

Georgia Institute of Technology, School of Ind. and Systems Engineering

Atamturk Alper - Barnhart Cynthia - Gelman Eric - Johnson Ellis - Nemhauser George - Vance Pamela H.

We present a model that combines the daily and exceptions crew pairing problems. This model explicitly decides which flights to add to the exceptions problem. The objective is to find a low-cost solution without sacrificing too much of the daily pattern in the resulting crew pairings.

TU4-I-CM5

A Discretization Result for Planar Median Problems with Barriers
Klamroth Kathrin

Universität Kaiserslautern

Hamacher Horst W.

In real world applications of location theory the development of a realistic model for the given problem plays an important role in the solution process. Especially in planar location problems we deal with a geometric representation of the considered area. Therefore we have to include geographic properties in the model such as barrier regions and/or forbidden regions. Barriers may be e.g. rivers, lakes, mountains, military regions or border lines.

In this talk, we will present solution strategies for the median problem under the consideration of barriers. It will be shown that a discretization of this nonconvex optimization problem leads to polynomial time algorithms for the case that distances are measured by polyhedral gauges. These results can be used to approximate optimal solutions for more general classes of distance functions.

WE4-E-CO21

Existence of Solutions for the Steady Sliding Problem
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Linköping University, Division of Mechanics

Keywords: LCP - contact mechanics - friction

We use the theory of discrete linear elastic mechanical structures, Coulomb's friction law and Signorini's contact conditions to formulate a mixed Linear Complementarity Problem (LCP) representing mechanical equilibrium states. One example from the class of physical situations we are modeling is the steady frictional sliding of an elastic block down an inclined plane. The mixed LCP does in general not have a structure such that standard results of LCP theory can be used to investigate its solvability. Indeed, for "large" friction coefficients examples of non-existence can be given. However, for "small" friction coefficients, we can in some important cases reformulate the problem so that conditions of positive semi-definiteness and copositivity can be put to use.

MO4-C-CO3

Asymptotic Constraint Qualifications and Global Error Bounds for Convex Inequalities
Klatte Diethard

Universität Zürich, Institut für Operations Research

Li Wu

Keywords: asymptotic constraint qualifications - convex inequalities - global error bounds

In this talk we study conditions for the existence of a global error bound in Hoffman's sense for approximate solutions of a system of convex inequalities. In the case of a bounded solution set or of linear inequalities, studies on global error bound are classical. In order to incorporate also unbounded solution sets of convex inequality systems, one has to require additional assumptions on the asymptotical behavior. In our talk we present various asymptotic constraint qualifications for the existence of global error bounds.
Many known conditions that ensure the existence of such a global error bound are shown to be equivalent to one of the following three conditions: (i) the bounded excess condition, (ii) Slater condition together with the asymptotic constraint qualification defined by Auslender and Crouzeix (1988), and (iii) positivity of normal directional derivatives of the maximum of the constraint functions introduced by Lewis and Pang (1996).

TH1-G-IN11

Convex Simple Integer Recourse Models
Klein Haneveld Willem K.

University of Groningen

Stougie Leen - Van der Vlerk Maarten H.

Keywords: convex - simple integer recourse

We consider the objective function of a simple recourse problem with fixed technology matrix and integer second-stage variables. Separability due to the simple recourse structure allows to study a one-dimensional version instead.

Based on an explicit formula for the objective function, we derive a complete description of the class of probability density functions such that the objective function is convex. This result is also stated in terms of random variables. Finally, we give a representation of convex simple integer recourse problems as continuous simple recourse problems, so that they can be solved by existing special purpose algorithms.

WE3-I-CM121

On the Minimal Unsatisfiability Problem for some Subclasses of CNF
Kleine Büning Hans

Universität Paderborn

Davydov Gennady - Davydova Inna

We consider the minimal unsatisfiability problem for propositional formulas in CNF for which the number of clauses depends on the number of variables. Minimal unsatisfiable means that the formula is unsatisfiable and deleting an arbitrary clause results a satisfiable formula. For formulas over n variables we show that no minimal unsatisfiable formulas with at most n clauses exist.

For the class of formulas with $n+1$ clauses we present an algorithm solving the minimal unsatisfiability problem in quadratic time. The algorithm is based on the observation that in a minimal unsatisfiable formula with $n+1$ clauses at least one variable occurs exactly twice.

Formulas over n variables and r clauses can be written as $n \times r$ –matrices. We prove that minimal unsatisfiable formulas with $n+1$ clauses represent so called basic matrices and vice versa.

FR1-E-CO21

A New Class of Semismooth Newton-Type Methods for Nonlinear Complementarity Problems

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Technische Universität Dresden

Kanzow Christian

Keywords: Newton method - generalized Jacobians - global convergence - nonlinear complementarity problems - quadratic convergence - semismoothness

We introduce a new, one-parametric class of NCP-functions. This class subsumes the Fischer function and reduces to the minimum function in a limiting case of the parameter. This new class of NCP-functions is used in order to reformulate the nonlinear complementarity problem as a nonsmooth system of equations. We present a detailed investigation of the properties of the equation operator, of the corresponding merit function as well as of a suitable semismooth Newton-type method. Finally, extensive numerical results are presented for this method being applied to a number of test problems.

WE2-I-CM120

Dynamic Flow Problems with Dedicated Arcs

Klinz Bettina

TU Graz

Woeginger Gerhard J.

A dynamic network consists of a directed graph with a source s, a sink t and capacities and integral transit times on the arcs. We investigate discrete dynamic network flow problems, where flow can be sent along an arc only at integral times and sending flow along an arc blocks this arc as long as the transmission continues. Such arcs are called dedicated arcs. We are mainly interested in questions of the type “Given an integral time bound T and an integral flow value v, is it possible to transmit v flow units from the source s to the sink t within T time units?”. The complexity of this question strongly depends on whether the values T and v are encoded in binary, in unary, or are constant. We provide a complete classification of all variants of this problem from the computational complexity point of view. Our results establish a sharp borderline between easy and difficult cases of this type of dynamic network flow problem.

TH1-E-CO11

Extended Lemke Algorithm for All Solutions of Bimatrix Games

Klinz Bettina

TU Graz

Kostreva Michael M.

Keywords: Lemke's algorithm - all solutions - bimatrix game

The extensions investigated are contained within a tree search for which the basic subproblem is solved by Lemke's complementary pivoting algorithm. It is shown how to modify the LCP matrix to guarantee that a solution will not be computed more than once, how to direct the search by principal pivoting, and how to prove implicit enumeration of the entire tree.

WE4-P-IN201

Single-machine problems with generalized precedence constraints

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Brucker Peter J.S.

Keywords: complexity results - generalized precedence constraints - single-machine problems

In a single-machine problem with generalized precedence constraints a set $N := \{1, \dots, n\}$ of jobs with processing times p_i has to be processed without preemption on a single machine. Furthermore, a set $R \subseteq N \times N$ of finish-start relations of the form $C_i + l_{ij} \leq S_j$ for $(i,j) \in R$ is given, where S_j denotes the starting time of job j, $C_i = S_i + p_i$ the finishing time of job i, and l_{ij} is an arbitrary real number. If $l_{ij} \geq 0$, this condition means that job j cannot be started earlier than l_{ij} time units after the finishing time of job i (minimal time lag). On the other hand, if $l_{ij} < 0$ holds, job j cannot start earlier than $|l_{ij}|$ time units before the finishing time of job i (maximal time lag). By setting $l_{ij} = 0$ “normal” precedence constraints can be modelled where job j cannot start before job i finishes.

An overview of known complexity results is given. Special subcases of problems with minimal time lags lead to new results for flow-shop problems with unit processing times and precedence constraints.

TH2-K-CM106

Development and Evaluation of Improved Tabu Search

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Sawa Toshiyuki - Furukawa Toshiyuki

Keywords: agenda - job shop - tabu search - variety measure

An improved search method has been developed by incorporating an agenda (solution pool) mechanism into the tabu search framework and it was evaluat ed through application to a job shop scheduling problem. The mechanism facilitates search from a solution in the agenda, while ne ighbor solutions being sequentially searched by the conventional tabu search . The tabu-list is dynamically synthesized for a selected solution, since th e individual history of the solution is quite different from the actual sear ch process. The tabu-list computation is based on attributes of "the precedi ng solution", "an opera-

tion applied to the solution", etc. which are attache d to a solution. The preceding solutions are traced and applied operations a re appended to generate the proper tabu-list. The collective tabu-list gener ation is more advantageous than an alternative method with the attribute of "a tabu-list applied to the solution" in the response to controlled change o f the tabu-list length as well as in the memory requirement. An extra memory management is implemented to maintain the minimum data of preceding solution s potentially traced from solutions in the agenda.

The bench mark problem was the shortest completion of 6 jobs with 6 mach ines. Case studies with 50 runs were done for the developed method and conve ntional search methods. Neighbor solutions of a solution are defined as thos e generated by a single exchange of adjacent processes in a machine-based Ga ntt chart of the solution. The results reveal that optimal solutions are more frequently (62ined by the developed method than by a conventional tabu search (32genetic algorithm (46e variety measure, which is the sum of variances of process start dates, tha t the improved performance is due to the enhanced variety of searched soluti ons owing to the agenda mechanism in the developed method.

MO4-K-CM106

A Taxonomy of Evolutionary Algorithms in Combinatorial Optimization

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Calegari Patrice - Coray Giovanni - Hertz Alain - Kuonen Pierre

Keywords: combinatorial optimization - evolutionary methods - genetic algorithms - scatter search - taxonomy

The domain of evolutionary algorithms (EAs) has attracted a lot of interest since the beginning of EA history. At that time, there was no ambiguity about what genetic algorithms (GAs) were. But now, it is common to find a GA described with the same pseudo-code as an EA in the literature. Although the difference between these two classes of algorithms is usually well explained, it seems that the distinction is often not clear. Of course this situation is not a good one, as it may lead to different problems, such as the same name for different algorithms or different names for the same algorithm.

Moreover, in the literature, work very often focus on the efficiency of some kind of operators (like crossover in GAs for example). In our opinion, the important points concerning the structure of the algorithms are too often ignored. This could be schematised by saying that the interest is more brought to the implementation of the EAs than to the meaning of the algorithm itself. The meaning of an EA is its philosophy, the high-level means it uses to achieve its goal.

For these reasons, we present a systematic means of describing the main features of EAs in a short-hand way. This should allow to inform readers/auditors about the algorithm's key elements in an easy way and to compare the characteristics of two algorithms *a priori* considered as different.

TU3-K-CM106

Behaviour of Meta-heuristics for the Simple Plant Location Problem

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Sobolev Institute of Mathematics

Alexandrov Dmitri

Keywords: facility location - genetic hybrids - simulated annealing - tabu search

In the paper we study the efficiency of the tabu search, genetic hybrids and simulated annealing methods for the simple plant location problem. We investigate behaviour of these methods under variation of some control parameters, initial points and populations, different search rules and others. These methods are compared with the branch and bound method and the Lagrangean heuristic as well. Computational results and further research directions are discussed.

TH3-E-CO21

Contact and Displacement Constraints in Structural Optimization Problems

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Keywords: contact mechanics - dispalcement constraints - structural optimization

We consider two equivalent formulations of a standard structural optimization problem: the minimum compliance formulation and the problem of maximization of minimal potential energy. For the sake of simplicity, we choose a particular problem of truss topology design. We further consider two types of additional constraints: the unilateral contact constraints and the so-called displacement constraints. We show that these, seemingly similar, constraints lead to completely different problems and that it is essential to combine the particular constraint with just one of the above formulations of the original problem. Accordingly, the numerical approach to the two resulting problems is essentially different. The contact constraints require only a slight modification of the interior-point code that was developed for the original uncostrained problem. The numerical treatment of the problem with displacement constraints is much more difficult. We suggest a reformulation of this problem as an MPEC (Mathematical Program with Equilibrium Constraints) and solve this problem by so-called Implicit Programming technique. Numerous examples illustrate the behaviour of the two algorithms and the difficulties connected with the displacement constraints.

FR3-D-CO124

Truss Topology Desing Problems solved by Interior-Point and Penalty-Barrier Methods

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Jarre Florian - Zibulevsky Michael

Keywords: barrier methods - convex programming - interior point methods - truss topology design

We present two methods for solving quadratically-constrained convex optimization problems that arise from truss topology design (TTD): a primal-dual interior-point method and a penalty/barrier multipliers method. We discuss the implementation details and behaviour of the two algorithms. We also mention other numerical approaches to the solution of different reformulations of the TTD problem and show the superiority of the above two methods.

TU3-R-IN203

Transforming VLSI Technology into Mathematical Models

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The field of VLSI design has generated a whole range of mathematical problems: The most obvious are the applications of combinatorial optimization in logic design, verification and layout, and the analysis of differential equations that occur in electrical analysis of VLSI designs. All applications result in very large problem sizes.

The time needed for breakthroughs in combinatorial optimization to be used in industry is usually rather long. It may take many years for research results from university to be build into commercial tools which are then provided to semiconductor companies. The Boebingen development laboratory of IBM has since many years a cooperation with the Institute for Discrete Mathematics at Bonn University. The research results developed by this team are almost immediately used for the processor design.

This paper will present some of the mathematical problems that arise in VLSI design. The basic placement and wiring problem is well understood and excellent solutions are availbable. The focus in this area has shifted to the optimization of electrical characteristics that determine the final cycle time of the system. Examples are the minimzation of path delays, clock tree optimization and crosstalk avoidance.

Whereas the optimization problems have attracted a considerable interest and the available algorithms could be improvedconsiderably, there are still many open problems in the field of design verification and checking. Today we are facing a situation, where the size of the VLSI chips is limited by the availability of checking tools rather than by the capacity of the optimization tools. Examples are the checking of mask data for ground rule violations which involves the verification of minimum and maximum distance or overlap of polygons in the two-dimensional plane, or the formal verification of the logic design.

WE1-I-CM121

Evaluation, Strength and Relevance of Variables of Boolean Functions

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RUTCOR - Rutgers University Center for Operations Research

Hammer Peter L. - Rothblum Uriel G.

The paper introduces measures of relevance for sets of variables in a classification knowledge base. Sets of variables which determine the outcome of a classification regardless of the values of the other variables have relevance 1. More generally, the relevance of a set of variables measures the expected degree of certainty of a classification when the values of the variables in the set are known. Properties of a class of relevance-type measures are studied. It is shown that the relevance of a set of variables is not less than that of any of its subsets. Cases of extreme relevance value are characterized. The relationship of relevance and the classic concept of "strength" of a Boolean variable is investigated, and it is proved that sets of stronger variables have higher relevance.

WE-am-SPO

Exploiting Sparsity in Primal-Dual Interior-Point Methods for Semidefinite Programming

Kojima Masakazu

Tokyo Institute of Technology

Fujisawa Katsuki - Nakata Kazuhide

The Helmberg-Rendl-Vanderbei-Wolkowicz/Kojima-Shindoh-Hara/ Monteiro and Nesterov-Todd search directions have been used in many primal-dual interior-point methods for semidefinite programs. This paper proposes an efficient method for computing the two directions when the semidefinite program to be solved is large scale and sparse.

WE4-I-CM4

Improved Approximation Algorithms for Unsplittable Flow Problems

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Stein Cliff

Keywords: approximation algorithms - network flow - path

In the single-source unsplittable flow problem we are given a graph G, a source vertex s and a set of sinks $t_1, \ldots, t_k$ with associated demands. We seek a single s-t_i flow path for each i so that the demands are satisfied and the total flow routed across any edge e is bounded by its capacity c_e. The problem is an NP-hard variant of max flow and a generalization of single-source disjoint paths with applications to scheduling, load balancing and virtual-circuit routing problems. In a significant development, constant-factor approximation algorithms were recently given for several natural optimization versions of the problem. In this paper we give a generic framework that yields simpler algorithms and significant improvements upon the constant factors. Our framework, with appropriate subroutines, applies to all optimization versions previously considered and treats in a unified manner directed and undirected graphs. For example consider minimizing maximum congestion, i.e. the maximum ratio over all edges e of the flow through e divided by the capacity c_e. We give a simple $(4 + o(1))$-approximation algorithm for both directed and undirected graphs. The previously known bounds were 16 and 8.25 respectively. We also supply the first constant factor approximation algorithm for minimum cost, minimum congestion unsplittable flow on directed graphs.

We also examine connections with parallel machine scheduling and show how unsplittable flow techiques can give improved approximation algorithms for problems with restricted sets of processing times. The approximations apply also to unsplittable flow problems with restricted sets of demands and for some special cases we obtain the best possible ratios, unless P=NP.

FR2-C-CO122

Second Order Global Optimality Conditions for Problems with Equality Constraints

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Keywords: global optimality - inertia tests

Consider the classical Lagrange type problem: minimize f(x), subject to $g_i(x) = 0, i = 1, 2, ..., m, x \in R^n$. In the lecture special classes of problems are investigated for which there exist second order sufficient conditions in terms of the inertia of the bordered Hessians of the Lagrangian ensuring global optimality for the local optimal solution of the problem given.

WE2-C-CO2

On Generalized Monotonicity and Minty Variational Principle. Applications to Optimization and to Dynamical Systems

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Giannessi Franco - Pellegrini Letizia

Keywords: generalized monotonicity - variational inequalities

Stampacchia and Minty Variational Inequalities are considered both in scalar and vector formats. They are interpreted in terms of Variational Principles and, when the operator is the gradient of a suitable functional, as Minimum Principles. Some properties of the images associated to them are established. Conditions under which the operator is a gradient are studied. Under suitable assumptions on the operator and the domain, the above inequalities turn out to be equivalent (same solutions). Each (scalar or vector) inequality is associated with the Lyapunov function for a dynamical system and multisystem. By embedding each inequality into a separation scheme, connections between Lyapunov Function and the Theory of Gap Functions from one side, and the search for a "primitive problem" of the inequality from the other side, are investigated. Interpretations of these results in terms of stability of systems and regularity of the inequalities are discussed.

TU1-A-IN2

On the Equivalence of some Classes of the Linear Programming Problems with System Matrix Parametrization

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Keywords: matrix parametrization - parametric linear programming

Parametric linear programming (LP) problems with a system matrix parametrization have proved to be highly complex. Most previous studies have allowed only one coefficient, a row (column), or few rows (columns) to be linearly dependent on a parameter. We consider a more general case where all the coefficients are linear or polynomial functions of the parameter and show that these problems, assuming some non-singularity conditions, are equivalent to the augmented LP problem with real system matrix coefficients.

TU3-T-CO22

A MIP-Based Approach to the Cutting Stock Problem with Minimum Production Quantity Constraint

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Nakagawa Yoshiyuki - Nishida Hajime - Sakai Nobuhiro

Keywords: cutting stock problem - mixed integer programming - pattern generation

This paper deals with the practical cutting stock problem. The cutting stock problem is the problem to decide an optimal assortment of orders into a master material. In a practical situation, the problem becomes a large model and it is complicated because it has various constraints. In our problem, the constraints include an exceptional constraint called 'minimum production quantity constraint (MPQC).' This constraint is needed to maintain a stable manufacturing operation, and to contribute to reducing the time of set-ups. In order to solve this problem, we employ the cutting pattern generation technique and mathematical programming. In general, the cutting stock problem is modeled as integer programming (IP) and the continuous relaxation technique is used to obtain candidate solutions. However, if all of the constraints are relaxed as continuous, it becomes difficult to obtain good candidate solutions which are expected to satisfy MPQC. In order to overcome this difficulty, we have developed two types of methods. The basic idea of the first one is to solve the problem as MIP in which the constraints except for MPQC are relaxed, then to select candidates of cutting patterns, and finally to solve the original problem as IP based on the candidates. The basic idea of the other method exploits sequential heuristics of cutting pattern generation to decide the assortment of certain orders which are likely to violate MPQC and the rest of the orders are solved using IP. We have developed the prototype system involving these two methods. This system provided reasonable solutions with high yields in practical computational time. The results by our system outperformed the results provided by other experts.

MO4-C-CO122

Cutting Plane/Tabu Search Algorithms for Low Rank Concave Quadratic Programming Problems

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Gao Chenggang

Keywords: global optimization - heuristic algorithm - low rank concave quadratic programming problem - rosen's cutting plane - tabu-search - tuy's cutting plane

In this paper, we will propose an efficient heuristic algorithm for solving concave quadratic programming problems whose rank of the objective function is relatively small. This algorithm is a combination of Tuy's cutting plane to eliminate the feasible region and a kind of tabu-search method to find a "good" vertex. We first generate a set V of vertices and select one of these vertices as a starting point at each step, and apply tabu-search and Tuy's cutting plane algorithm where the list of tabu consists of those vertices eliminated by cutting planes and those newly generated vertices by cutting planes. When all vertices of the set V are eliminated, the algorithm is terminated. This algorithm need not converge to a global minimum, but it can work very well when the rank is relatively small(up to seven). The incumbent solutions are in fact globally optimal for all tested problems. We also propose an alternative algorithm by incorporating Rosen's hyperrectangle cut. This algorithm is more efficient than the combination of Tuy's cutting plane and tabu-search.

FR3-F-IN203

Combined Relaxation Methods: Complexity Estimates and Applications

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Keywords: equilibrium problems - linear convergence - solution methods - variational inequalities

Combined relaxation methods can be viewed as further development of relaxation methods for systems of linear and convex inequalities. To guarantee the monotone decrease of the distance to all solutions we make use of auxiliary procedures. This approach allows us to construct simple and readily implementable solution methods for variational inequalities and general equilibrium problems. Within this framework, various iterative methods for problems with multi-valued underlying mappings (nonsmooth cost functions) and/or nonlinear convex constraints were also developed. Furthermore, combined relaxation methods are convergent under mild assumptions. In the variational inequality case, for instance, these assumptions hold if there exists a solution to the "dual" problem.

The convergence rates of combined relaxation methods were derived under additional assumptions. Various conditions which guarantee for these rates to be linear are also indicated.

Together with the known fields of applications including equilibrium problems in physics, economics and transportation sciences, we describe new ones. Namely, we show that combined relaxation methods are applicable to vector variational inequality, inverse vector optimization and lexicographical saddle point problems.

MO3-I-CM4

Coloring Distance Grid Graphs

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Altschuler Netanel

Keywords: distance graphs - graph coloring - max-clique

We consider the problem of coloring families of graphs, arising from grid graphs and distances constraints. We prove the value of the chromatic number of these graphs for certain distances by presenting efficient algorithm for optimal colorings of them. All the optimal colorings that we present, have the property that for large graphs, certain patern of the coloring is repeated in the coloring. We conjecture that this property is also true for every distance. We prove that for some distances, the following min-max equality *max clique* = *chromatic number*, is satisfied. Some relations to perfect graphs will be discussed.

TU4-U-IN10

Dynamic Programming Approach for Saving Energy in Mobile Communication

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Dolev Shlomi - Yukelson Dmitry

Keywords: binary trees - dynamic programming - guessing games - mobile computing

This paper explores the time/energy tradeoff in message transmission between mobile hosts and mobile support stations. Three algorithms are suggested two of which uses guessing games in which the mobile support station guesses the message to be transmitted by the mobile host and receives approving signal for successful guess from the mobile host. The first algorithm is designed to achieve the smallest expected amount of energy while obeying a time bounded for a message transmission. The second algorithm achieves the shortest expected transmission time while obeying a bound on the energy. This algorithm uses dynamic programming to construct an optimal tree (the tree constructed is of an independent interest) for the guessing game. Our third algorithm uses a different approach, approach that is based on the Lempel-Ziv compression algorithm. The time energy tradeoff is controlled by the choice of the length of the codes used to encode strings in the dictionary.

FR1-H-CO22

A value Efficiency Approach to Incorporating Preference Information in Data Envelopment Analysis

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Halme Merja - Joro Tarja - Salo Seppo K. - Wallenius Jyrki

Keywords: data envelopment analysis - efficiency analysis - multiple criteria decision making - value function

We develop a procedure and the requisite theory for incorporating preference information in a novel way in the classical efficiency analysis of Decision Making Units. The efficiency of Decision Making Units is defined in the spirit of Data Envelopment Analysis (DEA), complemented with Decision Makers preference information concerning the desirable structure of inputs and outputs. Our procedure begins by aiding the Decision Maker in searching for the most preferred combination of inputs and outputs of Decision Making Units (for short, Most Preferred Solution) which are efficient in DEA. Then, assuming that the Decision Makers Most Preferred Solution maximizes his/her underlying (unknown) value function at the moment when the search is terminated, we approximate the indifference contour of the value function at this point in terms of its possible tangents. Value Efficiency scores are then calculated for each Decision Making Unit comparing the inefficient units to units having the same value as the Most Preferred Solution. The resulting Value Efficiency scores are optimistic approximations of the true scores. The procedure and the resulting efficiency scores are immediately applicable to solving practical problems.

FR3-C-CO122

A Systematic Build-Up Method for Global Optimization of Large Molecular Structures

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Keywords: Lennard-Jones clusters - global optimization - molecular conformation - nonlocal order - stochastic algorithm

We discuss the development of a systematic build-up method for the global optimization of large molecular conformational problems. The method is based on an approach where a molecule is described in terms of a hierarchical nonlocal order. The order is assumed to capture all nonlocal relationships among the components of a molecule and represent how atoms combine into rigid clusters, level by level, to give the molecular structure. By this order the method is capable of reducing the complexity of the optimization problem by creating locally optimized subunits which are, in turn, optimized. We demonstrate that the order can be extracted from eigenvalues of the distance matrix of a molecule. Thus unfolded, the order manifests itself as a tree diagram, that encodes information about the formation of the molecule. In the tree, an element of each level identified as an atomic cluster, can be seen as two-dimensional geometric pattern comprised of elements from the lower level. The tree diagram has a new kind of symmetry and nonlocality such that clusters at all levels appear to be interrelated. By visualization, the tree is a window into the structure of a molecule. For example, the area of a pattern corresponding to a molecule has an observable meaning as it equals the absolute value of the determinant of its distance matrix.

A method is proposed to computationally approximate the tree diagrams. It is expected that this method can simulate natural molecular conformations. To provide the nonlocality, the method searches for global minima at each step not on the single surface of the total energy but on an ensemble of energy surfaces of individual atoms and atomic clusters in parallel. This leads to the collective dynamics of a molecular system that emerges from an interplay of these interrelated actions. We show that the method converges to a minimum energy conformation and that clusters exhibit cooperativity in molecule's geometrical assembling as they follow a strict nonlocal order. The search on an individual energy surface is a stochastic algorithm determined by a criterion according to which a configuration change is accepted or discarded. A criterion that specifies the best fit to the trees is discussed. A key tool in the study of the method is a technique proposed to detect structures similar to the trees. The development is numerically illustrated with large Lennard-Jones clusters.

MO3-R-IN203

VLSI-Design and Combinatorial Optimization - An Ongoing Project

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About ten years ago we started to look into VLSI-design problems using techniques from combinatorial optimization. Since then many different optimization problems came up and could be solved. Some of those new problems arose by looking into VLSI-design from different perspectives, some others by a drastic change of technology. Note that about ten years ago very fast chips has cycle times of about 50 nanoseconds, i.e. frequencies of 20 Megahertz. Right now we have to deal with 300 Megahertz and more (about 3 nanoseconds). Around the turn of the century we expect processor chips with 1 Gigahertz = 1000 Megahertz (1 nanosecond).

At the beginning of this development we had quite natural objective functions, e.g. for placement and routing maximum density or minimum total net length. Later on we had to model performance driven placement and routing and many special problems came up, like cycle minimization, clock tree layout, gridless routing, block-hardware-code optimization, etc. Right now and in the not too distant future we have to deal with transistor- and wire-sizing, logic otpimization in physical design, noise avoidance etc.

Among others the following combinatorial optimization techniques can be applied: network analysis, Steiner trees, min cost flow, knapsack, shortest path with obstacles, minimum mean cycle, quadratic optimization. Some of them will be discussed in subsequent talks in more detail.

We discuss here the general approach and some open problem which will come up in future designs.

However, it is very much satisfying to know, that highly complex chips could not be efficiently designed without very sophisticated combinatorial optimization techniques.

TH2-F-IN203

Optimal Active Suspension of Vehicles Using an On-Line Dynamic Programming Method

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Keywords: adaptive critic method - approximate dynamic programming - feedback control - neural network approximation - optimal active suspension

Recent research in automotive engineering has proven the superiority of active suspension systems for vehicles compared to conventional type passive suspension systems. They are superior both with respect to ride comfort and overall stiffness to resist body forces.
Usually, linear multi-body systems, so-called quarter car models, and quadratic cost functionals are considered to obtain an optimal feedback control law for active suspension by the well-known solution of an algebraic matrix Riccati equation. Furthermore, the road disturbance is assumed to be a step function.
To enable (almost) optimal suspension of arbitrary disturbances in real-time an "adaptive critic" method is introduced. It is based on approximate dynamic programming which avoids the so-called "curse of dimensionality" by using neural networks as generalizing function approximators for the value function and the feedback control. The network approximations are called critic network and action network, respectively. Radial basis function networks are choosen for approximation because locally-tuned processing units are especially suited

for incremental adaptation. Network training is done by Q-learning, which is a model-free adaptive critic method. Therefore, both nonlinear systems and systems without full information can be considered. The latter point is important since it is very expensive to get full state information for realistic vehicle models.
For the linear-quadratic control problem the proposed method is investigated and the quality of approximation is compared to the Riccati solution. Extensions to problems with more general disturbances, more realistic cost functionals and nonlinear dynamical systems will be discussed.

MO3-B-CO10

A Quasi-Interior Path-Following Method

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A path-following method is suggested for the convex mathematical programming problem using generalized barrier function.

The generalized barrier function is a parametrical function $G(u, t)$, which is finite on the feasible set C, but there is a decreasing family of sets $V(t), t \in T$, containing C, such that $G(ut)$ is a usual barrier function on $V(t)$.

The method is a predictor-corrector type one. The predictor part is a nonstationary minimization process based on $G(u, t)$ to obtain an approximation of the analitical center of $V(t)$, the corrector part is the modification of $V(t)$ and the corresponding $G(u, t)$.

We will see, if the nonstationary process is a gradient- or Newton-type and the generalized barrier function satisfies some addition conditions, then the path following method converges to the optimum and the rate of convergence can be defined.

FR1-D-CO124

Partial Pivoting as a Stabilization Technique in Interior Point Methods

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Keywords: interior point methods - numerical stability - pivoting - primal-dual methods

We consider numerical stability problems arising in interior point methods for linear programming in primal degenerate case. A stabilization technique based on partial pivoting is proposed and it is shown that it can be used for stabilization of primal, dual and primal-dual interior point methods. Numerical testing on highly degenerate real-life linear programming problems shows the efficiency of the new approach.

TH2-A-IN1

Steven Vajda, 1901-1995

Krarup Jakob

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Professor Steven Vajda, the true founding father of linear programming in Europe and Asia and the author of the second book ever written on the subject (Vajda, 1956) was born in Budapest in 1901 and passed away in England in December 1995. He managed to retire none less than three times from various positions before he in 1973 became Visiting Professor of Mathematics at Sussex University, in which role he continued actively for about 22 years, teaching and writing research papers, a record which is unsurpassed in the UK and probably anywhere outside the UK as well. A brief account of Vajda's achievements is accompanied by a review of two joint papers, "On Torricelliïs geometrical solution to a problem of Fermat", and "Visualizing duality" (both forthcoming).

TU4-I-CM4

Domination algorithms

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Keywords: design and analysis of algorithms - domination problem - graph algorithms

We consider the well researched NP-complete graph problems DOMINATING SET, INDEPENDENT DOMINATING SET, CONNECTED DOMINATING SET, TOTAL DOMINATING SET and MINIMUM DOMINATING CLIQUE as well as their weighted cases.

We demonstrate how intersection models and vertex orderings of special graph classes can be used to design efficient algorithms for the mentioned problems. We concentrate on well-known classes of perfect graphs, as e.g. interval graphs and permutation graphs, and on graph classes of recent interest, as e.g. AT-free graphs and dually chordal graphs.

FR2-V-CM106

A Tâtonnement Price-Quantity Adjustment Process in Semi-Algebraic Nonconvex Production Economies

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van den Elzen Antoon

Keywords: general equilibrium - globally convergent adjustment process - nonconvex production - semi-algebraic economy

We introduce an economically interpretable adjustment process that provides a dynamic motivation for the Walrasian equilibrium concept in a general equilibrium model of an economy with possibly nonconvex production technologies. The model is standard and based on Villar (1994). The adjustment process concerns a tâtonnement process in prices and production quantities which relates the adjustment in the price of a commodity to the excess demand on its underlying market, and the adjustment in every producer's production quantity of a commodity to the discrepancy between its current price level and the related component of a price vector considered as acceptable by this producer. The acceptable price vectors for every producer are adjusted accordingly along the adjustment process. We show that, for any semi-algebraic version of the model and for any starting tuple of prices, quantities, and corresponding vectors of acceptable prices, there exists at least one path of price vectors and production quantities converging to an equilibrium. Practically, this path can be followed with a simplicial algorithm.

WE4-W-CO15

Optimization Modeling on the Internet using Client-Server Technologies

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Maximal Software, Inc.

Keywords: client-server - internet - modeling language - optimization - web

Over the last few years, the Internet and the World-Wide-Web have become increasingly more important in the computer world as a new way of interfacing with the user. The MPL Modeling System is currently being developed to include Client-Server technologies, which will give the user new ways to solve optimization problems. The user will be able to dispatch over the Internet, large optimization problems to a solver, located on a server that has extended computing capabilites. All the connections to the solver will be handled automatically by the modeling system. We will discuss the current state-of-the-art and what the potential is for optimization on the Internet in the future.

TH4-W-CO15

The Impact of Distributed Computing on Optimization Modeling Interfaces

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Maximal Software, Inc.

Keywords: client-server - distributed computing - internet - modeling language - optimization - web

A unique feature of the MPL Modeling System is its direct link to solvers, which means the matrix is being transferred between the modeling system and the solver directly through memory. As there are no files involved, this offers seamless connection that is considerably faster and more robust than the traditional use files.

Now, with the increasing popularity of the Internet and the World-Wide-Web, the interfaces between modeling systems and solvers are being extended to handle distributed computing environments and client-server technologies.

We will discuss the current state-of-the-art of optimization modeling interfaces, and what impact, innovative technologies, such as distributed computing and software components, are likely to have in the near future.

FR1-L-CM201

Compound Decomposition Approach in Large-Scale Optimization

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Keywords: basis factorization - decomposition - interior point methods - simplex

Decomposition is widely recognized as a tool for solution and analysis of large-scale optimization problems with block structure. The decomposition approach is characterized by a peculiarity that influences the convergence of the decomposition methods essentially. Additional vertices (rows in the dual decomposition) arise in the restricted master problem, which cause the performance of additional iterations. The polyhedron of the original problem does not have those additional vertices. Let us call these vertices inner vertices of the master problem and iterations performed on these vertices will be referred to as inner iterations. As a result the solution process slows down significantly, especially as the optimum solution is approached what is sometimes termed "long-tail" convergence. Besides it is necessary to recover solution in original variables after obtaining optimal solution. In our work, we make an attempt to improve convergence of the decomposition methods and to develop new approaches in large-scale optimization. It is shown that the simplex method, the basis factorization and the decomposition can be analyzed from a unifying framework. We propose a development of the methods involved in these three groups, which we call the compound decomposition approach. It is proven that in the presented decomposition approach we succeed in avoiding inner iterations. Computational experiments on test problems show that the compound decomposition approach improves significantly the convergence of the methods under consideration. In our decomposition approach, a combination of the decomposition framework and steps of the interior point methods arises naturally to enhance the decomposition effect of the method. We propose to perform some iterations in the restricted master problem according to the path following methodology, introducing a nonlinear barrier in the objective function, while certain rules are checked. Then, we continue iterations as in the compound decomposition method. This combination allows us to discouple to a greater degree the solution of the master problem and subproblems, to reduce the number of the major cycles and to avoid tedious determination of optimal basis solution as in the decomposition or the interior point methods.

WE3-I-CM3

Routing Trains through a Railway Station

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Zwaneveld Peter

Keywords: node packing - optimization - railways - train routing

In this presentation we discuss the problem of routing trains through a railway station. This problem is relevant within the process of generating a timetable for a railway company, as well as within the process of assessing the required future railway infrastructure.

In general, the timetabling problem for a railway company consists of a track planning problem and a node planning problem. The track planning problem asks for arrival and departure times of trains from their consecutive railway stations, thereby taking into account the global railway infrastructure, the system of lines, and the connection requirements between the lines.

The node planning problem asks whether a solution to the track planning problem is feasible within the railway stations, thereby taking into account the detailed railway infrastructure within the stations, safety aspects, and certain service aspects towards the passengers. The railway stations are considered one-by-one, and the problem is to find an optimal assignment of trains to routes through the involved railway station.

In this presentation we first give a detailed description of the problem of routing trains through a railway station. Then we describe the complexity of the problem, and we present algorithms that were designed to solve it. In particular, we explain an approach based on dynamic programming, and another approach based on preprocessing, valid inequalities and branch-and-cut. We also present computational results based on real-life data involving several railway stations in the Netherlands. The described algorithms have been implemented in a Decision Support System that is currently being developed within Netherlands Railways.

TU2-I-CM121

Generalized Polymatroids on Partially Ordered Sets

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Keywords: face - greedy algorithm - polymatroid - polytope - poset - submodular

Ordered polymatroids are investigated. These polyhedra generalize polymatroids and are closely related to the greedy algorithm. Ordered polymatroids are defined by submodular rank functions with respect to the set of all antichains of a finite partially ordered set (poset).

Appropriate basis-concepts are discussed. The Core-Polytope Core(f) of an ordered polymatroid $\mathrm{P}(f)$ related to a submodular function f consists of all elements with maximal cardinality and does not coincide with the set $\mathrm{Max}(f)$ of all maximal elements of $\mathrm{P}(f)$. The set $\mathrm{Max}(f)$ is not a polyhedral set in general. But $\mathrm{Max}(f)$ consists of all bounded faces of the polyhedron $\mathrm{P}(f)$. The non-equivalence of the concepts $\mathrm{Core}(f)$ and $\mathrm{Max}(f)$ is a main difference between ordered and unordered polymatroids.

The paper gives a contraction theorem for ordered polymatroids which includes contraction properties of unordered polymatroids as a special case. The contraction theorem states that contraction polyhedra again are ordered polymatroids. Using contraction properties of ordered polymatroids facet-inducing inequalities for all bounded faces are derived. Each facet-inducing inequality corresponds to a partition of the underlying poset into antichains. Vertices of bounded faces are described by greedy-vectors.

Finally, a necessary and sufficient criterion for the equivalence Core(f) = Max(f) of both basis-concepts is given. This criterion uses modular pairs of antichains with respect to the submodular rank function f of $\mathrm{P}(f)$.

WE4-I-CM120

Node Weighted Network Upgrading Problems

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Marathe Madhav - Noltemeier Hartmut - Ravi S.S. - Ravi R. - Sundaram R. - Wirth H. C.

We study budget constrained optimal network upgrading problems. These problems aim at finding optimal strategies for improving a network under some cost measure subject to certain budget constraints. We are given an edge weighted graph G = (V,E) where nodes represent processors and edges represent bidirectional communication links. The processor at a node v in V can be upgraded at a cost of c(v). Such an upgrade reduces the delay of each link emanating from v. The goal is to find a minimum cost set of nodes to be upgraded so that the resulting network has a good performance with respect to some measure. We consider the problem under two measures, namely, the weight of a minimum spanning tree and the bottleneck weight of a minimum bottleneck spanning tree. We present approximation and hardness results for the problem. We prove that our approximation results are tight to within constant factors. Our approximation algorithms can be used to construct approximation algorithms for the dual versions of the problems where there is a budget constraint on the upgrading cost and the objectives are minimum weight spanning tree and minimum bottleneck weight spanning tree respectively.

TU2-A-IN1

On the Asymptotic Average Number of Efficient Vertices in Multiple Objective Linear Programming

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Keywords: efficient vertices - multiple objective linear programming - probabilistic analysis

Let $a_1, \ldots, a_m, c_1, \ldots, c_k$ be independent random points in $\Re^n$ that are independent and identically distributed spherically symmetrical in $\Re^n$ and let

$$X := \{x \in \Re^n \mid a_i^T x \leq 1, \, i = 1, \ldots, m\}$$

be the associated random polyhedron for $m \geq n \geq 2$. We consider multiple objective linear programming problems

$$\max_{x \in X} c_1^T x, \ \max_{x \in X} c_2^T x, \ \ldots, \ \max_{x \in X} c_k^T x$$

with $1 \leq k \leq n$. For distributions with algebraic tail in the unit ball, we investigate the asymptotic expected number of vertices in the efficient frontier of X with respect to $c_1, \ldots, c_k$ for fixed n, k and $m \to \infty$, which may serve as an average-case complexity measure for the multiple objectivelinear programming problem.

TH1-F-IN203

Parallel Computation of Optimal Feedback Controls

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Keywords: optimal control - parallel algorithms - real-time computation

The paper presents a new algorithm for the on-line computation of optimal feedback controls for technical systems that can be modelled by means of ordinary differential equations. For practical reasons it is very important that various control and/or state constraints can be taken into account. The method is developed especially for applications for which large deviations from the nominal solution have to be expected. Real life problems of this type will be given in the paper. The algorithm is based on the indirect approach for optimal control problems and it uses a linearisation of the unknown actual solution along a known neighboring trajectory. This yields a small system of linear equations in order to compute one correction of the controls. In order to dampen the linearisation error, several correction steps have to be executed. Contrary to former feedback methods, the neighboring trajectory is updated too at every correction step. By doing this, the robustness of the method is augmented drastically, while the computational effort at every correction step increases too. In order to guarantee the real-time applicability of the algorithm, a parallel version can be implemented, which compensates for the additional computational effort. A detailed derivation of the parallel algorithm along with numerical results for a realistic problem from aerospace engineering will be given in the paper.

FR2-U-IN10

Lagrange Relaxation and Assignment Ranking on an Assignment Problem with a 0-1 Side Constraint

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Keywords: Lagrange relaxation - assignment problems - assignment ranking

In this report, we will use Lagrange relaxation and Assignment ranking as computational tools in order to find a minimum cost assignment of order n (i.e., a minimum cost perfect matching in an n*n bipartite graph) consisting of a specified number of edges of one of the colors, in a bicolored incomplete n*n bipartite graph

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WE1-I-CM200

A Polynomial Time Algorithm for Computing the Nucleolus of Convex Games

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Keywords: complexity - cooperative games - solution concept

We introduce pseudo-convex games and we show that the prenucleolus of such games can be computed in polynomial time. Since convex games are pseudo-convex, and since the nucleolus coincides with the prenucleolus for convex games, it follows that the nucleolus of convex games can be computed in polynomial time.

MO4-C-CO3

Regularity, Ekeland-points and uniform lower Semicontinuity of Inverse Maps

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Humboldt-University Berlin

Keywords: Ekeland's variational principle - Lipschitz functions - inverse maps - metric regularity - multifunctions - stability of critical points

Metric regularity of multifunctions (or pseudo-Lipschitz behaviour of the inverse) will be characterized by uniform Lipschitz lower semicontinuity and by limits of Ekeland-points of distance functions in the original spaces, as well. As a consequence, the local solution behaviour under small Lipschitzian perturbations of (generalized) equations can be decribed. In addition, we discuss the relations between strong and metric regularity in a general framework and for critical points of optimization problems under different assumptions concerning shoothness.

MO4-K-CM106

A Distributed Heuristic for Finding Clusters in Vertex Sets

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Keywords: biological heuristic - clustering - graph

Let $G = (V, E)$ a simple graph. Many heuristics defined to tackle graph partitioning problems exhibit a great sensitivity to the choice of the initial partition and the probability of getting trapped into local optima seems to dramatically increased with the size of the graph. In an attempt to surmount such limitations, a new approach has been developped in the last few years : its basic underlying idea is to transform the combinatorial partitioning problem into one of clustering nature by constructing a one-to-one mapping between the graph vertices and points in a geometric space, generally R^p. We propose here a new stochastic algorithm to represent V on a two dimensional grid , so that close vertices according to a pre-defined l_1-dissimilarity d are regrouped on the same part of , and some order between small and high values of d is preserved. This approach originates from a model described by entomologists who, on observing societies of ants, have remarked that larvae and food are not scattered randomly about the nest, but are sorted into homogeneous piles. The heuristic consists in definig a set of moving automata which displace vertices of V - which are initially distributed randomly on , - according to probabilistic rules necessitating only local spatial information. In contrast with well-known approachs like multidimensional scaling this heuristic is distributed in the sense that no global optimisation criterion is calculated ; only local optimisations are carried out by the automata.

WE1-O-IN202

Efficiency Improvement for Cell Loss Rate Estimation in a Large ATM Switch

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Université de Montréal

We estimate, by simulation, the cell-loss rate in an ATM switch modeled as a large queueing network. Cell losses are rare events, so estimating their frequency by simulation is hard. We experiment with importance sampling as a mean of improving the simulation efficiency in that context. Huge improvements are obtained compared with naive simulation.

MO4-I-CM200

The Maximum Cardinality Bin Packing Problem

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Laporte Gilbert - Martello Silvano

In the Maximum Cardinality Bin Packing Problem (CBP), we are given m bins with the same known capacity and n items, each having a known size which may vary from an item to another. The objective is to maximize the number of items packed into the m bins without exceeding the bin capacity and without splitting the items. We first propose upper bounds on the optimal value of CBP and analyse their worst case performance. Then, several exact approaches for solving CBP are discussed. Computational experiments allow us to compare the proposed exact approaches and upper bounds.

TH4-L-CM201

COMPSys: Combinatorial Optimization Multi-Processing System

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Cornell University

Ralphs Theodore K. - Eso Marta - Trotter Leslie Earl

Keywords: branch and cut - combinatorial optimization - generic implementation - integer programming - parallel computation

We present COMPSys, a fully parallel, generic implementation of the branch-and-cut algorithm for integer programming. The user need only supply model-specific preprocessing and separation functions for this framework; the remaining components, e.g., search tree, linear programming, cut pool, and communication management, are entirely internal to the framework. The implementation runs in any parallel environment supported by the PVM message passing protocol. Parallelism is exploited in investigating the search tree nodes simultaneously and in overlapping the LP solution and cut generation computation at each node.

Additional distinctive features provide capability for: multiway branching, branching on cuts, column generation, two-phase search tree exploration, multiple cut pools, and a graphical user interface. Branching on cuts (an extension of the standard "branching on variables") enables exploitation of arbitrary valid linear congruence relations in the solution process. Column generation is used when problem size is intractably large; solution begins with a small set of variables likely to contain the nonzero elements of an optimal solution, then the remaining variables are gradually incorporated into the problem description, giving rise to a two-phase procedure: the problem is solved to optimality on the small (initial) set of variables then re-solved using the information developed during this first phase. Multiple cut pools servicing different regions of the search tree reduce the number of cuts to be tested at each search tree node while focusing computation on locally effective cuts. The graphical interface is designed to enable interactive cut generation for models with underlying graphical structure.

This code has been used for computational investigation of three distinct combinatorial optimization applications: traveling salesman, vehicle routing, and set partitioning (crew scheduling) models.

FR3-P-IN201

Job Shop Scheduling with Deadlines

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Balas Egon - Serafini Paolo - Vazacopoulos Alkis

We consider job shop scheduling problems with release dates and deadlines. The objective is makespan minimization if there are no tardy jobs, tardiness minimization otherwise. The problem is approached by using a Shifting Bottleneck strategy. The presence of deadlines motivates an iterative use of a particular one machine problem which is solved optimally. The overall procedure is heuristic and exhibits a good trade-off between computing time and solution quality.

WE1-C-CO122

Neural Networks and Constrained Optimization

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Keywords: constraints - hybrid systems - neural networks - prior knowledge

Neural Networks can be considered as an appropriate technique for the approximation of high-dimensional functions. The training of Neural Networks in order to minimize the generalization error requires first a large number of examples to learn, and second the examples should be well distributed in the input space. For practical applications, particularly for data from industrial process sensors, these requirements often cannot be satified.

Knowledge in addition to data (prior knowledge, hints, functional relations, etc.) is necessary in this situation. Often qualitative knowledge of the function to be optimized is known: monotonicity, upper and lower bounds, symmetries, invariances, etc. Analytic knowledge within some input regions can be combined with neural networks for other regions to a hybrid modell.

Depending on the kind and quality of the additional knowledge several techniques of constrained optimization will be proposed and discussed with regard to training of neural networks. Techniques of modified gradient descent will be compared with techniques of modified objective functions. Applying the proposed methods to real-world-problems shows the performance of the different approaches.

FR2-U-IN1

Solving the Multiple Depot Vehicle Scheduling Problem in a Major Scandinavian City

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Keywords: Lagrangean relaxation - multiple depot vehicle scheduling - network optimization

The *Vehicle Scheduling Problem (VSP)* deals with the assignment of vehicles to a set of transportation jobs. This problem arises within urban mass transit companies in order to construct a set of minimum cost daily schedules for the vehicles.

This paper deals with the NP-hard *Multi Depot Vehicle Scheduling Problem (MDVSP)*. The *MDVSP* is formulated as a time-space network model which is solved by Lagrangean relaxation. The Lagrangean multipliers are determined by sub-gradient optimization. The subproblems are solved by a general purpose algorithm for pure network flow problems. The model implemented is tested on two large scale real-life instances from an urban bus transit company situated in a major Scandinavian city.

TU1-L-CM201

Experiments with the Auction Algorithm for the Shortest Path Problem

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Pedersen Ib

Keywords: auction - experimental evaluation - parallel computing - shortest path

The auction approach for the shortest path problem as introduced by Bertsekas is tested experimentally. Parallel algorithms using the auction approach are developed and tested. Both the sequential and parallel auction algorithms perform significatly worse than a state-of-the-art Dijkstra-like reference algorithm.

MO3-B-CO11

A Theorem of the Alternative in Banach Lattices

Lasserre Jean Bernard

LAAS-CNRS

We consider the existence of solutions to the linear system Ax=b, x in S, where A :X -> Z is a linear mapping, S a convex cone and X is assumed to be the topological dual of a separable Banach space.

In general, a direct application of the Generalized Farkas Theorem of Craven and Koliha is not possible for a crucial closure assumption is not satisfied. However, in many applications of interest, X has the structure of a Banach lattice for a natural partial ordering (e.g. the L_p spaces for the Volterra and Fredholm-type equations or the Poisson equation).

We show that this particular structure permits to derive a simple necessary and sufficient condition for existence of solutions. Incidently, this result also provides a necessary and sufficient condition for existence of a solution *dominated* by some prespecified element x_0. The result simplifies even more if X has a unit vector.

Examples of Banach lattices are also provided.

TH-am-CO1

Cuts, Matrix Completions and Graph Rigidity

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Keywords: Euclidean distance matrix - cut - graph rigidity - matrix completion - metric polyhedra - positive semidefinite matrix

We consider several topics arising in distinct areas: cut and metric polyhedra in polyhedral combinatorics, completion problems for positive semidefinite matrices and Euclidean distance matrices in matrix theory and semidefinite programming, and graph realization and rigidity problems in distance geometry and structural topology.

These various topics are linked via the notions of cuts and metrics. Indeed, cuts can be encoded as positive semidefinite matrices and both positive semidefinite and Euclidean distance matrices yield points of the cut polytope or cone, after applying the functions $\frac{1}{\pi}\arccos(.)$ or $\sqrt{\ }$. Hence, necessary conditions for the existence of a completion can be formulated in terms of the cut and metric polyhedra. We present known results concerning the characterization of the instances for which these conditions suffice for ensuring the existence of a completion.

The matrix completion problem asks whether the unspecified entries of a partially defined matrix can be completed so as to yield a matrix satisfying a desired property, like being a positive semidefinite matrix or a Euclidean distance matrix. When fixing the dimension in the Euclidean distance matrix completion problem, we find the following graph realization problem: Given a graph $G = (V, E)$, nonnegative edge weights $(w_{ij})_{ij \in E}$ and an integer $d \geq 1$, do there exist vectors $u_i \in \Re^d$ $(i \in V)$ such that w_{ij} is equal to the Euclidean distance between u_i and u_j for every edge ij ?

The matrix completion problem is polynomial for some instances, like chordal graphs; but its exact complexity is not known in general. On the other hand, the graph realization problem is NP-complete, as well as the question of unicity of a realization. When dealing with generic realizations, unicity questions can be formulated in terms of rigid graphs, for which a complete characterization is known in dimension $d \leq 2$.

FR4-I-CM5

Deployment Scheduling for Aircraft Carriers

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Naval Postgraduate School

Schauppner Craig

Keywords: military application - network flow - scheduling

his talk describes the problem of scheduling aircraft carriers for deployment. In the literature, similar ship scheduling problems have been addressed as a set covering problem. For the deployment scheduling problem, such approach may not be suitable. Instead, the problem is formulated as a network flow problem with side constraints. When aircraft carriers are deployed to several areas, each is represented as a commodity flowing through the network. On the other hand, if all carriers are deployed to only one area, the problem reduces to a shortest path problem with side constraints. When a feasible solution exists, the simplex algorithm produces an integer solution to the shortest path problem automatically.

TU2-C-CO2

Computationally Efficient Feasible SQP Algorithms

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Tits André Leon

Keywords: feasibility - nonlinear programming - sequential quadratic programming

Feasible Sequential Quadratic Programming (FSQP) is a variation on the standard SQP scheme in that FSQP algorithms generate iterates that all lie within the feasible region. It has been observed that requiring feasible iterates has both algorithmic and application-oriented advantages. In addition, when employing an Armijo-type line search (FSQP-AL), the algorithm requires a monotone decrease in the objective function, which is often useful in applications. Current attempts at FSQP-AL, while enjoying much success in practice, require a great deal of computation in order to generate a new iterate. In this talk we describe some recent work aimed at reducing this problem. We show that the number of quadratic programs (QPs) can be reduced from three (or two and a linear least squares problem) to two (or one and a linear least squares problem) without without sacrificing the global and local convergence properties. Such an improvement is important, for example, when considering large-scale problems, where computational effort is at a premium. In applications where function evaluations are considered expensive, a non-monotone line search strategy (FSQP-NL) may be employed to eliminate an auxiliary function evaluation required by the FSQP-AL algorithm. Current attempts at FSQP-NL still require auxiliary function evaluations to “initialize” the process during the early iterations. In this talk we also describe a new non-monotone strategy which eliminates the need for such function evaluations during the early iterations.

MO4-N-CO15

New Features and Experiences with the CFSQP Software Package

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University of Maryland, Institute for Systems Research

Tits André Leon

Keywords: algorithm implementation - feasibility - nonlinear programming - sequential quadratic programming - software packages

CFSQP is a C implementation of the nonlinear programming algorithm FSQP, a variation on the standard SQP scheme generating feasible iterates. In the four and a half years since its first release, CFSQP has been in use at hundreds of sites worldwide and has benefitted from experience gained in numerous diverse applications. A special feature of CFSQP is its ability to efficiently handle large sets of objectives and/or constraints, such as those arising from discretized semi-infinite programming (SIP) problems. Such a feature is particularly useful, for example, in engineering design applications. Though not included in the currect release of CFSQP, for future releases we have been working on implementing the machinery to allow CFSQP to efficiently solve large-scale problems as well, i.e. problems with a large number of variables. In this talk we describe recent developments and experiences with CFSQP, as well as plans for new features in future releases.

FR1-C-CO3

D.c. Optimization Algorithm for Solving the Trust Region Subproblem

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Institut National des Sciences Appliquées de Rouen

Pham Dinh Tao

Keywords: DCA - Lanczos method - d.c. duality - d.c. optimization - global and local optimality - regularization techniques - trust region subproblem

The talk is devoted to the solution of the trust-region subproblem which is formulated as

$$\text{(TRSP)} \qquad \min\{\frac{1}{2}x^TAx + b^Tx : \quad \|x\| \leq r\},$$

where A is an $n \times n$ real symmetric matrix, $b \in I\!R^n$, r is a positive number and $\|\cdot\|$ denotes the Euclidean norm of $I\!R^n$.

Our proposed method is based on the d.c. (difference of convex functions) optimization algorithm in a local approach, called DCA. The DCA is an iterative method which is quite different from well known related algorithms. Thanks to the particular structure of the problem, the DCA becomes very simple (it requires only matrix-vector products) and, in practice, converges to a global solution. For checking the global optimality of solutions provided by the DCA the quite inexpensive Implicitly Restarted Lanczos Method of Sorensen has been used. A simple numerical procedure has been introduced (in case of nonglobal solutions) in order to find a feasible point having a smaller objective value and to restart the DCA with this point. It has been stated that in the nonconvex case (Problem (TRSP) with A being nonpositive semidefinite) the DCA with at most $2m+2$ restartings (m is the number of the distinct negative eigenvalues of A) requires only matrix-vector products too and converges to a global solution. Numerical simulations proved the robustness and the efficiency of the DCA with respect to related standard methods, especially in large scale problems.

FR4-C-CO122

A Branch and Bound Method via D.C. Optimization Algorithms and Ellipsoidal technique for Box Constrained Nonconvex Quadratic Problems

Le Thi Hoai An

Institut National des Sciences Appliquées de Rouen

Pham Dinh Tao

Keywords: DCA - ball constrained quadratic problem - box constrained quadratic problem - branch and bound - d.c. optimization - ellipsoidal technique

We propose a new branch and bound algorithm using a rectangular partition and ellipsoidal technique for solving the box constrained quadratic problem which is given by

$$\text{(QB)} \quad \min\{f(x) := \tfrac{1}{2}x^TAx + b^Tx : \\ -\infty < l_i \leq x_i \leq u_i < +\infty, i = 1, \dots, n\},$$

where A is an $(n \times n)$ symmetric matrix, $b, x \in I\!R^n$. The bounding procedures are investigated by d.c. (difference of convex functions) optimization algorithms, called DCA. This is based upon the fact that the application of the DCA to the problems of minimizing a quadratic form over an ellipsoid and/or over a box is efficient. Some details of the computational aspect of the algorithm are reported. Finally, numerical experiments on several test problems showing the efficiency of our algorithm are presented.

WE2-T-CO22

An Optimization-Based Approach to Shop Floor Scheduling of Semiconductor Wafer Fabrication

Leachman Robert C.

University of California at Berkeley

Due to its large scale and complexity, academic approaches to shop-floor scheduling of semiconductor wafer fabrication heretofore have been principally the domain of heuristics and control-theoretic policies. Formulation techniquesfor this problem are presented that lead to mostly integer solutions to linear programming relaxations of the integer programming formulation. The solution tothe relaxed LP problem is transformed into a feasible heuristic schedule using adeterministic simulation calculation. The resulting schedule is shown to be superior to that generated using the least slack dispatching heuristic in problems of realistic size.

TU3-L-CM201

Computational Experience with a General Purpose Mixed 0/1 Integer Solver

Lee Eva K.

School of Industrial and Systems Engineering

Keywords: computation - general purpose - integer programming - parallelism

A general-purpose mixed 0/1 integer programming solver will be presented. The solver is designed to take advantage of common substructures within MIP formulations and to apply cutting planes, primal heuristics and heuristic branching to assist in solving the MIP to optimality. In addition, an iterative cut strengthening procedure is introduced. Effectiveness of the solver will be demonstrated via its application to all 0/1 mixed integer programs in MIPLIB, as well as difficult real instances arising from machine learning and radiation treatment plan applications.

TU2-D-CO124

Warmstart in an Interior Point Method within a Parallel Branch-and-Bound Framework

Lee Eva K.

School of Industrial and Systems Engineering

Mitchell John E.

Keywords: branch and bound - interior point methods - parallel implementation - warmstart

An interior-point algorithm within a parallel branch-and-bound framework for solving nonlinear mixed integer programs is described. The nonlinear programming relaxations at each node are solved using an interior point SQP method. In contrast to solving the relaxation to optimality at each tree node, the relaxation is only solved to near-optimality. Analogous to employing advanced bases in simplex-based linear MIP solvers, a "dynamic" collection of warmstart vectors is kept to provide warmstart solutions at each node. The code has the capability to run in both shared-memory and distributed-memory parallel environments. Computational results on various classes of nonlinear mixed integer programs are presented.

TU4-L-CM201

A Parallel Interior-Point Based Branch-and-Bound Solver

Lee Eva K.

School of Industrial and Systems Engineering

Mitchell John E.

Keywords: branch and bound - interior point methods - parallel implementation

In this talk we describe a parallel implementation of an interior-point based branch-and-bound solver for solving nonlinear mixed integer programs. The implementation is built on TreadMarks, a distributed shared memory software environment that provides the abstraction of a network-wide virtual memory. Such an environment simplifies programming on networks of workstations, and facilitates portability across platform and network types. Strategies for initiating the parallel process, handling the list of active nodes, distributing work among processors, and sharing information between processors will be discussed. In addition, the creation and use of a dynamic collection of warm-start vectors at each node of the search tree will be described. The talk will conclude with a discussion of computational experience with various classes of nonlinear mixed integer programs.

FR2-I-CM121

On Dyadic Matrices

Lee Jon

University of Kentucky

Keywords: matroid - unimodular

A matrix is dyadic if every square nonsingular submatrix has determinant a signed power of 2 with integer exponent. These matrices generalize totally unimodular matrices. I will describe some recent results connecting these matrices with the orientations of matroids represented over the three-element field.

FR1-F-IN203

Inexact SQP Interior Point Method and Large Scale Optimal Control

Leibfritz Friedemann

University of Trier

Sachs Ekkehard W.

Optimal control problems with partial differential equations lead to large scale nonlinear optimization problems with constraints. An efficient solver which takes into account the structure and also the size of the problem is an inexact SQP method where the quadratic problems are solved iteratively. Based on a reformulation as a mixed nonlinear complementarity problem we give a measure when to terminate the iterative QP solver. For the latter we use an interior point algorithm. Under standard assumptions, local linear, superlinear and quadratic convergence can be proved. The numerical application is an optimal control problem from nonlinear heat conduction.

WE1-I-CM4

Pitfalls of using PQ-Trees in the Planarization of Graphs

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Institut für Informatik, Universität zu Köln

Jünger Michael A. - Mutzel Petra

Keywords: PQ-tree - maximal planar subgraph - planar leveled dag

A PQ-tree is a powerful data structure that represents the permutations of a finite set in which the members of specified subsets occur consecutively, and in which updates require linear time. The most well known applications of PQ-trees in Automatic Graph Drawing are planarity testing and embedding. Both are difficult to implement but very efficient, therefore PQ-trees have become standard tools in automatic graph drawing systems.

Other attempts to use algorithms based on PQ-trees for automatic graph drawing problems have not been successful. One well known example is the computation of maximal planar subgraphs. Several efforts have been made in the literature to solve the problem with PQ-trees following a certain strategy, the latest was presented in 1992. We show why every attempt that follows this strategy is forced to fail by describing a problem that is hidden within the used strategy. PQ-trees have also been proposed to test planarity of leveled directed acyclic graphs with several sources and sinks. We show why also this application leads to an incorrect algorithm.

Since the number of erroneous attempts involving PQ-trees for the solution of automatic graph drawing problems that have been presented in the literature have increased in recent years, we present a closer examination of the mistakes in order to prevent future research from constructing algorithms with similar errors.

FR4-B-CO10

Variation of the Duality Gap with Vvarious Dualization Schemes

Lemaréchal Claude

INRIA

Renaud Arnaud

Keywords: duality gap

Lagrangian relaxation is often an efficient tool to solve (large-scale) optimization problems, even nonconvex. However it introduces a duality gap, which should be small for the method to be really efficient. Here we make a qualitative study of the duality gap: given a nonconvex problem, we define a convex formulation having the same dual. This formulation involves a convexification in the product of the three spaces containing respectively the variables, the objective and the constraints. We apply our results to several relaxation schemes, one of which due to M. Guignard and S. Kim for certain combinatorial problems. We also study a specific application, highly nonlinear: the unit-commitment problem.

MO-pm-CO3

The Mystical Power of Twoness: in Memoriam Eugene L. Lawler

Lenstra Jan Karel

Dpt of Mathematics and Computing Science, Eindhoven University of Technology

Gene Lawler (1933–1994) was one of the founders of combinatorial optimization. His textbook *Combinatorial Optimization: Networks and Matroids* (1976) is one of the classics of the area. His research in sequencing and scheduling was instrumental in stimulating and unifying an area that, prior to his work, was a rather unsystematic hodgepodge. He also made significant contributions to algorithmic graph theory, complexity theory, and computational biology. In addition, he was a phenomenal expositor, and he was the social conscience of the Computer Science Division at Berkeley. In this lecture I will attempt to review his work.

FR2-D-CO124

A Limited Memory Interior Point Method for Nonlinearly Constrained Optimization

Leontiev Anatoli

COPPE / Federal University of Rio de Janeiro

Goldfeld Paulo - Duarte Andre - Herskovits Jose

Keywords: limited memory methods - nonlinear constrained optimization

We propose the use of limited memory representation of the quasi - Newton matrix in an interior point algorithm for nonlinear programming with equality and inequality contsraints. This algorithm is based on a general technique for feasible direction interior point algorithms that solves Karush - Kuhn -Tucker conditions by Newton - like primal - dual iterations. At each iteration, a descent direction is computed by solving a linear system. By perturbing the system, a feasible descent direction is then obtained. A line search is finally performed to get a new interior point with a lower objective. Newton, quasi - Newton or first order algorithms can be obtained with this technique. For the quasi - Newton algorithm, the convergence is superlinear if the line search step length becomes unitary near the solution. We also proposed a quasi - Newton algorithm that gets a unitary step by making a line search along a feasible arc. Complete theoretical results had already been obtained on this method, that also proved to be strong an efficient when applied to several test problems and to very large applications in Solid Mechanics. However, as the quasi - Newton matrix is full, a large amount of memory can be required. We describe the implementation of the limited memory technique based on the scheme proposed by Byrd, Nocedal and Schnabel and we also show several numerical results with large size test problems and applications in Structural Optimization. As far as we know, this is the first limited memory algorithm proposed for problems with nonlinear constraints.

TU4-G-IN11

Approximation of Stochastic Programs with Probability and Quantile Functionals

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Keywords: probability and quantile functions - stochastic programming

Approximate maximization of probability and quantile functionals $v(x)$ and $w_\alpha(x)$ of the form $v(x) = P(s \mid f(x(s), s) + leqt)$ and $w_\alpha(x) = min_t \ \{P(s \mid f(x(s), s) \leq t) \geq \alpha$ for a fixed $\alpha \in (0,1)$, is considered. Decision rules $x(s)$ belong to a bounded set C in reflexive L^p-spaces, $1 < p < \infty$, where $C = \{x(s) \mid \int_S \mid x(s) \mid^p \ \sigma(ds) \leq M^p < \infty\}$. Problems are discretized starting from weak convergence of a sequence of discrete measures $\{(m_n, s_n]\}$ to the initial atomless probability measure σ. Conditions, which will guarantee convergence of optimal values of approximate problems to optimal values of initial problems together with the discrete convergence of optimal solutions, will present.

TH2-D-CO124

Homogeneous Infeasible-Interior-Point Algorithm for the P*-Nonlinear Complementarity Problem

Lesaja Goran

Georgia Southern University

Potra Florian A.

Keywords: P_*-nonlinear complementarity problem - polynomial complexity - quadratic convergence

A P_*-Nonlinear Complementarity Problem as a generalization of the P_*-Linear Complementarity Problem is introduced. We show that the long-step version of the homogeneous self-dual interior-point algorithm could be used to solve this problem. The algorithm achieves linear global convergence and quadratic local convergence under the following assumptions: the function satisfies a scaled Lipschitz condition, the problem has a strictly complementary solution, and a particular submatrix of the Jacobian is nonsingular on some compact set.

WE2-U-IN10

Combinatorial Issues of Air Traffic Optimization

Letrouit Vincent

Leibniz/Imag

Fondacci Rémy - Goldschmidt Olivier

Keywords: air traffic optimization - network design - segments graph

The current airway network used by aircraft is composed of a set of segments which intersect on special points defined by radio beacons emitting signals from the ground. This network leads to an excess flight length, which is estimated for the European network to 8%. In the near future, the Global Positioning System (GPS), which can determine precisely the location of aircraft, might allow to design a network without using any more ground fixed radio beacons. So, we can project a new skyway network with straight airways between airports, allowing an airway to change level one or more times between its origin and destination, in order to avoid potential conflict points. We present some segment set combinatorial issues to achieve such a network. In particular, we propose heuristics or algorithms for the problems of the maximum clique, the coloration, the N-coloration and other more general problems of coloration of a set of segments. Finally, we discuss some results based on actual data analysis.

WE1-P-IN201

Hoist Scheduling for a Circuit Board Manufacturing Line - A Mixed Integer Programming Approach

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Yang Xiaoguang - Mak Raymond W.T. - Lam Kokin

Keywords: circuit-board manufacturing - cutting-plane approach - scheduling

In the manufacture of circuit boards, panels are immersed sequentially in a series of tanks containing chemical solutions. For each step in the processing sequence, each panel must soak in the tank for a (given) minimum amount of time; for most steps, there is also a maximum soak time. Many such circuit board production lines use programmable hoists. The panels are mounted on carriers which are lowered into and raised from the tanks, and transported from tank to tank by the hoists. The earliest such lines have only one hoist per line but, nowadays, lines with two, three or more hoists and about 30-40 tanks are commonly used. The sequence of hoist moves does not have to follow the sequence of processing steps for the circuit boards. By optimising the sequence of hoist moves, we can maximise the production throughput.

We consider simple cyclic schedules, where the hoist move-sequence repeats every cycle and one panel is completed per cycle. Philips and Unger (1976) developed the first mixed integer programming model for finding the hoist move schedule to minimise the cycle time for lines with only one hoist. We discuss how their formulation can be improved. We also present the first mixed integer formulation for the multi-hoist problem. We introduce new valid inequalities for these problem that can be used in a cutting-plane approach. We will discuss some modelling and algorithmic issues in the development of a cutting-plane approach for solving this problem and present some preliminary computational results.

TU3-C-CO122

An Extended Parametric Decomposition of the Optimization Problems

Levin Genrikh M.

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Keywords: decomposition - optimization problems - parametrization

Decomposition methods are one of the most efficient tools for solving complex optimization problems. At present, there were several approaches to development of these methods. The

propoused approach is based on special mixed parametrization of the initial problem. The parametrization permit to decompose it on a pair of hierarchically interconnected subproblem, which are immersed in a so-called "extended" subproblems.

The initial problem **A** is to find $x^* \in X^* = argmin\{g(x) : x \in X_A\}$, where $g : \mathbf{X} \to R$, $\mathbf{X} \subseteq R^n$ and $X_A \subseteq \mathbf{X}$. To construct the decomposition scheme we enter set $X \subseteq \mathbf{X}$ such, that $X \cap X^* \neq \emptyset$; a mapping w of set X into some set $\mathbf{Y}$ of possible values of an additional parameter y, $w(X) = Y \subseteq \mathbf{Y}$; functions $f : X \times \mathbf{Y} \to R$ and $h : X \times \mathbf{Y} \to R$; set $X(y) \subseteq X$ for each $y \in \mathbf{Y}$, and $X(y) \neq \emptyset$ for $y \in Y$. The decomposition scheme is formed by two interconnected problems: a problem **B'(y)** of the bottom level of finding $x^*(y) \in X^*(y) = argmin\{f(x, y) : x \in X(y)\}$, and problem **B"** of the top level of finding $y^* \in \mathbf{Y}^* = argmin\{H(y) : y \in Y\}$. Here $H(y) = h(x^*(y), y)$, and $H(y)$ is enough large number if $X(y) = \emptyset$.

In the report the sufficient conditions, providing both the decision of the initial problem **A** by means of the decision of the problem **B"** (i.e. $x^*(y^*) \in X^*$ if $y^* \in \mathbf{Y}^*$), and specific interrelation of so-called stationary areas and areas of local minimum of objective functions of the problems **B"** and **B'(y)** over sets $\mathbf{Y}$ and $X(y)$ with similar areas of the initial problem **A**, are considered:

1. $f(x, y) \geq f(x, w(x))$ and $h(x, y) \geq h(x, w(x))$ for any $y \in \mathbf{Y}$ and $x \in X(y)$.

2. $f(x_1, w(x_1)) \geq f(x_2, w(x_2))$ for any $x_1, x_2 \in X$ iff $g(x_1) \geq g(x_2)$.

3. $h(x_1, w(x_1)) \geq h(x_2, w(x_2))$ for any $x_1, x_2 \in X_A$ iff $f(x_1, w(x_1)) \geq f(x_2, w(x_2))$.

4. $h(x_1, y) \geq h(x_2, y)$ for any $y \in Y, x_1 \in w^{-1}(y)$ and $x_2 \in X^*(y) \cup argmin\{h(x, y) : x \in argmin\{f(x, y) : x \in w^{-1}(y)\}\}$.

5. $h(x_1, w(x_1)) > h(x_2, y)$ for any $y \in \mathbf{Y}, x_1 \in X \setminus X_A$ and $x_2 \in X_A \cap X(y) \setminus w^{-1}(y))$.

The basic attention is paid to the analysis of the specified interrelation under some additional assumptions. The stationary areas of the problem **B"** are classified in accordance with the character of their interrelation with stationary areas of the initial problem **A**. In particular, it is shown that in many real situations the problems **B"** and **B'(y)** can be selected such, that the existene of some types of stationary areas of the problem **B"** does not cause fundamental complications for its solving by iterative procedures, and the number of essential (from this point of view) areas of local minimum of the problem **B"** does not exceed the number of areas of local minimum of the problem **A**.

TH4-I-CM4

Cutpoints of Hypergraph Realizations

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Byelorussian State University

Melnikov Oleg

Keywords: cutpoints - graph - hypergraph realizations - hypergraphs

The conditions of the existence of cutpoints in the realizations of hypergraphs by the graphs are considered.

Let $H = (V, E)$ be a hypergraph, $G = (V, R)$ - some its realization and $E_0 \subset E$. Let's assume $E(v) = \{e \in E | v \in e\}$, $V_0 = \{v \in e | e \in E_0\}$, $H_0 = (V_0, E_0)$, $V_0^{'} = \{v \in V_0 | E(v) \subseteq E_0\}$, $V_0^{"} = \{v \in V_0 | E(v) \backslash E_0 \neq \emptyset\}$. We denote by $H_i = (V_i, E_i)$ the i-th connected component of the hypergraph $H^* = (V^*, E^*)$, $i \in \{1, ..., k\}$, where $V^* = V \backslash V_0^{'}$, $E^* = E \backslash E_0$, $\tilde{H} = (\tilde{W}, \tilde{E})$ be a hypergraph, resulted from the hypergraph H_0 by contracting each of sets $W_i = V_0^{"} \cap V_i$ in one vertex w_i , $i \in \{1, ..., k\}$. Let G_0 be a subgraph of the graph G, caused by the hypergraph H_0 , $\tilde{G}$ be a graph, resulted from the graph G_0 by contracting each of sets W_i in one vertex w_i, $i \in \{1, ..., k\}$.

The vertex $s \in V_0^{'}$ is a cutpoint of the realization G of the hypergraph H iff s is a cutpoint of the graph $\tilde{G}$. Thus the number of blocks containing the vertex s in both graphs G and $\tilde{G}$ is the same.

Let $V_{TM} = \{v \in V | E(v) \subset E\}$ and $\Omega(v) = \{E_0 \subset E | v \in V_0^{'}\}$.

The vertex $s \in V_{TM}$ is the cutpoint belonging to the p blocks of some realization of the coherent hypergraph H iff for any $E_0 \in \Omega(v)$ an appropriate hypergraph $\tilde{H}$ admits the realization in which the vertex s is the cutpoint belonging to the p blocks.

For $s \in V_{TM}$ the set $E(s)$ is the minimum set from $\Omega(s)$. Let's note some properties of this set connected to an opportunity realization of the hypergraph H by the graphs with cutpoint s.

For $v_1, v_2 \in V$ we assume $v_1 \leq v_2$ if $E(v_1) \subseteq E(v_2)$, $v_1 = v_2$ if $E(v_1) = E(v_2)$ and $v_1 < v_2$ if $E(v_1) \subset E(v_2)$. This relation derivates the order relation for the partition $\sum$ of the set V into the equivalence classes: for $S_1, S_2 \in \sum$ we put $S_1 \leq S_2$, if $s_1 \leq s_2$ for $s_1 \in S_1$ and $s_2 \in S_2$. Let $T(S) = \{S^{'} \in \sum | S^{'} \leq S\} \cup \{S\}$ and $P(S) = \{s \in S^{'} | S^{'} \in T(S)\}$. Hereinafter $s \in S \in \sum$ and $E_0 = E(S) \equiv E(s)$, thus, $V_0^{'} = P(S)$, $|W| \equiv p(S) = |P(S)| + k$ and $\tilde{H} = \tilde{H}(S)$. We denote by $G^*(H)$ such a realization of the hypergraph H, that for any $v_1, v_2 \in V$ the edge $v_1 v_2 \in R$ iff there exists the edge $e \in E$ such that $v_1, v_2 \in e$.

The vertex $s \in S \in \sum$ is the cutpoint of all realizations of the hypergraph H iff it is the cutpoint of the graph $G^*(\tilde{H}(S))$. Thus the minimum number of blocks containing the vertex s among all realizations of the hypergraph H coincides with number of blocks containing the vertex s in the graph $G^*(\tilde{H}(S))$.

If $|S| > 1$ there exists the realization of the hypergraph H without cutpoints from $S \in \sum$.

TH1-T-CO22

The Qualitative Nature of Hessians for Optimization Problems Governed by Partial Differential Equations

Lewis Robert Michael

ICASE

Keywords: Gauss-Newton - Hessian - infinite-dimensional optimization

We will discuss the qualitative nature of Hessians for optimization problems governed by partial differential equations (PDE). This discussion is motivated by the general formula for such Hessians. The application of particular interest is aerodynamic optimization.

We will show how the Hessian reflects the behavior of the governing PDE; in particular, we will see that Hessians for hyperbolic and incompletely parabolic problems can be qualitatively quite different from those for elliptic and parabolic problems. We will present some explicit examples to illustrate these distinctions; more generally they follow from the calculus of pseudodifferential and Fourier integral operators. We will also discuss the size and nature of the error one can encounter when using the Gauss-Newton approximation of such Hessians and show how the Gauss-Newton approximation can be qualitatively and quantitatively quite wrong.

We will give numerical evidence to support the analytical observations and discuss the consequences of these observations for numerical optimization, particularly in regards to constructing approximations and preconditioners for Hessians.

TU2-C-CO2

Nonlinear Programming without a penalty function

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Fletcher Roger

Keywords: SQP - filter - nonlinear programming - penalty function

In this paper the solution of nonlinear programming problems by a Sequential Quadratic Programming (SQP) trust–region algorithm is considered. The aim of the present work is to promote global convergence without the need to use a penalty function. Instead, a new concept of a “filter” is introduced which allows a step to be accepted if it reduces *either* the objective function *or* the constraint violation function. Numerical tests on a wide range of test problems are very encouraging and the new algorithm compares favourably with LANCELOT and an implementation of Sl_1QP.

MO4-B-CO11

Regularized Newton Methods for Minimization of Convex Quadratics Splines

Li Wu

Department of Mathematics and Statistics, Old Dominion University

Swetits John

Keywords: Newton method - convex quadratic splines - regularized Newton direction

Our main objective is to develop a Newton method that finds a minimizer of a convex quadratic spline f(x) in finitely many steps. The difficulty is that the Hessian of f(x) might be singular and standard regularization procedures would not allow finite termination. We will discuss several strategies that allow us to design Newton methods (with singular Hessians of f(x)) that find a minimizer of a convex quadratic spline f(x) in finitely many steps. Applications to quadratic programming problems will also be given.

TH1-E-CO21

Minimization of Quadratic Splines and Applications

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Keywords: quadratic programming - quadratic splines - unconstrained reformulation

Many minimization problems such as quadratic programming problems, absolute deviation regressions, and Chebyshev approximation problems, can be reformulated as the unconstrained minimization of quadratic spline functions. We will discuss some theoretical and computational issues related to the unconstrained minimization of quadratic splines as well as some applications.

WE2-C-CO3

Exact Penalty Functions for Constrained Minimization Problems and Regularized Gap Function for Variational Inequalities

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Department of Mathematics and Statistics, Old Dominion University

Peng Ji-ming

Keywords: exact penalty - regularized gap function - variational inequalities

By using the regularized gap function for variational inequalities, we introduce a new penalty function for general constrained minimization problems and reformulate the original problem as an unconstrained minimization problem on the whole Euclidean space. Under certain assumptions, it is shown that any stationary point of the penalty function is a stationary point of the original problem, and any local (or global) minimizer of the new problem is a local (or global) minimizer of the undertaking problem. A globally convergent hybrid Newton method is also presented for solving the new problem.

TH4-C-CO3

A Trust Region and Affine Scaling Method for Nonlinear Minimization with Linear Constraints

Li Yuying

Cornell University

Coleman Thomas

Keywords: Newton - affine scaling - trust region

A trust region idea is combined with an affine scaling Newton method for minimizing a nonlinear function with linear inequality constraints. We describe the proposed method and a reflection technique which is particularly useful in this context. Explicit sufficient decrease conditions and preliminary computation results will also be presented.

TU1-N-CO15

Sensitivity Analysis for Combinatorial Optimization Problems Based on Subsets of k-Best Solutions

Libura Marek

Systems Research Institute, Polish Academy of Sciences

S. van der Poort Edo - Sierksma Gerard - Van der Veen Jack A.A.

Keywords: combinatorial optimization - k-best - sensitivity analysis

We consider the combinatorial optimization problem: $\min\{\sum_{e\in F} c(e) : F \in \mathcal{F}\}$, where for a given finite set E, $c(e)$ denotes the weight of element $e \in E$, and $\mathcal{F}$ is a family of feasible subsets $\mathcal{F} \subseteq 2^E$. Assuming that a set of k-best solutions of this problem is known, we investigate the possibility of solving various sensitivity analysis questions concerning the weights of elements. We concentrate on the following problems:

– calculating so-called tolerances of weights with respect to an optimal solution, defined as maximum individual changes of weights preserving the optimality of this solution;

– describing the region of allowable simultaneous changes of weights provided by tolerances of single weights;

– computing so-called stability radius of an optimal solution, which gives the maximum simultaneous changes of weights preserving the optimality of this solution;

– determining the maximum relative error of a given feasible solution as a function of accuracy of estimating the weights of elements.

We illustrate presented results with examples of the symmetric traveling salesman problem.

TH3-B-CO10

An Unconstrained Convex Programming Approach to Linear Semi-infinite Programming

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Dept. of IOE, Univ. of Michigan

Fang Shu-Cherng - Wu Soon-Yi

Keywords: convex analysis - linear semi-infinite programming

An unconstrained convex programming dual approach for solving a class of linear semi-infinite programming problems is proposed. Both primal and dual convergence results are established under some basic assumptions. Numerical examples are also included to illustrate this approach.

WE1-L-CM201

Newton's Method for Large Bound-Constrained Optimization Problems

Lin Chih-Jen

Dept. of IOE, Univ. of Michigan

More Jorge J.

Keywords: Newton method - preconditioned conjugate gradient method

We present an algorithm which combines gradient projection ideas and trust region strategies to solve large-scale bound constrained problems. We prove that the algorithm is globally and quadratically convergent for degenerate problems. A preconditioned conjugate gradient method is used to solve the (possibly indefinite) subproblems. Numerical results are reported indicating the practical viability of this approach. Different incomplete Cholesky factorization strategies for preconditioning indefinite Hessian matrices are extensively studied. Special attention is paid to the case where the Hessian matrix is positive semi-definite and nearly singular.

FR1-U-IN1

Traffic Equilibrium Problems with Nonlinear Time/Money Relations

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Linköping University

Rydergren Clas - Lundgren Jan - Patriksson Michael

Keywords: multiple label shortest paths - traffic equilbria

We study traffic equilibrium problems, where users have a nonlinear value-of-time relation or where different user groups have different linear time/money relations. The second case is typically present when there are user groups of different wealth. The efficient solution of such problems is motivated in particular by the need to analyze the behaviour of traffic under link tolls.

For these problems we develop a (restricted simplicial) decomposition technique, in which path generation is achieved through multi attribute shortest path problems, solved by multiple labelling techniques.

We will present applications to some test cases.

WE3-W-CO15

Penalized Estimation of Free Knot Splines

Lindstrom Mary J.

University of Wisconsin - Madison

Polynomial splines are often used in statistical models for smooth response functions and densities. When the number and location of the knots are optimized, the fit is improved and the spline is a nonparametric model with locally determined smoothness. However, finding the optimal knot locations is historically difficult. This talk will present a new estimation approach that improves the computational properties of the problem by penalizing coalescing knots. The new estimator ensures continuous derivatives and has improved statistical properties over both equally spaced fixed knots and completely free knots.

TH2-I-CM4

Perfectly Contractile Graphs

Linhares-Sales Claudia

Universidade Federal Fluminense

Maffray Frédéric - Reed Bruce

Keywords: even pairs - perfect graph

A pair of vertices is called an even pair if every chordless path between them has even length. From this concept, two classes of perfect graphs were defined: the strict-quasi parity graphs and the perfectly contractile graphs. This last class is based on an algorithm that colors optimally the vertices of a perfect graph by even pair contractions. In order to characterize perfectly contractile graphs, Hazel Everett and Bruce Reed made a conjecture about their structure. We will present some partial results about this conjecture and some open problems.

WE4-B-CO10

An Exterior Newton Method for Convex Quadratic Programming

Liu Jianguo

University of North Texas, Math. Dept

Coleman Thomas

Keywords: Newton method - convex quadratic programming - dual problems - exterior methods

We propose an exterior Newton method for convex quadratic programming (QP) problems. This method is based on a dual formulation: a sequence of points is generated which monotonically decreases the dual objective function. We show that the generated sequence converges globally and quadratically to the solution (if the QP is feasible). Measures for detecting infeasibility are provided. The major computation in each iteration is to solve a KKT-like system. Therefore, given an effective symmetric sparse linear solver, the proposed method is suitable for large sparse problems. Preliminary numerical results are presented.

FR2-C-CO2

Abstract Convexity. A Fixed Point Result

Llinares Juan-Vicente

CEPREMAP

The aim of this paper is to present some new abstract convexity structures (mc-space and B'-simplicial convexity) and to relate them with other abstract convexity structures that we can find in the literature, (in particular,with c-spaces introduced by Horvath (1987, 1991) and siplicial convexity introduced by Bielawski(1987)). A a fixed point result in the context of mc-spaces as well as a generalization of the KKM lemma close the paper.

TH2-I-CM3

Optimal Vehicle Scheduling in Public Transit

Löbel Andreas

Konrad-Zuse-Zentrum für Informationstechnik Berlin

In this talk we deal with the NP-hard multiple-depot vehicle scheduling problem in public mass transit. The problem is formulated as a special integer multicommodity-flow problem, which we solve with a branch-and-cut approach with delayed column generation. The column generation includes new column generation techniques that are based on Lagrangean relaxations. We describe in detail all basic ingredients of our approach that are indispensable to solve truly large-scale real-world instances to optimality, and we report on computational investigations that are based on real-world instances from the cities of Berlin and Hamburg having up to 70 million decision variables.

WE1-C-CO3

Conical Algorithms for Concave Optimization

Locatelli Marco

University of Trier

Keywords: concave minimization - conical algorithms - omega-subdivisions

A well known global optimization problem is the minimization of a concave function over a polytope. Conical algorithms can be employed to solve such a problem. They are branch-and-bound algorithms, in which every node is represented by a cone and in which the solution of a linear program in each cone is the instrument through which cones may be excluded from further search or may be selected to be subdivided, i.e. to generate new nodes in the branch-and-bound tree. The subdivision of a cone may be done according to different rules. One well known rule is bisection, whose use guarantees finiteness of the algorithm but which is also mildly related to the information collected during the execution of the algorithm. A better subdivision rule is the omega-subdivison rule. The finiteness of the algorithm only based on this kind of subdivision, which was an open question in the literature, has been proved.

TU4-K-CM106

A Genetic Algorithm for Unconstrained Binary Quadratic Optimization

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DEIS - University of Bologna

Allemand Kim Alexandre - Liebling Thomas M.

Keywords: generic algorithm - unconstrained binary quadratic optimization

We present a new heuristic based on a genetic algorithm for the unconstrained quadratic 0-1 optimization, using a minimum range of the gradient algorithm (proposed by Pardalos P.M. and Rodgers G.P.) as intensification operator. A chromosome of our population is a boolean array of n components (the size of the problem). We select two parents from the population to generate a new chromosome. Components of identical value in both parents are copied in the new chromosome. The values of the other components are determinated recursively by applying a branch on one selected component followed by the intensification operator. Test problems are randomly generated by a method proposed by the above cited authors. We compare our results with the results obtained by a tabu approach especially for large size problems ($n > 100$).

FR4-P-IN11

On the Solution of a Large Scale Timetabling University Problem

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Laplagne Eduardo - Lin Min Chih - Gardini Waldo

Keywords: heuristics - integer programming - time tabling

A huge assignment problem appears at the beginning of each academic year at Buenos Aires University. New students have to spend two semesters taking courses that are common for students of several faculties before entering to the career of their choice. The are several sites spread around the city where these courses can be taken. Each student is required to make a first and second choice of preferred site and hours (morning,

early afternoon, or evening) .The administration opens courses and distributes the students trying to maximize their satisfaction. Rooms and sites capacities constraints, hours constraints, some academics constraints, and others have to be taken into account. By the time being teachers are assigned separately afterwards.
A mathematical model formulation for this problem it's stated and heuristics to be included in an interactive program used by the scheduler, are proposed .

WE2-B-CO10

An Approach to Stability in Linear Semi-Infinite Programming

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Keywords: feasible set - optimal set mapping - optimal value function - semi-infinite programming - stability - well-posedness

In this approach no hypothesis is required for the set indexing the constraints. So, a pseudometric has to be defined in order to measure the size of the perturbations. Lower semicontinuity of the feasible set mapping and boundedness of the optimal set, when they are simultaneously held (in which case the problem belongs to the interior set of solvable problems), entail almost all the favourable stability properties of the optimal set mapping and the optimal value function, as well as a certain type of value oriented well-posedness, in the Hadamard sense.

TH3-L-CM201

A Parallel Cholesky Factorization for Block Structured LP Problems

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Verbois Sebastien A.

Keywords: Cholesky factorization - interior point methods - parallel processing

The coefficient matrix of the symmetric linear system to be solved at each iteration of an interior point method exhibits a block structure when the LP constraint matrix is itself block structured. Pivoting strategies in the Cholesky factorization are aimed at preserving sparsity but not necessarily at distributing as much as possible the computational effort on multiple processors. We use a general model for ordering the block structure which enables us to develop pivoting strategies aimed at separability. We discuss an experimental implementation for staircase or multistage LP problems and show how pivoting for separability affects sparsity.

TH3-I-CM5

The Necessary Width for Channel Routing in the 2k (k>1) Layer Dogleg-Free Manhattan Model

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Technical University of Budapest

Keywords: VLSI design - combinatorial optimization

We discuss channel routing in the multilayer dogleg-free Manhattan model, the case when we have $l_H = l_V \geq 2$ layers (l_H and l_V denote the number of layers reserved for horizontal and vertical wire segments, respectively). The question, whether a channel with density d can be realised in this model with minimum width (that is, with width $\lceil d/l_H \rceil$) has been proved to be NP-complete (A. Recski), but an acceptable exponential algorithm is given, wich solves the problem in some cases. We discuss the advantages and disadvantages of this algorithm and show that the numbering of the nets, which should be irrelevant, influences the solvability.

TH3-I-CM200

The Vertex Set of a 0/1-Polytope is Strongly P-Enumerable

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Bussieck Michael R.

Keywords: 0-1 polytopes - computational complexity - convex polyhedra - strong P-enumerability - vertex enumeration

In this talk, we discuss the computational complexity of the following enumeration problem: Given a rational convex polyhedron P defined by a system of linear inequalities, output each vertex of P. It is still an open question whether there exists an algorithm for listing all vertices in running time polynomial in the input size and the output size. Informally speaking, a *linear* running time in the output size leads to the notion of $\mathcal{P}$*-enumerability* introduced by Valiant. The concept of *strong* $\mathcal{P}$*-enumerability* additionally requires an output independent space complexity of the respective algorithm. We give such an algorithm for polytopes, all of whose vertices are among the vertices of a polytope combinatorially equivalent to the hypercube. As most important special case, this class of polytopes contains all 0/1-polytopes. Our implementation based on the commercial LP solver CPLEX is superior to general vertex enumeration algorithms.

TU4-C-CO3

On Well-Posedness and Stability Analysis in Optimization

Lucchetti Roberto

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Zolezzi Tullio

Keywords: Hadamard and Tykhonov well-posedness - well-posedness by perturbations

We review the basic concepts of well–posedness in scalar optimization: Hadamard, Tykhonov, Levitin–Polyak and strong well–posedness. We discuss in some detail a more recent approach, well–posedness by perturbations. We provide several examples, paying special attention to mathematical and convex programming.

TU4-A-IN2

Stronger Eigenvalue Based Upper Bounds for Maximum Entropy Sampling

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Laboratorio Nacional de Computacao Cientifica

Malebranche Helios

Keywords: bounds - eigenvalues - maximum entropy - sampling

An exact solution algorithm for the problem of choosing a maximum entropy subset (of prespecified size) from a set of correlated random variables has been recently proposed in the literature. The algorithm addresses the Gaussian case and proposes eigenvalue based upper bounds for the problem. We propose to use those eigenvalue bounds to form an auxiliary problem from which stronger upper bounds for maximum entropy sampling could be obtained. An exact solution algorithm based on the idea is described and computationaly tested. Similar schemes could be derived for eigenvalue bounds proposed to other combinatorial optimisation problems. As an example, an extension to the quadratic assignment problem is given.

FR3-C-CO2

On the Convergence of Derivative Free Methods for Unconstrained Optimization

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Sciandrone Marco

Keywords: derivative free methods - unconstrained optimization

We consider the problem of the form

$$\min f(x)$$
$$x \in R^n,$$

where we assume that $f : R^n \to R$ is a continuously differentiable function and that its derivatives can be neither explicitly calculated nor approximated.

In this work we analyse and study the global convergence properties of unconstrained minimization methods employing only function values. In particular we describe new general conditions that can be considered, from one hand, an abstraction of the convergence results proposed in literature and, from the other hand, an attempt to identify the key ingredients that ensure the global convergence of a derivative free algorithm.

On the basis of these conditions we define new globally convergent derivative free methods. Some preliminary numerical results are presented and discussed.

MO3-L-CM201

Load Balancing Strategies for the Parallel Solution of Discrete Optimisations Problems

Lueling Reinhard

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Keywords: load balancing - parallel combinatorial optimisation

In this talk the dynamic load balancing of highly irregular parallel combinatorical optimization problems is addressed. The load balancing algorithms presented in this talk have been investigated for a number of applications on parallel computing systems collecting up to 1024 processors. The methods guarantee that the parallel combinatorical optimization algorithm achieves nearly linear speedup, even if the parallel computation takes only very short time.

Within the talk, the load balancing method is presented to solve Vertex Cover problems, Traveling Salesman problems and very large instances of the Quadratic Assignment Problem. A analytical justification of the load balancing method is given. Using these results it is possible to encapsulate the know - how of these methods in programming frames for the solution of combinatorial optimization problems using branch & bound methods.

An encapsulation of the load balancing method is presented in form of the Daisy library allowing the easy parallelization of sequential combinatorial optimization problem by solving the load balancing problem in a way which is efficient and easy to handle.

TU1-I-CM120

Solving Extensions of the Steiner Problem in Graphs with Strong Multicommodity Flow Formulations

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Universidade Federal de Minas Gerais

Keywords: Benders decomposition - Steiner tree - local access - network design - telecommunication networks

We talk about the importance of flow formulations for telecommunication network design, with a referencial model for local access networks. The objective is the cost minimization of the sum of the fixed (structural) and variable (operational) costs of all the arcs composing a tree that links the origin node to every demand node of a directed graph. The point that we emphasize now is that, instead of working with heuristcs based on weak onecommodity flow formulations, we might have better results with strong multicommodity flow formulations. The combinatorial nature and the large scale induced by such redundant formulations can be overcame by Benders decomposition, as an alternative to the resolution of the very large scale linear programming relaxations. The initial solution is obtained by the shortest path from the common origin to every destination node, thus being related to the minimal variable cost. On the other hand, the second topology is related to the minimal fixed cost, since it is derived from the minimal Steiner tree embedded problem. The first relaxed master problem is then invoked with the sharp cuts related to both the minimal operational cost and the minimal structural cost. A preliminar computational test with realistic data has shown very promising results, with the optimal solution being obtained in the second master iteration, and with the optimality assured at the end of the fourth master iteration. We discuss some extensions to cope with backbone networks, and how should be considered for flow models the relevant aspects of connectivity, survivability, modularity, routing and quality of service. We also remember that many heuristic approaches can be accommodated by the exact nature of the algorithm, thus providing a practical mean to verify the quality of heuristic solutions.

TH1-D-CO124

Interior Point Column Generation Algo-

rithms for Adaptive Filtering

Luo Zhi-Quan

McMaster University

Afkhamie Kaywan - Wong K. Max

Keywords: adaptive filtering - column generation - interior point methods

This paper presents a novel application of Interior Point Column Generation (IPCG) algorithms (with quadratic cuts) to adaptive filtering. One of their key features is that inequality constraints (that define the convex feasible region) are considered one at a time. This feature can be exploited in applications that require a solution to be updated adaptively. We give some background on IPCG algorithms and how they are used to solve convex feasibility problems. Then we apply IPCG to two classical filtering problems: adaptive channel equalization and adaptive system identification. Our simulation results show that, under adverse conditions (low signal-to-noise ratios, correlated input signals, potentially time varying systems) the IPCG exhibits convergence behavior superior to the Recursive Least Squares method (RLS), while under less adverse conditions, the IPCG algorithm consistently matches the RLS performance.

TU4-E-CO21

A Globally Convergent Sequential Quadratic Programming Algorithm for Mathematical Programs with Linear Complementarity Constraints

Luo Zhi-Quan

McMaster University

Fukushima Masao - Pang Jong-Shi

Keywords: MPEC - SQP

This paper presents a sequential quadratic programming algorithm for computing a stationary point of a mathematical program with linear complementarity constraints. The algorithm is based on a reformulation of the complementarity condition as a system of semismooth equations by means of Fischer-Burmeister functional, combined with a classical penalty function method for solving constrained optimization problems. Global convergence of the algorithm is established under appropriate assumptions. Some preliminary computational results are reported.

MO4-L-CM201

Issues for Porting the CPLEX Parallel Optimizers

Lustig Irvin J.

CPLEX Optimization, Inc.

CPLEX Optimization, Inc. now offers three parallel optimizers, a parallel mixed integer optimizer, a parallel barrier method, and a parallel dual simplex method. We will discuss the issues that have arisen in making these implementations portable across different vendor platforms, and related issues that arise in providing a robust parallel optimizer. Some details about the implementations of the different parallel algorithms will also be provided.

MO3-U-IN10

Short and Mid Term Energy Production Planning

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Ecole polytechnique fédérale de Lausanne

Liebling Thomas M. - Prodon Alain

Keywords: mixed integer programming - production planning

A chemical complex produces electricity to supply its own plants and surrounding consumers like small industries and villages. Their power-generating system includes hydro and thermal turbines, each subject to power limits, production costs, starting-up and shutting-down restrictions and costs.

In summer they usually produce enough energy to meet all the demand. In winter however, energy often has to be bought from an outside electricity company at a high price. The electricity company charges not only the amount of energy purchased, but adds a power penalty based on the average of the three power peaks of the month.

The electricity demand and the amount of water and steam available for the hydro and thermal units, respectively, are forecasted using prevision methods based on historical data.

Our main objective in this paper is to provide a mixed integer programming model helping to establish a least-cost schedule for the operation of the power-generating system over a period of one month, one week, and one day. We also present numerical results of a large scale implementation.

FR3-A-IN2

A Trust Region Algorithm for Mixed Zero-One Nonlinear Programming

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Federal University of Rio de Janeiro

Mauricio David S. - Paula Junior Geraldo Galdino

Keywords: combinatorial optimization - mixed 0-1 nonlinear programming - steepest descent - trust region method

A wide range of optimization problems arising from engineering applications can be formulated as Mixed 0-1 Nonlinear Programming (PNLM-01). Mauricio and Maculan (1997) suggest a trust region scheme for solving Pure 0-1 Nonlinear Programming Problems. This scheme has showed 100% efficiency and slowly computational time on several test problems with up to 1024 Boolean variables. We present an extension of the trust region scheme for solving PNLM-01. The proposed algorithm in each iteration to solve a trust region model for computing a descent solution. This model can be solved by search linear algorithm and $O(nlog(n))$ algorithm (n is a number of Boolean variables). The algorithm finish when some an optimality condition is verified or a descent solution can not be found. Numerical results on large test problems are reports.

MO4-N-CO15

Modelling and Optimization with Mathematica

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MathConsult Dr. R. Mäder

Keywords: interval arithmetic - mathematica - modelling - optimization - technical computing - visualization

Mathematica combines advanced numerical methods, arbitrary-precision arithmetic, graphics, symbolic manipulation, and flexible data import and export options in an extensible technical computing system.

We survey the built-in and add-on capabilities in the areas of interest to attendees of this conference in an on-line demonstration. Topics of the talk include local and global optimization, interval methods, visualization, and parallel computing.

WE4-C-CO122

Simulating the Interval Optimization Method in Real Arithmetic

Madsen Kaj

IMM, Technical University of Denmark

Zertchaninov Serguei

Keywords: branch and bound - global optimization

The interval branch-and-bound method for global optimization has proved very efficient on a large class of problems. The limitations of its applicability is mainly caused by the following two reasons: 1. An explicit expression for the function calculation must be known. 2. In general the computing time grows exponentially with the number of variables. The second disadvantage is inherent in the problem, so in general one should never expect to be able so solve problems in more than 30-40 variables (by any method).

We present a real version of the interval branch-and-bound method. The first disadvantage is eliminated, but unfortunately also the safety of the interval method is lost. Because of the second disadvantage the new algorithm in principple runs infinitely. The computer is loaded with information about the function, the information being "tightest" in domains where the function seems to be most interesting. The stopping criterion is a time limit set up by the user. For instance the user can inspect the course of the iteration, and stop if no improvement has occured for a long time. Numerical experiments will be presented. Since we use well known test functions we can detect whether (and when) the solution is found, and it turns out that the method is both safe and fast on the problems tested.

MO4-B-CO11

Use of Piecewise Quadratic Functions for Linear and Quadratic Programming

Madsen Kaj

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Keywords: linear programming - quadratic programming - smoothing method

We consider the problem of minimizing a function F which is convex, continuously differentiable and composed by a finite number quadratic functions. It is demonstrated that the Newton method which exact line searches efficiently solves the problem. Next it is demonstrated how this special Newton iteration can be applied to solve the Linear and convex Quadratic Programming problems efficiently. The key idea is that the duals of these problems are of the type F.

FR2-U-IN1

K-Path Cuts for the Vehicle Routing Problem with Time Windows

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The Technical University of Denmark

Keywords: time windows - valid inequalities - vehicle routing

The paper presents a new optimization method for the Vehicle Routing Problem with Time Windows (VRPTW). The VRPTW is a generalization of the Vehicle Routing Problem in which the service of a customer must start within a given time window. Our method is based on Dantzig-Wolfe decomposition in which the coupling constraints is the constraint set requiring that each customer must be serviced. The subproblem is a Shortest Path Problem with Time Windows and Capacity Constraints. To get stronger bounds a number of strong valid inequalities are generated and incorporated in the master problem as needed. In particular a new type of valid inequality denoted k-path cuts seems to produce very good bounds. Branch and Bound is applied to obtain an integer solution to the VRPTW. The branching strategy is primarily based on branching on the number of vehicles (if it is fractional), and secondary on branching on the flow variables. The algorithm has been implemented and tested on a series of well known data sets of size up to 100 customers. Furthermore a 150 customer problem has been solved to optimality. The algorithm turns out to be faster than other algorithms considered in the literature, and we have succeeded in solving several previously unsolved problems to optimality.

TH3-E-CO11

Averaging with Well Behaved Maps for Solving Fixed Point and Variational Inequality Problems

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Epelman Marina - Perakis Georgia

Keywords: fixed point problems - variational inequalities

Algorithms for solving problems in many applied settings, establish a map whose iterative application leads to a fixed point solution that solves the original problem. The convergence of the algorithmic map to a fixed point solution often requires strong assumptions that restrict the domain of applicability of the algorithm. In many instances, various forms of averaging will extend the range of applicability of the algorithmic (fixed point) map. In this talk, we examine a general averaging framework for solving fixed point problems. The key idea is to consider averaging with maps that are "well" behaved in order to counteract the "bad" properties of the fixed point (algorithmic) map. Our framework considers averaging with two types of well behaved maps; identity and contractive maps. We combine these maps in various ways and establish convergence for several forms of averaging. When applied to fixed point and variational inequality problems, these schemes give rise to several known as well as new methods.

TU3-I-CM4

A Characterization of Hereditary UIM Graphs

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Wang Tao-Ming

Keywords: intersection graphs

A graph G is uniquely *intersectable with respect to multifamilies (UIM)* if there is a unique multifamily α (upto isomorphism) of subsets of a minimum cardinality set so that G is isomorphic to the intersection graph of α. A graph is *hereditary UIM* if every induced subgraph is UIM. We characterize hereditary UIM graphs by forbidden subgraphs. This class properly contains previously known classes of UIM graphs and also the class of trivially perfect graphs.

FR4-C-CO3

Capacity and Flow Assignment of Data Networks by Generalized Benders Decomposition

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Keywords: data networks - decomposition methods - multicommodity flow - network optimization

A mixed-integer non linear model is proposed to optimize the joint assignment of capacities and flows (the CFA problem) in a communication network. Discrete capacities are considered and a total average delay upper bound models the grade of service of the desired network. Generalized Benders decomposition induces convex multicommodity flow subproblems on successive topologies proposed by the master program. These problems are solved by an efficient Proximal Decomposition algorithm which distributes computations among arcs and candidate paths of the network. Numerical tests on small- to medium-size networks show the ability of the approach to obtain optimal solutions to some class of (CFA) problems.

FR2-I-CM120

On the Linear Relaxation of the 2-Node Connected Subgraph Polytope

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Charles Nocq

Keywords: 2-node connected subgraph - linear relaxation - minimal vertices - polytope

We consider the polytope $P(G)$, the linear relaxation of the 2-node connected subgraph polytope of a graph G.That is the polytope given by the trivial and the cut inequalities. We define an ordering on the extreme points of $P(G)$, and we characterize those fractional extreme points which are minimal with respect to that ordering. As a consequence we obtain a polynomial method to separate a minimal fractional extreme point of $P(G)$. And we identify a new class of facets of the 2-node connected subgraph polytope that generalizes the so-called odd-wheel inequalities.

FR3-I-CM200

Short-Term Modelling In Refinery Planning

Main Roger Anthony

BP Oil

Refinery planning has been a traditional use of LP. With the developments in hardware and software, it has become possible to create and solve more detailed and more accurate models of refineries. This paper looks at the assumptions inherent in building or using models with non-linear components, and how they relate to the requirements of the planning process. Techniques developed at BP for solving the problems within the framework of existing solution methods are outlined. Some of the difficulties which can be encountered in practice are described, and some unanswered questions will be posed.

FR1-C-CO2

Nonsmooth Optimization Methods Applied to Hemivariational Inequalities

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Luksan Ladislav - Miettinen Markku

Keywords: bundle methods - nonconvex energy functions - nondifferentiable programming

Hemivariational inequalities can be considered as a generalization of variational inequalities. Their origin is in nonsmooth mechanics of solid, especially in nonmonotone contact problems. The solution of a hemivariational inequality proves to be a substationary point of some functional, and thus can be found by the nonsmooth and nonconvex optimization methods. We consider two type of bundle methods in order to solve hemivariational inequalities numerically: proximal bundle and bundle-Newton methods. Proximal bundle method is based on first order polyhedral approximation of the locally Lipschitz continuous objective function. To obtain better convergence rate bundle-Newton method contains also some second order information of the objective function in the form of approximate Hessian. Since the optimization problem arising in the hemivariational inequalities has a dominated quadratic part the second order method should be a good choice. The main question in the functioning of the methods is how remarkable is the advantege of the possible better convergence rate of bundle-Newton method when compared to the increased calculation demand.

WE4-I-CM121

Bidual Horn functions

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Ibaraki Toshihide - Eiter Thomas

Keywords: Horn functions - boolean functions - production rules

Horn Boolean functions have been extensively studied because the associated Horn rules form a basis of production rules and logic programming in expert systems, and because SAT for

Horn clauses is polynomially solvable. We introduce in this paper bidual Horn functions, which are the Horn functions f such that its dual f^d is also Horn. Such functions are important in applications because both of its true set and false set can be characterized by Horn rules. The class of bidual Horn functions lies between the class of positive (i.e., monotone) functions and the class of Horn functions. We present a polynomial time algorithm for recognition of bidual Horn functions from a Horn DNF (disjunctive normal form), while we can show that recognition of bidual Horn functions from a general DNF is co-NP-complete. We then show that every irredundant prime DNF of a bidual Horn function f is a term-shortest DNF. Our major contribution is to show that a literal-shortest DNF for f can be computed in polynomial time from a given Horn DNF, whereas the same problem for general Horn functions f is NP-hard.

MO3-N-CO15

Model Analysis for Decision Support: Approach, Software and Applications

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Keywords: engineering applications - environmental applications - goal programming - linear programming - multicriteria optimization - nonlinear programming

Decision making often requires analysis of large amount of data and complex relations. In such cases, an analysis of a mathematical model can support rational decision making. Computerized tools designed and implemented for such purposes are called Decision Support Systems (DSS). A DSS helps in the evaluation of consequences of given decisions and advises what decision would be the best for achieving a given set of goals. In a traditional optimization approach, only one criterion is used as a goal function, and constraints are set for other criteria. Recently, multicriteria model analyses (MCMA) are being used more widely. The advantages of using MCMA are not only because of their ability of handling several goals, which clearly better corresponds to needs of decision support because most real-life problems are multiobjective. The main advantage of a proper implementation of MCMA is due the way it is used. Namely, MCMA helps to analyze the problem rather than providing an optimal solution. In typical situations, a specification of attainable goals is practically impossible. Therefore a user interactively changes goals upon analysis of feasible solutions obtained for previously specified goals.

An overview of the applied methodology to aspiration-led multiple-criteria model analysis (which is an extension of the goal programming) will be given. The corresponding approach to design and implementation of model-based decision support systems will be presented and illustrated by its application to the regional water quality management problem, to land use planning, and to engineering problems.

The approach to be presented allows for reuse of most of the components needed for a DSS. Experiences with the design, implementation and applications of such modular tools for decision analysis will be reported.

WE4-U-IN10

Multicommodity Flow Network Survivability Analysis

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Keywords: minimax - multicriterial - multiflow networks - survivability

Multicommodity Flow Network (MFN) is the accepted mathematical model of communication networks. These networks consolidate many users with their own flow demands that compete for edges/nodes' capacities. Thus, one of the problems is to find the strategy of multiflow distribution in such systems. Different conceptions of optimal distribution are studied in the paper. We are going to consider the strategies which maximize the following criteria: 1) the whole vector of flows, 2) its minimal component, and 3) lexicographical minimum of the levels of demands' provision. The problem of MFN survivability analysis is to estimate the criteria decrease as a result of edge/node capacity reduction (or annulment) if the defeated edges/nodes are unknown beforehand. In order to formalize this problem, we have developed an original methodology that takes into account the multi-objective specificity of MFN and non-uniqueness of offensive strategy. Developed approach has been applied for survivability analysis of several small scale models. Survivability dependence on the network graph is studied. It occures that a tree may be in some sense less vulnerable than a full graph. Some appllcations of our methodology to investigation of the survivability of telecommunication and power networks lay on the Territory of the former Soviet Union are available. Such investigations are very important today after the country has split and the risk of communication disturbance has increased.

Various numerical methods for lexicographical programming with respect to networks as well as multicriterial optimization and minimaximization technique are suggested in the paper. Additionally, the authors consider the problem with unknown demands and network synthesis with security constraints.

MO3-K-CM106

Data Mining via Concave Minimization

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Bradley Paul - Street Nick

Keywords: clustering - data mining - k-median algorithm

A fundamental problem of data mining is that of assigning m points in the n-dimensional real space R^n to k clusters and extracting distinct information from the various clusters. This problem is formulated as that of determining k centers in R^n such that the sum of distances of each point to the nearest center is minimized. If a polyhedral distance is used, the problem can be formulated as that of minimizing a piecewise-linear concave function on a polyhedral set which is shown to be equivalent to minimizing a bilinear function on a polyhedral set. A fast finite k-Median Algorithm consisting of solving few linear programs in closed form leads to a stationary point of the bilinear program. Computational testing on a number of real-world databases was carried out. On the Wisconsin Diagnostic Breast Cancer (WDBC) database, k-Median training set correctness was comparable to that of the k-Mean Algorithm, however its testing set correctness was better. Additionally, on the Wisconsin Prognostic Breast Cancer (WPBC) database, distinct and clinically important survival curves were extracted from the database by the k-Median Algorithm, whereas the k-Mean Algorithm failed to obtain such distinct survival curves for the same database.

MO4-E-CO21

Minimum-Support Solutions of Mathematical Programs

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Keywords: concave minimization - minimum cardinality

Motivated by the successful application of mathematical programming techniques to difficult machine learning problems, we seek solutions of concave minimization problems over polyhedral sets with a minimum number of nonzero components. We prove that if such problems have a solution, they have a vertex solution with a minimal number of zeros. This includes linear programs and general linear complementarity problems. A smooth concave exponential approximation to a step function solves the minimum support problem exactly for a finite value of the smoothing parameter. A fast finite linear-programming iterative method terminates at a stationary point, which for many important real world problems provides very useful answers. Utilizing the complementarity property of linear programs and linear complementarity problems, an upper bound on the number of nonzeros can be obtained by solving a single convex program on a polyhedral set.

TH4-B-CO10

Feature Selection by Mathematical Programming

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Keywords: concave minimization - feature selection - machine learning

The problem of discriminating between two finite point sets in n-dimensional feature space by a separating plane that utilizes as few of the features as possible, is formulated as a mathematical program with a parametric objective function and linear constraints. The step function that appears in the objective function can be approximated by a sigmoid or by a concave exponential on the nonnegative real line, or it can be treated exactly by considering the equivalent linear program with equilibrium constraints (LPEC). Computational tests of these three approaches on publicly available real-world databases have been carried out and compared with an adaptation of the optimal brain damage (OBD) method for reducing neural network complexity. One feature selection algorithm via concave minimization (FSV) improved cross-validation on a cancer prognosis database by 23.7% while reducing problem features from 32 to 4.

WE2-K-CM106

ANT-QAP: Approximate Nondeterministic Tree-search for the Quadratic Assignment Problem

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Keywords: combinatorial optimization - evolutionary methods - meta-heuristics

This paper presents a new version of the Ant-system heuristic and its application to the Quadratic Assignment Problem. Significant improvement over the published Ant algorithm has been obtained by introducing as a structural component of the metaheuristic algorithm the use of a bounding function, and by redesigning the trail updating procedure. The resulting algorithm can be considered as an approximate tree-search procedure with a randomized branching rule and an adaptive memory component, which captures global indications from the history of the search process to be used as guidance in future exploration. The general ANT procedure has been used for solving a significant number of symmetric and asymmetric QAP instances, taken from the QAP library. Computational results show that the new ANT algorithm is now competitive with the better performing metaheuristic approaches presented in the literature, both with respect to the quality of the solutions found and to the CPU time required.

TH2-I-CM121

New Lower and Upper Bounds for the Frequency Assignment Problem

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Sassano Antonio

Keywords: frequency assignment - integer programming

The Frequency Assignment Problem (FAP) is the problem of efficiently assigning radio-frequencies to transmitters in such a way that close transmitters do not interfere, and so that the highest frequency assigned is minimized. This sort of problems arise in telecomunication systems, such as cellular networks or radio and television broadcasting. We present a new formulation for (FAP) based on a generalization of the well known Hamiltonian Path relaxation. This formulation allows us to compute better lower and upper bounds for (FAP).

TU3-A-IN2

A Cutting Plane Procedure for Mixed 0-1 Programming Problems

Marchand Hugues

Columbia University and CORE (U.C.L.)

Ceria Sebastián - Wolsey Laurence Alexander

In this paper we present a systematic way to generate cuts for mixed 0-1 programming problems. Using facets obtained by projection and lifting of elementary MIP sets called the *0-1 Knapsack Set* and the *Continuous 0-1 Knapsack Set*, we develop a cutting-plane procedure to tighten LP-formulations of more general MIP sets. This approach can be seen as a generalization of the lifted cover cut generation for pure 0-1 programming problems. We give numerical results of a Branch-and-Cut scheme based on this cutting-plane procedure.

TH1-E-CO21

Reformulations of a Bicriterion Equilibrium Problem

Marcotte Patrice

Université de Montréal

This presentation is concerned with an equilibrium model where demand is split among service users according to a continuous probability function. We discuss several formulations, both finite and infinite-dimensional, of this model, together with their respective convexity and/or monotonicity properties.

FR1-U-IN1

Strategic Approach to Capacitated Traffic Assignment.

Marcotte Patrice

Université de Montréal

Nguyen Sang

Traditional models of traffic assignment usually assume that flow is distributed along paths of the underlying network. In this presentation, we argue that several models can be enhanced by considering that the physical path travelled by a given user depends on a sequence of events (random or not) that occur at the nodes of the network, and whose outcome is only revealed once the user accesses the given node. These situations call for a more sophisticated behaviour than simply selecting an origin-destination path. Users must behave 'strategically' and take into account the contingency that a desirable path become unavailable, from a certain node on to the destination. Such a behaviour can be represented by means of hyperpaths in generalized graphs know as hypergraphs.

FR1-P-IN201

A Branch-and-Cut Algorithm for a Precedence Constrained Single Machine Scheduling Problem

Margot François

Michigan Technological University

Queyranne Maurice - Wang Yaoguang

Keywords: branch and cut - precedence constraints - single machine scheduling

We consider the following single machine scheduling problem, denoted $1|\text{prec}|\sum_j w_j C_j$ in the scheduling literature: a set N of n jobs is to be processed nonpreemptively on a single machine, which can process only one job at a time. Associated with each job j are a positive processing time p_j and a nonnegative weight w_j. A feasible job schedule must obey a partial order specified by an acyclic graph $G = (N, \mathcal{A})$. The objective is to find a feasible sequence (or *schedule*) of jobs which minimizes the weighted sum $\sum_{j\in N} w_j C_j$ of completion times.

We use a completion time formulation, review a few classes of facet defining inequalities. We also present new types of decomposition of the problem into smaller subproblems and their use inside a Branch-and-Cut algorithm, generalizing the decompositions known as Sydney's decompositions. We discuss fixing strategies, branching alternatives and cut generations and report results for problems with up to 120 jobs.

WE4-L-CM201

Using Restricted Simplicial Decomposition within Partial Linearization Methods

Marin Angel

Universidad Polytechnica de Madrid

Ricardo Garcia

Keywords: assignment model - large scale mathematical programming - partial linearization - restricted simplicial decomposition

The class of Partial Linearization methods may be shortly described as a primal method, where a search direction is obtained from a convex auxiliary submodel, which is defined by an approax of the original objective function through a first order approximation of an additive part of an equivalent reformulation. The direction defined by the solution of the described submodel is a descent direction with respect to the original objective. A line search is made with respect to this function in the previous direction.

Restricted Simplicial decomposition is a price decomposition designed for large-scale pseudoconvex problems with a set of linear constraints. The decomposition iterates by solving a linear submodel and a "small" nonlinear master model defined with the simplex constraints. The number of master variables is "restricted" to a given parameter.

The Restricted Simplicial strategy is extended to the Partial Linearization methodology. The submodel proposed by the Partial Linearization generates points of the feasible solution set, and the master model find the optimum within the convex hull of a subset of those points.

The convergence results are presented and the new method is applied to solve traffic assignment problems.

WE1-L-CM201

Solving Convex Models with Special Structure

Marin Angel

Universidad Polytechnica de Madrid

Salmeron Javier

Keywords: Kunh-tucker methodology - expansion capacity - large scale mathematical programming

A method for solving two particular convex models is presented. Each of these involve a convex objective function and bound constraints associated to disaggregated levels of the optimization variable. Although both models can be considered simple, they are very useful as submodels of other large size mathematical programming problems. In particular, the authors have found them after implementing Benders Decomposition or Lagrangean Relaxation-Decomposition applied to continuous or mixed integer multi-period expansion capacity problems.

These models appear in problems with uncertain variables, for instance, the demand. The constraint associated to meet it at the facility location and capacity acquisition problem may be treated adding a risk function associated to verify the constraint into the objective function and bounds at two levels of disaggregation of the decision variables.

Other possible adaptations of the proposed methodology are: maintenance operation planning or resource optimization for multi-activity; solving special cases of piece-wise linealization of convex functions; solving the transport model using a progressive equilibration algorithm when the market demand is uncertain., etc.

In all these cases the special structure of a convex model appear with a linear term on the objective function associated to the disaggregated optimization variable and a non linear convex term relative to a linear combination of those. The constraints are double bounds in relation with both types of disaggregation. The primal and dual solution is obtained taking the advantage of this structure using the Kunh-Tucker optimal conditions, leading to very good computational implementations.

FR2-G-IN11

Refinement Strategies in Stochastic Multistage Linear Programming

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Keywords: approximation algorithms - discretization - refinement scheme

Linear stochastic multistage programs are considered where uncertain data evolve according to a multidimensional discrete time stochastic process. These mathematical programs are solved with the barycentric approximation technique, which provides a discretication of the stochastic process. In the convex case an inner and outer approximation of the value functions is obtained that helps assess the accuracy of the solution.

In this talk I focus on how to improve the discretization of the stochastic process, taking into account nested optimizatin and integration of the dynamic, implicitely given value functions. The evolvement of the errors across the nodes of the scenario trees and the corresponding domains are analysed. Computational results will be presented illustrating the effort and accuracy with which practical problems are currently solved.

TH3-L-CM201

Exploring Sparse Simplex Algorithms on Distributed Memory Multiprocessor

Maros Istvan

Imperial College, Dept. of Computing

Hajian M. - Mitra Gautam

We undertake a computational analysis of the algorithmic components of the sparse simplex (SSX) method and consider the effect of alternative SSx solutions strategies. We then combine these alternative strategies within an asynchronous control structure of a parallel algorithm implemented on a distributed memory multiprocessor machine. Our experimental investigation sheds a new light on the structure of SSX and its adaption on a parallel platform.

TU1-I-CM120

The Dynamic Predicate Stashing Copy Problem and the Steiner Problem in Graphs

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University of Amsterdam

Keywords: Steiner problem in graphs - network design

The Dynamic Predicate Stashing Copy Problem (DPSCP) deals with managing an information-network consisting of customers and a server. The information changes over time. The server-computer of the network contains always perfectly updated information. This information is contained in a file. Client-computers receive this file from the server-computer (i.e. the file is stashed on their computer). A client-computer can contain information of a certain 'age'. The maximum time between updates, the so called 'predicate', assures the client that the information stashed on his computer is not older than he specifies. For a given time-period, the DPSCP consists of finding the minimum propagation cost of stashed copies subject to predicate restrictions imposed by the users. We transform the DPSCP to the Steiner Problem in Graphs. We discuss the implications of this transformation and give numerical results.

TU2-I-CM5

Building an Airline Schedule: where to fly and when

Marsten Roy

Cutting Edge Optimization

Keywords: airline scheduling

This paper will present work done for Delta Air Lines on the strategic questions of where to fly and when to fly. These decisions must be made in the context of projected (origin, destination) demand, the schedules of all competitors, and the available aircraft fleet. We have made a modest beginning at addressing this very challenging combinatorial optimization problem.

MO4-I-CM121

Alternate Parameter of Fractal Objects and its Use

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Turchina Valentina Andrejevna

Keywords: density - dimensions - fluctuations - fractal

It is known, that the most adequate modeling of many real objects and processes are possible with help of fractal functions and sets. In the theory of fractals one of main parameters describing fractal objects is fractal dimension and its versions (dimension of similarity, dimension of cluster, etc.). However, sensible use of these parameters for the analysis fractal objects in problems of optimization inconveni- ently, in particularly because of large volume of calculations. Therefore,the authors of this work offer alternative kind of parameter, enabling to characterize "density" of filling the fractal curve space.It has managed to establish by numerical calculations, that there is some dependence between received size of parameter and the scope fluctuation of fractal function. Besides, it is noticed that each fractal function has a determined spectrum of fluctuations, which in some approach also connected with this "density's dimension". On the basis of these data it is possible,with the help of the Voss's method for construction fractal curves and surfaces, to build a fractal "approximational polynomial". For this purpose on each interval of app- roximation it is necessary to replace in appropriate expression a cons- tant spectrum on necessary variable one and add "fluctuational"variable. At such approach , for increasing of the accuracy of approximation it would be enough to expand the fractal spectrum. Received fractal "poly- nomial" can be used in problems of the optimization.

TU2-G-IN11

Adaptive Stochastic Path Planning for Robots

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Keywords: adaptive control - stochastic optimization

In optimal path planning for robots, by offline computation a feasible reference trajectory $q_0(t)$, $t \geq t_0$, and an open loop control $u_0(t)$, $t \geq t_0$, is determined by means of an appropriate performance criterion (e.g. total run time, total energy consumption). By means of standard feedback control, deviations of the actual path from a reference path can be compensated. Since at later time instants $t_j > t_0$, $j = 1, 2, ...$, further informations on the parameters of the robot and its environment (task) are available, e.g. by identification procedures, improvements $q_j(t)$, $u_j(t)$, $t \geq t_j$, of the initial reference trajectory q_0 and the open loop control u_0, resp., can be determined again by stochastic optimal path planning for the remaining time interval $(t_j, t_f^{(j)})$, $j = 1, 2, ...$, and by using the informations available up to time t_j. The computation of the solutions q_j, u_j, $j = 1, 2, ...$, in real time is considered, and applications to simple robots are given.

FR2-A-IN2

Decomposing Matrices into Blocks

Martin Alexander

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Borndörfer Ralf - Ferreira Carlos E.

Keywords: cutting plane methods - integer programming - matrix decomposition

In this talk we investigate whether matrices arising from linear or integer programming problems can be decomposed into so-called bordered block diagonal form. Given some matrix A, we try to assign as many rows as possible to some number β of blocks of size κ such that no two rows assigned to different blocks intersect in a common column. Bordered block diagonal form is desirable because it can guide and speed up the solution process for linear and integer programming problems. We attack this matrix decomposition problem from a polyhedral point of view and develop a branch-and-cut algorithm. We present several new classes of valid and facet-defining inequalities, discuss separation algorithms and the success of primal heuristics. Our computational results show that various matrices from the LP- and MIP-libraries Netlib and Miplib can indeed be decomposed into bordered block diagonal form.

FR2-E-CO21

Solving Complementarity Problems by Means of a New Smooth Constrained Nonlinear Solver

Martínez José Mario

University of Campinas - Institute of Mathematics

Hobbs Benjamin

Keywords: box constraints - complementarity - convex constraints - global convergence - inexact Newton method - nonlinear systems

Given $F : R^n \to R^m$ and Ω a closed and convex set, the problem of finding $x \in R^n$ such that $x \in \Omega$ and $F(x) = 0$ is considered. For solving this problem an algorithm of Inexact-Newton type is defined. Global and local convergence proofs are presented. As a practical application, the Horizontal Nonlinear Complementarity Problem is introduced. It is shown that the Inexact-Newton algorithm can be applied to this problem. Numerical experiments are presented.

FR4-C-CO2

Characterization of R-evenly quasiconvex functions

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Universitat Autonoma de Barcelona

Keywords: duality - generalized conjugation - quasiconvex functions

A function defined on a locally convex space is called evenly quasiconvex if its level sets are intersections of families of open halfspaces. If, furthermore, the closures of these open halfspaces do not contain the origin then the function is called R-evenly quasiconvex. In rhis paper, R-evenly quasiconvex functions are characterized as those evenly-quasiconvex functions that satisfy a certain simple relation with their lower semicontinuous hulls.

TU4-I-CM120

A Sequential Approach for the Capacitated Minimum Spanning Tree Problem

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Gouveia Luis E. N.

We consider a hop-indexed flow model for the Capacitated Minimum Spanning Tree Problem (CMSTP) which is a generalization of a well known single-commodity flow model. The LP bound of the new formulation produces the best bounds for a set of tests (tests with the root in the corner) which have been characterized as hard by most of the available lower bounding schemes. The defficiency of the new formulation is the range of variation of the extra hop index which leads to storage problems when instances with 100 nodes or more are tried. We propose several levels of aggregation of the original formulation yielding a sequence of models with fewer variables than the original model and whose LP relaxation is weaker than the original formulation but still stronger than the single-commodity flow model. We suggest a sequential approach for the CMSTP where reduction tests aplied to more compact models are used to eliminate variables from the less compact models, making them more pratical to use from a computational point of view. Computational results from benchmark instances are given.

MO4-I-IN202

Duality Relations for Variational Inequalities with Applications to Network Flows

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DEPARTMENT OF MATHEMATICS, UNIVERSITY OF PISA

Castellani M. - Musse Jama J.

Some recent investigations have stressed the importance of extending the duality theory of constrained extrema to the field of Variational Inequalities (VI).

The VI models go beyond optimization and have shown to interpret very well real equilibria. One of the latest real problems which have been led to VI is that of equilibrium flows in a network. The advantage shown by VI models consists in not requiring the existence of a global (with respect to the network) functional (as lost-time,cost,utility,energy) whose minimum point would define the equilibrium. The Wardrop principle is an example of equilibrium stated as a Variational Inequality.

In the present lecture, a generalization of the well-known minimum cost network-flow problem, formulated as a Variational Inequality, will be considered. It will be shown that,by means of the classic results of the duality theory for constrained extremum problems, it is possible to relate to the Variational Inequality a dual problem, whose solutions can be interpreted in terms of potentials associated to the nodes and the arcs of the network.

TU3-U-IN10

The Base Station Location and the Channel Allocation Problems in Cellular Systems

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UNIVERSIDADE FEDERAL DE MINAS GERAIS, DEPARTAMENTO C. COMPUTAÇÃO

Floriani Lauro

Keywords: algorithms - channel allocation - location - optimization

In the near future, the demand for mobile phones, portable computers and personnal communication systems with a wireless network interface is experiencing very rapid growth. In cellular radio telephone service an urban service area is split into small areas that are called cells. A base station is installed for each cell and a set of frequencies must be allocated to meet its local demand. The growth of cellular usage during the last years has been almost exponential. In this context, the number of base station is increasing very fast and a better spatial frequency or channel allocation must be considered. The frequency spectrum is limited, but within noncontiguous cells, allocated frequencies can be reused.

There are different ways to focus the base station location problem. Depending on the main objectives to be reached, we can discuss at least three criteria: the total coverage, the maximal spatial channel utilization and the maximal number of channels per users. In all cases we are adopting an independent signal propagation model.

This paper explores the base station location and the channel allocation problems. We propose mixed integer programming models to explore the tradeoff between the cell area and channel availability. We focus on algorithms to optimize the total coverage of an urban service area and to achieve some quality of service requirements in the communication system.

We present a mathematical model with a set of coverage constraints. We ran some instances and the optmization package showed good performance for real data tests. This model provides flexibility to systems designers, exploring the cell overlapping and reducing the cell areas for more efficient spatial frequency allocation.

MO3-A-IN1

On the Finiteness of the Criss-Cross Method

Matsui Tomomi

UNIVERSITY OF TOKYO

Keywords: linear programming - pivoting algorithm

The criss-cross method is an extremely simple pivot algorithm for linear programming proposed by Terlaky and Wang. In this talk, we prove the finiteness of the criss-cross method by showing a certain binary number of bounded digits associated with each iteration increases monotonically. Our proof immediately suggests the possibility of relaxing the pivoting selection in the criss-cross method without sacrificing the finiteness.

TU3-A-IN1

An Algorithm for Generating All the Bases of Equality Systems

Matsui Yasuko

TOKYO METROPOLITAN UNIVERSITY

Matsui Tomomi

Keywords: basic solutions - enumeration - equarity system - matrix - pivot

In this talk, we propose an algorithm which generates all the bases of an equality system $Ax = b$. We assume that the matrix A is row full rank. Our algorithm generates all the basic solutions and the inverse matrices of corresponding bases in $\mathrm{O}(rn^2 + \beta r^2)$ time and $\mathrm{O}(rn)$ space where β is the number of bases, r is the rank of the given matrix A and n is the number of columns of A. The space requirement of our algorithm does not depend on the number of outputs. So, our algorithm belongs to the class of polynomial time delay enumeration algorithms in a strong sence.

In our algorithm, the time complexity to find an additional output does not depend on the number of columns of A. So, our algorithm has an advantage when the number of columns is sufficiently smaller than the number of rows of the given matrix.

TH2-W-CO15

Towards a Formalism for Algebraic Modeling Languages

Maturana Sergio V.

Catholic University of Chile

Modeling languages that resemble algebraic notation, yet can be processed by a computer program, have improved both the efficiency and reliability of the application of mathematical programming technology. Most of these modeling languages claim to be algebraic, since they resemble the algebraic notation used in textbooks. Although many algebraic modeling languages (AMLs) have been proposed —AMPL, GAMS, and LINGO, among others— none of them has formally defined what exactly is an AML. SML, on the other hand, is a modeling language based on Structured Modeling, which is a formalism based on discrete mathematics proposed by Geoffrion, to provide a foundation for computer-based modeling environments.

All modeling languages require a translator, which is a computer program that translates the high level modeling language representation, to the low level representation required by the solver. The lack of a formalism makes it more difficult to implement a translator for a modeling language. As part of an effort to facilitate the implementation of modeling language translators, a formalism for AMLs was developed to serve as the basis for a precise definition of a High-level Intermediate Representation for Algebraic Modeling languages, called HIRAM.

Although more research is needed in this area, the formalism we developed is simple, yet general enough, to represent an important class of AMLs. In particular, we concentrated our efforts on indexing structures which are by far the most complex part of modeling languages, but also where most of its representational power resides. For this we chose to use the basic notions of set theory to formalize the definition of index sets. The resulting formalism can represent the indexing structures of most AMLs, such as AMPL, GAMS, and LINGO, as well as some extensions that have been proposed. It also supports an important subset of SML.

FR3-A-IN2

A Boolean Penalty for Zero-One Global Optimization

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Maculan Nelson

Keywords: 0-1 global optimization - 0-1 nonlinear programming - combinatorial optimization - discrete penalty

We introduced a discrete penalty called Boolean Penalty for zero-one constrained global optimization (PGO-01). The Main importance of Boolean Penalty is the fact, that this one enable change the PGO-01 problem to compute the least root of the continue, real and nonicreasing function. Optimality condition, Boolean penalty algorithm and numerical results are showed.

TH2-G-IN11

Testing SLP Codes and Methods

Mayer Janos

IOR University of Zurich

Kall Peter

In the first part of the lecture we briefly discuss general aspects of testing stochastic linear programming (SLP) codes and methods. The role of uniform testing environments, working with test problem batteries and difficulties with drawing conclusions concerning solution methods will be considered.

The second part is devoted to an overview on the testing features of SLP-IOR, our model management system for SLP. The presentation will be concentrated on features involving test problem batteries. Besides working with test problem batteries consisting of SLP problems from the literature these features include a new version of GENSLP for randomly generating test problem batteries of two stage and multistage recourse problems as well as jointly chance constrained problems. A separate facility serves for generating batteries which consist of variants of a test problem, e.g. of a problem with a real-life background from the literature. The variants are generated by imposing random perturbations on selected parts of the data structure. The system includes facilities for manipulating whole test problem batteries. These include e.g. discretizing the probability distribution or choosing a normal distribution for each member of the battery. SLP-IOR supports performing and documenting comparative test runs with a test battery and several solvers.

In the third part we present comparative computational results obtained by utilizing SLP-IOR. Computational results involving several test problem batteries and SLP codes (solvers) will be presented, for the model classes mentioned above.

TU3-C-CO3

The Algorithms for the Lower-Semi-Continuous Almost Everywhere Locally Lipschitz Minimization Problems Without Derivatives

Mayergoiz Moysey Mike

Dynamic Resources, Inc.

Keywords: algorithmic problems

There will be proved :

1. The set of the measurable on every direction an almost everywhere locally Lipschitz defined on $\Re^n$ functions belongs to the set of the measurable an almost everywhere locally Lipschitz on the whole $\Re^n$ functions.

2. If a funvtion f is a measurable (by Lebesque) and an almost everywhere locally Lipschitz on the whole space $\Re^n$ then a is on an almost every direction an almost everywhere locally Lipschitz.

There will be proposed and established the most apropriate step-length for such optimization problems.

On the basis of the linear and quadratic interpolations in the multidimensional spaces, theory of the distributions the most appropriate choices of the directions will be proposed, established, and applied too.

WE3-C-CO122

The Correlation Between the Quasi-

Newton-Kantovich Methods for the Multiple Solutions of the Nonlinear Operator Equations and the Quadratic Convergence of Primal-dual Interior Point Degenerate Linear Programming Algorithm

Mayergoiz Moysey Mike

Dynamic Resources, Inc.

Keywords: algorithmic problems

There will be shown:

An arbitrary degenerate Linear Programming problem corresponds to the second multiplicity of the solutions of the mildly nonlinear problem with the point of view of the multiplicity of the solutions of the nonlinear operator equations.

There will be proved:

Each one-point iterative process with a superlinear and consequently, quadratic convergence has the property of an interiority with respect to a solid normal cone in a Banach space.

Finally, on the basis of the Schmidt resolution, spectral variation, F. Riesz's integral an easily realizable modification of the quasi-Newton-Kantarovich methods which has a quadratic convergence for an arbitrary degenerate Linear Programming problem will be presented and established.

TH3-C-CO122

The Necessary Conditions and Algorithms for the Multiextremal Problems

Mayergoiz Moysey Mike

Dynamic Resources, Inc.

Keywords: algorithmic problems

On the basis of the homology, homotopy, fibering, and complex projective varieties the nonlocal necessary conditions and algorithms for the proper and improper multiextremal problems will be presented, established, and developed.

TH3-I-CM121

Logical Analysis of Data for Multi-Class Learning

Mayoraz Eddy

IDIAP

Moreira Miguel

Logical Analysis of Data (LAD in short) is a new methodology for extracting knowledge from data. Lately, it has been proved to be very efficient for the induction of classification rules from samples and it has been compared favorably with the most efficient learning methods existing in statistics, neural networks and machine learning. However, just as a few other techniques (Bayesian classifiers, single perceptron, etc), LAD has been specifically designed to handle classification problems involving two classes, while many real life applications are multi-class (set of diseases, 10-digits, 26-characters, 61-phonemes, etc).

Several methods are proposed in the literature for the decomposition of a multi-partition into a series of bi-partitions so that a learning method handling only bi-partitions can be used to tackle with more general problems. The *one-per-class* and the *pairwise-coupling* decompositions are the most common ones and a new method based on *error-correcting codes* has been recently proposed. An improvement of the latter has been lately suggested by the authors in a general context (*i.e.* independently of the learning method used) and enhanced recombination methods have been elaborated. Based on this expertise, we extend LAD to handle multi-partition learning problems. The *pattern*—building block of LAD—is generalized and the smallest patterns are used to guide the decomposition. Different recombination methods are also investigated.

Two opposite approaches are emerging : a *coarse-grained* and a *fine-grained* decomposition. While the first one suits problems with large databases (thousands of data) and will produce robust but large theories, the second is restricted to small databases (up to several hundreds of data) and it will lead to more compact theories with the advantage of being able to disclose multi-modal classes.

MO3-G-IN11

Stochastic Dynamic Programming and Behavioral Ecology Problems

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Chita Institute of Natural Resources

Perrin Nicolas

Keywords: Bellman equation - dynamic programming

We will consider some applications of stochastic dynamic programming in behavioral ecology problems such as sequential mate choice, optimal choice of the place of foraging, ESS approach to optimal foraging and others.

Sequential choice poses a series of constraints on the mating and foraging process in terms of time, energy and risks involved in the search. We provide here an analytical model of adaptive search and information updating based on Bellman equation analyses. We treat the problem with or without time-horizon, and with or without searching costs.

MO3-P-IN201

Production Planning and Scheduling with Flexible Resources

Mazzola Joseph B.

Duke University

Daniels Richard L.

Keywords: flexibile resources - production planning - resource constrained - scheduling

Resource flexibility refers to production environments in which one or more renewable resources, each available in limited supply, can be dynamically reallocated among work tasks to improve production effectiveness and efficiency. Labor, when appropriately cross-trained to handle a variety of tasks on the shop floor, constitutes one example of a flexible resource. Recent research has demonstrated that substantial improvements in manufacturing system performance can result from scheduling with resource flexibility. We review developments in flexible-resource scheduling in both serial machine and parallel machine scheduling environments. We also discuss recent advances in flexible-resource scheduling, including a hierarchical framework for production planning and scheduling with flexible resources which allows for the production-planning function to be integrated across the strategic, tactical, and operational decision levels. The hierarchical framework is also useful for establishing a research agenda spanning both theoretical and applied research.

WE1-O-IN202

On the Exact Asymptotics of the Fast Teller Queue

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U. Ottawa, Department of Mathematics and Statistics

Beck Benoit - Dabrowski André

Keywords: change of measure - fast teller queue - rare events

On the exact asymptotics of the fast teller queue.

The asymptotics of the queue size of a fast teller system with c hetrogeneous servers was studied by Sadowsky and Szpankowski. Here we make an extension by allowing s independent sources of customers. Each source is modeled by a renewal point process with batch arrivals and we do not assume the sources are necessarily identically distributed. For simplicity we shall only discuss a time-slotted system. We first find a harmonic function h for a associated work load process. The h-transform of the fast teller system gives an overloaded fast teller system.

We can now apply the theory in McDonald (1996) to give the tail of the distribution of the queue in steady state plus the asymptotics of the mean time between large deviations of the queue size. The constants in the expressions for the exact asymptotics can rapidly be obtained by simulating the overloaded fast teller system. We apply these results to an ATM buffer which receives cells from many bursty sources and is emptied by several parallel servers.

FR4-A-IN2

Sketches on Reformulating Linear Integer Programs and the Fibonacci Sequence

McDonnell Francis James

Loughborough University

TH1-I-CM200

A Tabu Search Perturbation Procedures for the Fleet Mix Problem with Time Windows

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Université de Versailles- Laboratoire PRISM.

Poujade Stephane - Lemarie Bernard - Roucairol Catherine

Keywords: fleet mix - global moves - local moves - metaheuristics - time windows - vehicle routing

The problem we deal with is to organize mail collecting at several customer sites which are scattered around an urban area. It involves the design of a set of minimum cost routes, originating and terminating at a central depot, for a heterogenous fleet of vehicles which services those customer sites with known demands.

A tabu search approach including a large variety of moves is developped for determining the most economical vehicle fleet mix (cheapest cost incorporating routing and fixed vehicle costs) without violating constraints such as time restrictions and capacity.

Our work is focused on perturbation procedures applied within the routes in order to improve the utilisation of the all types of vehicles in the fleet and to reduce as much as possible the vehicles'variable costs which are considerably higher than the fixed ones.

The best known heuristics up to now use moves that exchange customers between routes. We obviously don't need to call into question the efficiency of these heuristics, but we note that they favour the optimisation of one route only, hence a local exploration and not the solutions far from the starting solution. We call them Local moves. In order to widen the exploration of the solutions, we propose new moves that change deeply the structure of the solution. They are called Global moves.

This approach has been tested on a practical problem occuring in mail collecting.

TU4-N-CO15

Application of IMPS Tools to ATM Network Planning

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Keywords: chance-constrained programming - modeling uncertainty - stochastic traffic

The planning of multimedia networks involves problems with uncertainties of different natures: one is related to the stochasticity of traffic sources and the other concerns modelling uncertainty reflecting technical implementations and management strategies translated into different network model formulations. The rapid development of ATM switches and the corporate competitive interests of telecommunication companies in introducing ATM networks make modelling uncertainty a significant problem for capital investment decisions, whereas the correct representations of multimedia stochastic traffic flows are challenging problems for performance analysis. To handle both kinds of uncertainty we have developed a decision support system consisting of the set of network models and a set of procedures for capacity allocation with random demands. The principal model involved is the Path and Capacity Allocation (PCA) model. We used chanced-constrained programming to account for traffic stochasticity. This formulation permits us to separate the probabilistic calculations from deterministic network flow modelling. We consider a set of 18 model variants for analysis of the network. The first system prototype consists of both existing and specially designed components within MAPINFO and interfaces with MODLER for the design of BT networks. A new prototype is also being implemented within the AIMMS modelling system, resulting in flexible tool for ATM network design.

TU2-L-CM201

Parallel Search Algorithms for Constraint Satisfaction Problems

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Habbas Zineb - Herrmann Francine - Singer Daniel

Keywords: constraint satisfaction - intelligent backtrack - load balancing - parallel computing - parallel search algorithm

Constraints Satisfaction Problem (CSP) is a well studied example of the NP-complete family. Constraint Satisfaction Problems (CSP) are widely used to express and to solve a great class of problems in Artificial Intelligence, CAD Systems, Graph Coloring ...etc. CSPs have been defined by U. Montanari as a 3-tuple $\mathcal{P} = (X, D, C)$. Here, X is a set of variables where each X_i can be valued by one of the value of D_i which is called domain of variable X_i. In addition, we have a set of binary constraints C where the constraint $C_{i,j}$ is a relation between X_i and X_j and if $C_{i,j}$ is null there is no constraint acting from X_i to X_j. Solving a CSP means finding an assignment for each variable $X_i \in X$ that satisfies all constraints in C. There are a number of variants of this problem such as existence of a solution, finding a solution, finding all the solutions or counting the number of solutions. Finding a consistent assignment for a CSP has been widely studied, but most of the proposed algorithms are improvements of the simple enumerative search: backtracking algorithm. The main drawback of the backtrack algorithm is its computational cost. Among many, Prosser proposed to combine different search behaviours, in order to extract an intelligent hybrid backtrack search algorithms family. Our purpose is to follow this approach in order to present an explicit formulation for a generic parallel search algorithm with message passing, as a general paradigm, based on typical parallel behaviours, such as load balancing policy, giving rise to parallel hybrids. From this paradigm, we exhibit parallel search algorithms such as parallel backtracking, parallel backjumping and parallel forward checking, we experiment on a Connection Machine with 128 processors. We compar their performances in the so called mushy region i.e. the region where hard problems are harder. Our performance parameters are both the CPU time and the number of constraint checking. Our first results are the following ones: For parallel classical backtracking, the most significant observation is that the speedup obtained with dynamic load balancing is twice more than the best speedup obtained with static load balancing. In addition the speedup in number of constraint checking is superlinear. Hence, our perspective is to refine our study by using other intelligent backtrack and by increasing the problem size.

TH1-C-CO3

On a New Vector Norm for Optimzation Problems

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CERFACS

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Keywords: curve fitting - multicriteria optimization - nonlinear programming - vector norm

A new family of vector norms $\|f\|_\epsilon$, where $\epsilon \in [0,1]$ is a parameter and $f \in R^m$, was suggested in 1988 by O. Burdakov. They don't belong to the set of l_p norms, that are traditionally used in optimization. Nevertheless, l_2 and l_∞ norms are special cases of the family corresponding to the parameter values $\epsilon = 1$ and $\epsilon = 0$, respectively. For $\epsilon \in (0,1)$, the function $\|f\|_\epsilon^2$ has some advantages over the functions $\|f\|_2^2$ and $\|f\|_\infty$, when applied for solving nonlinear inverse problems. This function is continuously differentiable over f (in contrast to $\|f\|_\infty$) and does not depend on all components f_i, but on some subset of them (in contrast to $\|f\|_2^2$). Thus, in order to compute the gradient $\nabla_x \|f(x)\|_\epsilon^2$, where the mapping $f: R^n \to R^m$ is supposed to be differentiable, it is not necessary to compute gradients $\nabla_x f_i(x)$ for all i, $1 \leq i \leq m$, but only for a subset of these indices. This means, that the optimization solvers, when applied to minimization of $\|f(x)\|_\epsilon^2$ over x, require less computation of derivatives than in the case of $\|f(x)\|_2^2$. We present some new results concerning the new norms and consider their applications for solving nonlinear inverse problems as well as nonlinear programming, multicriteria optimization and other optimization problems.

WE3-C-CO3

Strategic Gaming Analysis for Electric Power Networks: An MPEC Approach

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Keywords: electric power - equilibrium constraints - gaming application

Strategic Gaming Analysis for Electric Power Network : An MPEC Approach

We will present a strategic gaming model in an oligopolistic market economy consisting of several dominant firms in a complex electric power network. Each firm controls a certain number of power plants and its goal is to maximize profits via the submission of bids in its supply function while anticipating its rivals' actions. The single-firm model is formulated as a Mathematical Program with Equilibrium Constraints (MPECs) with a parameter-dependent spatial price equilibrium problem as the inner problem along with Kirchoff's law to describe the characteristics of AC power systems. A penalty interior point algorithm is used to compute a local optimal solution of the MPEC. Numerical examples based on realistic networks will be presented. Some preliminary results will be discussed related to the multifirm problem, which is a Nash game with each player solving an MPEC of the single-firm type.

TU1-C-CO3

Large-Scale Graph Partition Assignment Problems

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Donaldson William - Christou Ioannis

Keywords: genetic algorithms - graph partitioning - large scale optimization - nonlinear assignment problems

We present an efficient method for the problem of determining optimal balanced assignments of processors to tasks associated with the cells of a grid graph. The total perimeter of the corresponding partition, which corresponds to the amount of interprocessor communication associated with the task assignments, is to be minimized subject to load balancing equi-partition constraints for the subdomains. The most natural and compact algebraic formulation of this problem is as a quadratic assignment problem, but with this approach the number of variables for standard test problems can easily reach one billion. Our method is based upon decomposition techniques that utilize genetic algorithms and knapsack techniques to coordinate optimal or near-optimal solutions of subproblems (having appropriately modified objective functions) that correspond to the determination of good assignments of individual processors to grid cells not yet assigned to other processors. We prove under some mild assumptions, that as the problem size grows large in all parameters, the relative error bound associated with certain feasible solutions generated in this manner must approach zero. We also present computational results from a high-level parallel genetic algorithm that utilizes this method, and show that this algorithm substantially outperforms standard graph partitioning methods on grid graphs with as many as 10^8 cells partitioned into 10^5 subdomains.

FR3-U-IN1

Decomposition and Coordination for Large Systems Design Optimization

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Keywords: coordination - decomposition - design optimization - systems design

Design of large complex systems may require decomposition of the original design problem and coordinated solution of the resulting subproblems. Evaluation of system performance and sensitivities typically entails the use of multiple stand-alone software tools conceived for individual subsystem simulation or analysis. All-in-one synthesis approaches may not be appropriate given the dissimilarities among subsystems model characteristics and analysis requirements and the large dimensionality of the problem. We present a system design methodology that uses mathematical optimization with formal model-based decomposition and coordination strategies. Moreover, we describe how partitioned model structure may affect the solution coordination and even the optimization problem formulation. The methodology enables cooperation among design agents (humans or computers) that may be physically separated or operating under diverse environments; multiple levels of model abstraction and fidelity; and reconfigurability of the design problem.

MO4-B-CO10

On The Behavior of The Partial Inverse Method

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Keywords: partial inverse method - proximal point algorithm

The aim of this paper is to show that the proximal point algorithm applied to the partial inverse T_A of the subdifferential of a closed convex proper function f, with respect to a subspace A, enjoys nice convergence properties. As soon as a zero of T_A exists, it is well known that this so called Partial Inverse Method (PIM in short) provides a minimizer of f on A as well as a dual solution, i.e. a minimizer of the conjugate of f on $A^{\perp}$. When the primal or the dual problem is unfeasible, we introduce a concept of fair solution and we give conditions, which guarantee that some sequences induced by PIM converge to such fair solutions. These conditions are mainly based on the position of the least norm element of the closure of the range of T_A. Several examples illustrate these convergence properties. We also apply the results to the problem of finding a point in an intersection of several closed convex sets.

TU2-R-IN203

Enumerating Mixed-Cell Configuration

Michiels Tom

K.U.Leuven

Verschelde Jan

By means of the Cayley trick the problem of enumerating all regular fine-mixed subdivisions is reduced to enumerating all regular triangulations. The set of all regular triangulations is well understood thanks to the bijection with the vertices of the secondary polytope. However, because we are only interested in the configurations of mixed cells in a mixed subdivision, we want to avoid dealing with other cells. We propose a operator derived from the bistellar flip for regular triangulations to modify a mixed-cell configuration.

TH4-H-CO22

Comparison of Some Reference Point-based Methods for Multiobjective Optimization

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Makela Marko M.

Keywords: decision support systems - multicriteria optimization - nonconvex optimization - nondifferentiable optimization - world wide web

Reference points are an efficient way of realizing interactive decision making when solving multiobjective optimization problems. They represent a natural way of thinking for the decision maker where desirable levels for each objective function are specified. We describe some reference point-based multiobjective optimization methods capable of solving nonconvex and nondifferentiable problems. The methods are compared both theoretically and numerically. In spite of a common conceptual background the methods differ in handling the information specified by the decision maker. The numerical comparison criteria are computational efficiency and usage controllability.

We also introduce and compare implementations in the Internet where the World-Wide Web provides a graphical user interface. This new way of realizing an interactive decision support system enables flexible and efficient solution of even complicated problems. Distributed interface with graphical visualization possibilities offers flexibility and support for the decision maker. On the other hand, centralized computing means efficient computing regardless of the computer capacity of the user.

The different methods and implementations share a bundle-based nondifferentiable optimizer. This underlying solver

makes it possible to solve a wide range of even nonsmooth and nonconvex problems. A common solver is also important in a reliable comparison of the performance of different multi-objective optimization algorithms.

TH2-B-CO10

$\mathcal{VU}$-Decomposition Derivatives for Convex Max-Functions. Part II

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Sagastizábal Claudia

Keywords: $\mathcal{U}$-Lagrangian - convex optimization - eigenvalue optimization - max-functions - second order derivatives

This talk is a follow-up of *$\mathcal{VU}$-decomposition derivatives for convex max-functions. Part I*, where only the finite case was considered. Here we address a more general problem, namely

$$\min_{x \in \Re^N} f(x)$$

with $f(x) = \max\{f_y(x) : y \in Y$, a nonempty compact subset of $\Re^M$.

This setting includes many interesting problems, such as ones coming from eigenvalue optimization and from dualization of structured problems.

In Part I we showed how the V-U-objects can be used to design conceptual superlinearly convergent algorithms for minimizing f. Here we state general conditions for the existence of a U-Hessian, as well as the relation between the U-Hessian and the Hessian of the ordinary Lagrangian. These conditions are weaker than the strong second order sufficient conditions for optimality used in Part I.

Also, we give some examples to illustrate our approach and the generality of our assumptions. Finally, we sketch on-going work on how to approximate V, U, and related quantities in order to develop practical algorithms.

FR3-H-CO22

Optimality and Credibility in Stackelberg Games with Reversed Information Structures

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Catholic University in Milan

Pieri G.

A static Stackelberg game with reversed information structure appears as follows:

G_L and G_F are two strategy-spaces corresponding to the two players L (the leader) and F (the follower). U_L and U_F are two decision-spaces respectively.

$J_L : G_L \times G_F \to \Re$ and $J_F : G_L \times G_F \to \Re$ are the two cost-functionals. G_L is the set of all mappings from U_F to U_L and $G_F = U_F$; in this way, F acts before L and L selects his choice after F, knowing the strategy of F, so that the choice of L is a function of the choice of F.

In this context are well-known optimality conditions to have an equilibrium point for the Stackelberg game based on the introduction of the "inducible region", using incentive (or threat-strategies); for instance see B. Tolwinsky 1983.

In 1984 Lhu, Zheng and Ho gave an idea of "credibility" of a strategy based on the verification of some optimality principles under very restrictive hypotheses, so that a leader's strategy is fully credible only for a restricted class of games.

In this paper we give a weaker definition of credibility for the dynamic case that corresponds, in this paper, to the repeated static game in n time-intervals, with a cost-functional which is the sum of all costs of the single games and give conditions to have an equilibrium.

Examples and applications to financial problems are given.

TU1-I-CM5

New Integer Formulations of Routing Problems Based on a Two-Commodity Network Flow Approach

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Baldacci Roberto - Hadjiconstantinou Eleni

Keywords: combinatorial optimization - vehicle routing

We describe a two-commodity network flow approach to derive new integer programming formulations for routing problems like the Capacitated Vehicle Routing Problem (CVRP), the multi-depot CVRP, the CVRP with Backhauls and the Capacitated Arc Routing (CARP). These formulations are used to derive new lower bounds based on lagrangean relaxation and on linear relaxation with the addition of valid inequalities. Preliminary computational results indicate the effectiveness of the proposed methods.

WE4-P-IN201

An heuristic procedure for the Multi-Mode Resource Constrained Project Scheduling Problem based on Benders' decomposition

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Maniezzo Vittorio

Keywords: Benders decomposition - combinatorial optimization - heuristics - project scheduling

We consider a project of n activities subject to precedence and resource constraints, where each activity must be executed in one out of a set of possible modes. The mode defines the duration and the resource usage per period of both renewable and non renewable resources. The Multi-Mode Resource Constrained Project Scheduling Problem (MRCPSP) objective is to schedule each activity in one of its modes and to find the starting time of each activity in order to minimize the makespan, satisfying precedence and resource constraints. We describe a new 0-1 integer programming formulation that is used to derive new lower bounds for the MRCPSP. A new heuristic procedure based on Benders decomposition is presented. The master problem corresponds to the assignment of one mode to each activity, while the subproblem is a Single Mode Resource Constrained Project Scheduling Problem (RCPSP). At each iteration both the master and the subproblem are solved heuristically; furthermore, we compute a lower bound on the RCPSP, that provides a valid Benders' cut for the master problem. Computational results on three sets of benchmark problems show that the new heuristic procedure is competitive with the best heuristics presented in the literature.

FR3-L-CM201

Integer Stochastic Programming (ISP) for Planning and Scheduling: Parallel Computational Solution

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Mitra Gautam - Messina Enza - Lucas Cormac Anthony

Two stage stochastic programming problems become computationally intractable when the decision variables are restricted to discrete values. Applying Benders decomposition approach to small but real life planning-scheduling, we have been able to achieve good computational solutions for two stage ISPs with discrete variables occurring in the first stage problem only.

WE3-D-CO124

A Long Step Cutting Plane Algorithm That Uses the Volumetric Barrier

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Keywords: interior point methods - long step - volumetric barrier

A cutting plane method for linear/convex programming is described. It is based on the volumetric barrier, introduced by Vaidya. The algorithm is a long step one, and has a complexity of $O(n^{1.5}L)$ Newton steps. This is better than the $O(n\sqrt{m}L)$ complexity of non-cutting plane long step methods based on the volumetric barrier, but it is however worse than Vaidya's original $O(nL)$ result (which is not a long step algorithm). Major features of our algorithm are that when adding cuts we add them right through the current point, and when seeking progress in the objective, the duality gap is reduced by half (not provably true for Vaidya's original algorithm). Further, we generate primal as well as dual iterates, making this applicable in the column generation context as well. Vaidya's algorithm has been used as a subroutine to obtain the best complexity for several combinatorial optimization problems – e.g, the Held-Karp lower bound for the Traveling Salesperson Problem. While our complexity result is weaker, this long step cutting plane algorithm is likely to be computationally more promising on such combinatorial optimization problems with an exponential number of constraints. We also discuss a multiple cuts version — where upto $p \leq n$ 'selectively orthonormalized' cuts are added through the current point. This has a complexity of $O(n^{1.5}Lp \log p)$ quasi Newton steps.

TH1-D-CO124

Solving Integer Programming Problems with an Interior Point Cutting Plane Algorithm

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Rensselaer Polytechnic Institute

We describe an interior point cutting plane algorithm for solving integer programming problems. We discuss experience on two classes of problems. For finding the ground state of an Ising spin glass, the algorithm is able to solve larger instances than previously reported. For linear ordering problems, the interior point code is used in combination with a simplex cutting plane algorithm, resulting in a dramatic speedup over the pure simplex cutting plane code. Computational results are given for randomly generated problems.

TH2-L-CM201

A Distributed Processing Algorithm for Solving Integer Programs

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Brunel University

Hajian M. - Ellison E.F.D.

The sequential branch and bound algorithm is the most established method for solving mixed integer and discrete programming problems. It is based on the tree search of the possible subproblems of the original problem. There are two goals in carrying out a tree search, namely, (i) finding a good and ultimately the best integer solution, and (ii) to prove that the best solution has been found or no integer feasible solution exists. We call these the state 1 and 2 of tree search. In general it is extremely difficult to choose the ideal search straegy in stage 1 or stage 2 for a given integer = programming (IP) problem. On the other hand by investigating a number of different strategies (and hence different search trees) a good solution can be reached quickly in respect of many practical IP problems. Starting from this observation a parallel branch and bound algorithm has been designed which exploits this two stage approach.

FR4-L-CM201

Constraint Classification, Preprocessing and a Branch and Relax Approach to solving Mixed Integer Programming Models

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Brunel University

Kulanathan Kulajaran - Ellison Frank - Nygreen Bjørn

Preprocessing in Integer Programming (IP) is acknowledged to be an analytical as well as logical approach towards resolving many practical IP problems. The effectiveness of IP preprocessing depends heavily on how it exploits the structure of a single or a group of constraints to which it is applied. Identification of certain well known constraint classes also helps to generate specialized restrictions which are known to speed up the solution process. In this paper we set out a comprehensive classification of constraints found in a wide range of practical Mixed Integer Programming (MIP) problems. We describe a set of procedures which identify their structures and carry out preliminary preprocessing of the MIP constraints at the same time. To take advantage of the preprocessing results we have extended the branch and bound (b&b) procedure such that in addition to imposing bounds on variables we can also relax constraints. Experimental results for the well known set of MIPLIB models as well as other industrial MIP models are given. These results summarize the structure of the models and also illustrate the effectiveness of preprocessing and postprocessing in speeding up the solution process within a branch-fix

and -relax paradigm for the tree search.

WE1-K-CM106

Approximation Algorithms for Packing Problems with Orthogonal Rotations

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Keywords: approximation algorithms - asymptotic performance - packing problems

We consider three packing problems, where orthogonal rotations are allowed. We present approximation algorithms for these problems and analyse their asymptotic performance ratio.

The first problem concerns *on-line packing of rectangles into squares*. The objective is to minimize the number of squares needed.

The second problem is a *special case of the three-dimensional on-line strip-packing problem*. This problem consists in packing a list of boxes into a box with square bottom and unbounded height. The packing must be orthogonal and 90° rotations are only allowed around the z-axis (that is, the boxes may be rotated but may not be turned upside down). The objective is to minimize the height of the packing.

The third problem concerns the *container packing problem*. This problem consists in packing a list of boxes into a minimum number of boxes of the same type (containers). Rotations of 90° are allowed around any of the axes.

For the first two problems we present algorithms, both with an asymptotic performance ratio close to 2.6875. For the third problem, and a special case of it where all boxes are cubes, we present algorithms with an asymptotic performance ratio close to 4.883 and 3.466, respectively.

TU4-D-CO124

Global and Polynomial-Time Convergence of an Infeasible-Interior-Point Algorithm Using Inexact Computation

Mizuno Shinji

The Institute of Statistical Mathematics

Jarre Florian

In this paper, we propose an infeasible-interior-point algorithm for solving a primal-dual linear programming problem. The algorithm uses inexact computations for solving a linear system of equations at each iteration. Under a very mild assumption on the inexactness we show that the algorithm finds an approximate solution of the linear program or detects infeasibility of the program. The assumption on the inexact computation is satisfied if the approximation to the solution of the linear system is just a little bit "better" than the trivial approximation 0. We also give a sufficient condition to achieve polynomial-time convergence of the algorithm.

WE2-D-CO124

A Modified Layered-Step Interior-Point Algorithm for Linear Programming

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The Institute of Statistical Mathematics

Megiddo Nimrod - Tsuchiya Takashi

Keywords: crossover events - layered-step interior-point method - linear programming - path of centers

The layered-step interior-point algorithm was introduced by Vavasis and Ye. The algorithm accelerates the path following interior-point algorithm and its arithmetic complexity depends only on the coefficient matrix A. The main drawback of the algorithm is the use of an unknown big constant $\bar{\chi}_A$ in computing the search direction and to initiate the algorithm. We propose a modified layered-step interior-point algorithm which does not use the big constant in computing the search direction. The constant is required only for initialization when an well-centered feasible solution is not available, and it is not required if an upper bound on the norm of a primal-dual optimal solution is known in advance. The complexity of the simplified algorithm is the same as that of Vavasis and Ye.

FR3-U-IN10

Mixed-Integer Programming Fleet Management Models and Algorithms for an Oil Tanker Routing and Scheduling Problem

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Kuwait University

Sherali Hanif D.

This paper explores models and algorithms for routing and scheduling ships in a maritime transportation system. The principal thrust of this research effort is focused at the Kuwait Petroleum Corporation (KPC) Problem. This problem is of great economic significance to the State of Kuwait, whose economy has been traditionally dominated to a large extent by the oil sector. Any enhancement in the existing ad-hoc scheduling procedure has the potential for significant savings. A mixed-integer programming model for the KPC problem is constructed in this paper. The resulting mathematical formulation is rather complex to solvce due to (1) the overwhelming problem size for a typical demand contract scenario, and (2) the integrality conditions. Accordingly, attempting to solve this formulation for a typical demand contract scenario without any aggregation and partitioning schemes is theoratically complex and computationnally intractable. Motivated by the complexity of the above model, an aggregate model that retains the principal features of the KPC problem is formulated. This model is computationnally far more tractable than the initial model, and consequently it is utilized to construct a good quality heuristic solution for the KPC problem. The initial formulation is solved using CPLEX 4.0 MIP capabilities for a number of relatively small-sized test cases, and pertinent results and computational difficulties are reported. The aggregate formulation is solved using CPLEX 4.0 MIP in concert with specialized rolling horizon solution algorithms and related results are reported. The rolling horizon solution algorithms enabled us to enhance solutions obtained by directly solving the aggregate formulation and to handle practical sized problems that could not be handled by directly solving the aggregate model. An adhoc routing procedure that is intended to simulate the current KPC scheduling practice is discussed in this paper. It was shown that results obtained via using the rolling horizon algorithms are at least as good as, and of-

ten substantially better than, results obtained via the adhoc procedure.

WE3-E-CO11

Complementary Pivoting Methods for a Class of Non-Zero Sum Stochastic Game Problems

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Keywords: Nash equilibrium - complementary pivoting - stochastic game

It is well known that complementary pivoting methods originated from the attempts to compute a Nash equilibrium pair of pay-offs and a pair of corresponding mixed strategies for a non-zero sum two player game (also called a bimatrix game). In this talk we discuss the possibility of using these algorithms to compute Nash equilibrium points and corresponding strategies in certain non-zero sum stochastic games. The major step is to obtain a complementarity formulation to which a complementary pivoting method can be sucessfully applied.

TU1-P-IN201

Approximation Algorithms for Scheduling Problems with Communication Delays

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Schäffter Markus - Schulz Andreas S.

Keywords: approximation algorithms - communication delays - scheduling

In the last few years, multi-processor scheduling with interprocessor communication delays has received increasing attention. This is due to the more realistic constraints in modeling parallel processor systems.

We develop approximation algorithms for minimizing the makespan and the weighted sum of completion times for "small" communication delays, arbitrary precedence constraints, and parallel identical processors.

The common underlying idea of our algorithms is to compute first a schedule by LP-relaxation and rounding that regards all constraints except for the processor restrictions. This schedule is then used to construct a provable good feasible schedule for a limited number of processors by a suitable generalization of Graham's list scheduling rule. We thus obtain a simple $\frac{7}{3}$-approximation algorithm for the makespan, and a 6.14232-approximation algorithm for the weighted sum of completion times.

Complementing these results, we obtain new polynomial-time exact algorithms and NP-completeness results on the class of series-parallel precedence constraints.

MO3-G-IN11

A Probabilistic Approach to Stochastic PERT

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In stochastic PERT network representing a project, each arc stands for activity and each node indicates the completion of all activities leading to that node. With each arc is associated a random variable which designates the duration of the activity represented by that arc. The presence of random variables reflects well the inherent random nature of stochastic PERT, however, makes it very difficult to solve. By this reason, the existing methods for solving stochastic PERT problems are heavily based on "predeterminization process", i.e. deterministic quantities are first introduced to substitute the random variables representing activity durations, and some deterministic techniques are used to solve the problem. The aftermath of it is an overdeterminization of stochastic PERT. We present an approach to treat the completion time of stochastic PERT that avoids immediate determinization of durations of activities. We develop bounds and approximations to the probability distribution function of the random completion time. Numerical results on bounds will be presented. Also, we give an illustrative numerical example.

WE3-D-CO123

A Newton Potential Reduction Method for Constrained Equation and its Applications to Nonlinear Semidefinite Programming.

Monteiro Renato D. C.

Georgia Tech

Pang Jong-Shi

Keywords: complementarity problems - constrained equation - interior point methods - nonlinear semidefinite programming - potential reduction - primal-dual

This paper presents a general Newton potential reduction method for solving a constrained system of nonlinear equations. A main convergence result for the method is established. Specializations of the method to semidefinite nonlinear programs and monotone complementarity problems in symmetric matrices are discussed.

FR1-D-CO123

Polynomial Convergence of a New Family of Primal-Dual Algorithms for Semidefinite Programming

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Georgia Tech

Tsuchiya Takashi

Keywords: path following - polynomial convergence - primal-dual - semidefinite programming

This paper establishes the polynomial convergence of a new class of (feasible) primal-dual interior-point path following algorithms for semidefinite programming (SDP) whose search directions are obtained by applying Newton method to the symmetric central path equation

$$(P^T XP)^{1/2}(P^{-1}SP^{-T})(P^T XP)^{1/2} - \mu I = 0,$$

where P is a nonsingular matrix. Specifically, we show that the short-step path following algorithm based on the Frobenius norm neighborhood and the semilong-step path following algorithm based on the operator 2-norm neighborhood have

$O(\sqrt{n}L)$ and $O(nL)$ iteration-complexity bounds, respectively. When $P = I$, this yields the first polynomially convergent semilong-step algorithm based on a pure Newton direction. Restricting the scaling matrix P at each iteration to a certain subset of nonsingular matrices, we are able to establish an $O(n^{3/2}L)$ iteration-complexity for the long-step path following method. The resulting subclass of search directions contains both the Nesterov-Todd direction and the Helmberg-Rendl-Vanderbei-Wolkowicz/Kojima-Shindoh-Hara/Monteiro direction.

WE4-C-CO3

Copilot - Successive Linear Programming with Trust Regions for Constrained Optimization

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Keywords: nonlinear programming - successive linear programming - trust region

COPILOT (Constrained Optimization Programmed Iteratively, Linearly, Over Trust-regions) is software that solves general constrained nonlinear optimization problems using successive linear programming. It uses a trust region approach to form a series of feasible linear programs and lets any LP solver optimize those programs. It is designed in an object-oriented style to permit the integration of many kinds of problem specifications and many kinds of LP solvers. With only linear approximations to objective functions available, the trust region shape is a critical factor that determines how fast the method converges, because linear optima are likely to be found at vertices or along edges of the trust region. COPILOT chooses trust regions that have vertices in conjugate directions. COPILOT has been tested on problems from the CUTE benchmark set and on several MDO problems, and the talk includes a report of results of these tests.

TH4-E-CO21

Automatic Preconditioning by Quasi-Newton Updating

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ITAM

Nocedal Jorge

When the conjugate gradient method is used to solve symmetric and positive definite systems $Ax = b$, the information generated during the iteration can be used to define a limited memory quasi Newton matrix. In this talk we will show that this matrix can be a good preconditioner for solving systems of equations $Ax = b$, with multiple right hand side vectors, or for solving a series of slowly varying systems $A_k x = b_k$. The new automatic preconditioner is well suited for the case when the matrix A is not known explicitly, but only products of A times vectors can be computed. Numerical tests are reported on matrices arising in some finite element models.

FR4-W-CO15

The Network-Enabled Optimization System (NEOS) Server

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Argonne National Laboratory

Czyzyk Joseph - Mesnier Michael

Keywords: automatic differentiation - complementarity problems - computational servers - constrained optimization - distributed computing - internet - large scale optimization - linear networks - linear programming - problem solving environments - stochastic linear programming

The Network-Enabled Optimization System (NEOS) is an environment for solving optimization problems over the Internet. Users submit optimization problems to the NEOS Server via e-mail, the World Wide Web, or the NEOS Submission Tool. The NEOS Server locates the appropriate optimization solver, computes all additional information (for example, derivatives and sparsity patterns) required by the solver, links the optimization problem with the solver, and returns a solution. Version 2.0 of the Server incorporates a new look, new interfaces, and new solvers. Of particular interest among the solvers, are LANCELOT (nonlinearly constrained optimization problems), PATH (mixed nonlinear complementarity problems), PCx (linear programming), and L-BFGS-B (bound-constrained, large-scale optimization problems). We provide an overview of the Server, discussing the design and implementation of the NEOS Server.

WE1-E-CO11

The NEOS Server for Complementarity Problems: PATH

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Ferris Michael C. - Mesnier Michael

Keywords: automatic differentiation - complementarity problems - computational servers - distributed computing - internet - large scale optimization - path - problem solving environments

The Network-Enabled Optimization System (NEOS) is an environment for solving optimization problems over the Internet. Users submit optimization problems to the NEOS Server via e-mail, the World Wide Web, or the NEOS Submission Tool. The NEOS Server locates the appropriate optimization solver, computes all additional information (for example, derivatives and sparsity patterns) required by the solver, links the optimization problem with the solver, and returns a solution.

We describe a particular solver, PATH, for the solution of mixed complementarity problems and describe how PATH (or any other solver) can be registered with the NEOS Server. We also provide details on how complementarity problems are solved on the NEOS Server. These details include a description of how the Jacobian matrix of the defining nonlinear function is derived using ADIFOR, and how the resulting problems are solved on available (idle) workstations at the University of Wisconsin using the Condor system.

TH4-F-IN203

A Stochastic Programming Approach to Manufacturing Flow Control

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Université de Genève

Haurie Alain

Keywords: manufacturing systems - piecewise deterministic systems - stochastic control - stochastic programming

This paper proposes an implementation of a stochastic programming approach for the numerical approximation of the optimal control in a multipart multimachine flexible manufacturing system subject to random failures. The method exploits the fact that a hybrid piecewise deterministic control system with jump rates independent of the continuous state and control obeys the same assumptions as those governing the stochastic programming method developed in the realm of mathematical programming by Dantzig, Wets, Rockafellar and more recently Infanger, King and many others. In our implementation we proceed through the following steps:

1. Discretize over time the state equation dynamics
2. Simulate a set of sample paths for the stochastic process governing the failure and repair sequences of the machines
3. Construct an event tree from this set of sample paths and associate a stochastic programming model correponding to the discretized state equations
4. solve the (large scale) linear programming problem resulting from the extensive form for different initial states
5. infer the approximate optimal policy.

The paper establishes the convergence of the optimal value function of the sampled problem toward the optimal value function of the stochastic control problem when the sample size and the discretization mesh tend to ∞ and 0 respectively. Numerical experiments show that the method can provide insights about the optimal control for FMS models having many parts and machines. These models are notoriously difficult to solve numerically through a direct dynamic programming approach.

WE3-C-CO2

Weak Bilevel Programming Problem with Convex Data

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Università di Napoli Federico II, Dipartimento di Matematica e Applicazioni

Loridan Pierre

Keywords: Molodtsov method - Stackelberg games - approximation algorithms - bilevel programming - epiconvergence - limits of sets

We are concerned with bilevel programming problem (WBPP) corresponding to weak Stackelberg games such that the leader cannot influence the follower and the reaction set of the follower is a set-valued function. Based on a method due to Molodtsov and on some properties previously obtained by the authors, we present some approximate results for WBPP, by a sequence odf strong bilevel programming problems, in the case of convex data and inequality constraints.

TH2-C-CO3

Well Posedness and Generalized Lagrangian

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Keywords: Tichonov well-posedness - generalized Lagrangian - saddle points

Some concepts of well-posedness for a saddle point problem will be presented together with the connections between the well-posedness of a minimum point and the well-posedness of the saddle point problem defined by a generalized Lagrangian (associated to a family of perturbations) extending the previous results obtained by Cavazzuti and Morgan ("Well posed saddle point problem", Lecture Note in Pure and Applied Mathematics, Vol. 86, 1983) for Tichonov well-posedness. Application will be given, particularly for the classical and penalty Lagrangian.

TU1-C-CO2

Pseudomonotonicity in Optimization Problems with Variational Inequality Constraints

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Lignola M. Beatrice

Keywords: existence - optimization problems - variational inequalities - variational inequality constraints - well-posedness

An optimization problem with variational inequality constraints (also called a mathematical program with equilibrium constraints, MPEC, when a finite number of inequalities is also involved) will be considered. Namely a bivariate real valued function has to be minimized on a subset defined by the solutions of a parametric variational inequality. Existence and well-posedness for such problem will be discussed under monotonicity or pseudomonotonicity assumptions of the parametric variational inequality operator.

TU4-E-CO11

Lemke Paths for P-matrix LCPs

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Keywords: linear complementarity problem - polytope

We study the lengths of certain paths connecting two vertices of a simple d-polytope. In the case in which the matrix realizing the polytope has a certain set of d submatrices that are P-pairs, the paths are all of length d. On the other hand, when none of these submatrices is a P-pair, the paths can all grow exponentially in d. Results are presented for the case when some, but not all, of the submatrices are P-pairs.

TU1-G-IN11

Monte Carlo Solution Techniques for Stochastic Programs

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The University of Texas at Austin

Wood Kevin

Keywords: Monte Carlo approximations - two-stage and multi-stage recourse problems

A stochastic program with solution value z^* is often approximately solved by randomly sampling observations of the program's stochastic parameters, and by then solving the resulting approximating problem for $(\hat{x}, \hat{z})$. We show that, in expectation, $\hat{z}$ is a lower bound on z^* for minimization problems. This result is used to construct confidence intervals on the optimality gap for a candidate solution, e.g., for $\hat{x}$ to a two-stage stochastic program and for a candidate solution policy to a multi-stage program. A sampling procedure based on common random numbers ensures non-negative estimates of the optimality gap and can provide significant variance reduction over naive sampling. Computational results are presented.

TH3-W-CO15

Optimisation Based Decision Modelling: Introducing Structure, Interaction and Customisation

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Lucas Cormac Anthony - Mitra Gautam

Keywords: data envelopment analysis - data modelling - decision support systems - hyperlink - linear programming - multidimensional database - online analytical processing - optimization modelling

In this paper, we explain how structure in the model data can be captured in optimisation based decision models. The data and optimisation modelling environment (DOME) developed by the authors not only supports this modelling paradigm, it also provides hyperlink based interaction. This approach enables the modeller to investigate data items, symbolic models, the solver engine and carry out solution analysis within the consolidated environment. These concepts and the customisation of DSS applications are illustrated with reference to a data envelopment analysis (DEA) model.

TU1-R-IN203

Improved Approximations for Minimum Cardinality Quadrangulations of Finite Element Meshes

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Weihe Karsten

Keywords: T-joins - approximation algorithms - b-matchings - quadrilateral mesh generation

Conformal mesh refinement has gained much attention as a necessary preprocessing step for the finite element method in the computer-aided design of machines, vehicles, and many other technical devices. For many applications, such as torsion problems and crash simulations, it is important to have mesh refinements into quadrilaterals. In this talk, we consider the problem of constructing a minimum-cardinality conformal mesh refinement into quadrilaterals. However, this problem is NP–hard, which motivates the search for good approximations. The previously best known performance guarantee has been achieved by a linear-time algorithm with a factor of 4. We give improved approximation algorithms. In particular, for meshes without so-called folding edges, we now present a 1.867–approximation algorithm. This algorithm requires $O(n\,m\log n)$ time, where n is the number of polygons and m the number of edges in the mesh. The asymptotic complexity of the latter algorithm is dominated by solving a T-join, or equivalently, a minimum–cost perfect b–matching problem in a certain variant of the dual graph of the mesh.

TU2-I-CM120

On the Dynamic Travelling Salesman and Dynamic Travelling Shortest Paths Problems

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University of Kaiserslautern

Hamacher Horst W.

Keywords: DTSP - TDTSP - TSP - branch and bound - shortest path

When computing shortest paths or shortest tours one usually assumes that the cost of transport is constant in time, which doesn't hold for real-world applications. This talk will deal with the Dynamic Travelling Salesman Problem (DTSP), a natural generalization to the Travelling Salesman Problem (TSP), which is about finding the cheapest tour through n cities, where the cost and delay of each link depend arbitrarily on the time. We will present structural properties and complexity issues of the DTSP. It will be shown that the notion of shortest paths can be analogously generalized and thus the problem can be solved numerically by means of a langrangean-style relaxation. Furtheron we will asses the relationship of our approach to similiar ones for the TSP and the Time-Dependent TSP (TDTSP).

FR4-W-CO15

MatSe: Optimization Services on the Internet

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Asche Matthias

Keywords: algorithms - distributed computing - internet - java

The MatSe project (*Mat*hematical *Se*rvers on the Internet) is developing an infrastructure to set up servers that provide access to optimization algorithms on the Internet. Servers are designed such that resarchers in the field could easily set them up on their machines and integrate new algorithms.

Users of MatSe servers contact a brokerage server through a Java applet or through communication objects integrated in C++ programs. The brokerage responds with interfaces to registered algorithms at researcher's servers.

The talk will present the MatSe system along examples of registered services. In particular it shows how the benchmark generator *Progen* for resource constrained project scheduling can be used through MatSe.

WE2-W-CO15

DecisionNet: Global Access to Optimization Models and Algorithms

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Kirishnan Ramayya - Bhargava Hemant

Keywords: java - modeling language - software agents - www

The World Wide Web has emerged as an important and popular medium to host information-based services. However, the Web could also serve as a medium for providing online access to models and algorithms. In this talk we present the key ideas underlying the DecisionNet project. DecisionNet is a prototypical electronic market for online access to a class of model-based technologies used in analytical decision making.

The focus of our presentation will relate to issues such as support for interoperability between technologies implemented using different tools, customer support in executing technologies, and support for providers to add new technologies to the market. We will propose a conceptual model of an information technology (IT) infrastructure that provides such support. Prototypes that implement parts of this model using WWW technology, Databases and Java will be discussed. We will use the capability to register and execute GAMS model schemas in DecisionNet illustratively. We will highlight the software agent-based IT architecture of our proposal. The software agents encapsulate the meta information supplied by providers in the form of applets. These applets serve as user-interfaces by which consumers may initialize registered models with data and solve them on a remote LP solver.

FR4-D-CO124

Prima-Dual Affine-Scaling Algorithm Fails for Semidefinite Programming

Muramatsu Masakazu

Princeton University

Vanderbei Robert J.

Keywords: affine scaling - primal-dual interior-point algorithm - semidefinite programming

We give an example of semidefinite programming in which the HRVW/KSH/M-type primal-dual affine-scaling algorithm fails to converge to the optimal solution. We prove that, for any step-size, there exists an intitial point from which the sequence generated by the primal-dual affine-scaling algorithm converges to a non-optimal point. The initial points can be chosen arbitrarily close to the optimal solution. Both the primal and dual problems have interior feasible solutions, unique optimal solutions which satisfy strict complementarity, and are nondegenerate everywhere. In fact, the semidefinite programming problem discussed here is the same as the one proposed by Muramatsu [Mu96], for which the primal affine-scaling algorithm also fails to converge to the optimal solution.

MO3-I-CM121

L-convex Functions and Their Fundamental Properties

Murota Kazuo

RIMS, Kyoto University

Keywords: convexity - lattice of integers - submodular function

The relationship between submodular functions and convex functions was made clear in the eighties through the works of A. Frank, S. Fujishige, and L. Lovász. In particular, a set function is submodular if and only if the so-called Lovász extension of that function is convex. The Lovász extension of a submodular function is (i) positively homogeneous, (ii) submodular on the vector lattice, and (iii) linear in the direction of $(1, 1, \cdots, 1)$. For an integer-valued submodular function, the restriction of the Lovász extension to integer lattice points yields a function $g : \mathbf{Z}^n \to \mathbf{Z} \cup \{+\infty\}$ that may be regarded as a discrete convex function.

Throwing away the homogeneity condition (i), we say a function $g : \mathbf{Z}^n \to \mathbf{Z} \cup \{+\infty\}$ is L-convex if it satisfies (ii) and (iii). We show that an L-convex function can be extended to a convex function by means of "local" Lovász extension, and that the discrete separation theorem of A. Frank extends to a pair of L-convex/concave functions with an integrality assertion.

FR4-I-CM121

Discrete Convex Analysis through Valuated Matroids

Murota Kazuo

RIMS, Kyoto University

Keywords: conjugacy - convexity - duality - valuated matroid

A theory of "discrete convex analysis" is developed for integer-valued functions on integer lattice points to explore a novel duality framework in nonlinear integer programming. The theory parallels the ordinary convex analysis, covering discrete analogues of conjugacy, subgradients, the Fenchel min-max duality, separation theorems, etc. The technical development is based on an extension of valuated matroids to M-convex functions.

A function $f : \mathbf{Z}^V \to \mathbf{Z} \cup \{+\infty\}$ is said to be M-convex if it satisfies an exchange axiom: For any $x, y \in \mathbf{Z}^V$ with $f(x) < +\infty$ and $f(y) < +\infty$ and for any $u \in V$ with $x(u) > x(u)$, there exists $v \in V$ such that $x(v) < y(v)$ and $f(x) + f(y) \geq f(x - \chi_u + \chi_v) + f(y + \chi_u - \chi_v)$, where χ_u denotes the characteristic vector of $u \in V$. The submodular flow problem with an M-convex cost function admits a natural extension of the well-known optimality criterion in terms of potentials. The optimality criterion can be reformulated into a discrete separation theorem for a pair of M-convex/concave functions.

TU4-E-CO11

A Characterization of the Class P_1.

Murthy G. S. R.

Indian Statistical Institute

Parthasarathy T.

Keywords: P_1-matrices - U-matrices - linear complementarity

Let $A \in R^{n \times n}$. Call A a P_1 matrix if determinant of A is zero and the other principal minors of A are positive. Using a nice result of Cottle and Stone (Math. Progg 1987), we give a characterization of the class P_1 through the class of

U-matrices.

TU4-E-CO11

Some Recent Results on the Linear Complementarity Problem

Murthy G. S. R.

Indian Statistical Institute

Keywords: Q_0-matrices - fully semimonotone matrices - principal pivot transforms - sign structures

In this talk we present a number of general and very interesting results on the linear complementarity problem using simple sign structure analysis. The main results are : (i) within the class of column adequate matrices, a matrix is in Q_0 if, and only if, it is completely Q_0 (ii) for the class of fully copositive matrices (C_0^f) introduced by Murthy and Parthasarathy we provide a sufficient condition under which a matrix is in P_0 and as a corollary of this result, we give an alternative proof of the result that $C_0^f \cap Q_0 \subset P_0$, (iii) if $A \in C_0^f$-matrix is in Q_0, then A^t all PPTs of A^t are also completely Q_0, (iv) Other results to be presented in this talk may have an implication to the conjecture that nondegenerate INS-matrices are Lipschitzian.

TU2-I-CM200

Optimization on Hierarchical Graphs

Mutzel Petra

Max-Planck-Institut f. Informatik

Keywords: crossing minimization - layer-planarization - polyhedral combinatorics

We study optimization problems on hierarchical graphs that have applications in Automatic Graph Drawing and Computational Biology. We try to improve the layout of hierarchical graph drawing methods considerably by investigating the *straightline crossing minimization problem* and the *k-layer planarization problem*. In particular, we report on our polyhedral studies of the above mentioned problems for two sequences. Depending on the number of layers, in which the vertices can be permuted freely (zero, one or two) different versions of the problems arise. In Computational Biology, we consider the *maximum weight trace problem* for two sequences, which appears in the context of *multiple sequence alignment*.

We will see how all these problems are tightly connected to each other and to the well-known linear ordering problem. E.g., the maximum weight trace problem for two sequences is equivalent to the 2-layer planarization problem with both layers fix. The straightline crossing minimization problem on two layers with one layer fixed can be transformed to the linear ordering problem. All facet-defining inequalities for the linear ordering polytope are still facet-defining for the polytope associated with the 2-layer planarization problem with one fixed layer.

FR1-C-CO3

D. C. Optimization and Convex-Concave Programming Approaches to Optimizing over the Efficient Set

Muu Le Dung

Institute of Mathematics

Pham Dinh Tao - Le Thi Hoai An

We consider problem of optimizong a real valued function f over the efficient set of a linear multiple objective programming problem. The main difficulty of this problem arises from the fact that the efficient set, in general, is non-convex and not given explicitely. We present some equivalent formulations of this problem with various kinds of the objective function. We propose two methods for solving this problem locally and globally by using d.c. optimization and convex-concave programming. The first method is an application of a general scheme, called DCA, proposed first by Pham Dinh Tao and Bernoussi, for solving a broad class of d. c. optimization. This method has been shown to be efficient for locally optimizing a convex. a concave or an indefinite quadratic function over the efficient set of large-scale linear multiple objective programming problem. The second method is based upon a convex-concave formulation of the problem. It allows globally solving the problem with convex and concave objective functions. The proposed algorithm is efficient when the number of the criteria is relatively small (≤ 10) the number of variables may be somewhat large (several hundreds).

TH3-I-CM120

On the Hub Cover Network Design Problem

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Chang Suk-Gwon

Keywords: hub cover - network design

Given an undirected graph whose nodes are partitioned into mutually exclusive and exhaustive node sets, the hub cover network design problem is the problem of finding a minimum cost hub cover network which includes exactly one node as a hub from each node set and has a logically full-meshed topology. Here, we show the computational complexity of the problem, investigate its polyhedral structure and develop a solution procedure for solving the problem.

FR3-I-CM5

Solving Symmetric Traveling Salesman Problems to optimality: where do we go now?

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Laboratoire de Modélisation et de Calcul de Grenoble

Toth Paolo

Keywords: branch and cut - linear programming - separation - traveling salesman problem

Recent reports on exact solutions to very large Symmetric Traveling Salesman instances seem to spread the idea that researches in that field are now way beyond the reach of newcomers and therefore the field promised to a peaceful death. We will try, in this talk, to convince the audience that this is absolutely not the case. We will show how the study of the resolution by Branch and Cut of small instances can yield drastic improvement on the solution time of larger problems. We will give our view of the difference between small and large instances when it comes to solving them to optimality by Branch and Cut. This view differs quite a bit with the one that has been spread lately in the community. Finally we will point out areas of research that should lead to improvements in the solution times of very large instances.

TU2-G-IN11

A Generalization of the Model Gravity

Nagy Tamas

University of Miskolc

Keywords: entropy programming - mathematical programming - prediction of input-output tables

Prediction of input-output tables is often used in the examination of traffic structures and branch links. The elements of an input-output table mean the numerical values of quantities flowing between input and output points. The aim of prediction is to predict the distribution of the quantity in flow for a future point of time on the basis of the present state. Two types of model can be applied for the purpose of prediction depending on what future dates are known. The two models are the increment factor type and the gravitation type. This paper deals with the generalization of the model Gravity which belongs to the models of the gravitation type. We formulate such an optimization problem in which some constraints are not required to be exactly satisfied rather the deviation of the two sides is put into the objective function in such a way that the weighted average of the original objective function and the deviation should be minimal. The I-divergence is used as the deviation of a given vector from a given other one. An efficient algorithm is developed for solving this optimization problem.

TH1-A-IN2

The LEDA Platform of Combinatorial and Geometric Computing

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Mehlhorn Kurt

Keywords: algorithms - combinatorial computing - data structures - software construction

LEDA is a Library of Efficient Data Types and Algorithms. It aims at providing a comprehensive software platform for combinatorial and geometric computing. Combinatorial and geometric computing is a core area of computer science. In fact, most CS curricula contain a course in data structures and algorithms. The area deals with objects such as graphs, sequences, dictionaries, trees, shortest paths, flows, matchings, points, segments, lines, convex hulls, and Voronoi Diagrams and forms the basis for application areas such as discrete optimization, scheduling, traffic control, CAD, and graphics. LEDA is used worldwide at many academic sites. A commercial version is marketed by LEDA Software GmbH.

In the talk we will discuss the main aspects of the LEDA system such as coverage, ease of use, correctness, efficiency, and implementation. We will also discuss some recent theoretical developments dealing with program checking, running time prediction, and correct implementation of geometric algorithms.

FR3-C-CO123

Pattern Classification by Mathematical Programming

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Keywords: fuzzy programming - goal programming - multi-objective optimization - pattern classification

The pattern classification is one of main themes in the pattern recognition, and has been being tackled by several methods such as the statistic one, artificial neural networks, mathematical programming and so on. Among them, the multi-surface method proposed by Mangasarian is very attractive, because it can provide an exact discrimination function even for highly nonlinear problems without any assumption on the data distribution. However, the method produces often too complicated discrimination surfaces which cause poor genralization ability.

In this paper, several trials from mathematical programming approach in order to overcome the difficulties of the multi-surface method will be suggested: One of them is the utilization of the goal programming or another multi- objective programming. There, the auxiliary linear programming problem is formulated as a goal programming or a multi-objective programming in order to get as simple discrimination curve as possible. Further one is to apply the fuzzy programming by which we can get fuzzy discrimination curves with gray zones.

In addition, it will be shown that using the suggested methods, the additional learning can be easily made. These features of the methods make the discrimination more realistic. The effectiveness of the methods are shown on the basis of some applications.

MO3-A-IN1

Some Practical Behaviors of Least Index Methods for LP and LCP

Namiki Makoto

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Keywords: LCP - LP - least index method - pivoting algorithm

We will talk about some behaviors of the least index pivoting algorithms for LP and LCP.

In 1972, Murty presented a least index method for solving LCPs with P-matrices. We show that the expected number of pivots of this algorithm for solving Murty's exponetial example with a random permutation of variable indices is exactly equal to n.

The second is about the criss-cross method for LP developed by Terlaky and Wang. We propose practical improvements of the criss-cross method motivated by the flexibility posed by Fukuda-Matsui. Some results of numerical tests will be also reported.

TU1-I-CM121

The Polymatroid Membership Problem

with Matroid Expansion

Narayanan H.

EE Dept.

Keywords: matroid - membership problem - polymatroid

In this paper we consider the solution of the polymatroid membership problem given a matroid expansion of the polymatroid. (Let $\mathcal{M}$ be a matroid on $\hat{S}$ and let S be a partition of $\hat{S}$. Let $r(\cdot)$ be the rank function of the matroid. Let $\rho(X_S) \equiv r(\bigcup X_i), X_i \in X_S \subseteq S$, be a function defined on subsets of S. Then $\rho(\cdot)$ is a polymatroid rank function and $\mathcal{M}$ is called a matroid expansion of the polymatroid. The membership problem is that of maximising the function $w(X) - \rho(X)$ over subsets of S for a given weight function $w(\cdot)$ on S.)

We take $w(\cdot)$ to be integral and consider two cases:

- The expansion matroid is general.
- The expansion matroid is graphic with underlying graph $\mathcal{G}$.

In the first case we give a general $O(|\hat{S}|^3)$ algorithm for the solution of the membership problem based on the matroid union algorithm. In the second case we give two alternative algorithms, both network flow based, but one of which works on edge subsets and the other, on vertex subsets of $\mathcal{G}$. The complexity of these algorithms is $O(|V(\mathcal{G})|^2)$.

MO3-I-CM200

The Principal Partition and the Principal Lattice of Partitions - Connections and Analogies

Narayanan H.

EE Dept.

Keywords: principal lattice of partitions - principal partition - submodular function

Let $f(.)$ be a submodular function on subsets of S and let $g(.)$ be a nonnegative weight function on S.
The principal partition of (f, g) is the collection of all subsets of S which minimize

$$f(X) + \lambda g(S - X), X \subseteq S \quad for\ some\ \lambda.$$

The principal lattice of partitions of $f(.)$ is the collection of all partitions of S which minimize

$$\Sigma_{N_i \in \Pi}(f(N_i)) - \lambda|\Pi|, \quad \Pi\ a\ partition\ of\ S.$$

The principal partition came under intense scrutiny during 1967-1985, while the principal lattice of partitions was formulated only in 1986. In the present paper we point out the very strong structural analogies that exist between the two concepts and also discuss certain special situations where the structure of one of them can be inferred from the other.

TU4-I-CM121

On Flexibility in Optimization Problems

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Keywords: combinatorial optimization - complexity - flexibility - matroid

If we know a maximum flow in a network, we can“delete” the zero flow arc and obtain a “cheaper” network which ensures us the same “performance” of the original. But if the arc capacities vary between two bounds associated which each arc, how can we know which arcs can be “deleted” so as to obtain a “cheaper” network with the same performance in “all the possible states”? This is the question defining the “flexibility” problem associated to max-flow.

This kind of questions can be extended to other optimization problems. In our work we prove the NP-completeness of the flexibility problem associated to max-flow and we work on the Combinatorial Optimization Problem obtaining results relating the computational complexity of the optimization problem and the computational complexity of the flexibility problem associated to it. In particular, we prove the polinomiality of the flexibility problem associated to the maximum independent set in a matroid.

TU3-D-CO123

Conditioning of Semidefinite Programs

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Courant Institute of Mathematical Sciences

Overton Michael L.

Keywords: condition number - linear programming - perturbation theory - semidefinite programming

We study the conditioning of semidefinite programs by analyzing the effect of small perturbations in problem data on the solution. Under the assumptions of nondegeneracy and strict complementarity, an explicit bound on the change in the solution is derived in a primal-dual framework, using tools from the Kantorovich theory. A discussion of these results for linear programming is also included.

TH1-K-CM106

An Outer Approximate Subdifferential Method for Piecewise Affine Optimization

Neame Philip James

Department of Mathematics, University of Melbourne

Ralph Danny - Boland Natashia

Keywords: approximate subdifferential - piecewise affine functions - uncapacitated facility location

Piecewise affine functions arise from Lagrangian duals of integer programming problems, and optimizing them provides good bounds for use in a branch and bound method. Methods such as the subgradient method and bundle methods assume only one subgradient is available at each point, but in many situations there is more information available. We present a new method for optimizing such functions, which is related to steepest descent, but uses an outer approximation to the subdifferential to avoid some of the numerical problems with the steepest descent approach. We provide convergence results for a class of outer approximations, and then develop a practical algorithm using such an approximation for the compact dual to the linear programming relaxation of the uncapacitated fa-

cility location problem. We make a numerical comparison of our outer approximation method with the projection method of Conn and Cornuéjols, and the bundle method of Schramm and Zowe.

TU4-T-CO22

A Linear Programming Approach to Support Production Planning

Negenman Ebbe Gerard

Eindhoven University of Technology

Keywords: MRP - linear programming - network flow - production planning

This paper can be seen as a contribution to the development of further adequate models for production planning. We focus on production environments where a fixed number of final products are produced, all of which may consist of several components. These components may also consist of several other components, etc. The demand for the final products is exogenously determined. We assume the existence of lead times for each item and also realistic capacity constraints on the number of items made in a time interval. We discuss a linear programming approach to solve the problem, where we explicitly minimize a weighted sum of inventory costs and costs due to lost sales. We show that the imposed capacity constraints can be translated via network flow theory to constraints which can easily be added to a linear programming model. The result is a production planning model which abstracts from to much detail.

MO4-I-CM5

Recent Developments and Future Directions in Airline Scheduling Problems

Nemhauser George

Georgia Institute of Technology, School of Industrial and Systems Engineering

Keywords: airline scheduling

In this talk we present an overview of optimization problems that arise in airline schedule models including fleet assignment and crew scheduling. Typically, optimization has been used to solve planning models but not in operations where on-line rescheduling must be done because of inclement weather and equipment failures. We will discuss models that are used for operations and also models that attempt to integrate planning and operations.

TU3-L-CM201

Lifted Flow Cover Inequalities for Mixed 0-1 Integer Programming

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Georgia Institute of Technology, School of Industrial and Systems Engineering

Gu Zonghao - Savelsbergh Martin W.P.

Keywords: computational results - cutting plane methods - mixed integer programming

We investigate strong inequalities for mixed 0-1 integer programs derived from flow cover inequalities. Flow cover inequalities are usually not facet defining and need to be lifted to obtain stronger inequalities. However, because of the sequential nature of the standard lifting techniques and the complexity of the optimization problems that have to be solved to obtain lifting coefficients, lifting of flow cover inequalities is computationally very demanding. We present a computationally efficient way to lift flow cover inequalities based on sequence independent lifting techniques and computational results that justify the effectiveness of our lifting procedures.

TH1-D-CO123

On Self-Concordant Convex-Concave Functions

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Keywords: interior point methods - saddle points

The self-concordance-based approach is the standard framework for developing interior point polynomial methods for Convex Programming. To the moment the approach was mainly used for convex optimization; as about other problems with convex structure, e.g., convex-concave two-person zero sum games, the approach in question is in a rather preliminary stage. The goal of the talk is to introduce the notion of a *self-concordant convex-concave function* and to demonstrate that these functions inherit basically all attractive properties of their convex prototypes. In particular, we present a path-following polynomial time interior point method for approximating saddle points of "good enough" convex-concave functions – those admitting natural self-concordant regularizations. The approach is illustrated by its application to the problem of inscribing the largest volume ellipsoid into a given polytope; here the machinery in question yields the best known so far polynomial time complexity bounds.

TH1-I-CM4

An Efficient Algorithm for the Minimum-Range Ideal Problem and Related Topics

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Keywords: algorithms - combinatorial optimization - ideal - minimum-range - partially ordered set

Suppose we are given a poset (partially ordered set) $\mathcal{P} = (E, \preceq)$, a real-valued weight $w(e)$ associated with each element $e \in E$ and a positive integer k. We consider the problem which asks to find an ideal of size k of $\mathcal{P}$ such that the range of the weights of the elements of this ideal is the minimum for all ideals that can be constructed from $\mathcal{P}$. We call this problem the minimum-range ideal problem. This paper shows an $\mathrm{O}(n \log n + m)$ algorithm for this problem, where n is the size of E and m is the smallest number of arcs to represent $\mathcal{P}$. This algorithm is different from the algorithms proposed for the other minimum-range combinatorial problems. It is also proved that this problem has an $\Omega(n \log n + m)$ lower bound. This means that the algorithm presented in this paper is optimal.

WE3-E-CO11

Vertical Linear Complementarity in some Zero-Sum Stochastic Game Problems

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Indian Statistical Institute

Keywords: Cottle-Dantzig algorithm - VLCP - arat games - discounted switching control games

In this paper we consider zero-sum two person stochastic games with additive reward and additive transition property and formulate the problem of finding the value vector and corresponding optimal strategies in the discounted case as a vertical linear complementarity problem solvable by Cottle-Dantzig algorithm. We also consider discounted switching control games in which the law of motion is controlled by player I alone in a subset of states and is controlled by Player II alone in the remaining states. The problem of finding a value vector and optimal strategies using a complementarity formulation is also discussed.

TH-pm-SPO

Interior-Point Methods: an Old and New Approach to Nonlinear Programming

Nesterov Yurii E.

Université Catholique de Louvain

In this paper we discuss the main concepts of structural optimization, a field of nonlinear programming, which was formed by the intensive development of modern interior-point schemes.

MO3-D-CO124

Semidefinite Relaxation and Non-Convex Quadratic Optimization

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Université Catholique de Louvain

Keywords: global optimization - quadratic optimization - robust optimization - semidefinite programming

We show that semidefinite relaxation of boolean quadratic maximization problem with indefinite matrix provides us with a fixed absolute accuracy estimate for the exact solution. Using this result we derive fixed absolute accuracy bounds for mixed boolean problems, piece-wise linear problems and minimax problems. We discuss some applications of the results in robust optimization.

TU4-C-CO122

Quadratic Programming Techniques in Branch and Bound Methods

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Keywords: branch and bound - convexification - modified Cholesky factorization - quadratic programming - second order information - underestimation

Many branch and bound methods for the global optimization of continuous functions with continuous constraints depend on the construction of good one-sided estimators for objective function and constraints. In this talk, it is shown how to construct quadratic underestimators for nonlinear programs in block separable form, and how to use these quadratic underestimators efficiently for the elimination or reduction of subboxes of the feasible domain. Under additional assumptions, it can be shown that there is a (problem-dependent) number $d_{\min}$ such that every box of diameter $< d_{\min}$ is either eliminated or reduced to a single point. This guarantees finite termination of branch and bound algorithms that employ this technique.

WE4-P-IN201

New Results on Heuristic Algorithms for Resource-Constrained Project Scheduling with Minimum and Maximum Time Lags

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Keywords: activity-on-node networks - heuristics - project scheduling

New results on heuristic algorithms for approximately minimizing the duration of a project subject to minimum and maximum time lags between the activities of the project and limited availability of renewable resources are considered. Such a project can be modelled by a cyclic activity-on-node network.

At first, an overview of exact and heuristic methods for the project scheduling problem in question is given.

After that, we deal with priority-rule methods, which can approximately solve instances with 1000 activities and several resources in reasonable time. Two generation schemes for constructing feasible schedules based upon an appropriate strict order in the set of activities are discussed: the serial and parallel schemes. Two different kinds of heuristic procedures are proposed. The sequential or direct method processes the activities or respectively nodes of the project network one after another without considering the strong components separately. The contraction method uses a bottom-up technique. First, a feasible subschedule is determined for each strong component. Second, each strong component is replaced by a single node and the resulting acyclic network is treated by the direct method.

In conclusion, some results from an experimental performance analysis of the heuristics proposed are given using a new network generator. In particular, several parameters which have the strongest impact on the hardness of problem instances are discussed

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TH4-U-IN1

A Robust Linear Programming Approach to the Optimal, Placement and Intensity of Radiotherapy Beams in the Treatment of Benign and Malignant Lesions

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Holder Allen - Humphries Stephen Martin - McCourt Stephen Laurence

Keywords: linear programming - radiotherapy

In this effort we offer a novel and highly structured approach to the optimal beam arrangement and beam intensity problem in the radiation therapy treatment of benign and malignant lesions. The method employs a combination of the fully discretized Radon transform and linear programming in a way that accommodates the aspirations of the user. A number of investigators have pursued this problem yet a clinically viable method has not been forthcoming. In a very natural way our model permits optimization using: any combination of photon or electron energies (the most frequently used modalities); three dimensional patient image data; any desired normal tissue and lesion dose constraints (dose is the absorption of energy per unit mass); fully modulated beams or discrete predetermined beam shapes; a limited number of beam angles or a "conformal" solution with many beams; penalty terms for undesirable beam angles; pixel by pixel or region average dose constraints, as well as other subtle issues. The objective functions may be: maximize the minimum lesion dose or minimize the maximum of some critical structure dose. We offer a linear goal programming variant of the method and discuss sensitivity analysis issues. We demonstrate a sufficient condition for the coefficient matrix to have full row rank and we are able to show many clinical examples from an industrial prototype version.

WE3-C-CO3

The Development of a Multiperiod Bilevel Model of an Aluminium Smelter Incorporating an Overriding Intertemporal Capacity Transfer Subproblem

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Keywords: applied modelling - bilevel programming - nonlinear programming

In this paper, an existing model of a multiperiod nonlinear bilevel formulation of an aluminium smelter which allows for the transfer of stocks of raw materials is extended to allow for the intertemporal transfer of capacity through the transfer of intermediate products. The situation arises in reality where a part of the smelter is closed for scheduled maintenance and in order to adhere to the "prime directive" of an aluminium smelter, "don't stop production", it is necessary to transfer capacity from previous months to the month in question. Capacity per se can't be transfered, however, the stocks of needed intermediate raw materials (i.e., partly processed materials required for the next stage of production) can be, thus allowing the plant to continue operation. In building the necessary infrastructure into the existing multiperiod model, a number of substantial alterations were required. The most important change was the introduction of additional variables facilitating the separation of the process of manufacture and use of baked anodes (the production of which is the second main activity of a smelter). When the need for capacity transfer arises, it does as a result of a specific infeasibility and requires the solution of a more conventional nonlinear multiperiod submodel, representing the subproblem of building up sufficient stocks of baked anodes (the intermediate product) such that feasibility in the month in question is attained. The stocks of baked anodes are required to be largest prior to use. The need to attain feasibility overrides the normal bilevel objective functions and the solution obtained remains fixed over the periods effected by the submodel. Solution of this subproblem is obtained using Lagrangian methods. Additional work on the solution procedure is also highlighted.

TU2-C-CO3

The Development of Modifications to Cobweb and Single Constraint Grid Search Procedures with the Aim of Improving their Efficiency and Robustness

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Keywords: grid search algorithms - heuristics - vertex enumeration

In this paper, several new developments are suggested to increase the efficiency of grid search procedures within vertex enumeration algorithms based on both the classical cobweb technique (a two constraint approach) and a single constraint approach. This increase in efficiency is required since the grid search procedure is a part of a solution algorithm being developed to assist in solving a nonlinear bilevel multiperiod model of an aluminium smelter. The classical cobweb technique is shown to be quite fast but is subject to some serious problems associated with nonconvergence when used in this application. However, with the incorporation of several improvements (based on the introduction of a step procedure) into the classical cobweb technique, the problems of nonconvergence are removed. Also, improvements are made to the normal single constraint technique again making use of the "best" step sizes and starting points.In determining the "best" initial step in both the cobweb and single constraint approaches, approximations to the constraints are made using second degree polynomials. The determination of the initial step plus the concept of determining an efficient (or "best") step size substantially improve the efficiency and robustness of the grid search procedures. The efficacy of the improvements is demonstrated on a suite of test problems which involve varying degrees of complexity (often leading to nonconvergence if the classical cobweb technique is used).

TH1-I-CM5

Sandwich Approximation for Restricted Location Problems

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Kaefer Barbara

Keywords: approximation algorithms - global optimization - location theory

In location planning one is typically concerned with finding a good location for one or several new facilities with respect to a given set of existing facilities. When looking for new locations in modeling real-world problems, we are often confronted with forbidden regions, in which the placement of new facilities is not allowed, such as nature reserves or lakes. Furthermore these forbidden regions may have complicated shapes. It may be therefore useful or even necessary to use approximations of such forbidden regions when trying to solve these restricted location problems.

In this talk we develop error bounds for the approximative solution of restricted planar location problems using the so called

sandwich algorithm. The number of approximation steps required to achieve a specified error bound is analyzed. As examples of these approximation schemes, we discuss Weber problems with round norms and polyhedral norms. Also computational results are presented.

MO4-B-CO11

Implementation of Piecewise Quadratic Functions for Quadratic Programming

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Keywords: numerical linear algebra - quadratic programming - smoothing method

Following the contribution of Kaj Madsen, we give some details of how the method can be efficiently implemented. This includes the estimation of the smallest singular value of a triangular matrix and rank-one up– and downdating of the factorization of a symmetric, positive definite matrix, needed during the Newton iteration.

The performance of the algorithm is compared experimentally with a number of competing methods.

TU2-P-IN201

Dynamic and Stochastic Scheduling: A Mathematical Programming Approach

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Keywords: stochastic scheduling

In the last few years significant progress has been made on a mathematical programming-based approach to the formulation and solution of dynamic and stochastic scheduling problems. We review recent contributions to this body of work. For scheduling problems solved by a priority-index rule, such as multi-armed bandit problems and one-machine scheduling with out-forest precedence constraints, we present a unified framework based on exact LP formulations (LPs over extended polymatroids). For some computationally intractable problems, such as scheduling in multiclass queueing networks, we present linear and semidefinite programming relaxations, from which heuristic solutions, with performance guarantees, are extracted. These formulations are obtained in a unifying way, by expressing system conservation laws as constraints on achievable performance. The results reviewed were obtained by the author in collaboration with D. Bertsimas and K.D. Glazebrook.

WE2-I-CM4

On Lifting Facets for Clique Reductions

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Keywords: clique reduction - stable set polytope

Given a graph $G = (V, E)$, let $P(G)$ denote the stable set polytope associated with G, i.e., the convex hull of the incidence vectors of all stable sets of G.

Let K be a clique of G. A set V' of nodes of G is said to *cover* K if every node of K is adjacent to some node of V'. According to the definition given by Sassano, we say that the clique K is *reducible* if any stable set of G which covers K and is minimal with this property has cardinality two. If K is reducible, let $G|K$ denote the graph obtained from G by deleting the nodes of K and joining two as yet non-adjacent nodes u and v of $N(K)$ if and only if the set $\{u, v\}$ covers K. The operation which produces $G|K$ from G is called *clique reduction* and has been defined by Lovász and Plummer.

A strong combinatorial relationship between G and $G|K$ holds: namely every stable set of $G|K$ can be extended to obtain a stable set of G by adding a suitable node of K. Such property can be used to demonstrate polyhedral results on the stable set polytope, for example it was used to characterize the rank facets of $P(G)$ when G is a claw-free graph.

Hence, It is of interest to study in general the polyhedral relationship between G and $G|K$. In particular, one is interested in describing operations which produce valid inequalities for $P(G)$ from valid inequalities for $P(G|K)$ and conditions under which facet-defining inequalities are produced. In this paper we consider one such operation, the *lifting*, and provide a sufficient condition which guarantees that a facet-defining inequality for $P(G|K)$ is lifted to a facet-defining inequality for $P(G)$. This result enables us to describe new non-trivial classes of facet-defining inequalities for the vertex-packing polytope.

WE2-L-CM201

An Interior Point Method for Large Scale Nonlinear Programming

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Byrd Richard H. - Hribar Mary Elizabeth

Keywords: interior point methods - large scale optimization - nonlinear programming

We analyze the numerical performance of a new interior point method for large scale nonlinear programming. First we consider its ability to approach the solution from remote starting points and its behavior on highly non-convex problems. Then we show that the method can achieve fast asymptotic speed and high accuracy, and show how to implement it so that ill-conditioning does not occur near the solution. We contrast our approach with other interior point methods for nonlinear programming and conclude by comparing our code with LANCELOT and Snopt on a suite of test problems.

TH3-I-CM120

Modifying Edges in a Network to Obtain Low Cost Trees

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Krumke Sven Oliver - Marathe Madhav - Ravi S.S. - Drangmeister K. U.

We consider the problem of reducing the edge lengths of a given network so that the modified network has a spanning tree of small total length. It is assumed that each edge of the given network has an associated function that specifies the cost of shortening the edge by a given amount and that there is a budget on the total reduction cost. The goal is to develop a reduction strategy satisfying the budget constraint so that the total length of a minimum spanning tree in the modified network is the smallest possible over all reduction strategies that obey the budget constraint.

We show that in general the problem of computing an optimal reduction strategy for modifying the network as above is NP-hard and present polynomial time approximation algorithms for the problem, where the cost functions are allowed to be taken from a broad class of functions. For the case of linear cost functions we improve our results in terms of both running time and performance.

Our results can be extended to obtain approximation algorithms for more general network design problems such as Steiner trees and generalized Steiner networks.

TH2-K-CM106

A Tabu Search Approach to the CSP (Constraint Satisfaction Problem) as a General Problem Solver

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Ibaraki Toshihide

Keywords: constraint satisfaction - generalized assignment problem - nurse scheduling - tabu search - time tabling

Many combinatorial problems, including a variety of combinatorial optimization problems, can be naturally formulated as constraint satisfaction problems (CSP). We develop in this paper a tabu search based algorithm for the CSP as a foundation for a general problem solver. In addition to the basic components of tabu search, we incorporate a number of elaborations, such as an automatic control mechanism for the tabu tenure, modification of the penalty function to handle objective functions, and enlargement of the neighborhood by allowing swap operations. Computational results with our algorithm are reported for various problems selected from a wide range of applications, i.e., graph coloring, generalized assignment, set covering, timetabling and nurse scheduling. Our results appear to be competitive with those of existing algorithms specially developed for the respective problem domains.

WE1-P-IN201

Sets Formulation to Schedule Mixed Batch/Continuous Process Plants with Variable Cycle Time

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Lee Peter

Keywords: mixed integer linear programming - scheduling - variable cycle timeset covering

Effective scheduling of operations in the process industry has the potential to achieve high economic returns. Process plants containing both batch and continuous units present a more difficult scheduling problem. When these processes are modelled with batch cycle times as decision variables, the complexity of the problem is increased significantly. These problems are traditionally modelled as job-shop scheduling problems, but are extremely difficult to solve as they are NPhard.

When mixed-batch/continuous processes are modelled with batch cycle times as decision variables, the complexity of the problem is increased significantly from its already difficult counterpart. Many solution methods, such as the traditional job-shop scheduling formulation require unacceptable amounts of time/memory to solve even a simple problem. However, the incorporation of variable batch cycle times into the scheduling model is import as it increases the profitability by enabling the "best" cycle time to be selected.

A formulation based on set-covering which constructs feasible sub-schedules for the operation of the batch units is considered. The problem is then to choose a selection of sub-schedules to constitute the best overall solution schedule resulting in a mixed integer linear programming problem. Modelling considerations, such as identifying and generating sub-schedules are discussed. These determine whether the optimal solution is within the search space of the problem as well as having considerable impact over the performance of this formulation.

An application is considered consisting of multiple batch units discharging into a single storage facility, followed by a continuous production unit. The resulting solution schedules, and the problem complexity are compared to those for the traditional job-shop formulation. It is found that applying a set-covering structure to this problem has the potential for significant computational savings.

FR4-P-IN11

Railway Timetabling using Lagrangian Relaxation

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Keywords: Lagrangean relaxation - railway timetabling - subgradient methods

We present a novel optimization approach for the timetabling problem of a railway company, i.e. scheduling of a set of trains, not violating track capacity constraints, so as to obtain a profit maximizing timetable. The scheduling decisions are based on estimates of the value of running different types of service at specified times.

The problem can be handled as a very large integer programming problem. We have used a Lagrangian relaxation approach, in which the track capacity constraints are relaxed and assigned prices, so that the problem separates into one dynamic program for each physical train. The number of dual variables is very large. However, it turns out that only a small fraction of these are nonzero, which one may take advantage of in the dual updating schemes.

The approach has been tested on a realistic example suggested by the Swedish National Railway Administration (Banverket). This example contains 18 passenger trains and 8 freight trains to be scheduled during a day on a stretch of single track, consisting of 17 stations. The computation times are rather modest and the obtained timetables are within a few percent of optimality.

TH1-I-CM121

Binary Metrics, Multiflows and Clutters II

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Keywords: binary matroids - clutters

Binary clutters are closely related to binary matroids. Their graph theoretic applications include, besides multiflow problems, the problem of integer T-join packings and integer packings of one sided paths embedded in non-orientable surfaces. We show the connection of Lehman's theorem on minimal non-ideal clutters to multiflows in binary matroids. This leads to a sharpening of Lehman's theorem (and our earlier results) in the binary case. We state a corresponding reformulation of a conjecture of Seymour on minimal non-ideal binary clutters.

MO4-C-CO122

Global Quadratic Optimization Using Bezier Methods

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Keywords: Bezier methods - global optimization - nonconvex quadratic optimization

We present a new approach for globally minimizing a nonconvex quadratic function over a polytope based on multivariate Bezier polynomials on a simplex. It is demonstrated that Bezier methods are ideally suited for global optimization due to global properties of the so-called Bezier points. By means of these properties we derive a new global optimality criterion which can be used also for constructing tight lower bounds. Moreover, Bezier methods can be used for local optimization and for reducing the dimension. Numerical results will be presented.

FR4-L-CM201

Modelling of Augmented Makespan Problems (AMAPs): Computational Experience of Applying Integer Presolve at the Modelling Stage

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Keywords: integer presolve - modeling

An Augmented Makespan Assignment Problem (AMAP), which is a variation of the Generalised Assignment Problem (GAP), is analysed in this paper. In this problem we minimise the makespan for producing several products with each on one of several machines. The data instances are such that some of the available machines are identical, which in turn leads to mixed integer programming problems that have many optimal integer solutions. Most commercial software for mathematical programming therefore has problems proving that the solution they find is an optimal one.

Even optimization software that does some integer preprocessing on the system of linear relations, has problems in solving a straight forward formulation of the model. Darby-Dowman et. al. investigated this model and found it difficult to solve as an IP.

We show that if more of the model structure is highlighted at the modelling stage, and these are exploited in preprocessing the formulation before the problem matrix is produced, then we get easily solvable integer programs for the data instances under consideration. We give computational results for five different commercial codes with and without our preprocessing at the modelling stage.

TU1-K-CM106

A Task Allocation Problem in Machine with Time Windows and Precedence Constraints: New Upper Bound by a Hibrid Metaheuristic

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Keywords: genetic algorithms - meta-heuristics

We present a new hybrid heuristic procedure that generates approximate solutions for the Generalization of a Task Allocation Problem in a set of machines, executed by a vehicle, incorporating Time-Windows and Precedence Constraints. This problem is a generalization of the Travelling Salesman Problem (TSP) and it is also known in the literature as the Travelling Purchaser Problem (TPP) with Time Windows and Precedence Constraints (TPP-TWP). In short, the TPP-TWP can be described as a set T of n tasks and set M of m machines where the tasks should be processed. To the set M should be added the source machine s that doesn't process any tasks. We assume that each task can be executed by at least one machine, that each machine has one time-window [a,b] in which the tasks allocated to it should be executed and that some tasks have precedence constraints. Therefore, the objective of the TPP-TWP is to find out one route for the vehicle beginning in the source machine, visiting a subset of M, distributing the tasks and ending in the source machine, minimizing the time spent on processing the tasks and travelling between the machines.

At first, we present one mathematical formulation describing the TPP-TWP as an Integer Linear Programming model. Then, we propose a heuristic procedure that initially transforms the TPP-TWP in a set of Shortest Path Problems with Time-Windows constraints (SPP-TW), showing that the solution of each existing SPP-TW could be interpreted as a feasible solution of the TPP-TWP. As there is a large number of SPP-TW for each TPP-TWP, we propose a Genetic Algorithm to select part of the existing SPP-TW.

In our Genetic Algorithm (GA), the chromosome is an integer array of n components, representing the processing order of the n tasks of the TPP-TWP. Thus, the GA objective is to generate many arrays satisfying the precedence constraints. The task allocation problem in the machines is solved by the SPP-TW meeting the time-windows constraints. The genetic operator of our GA uses the concepts of the best existing genetic operator for the TSP, known in the literature as ERX (edge recombination operator), adapted to our TPP-TWP.

Observing the results of exhaustive numeric tests, we realize that our heuristic algorithm provides good quality solutions

for the TPP-TWP in a reduced computational time.

WE1-I-CM4

A Polyhedral Approach to the Multi-Layer Crossing Number Problem

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Keywords: crossing number - cutting plane methods - multi-layered graphs - polyhedral theory

In this paper, we study the multi-layered crossing number problem. First, we present an integer programming formulation for the crossing number problem on multi-layered graphs. Polyhedral theory is then conducted on the polytope associated with our formulation for the 2-layer crossing number problem and several classes of facets are derived. We then present a cutting plane algorithm for the 2-layer crossing number problem based on the facets obtained. Numerical results on computing the lower bounds for a set of instances are reported.

TU2-K-CM106

A Simple, Yet Effective, Local Search Algorithm for the Steiner Triple Set Covering Problem

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Keywords: Steiner triple system - local search - set covering problem

We discuss a set covering problem, introduced by Fulkerson et al. in 1974, that arises from computing the 1-width of incidence matrices of Steiner triple systems. In literature the 0-1 integer linear programming format of the associated set covering problem has been used for bench marking purposes because it is hard and has yet a relatively low number of variables. Moreover, a class of problem instances can be simply generated and optimal covers for its smallest members are known. In our paper we discuss the literature and present improvements of the best known covers for the two largest problems in this class that were considered so far. Furthermore, we discuss the algorithm that we used to search for the covers. It is based on a simple, yet very effective, local search heuristic for tackling difficult satisfiability problems. It consists of several independent nearest neighbor walks over the corner points of the unit hypercube of appropriate dimension. The best result encountered, then, is returned as the solution.

TU1-I-IN202

An Extended Model for the Traveling Salesman Model: Some Polyhedral Results and Implications

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Keywords: computational complexity - integer and combinatorial programming

An extended integer programming model for the traveling salesman problem (TSP), which also solves the quadratic assignment (QAP) problem by changing the objective function coefficients only, is discussed. The model is further extended by the introduction of 3-clique equalities first. Then it is demonstrated that the linear programming relaxation of the model still contains noninteger extreme points. Then we go on to develop a valid inequality and discuss its relation to the description of the TSP (QAP) polytope.

TU4-U-IN10

One and two Stage Dantzig-Wolfe Decomposition for the Survivability in Multi-Service Telecommunications Networks Problem

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Ouveysi Iradj - Wirth Andrew

Keywords: linear programming - survivability - telecommunications

We analyse the problem of providing a minimum cost multi-service network subject to one link failure scenarios. We consider a fully meshed network for which the origin-destination demand is satisfied by using direct or two hop-paths. Flows for any one service are bounded above on any link. We provide a large scale linear programming formulation of this problem which gives the optimal solution. Since solving this model for large networks is impractical an efficient heuristic is proposed and implemented. One and two stage Dantzig-Wolfe decomposition are also used to decrease the complexity of the problem

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MO4-R-IN203

Extension of Traveling Salesman Heuristics for Vehicle Routing and Experiments with a Digital Road Map

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Keywords: digital road map - traveling salesman problem - vehicle routing

We propose heuristics for the vehicle routing problem (VRP), obtained by extending existing heuristics for the traveling salesman problem (TSP). The VRP discussed in this report consists in finding minimum-cost delivery routes for a set of vehicles, starting and terminating at a single depot, to serve a set of customers scattered geographically. A fixed capacity is given for each vehicle, and each customer is assigned an amount to be delivered. As an application of heuristics for the VRP we discuss a route optimization for a courier service in an area of Japan.

We first propose a heuristic for the VRP obtained by extending the Lin-Kernighan (LK) algorithm to perform the variable k-Opt, which is known to find a near-optimal solution to the TSP. We show that the LK algorithm can be applied to the VRP by incorporating an efficient way of checking the capacity of each vehicle, and by transforming a set of routes into a single route. We extend the LK's feasibility criterion to in-

clude the capacity constraints of each vehicle, and introduce an algorithm for checking the capacity with use of a splay tree.

We then point out that use of a digital road map is essential in solving this problem, since the average speed of a vehicle assigned to a road may differ from that assigned to another road by up to four times. We show that the LK algorithm extended for the Euclidean VRP can also be applicable to the VRP performed on a digital road map by modifying the search radii of near-point searches. The solutions and execution times given by the LK algorithm for the Euclidean VRP and the road-map-based VRP are compared, and we discuss the use of a solution for the Euclidean VRP as an initial solution for the road-map-based VRP.

MO4-D-CO123

A New Class of Preconditioners for Large-Scale Linear Systems from Interior Point Methods for Linear Programming

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Keywords: interior point methods - linear programming - preconditioners

A new class of preconditioners for the iterative solution of the linear systems arising from interior point methods is proposed. For many of these methods, the linear system called augmented system is symmetric and indefinite. This system can be reduced to the Schur complement system which is positive definite. Then, the solution for the linear system is usually computed via the Cholesky factorization. This factorization can be dense for some classes of problems. Therefore, an alternative approach is the use of iterative methods. Since these systems are very ill-conditioned near a solution of the linear programming problem, it is crucial to develop efficient preconditioners. We show that all preconditioners for the Schur complement system have an equivalent for the augmented system while the opposite is not true. Therefore, it is better to work with the augmented system. The theoretical properties of the new preconditioners are discussed. This class works better near a solution of the linear programming problem when the linear systems are highly ill-conditioned. It is possible to reduce the indefinite preconditioned system to a positive definite one of the size of the Schur complement. This class of preconditioners relies on the computation of an LU factorization of a subset of columns of the matrix of constraints. The techniques developed for a competitive implementation are rather sophisticated since the subset of columns is not known a priori. The new preconditioner compares favorably with the Cholesky factorization approach for large problems. It performs better on classes of problems whose Cholesky factorization contains a large number of nonzero entries.

TH4-D-CO124

Stabilizing Cutting Planes Method with Analytic Center for Nonsmooth Convex Programming

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Keywords: interior point methods - nonlinear programming - nonsmooth convex programming

We propose an algorithm for minimizing nondifferentiable convex functions. In our method we consider the unconstrained case, and, as usually, it is assumed that for any point it is known an oracle, the value of the function and some subgradient. When the model of cutting planes is considered, the stabilization achieved by bundle methods is the most popular approach. Recently, interior point methods that use analytic center technique are another way of guarantee stability. In our method the main features are the stability and the partial using of analytic center method. Given a convex polytope that contains, at least , one solution of the problem, we use points close to the central path of a polytope which is constructed from the original and the subgradient cuts. One of the major difficulties in applying the analytic center method in a cutting plane environment lies on the recovering of the interior point when a new inequality is incorporated to the bundle. This is accomplished by using some recent results on the recovering of the analytic center in perturbed polytope and quadratic regions. The evolution of the bundle of information, gained at each iteration, is evaluated and we use a build-down strategy to keep a manageable size. Since we have a measure for introducing a new constraint without disturbing the proximity to the central path, we apply this in the analysis of the effect of deleting some constraint introduced earlier. The convergence is established and we present numerical tests with typical problems from literature.

TU4-L-CM201

Performance Evaluation for Parallel Branch-and-Bound Method on a Cluster of Workstations

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Ebara Hiroyuki - Nakano Hideo

Keywords: TSP - branch and bound - parallel processing

The branch-and-bound method is an important algorithm applied for solving the combinatorial optimization problems. But, its running time grows exponentially in the problem size. So, several parallel branch-and-bound methods are developed.

Recently, the computers on the distributed environment, like LAN, are widely used. To realize parallel branch-and-bound method on this environment, it is proposed that the master processor are connected with slave processors in star-shaped, and each slave processor works on active sub problems independently.

In this case, the load assigned to each slave processor is very different in size. And it is very hard to estimate the difference of each load in advance.

In addition to the load size, each computer that forms the virtual parallel computer has not same ability. Also, because it is not possible to use each computer without other users, the ability of each computer is varying in time. So traditional load distribution policies for the practical parallel computer is not efficient to the parallel branch-and-bound method on this environment.

In this paper, we build the parallel branch-and-bound method to solve TSP(Traveling Salesman Problem) on this environment. We propose three strategies for reassigning active sub problems from the master processor to slave processors. The first strategy is that the master processor assigns the only one sub problem to the idle slave processor from its problem pool. The second strategy is that the master processor redistributes sub problems to all slave processors to make equal the number of sub problems. Last strategy is the combination of above two strategies.

Based on the computational experiments, we examine our strategies with the total processing time, the number of sub problems transfered, and the number of the sub problems processed by the each slave processor.

WE1-R-IN203

Voronoi Diagram for the Dually Flat Space

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Keywords: Legendre transformation - Voronoi diagram - divergence - dually flat space

Voronoi diagram, structure of approximation for a points set, is not only a main object of computational geometry but also is very useful for robotics, VLSI CAD, computer graphics, etc., In this talk we investigate generalized Voronoi diagrams on some Riemannian space, an extension of Euclidean space, specifically on a dually flat space in information geometry. In this space, the distance-like divergence is uniquely determined, and this divergence is used to define the generalized Voronoi diagram. As the divergence does not satisfy the symmetry of distance, two Voronoi diagrams (∇-,∇^*-Voronoi diagram) can be defined by the direction of divergence in that space. The combinatorial and computational complexity of the Voronoi diagrams is bounded.

In the viewpoint of the convex analysis two Voronoi diagrams can be defined if there exists a convex function ψ. The dual space is determined for the convex function ψ by the Legendre transformation. The divergence can be determined also. The Voronoi diagram can be defined in each of primal and dual spaces. In this case we obtain the combinatorial and computational complexity of these Voronoi diagrams by similar way above. We claim that the dually flat space is self-dual in the point of view of the convex analysis, but the two coordinates of the space is diffrent.

As an example of the dually flat space, a statistical parametric space of exponential family is considered. In this space the divergence becomes the Kullback-Leibler divergence which is useful in statistical and information theory. By this divergence we can define the Voronoi diagram and the statistical proximity structure can be analyzed by our framework.

TU1-I-CM200

A Polynomial Time Algorithm for Vertex Enumeration and Optimization over Shaped Partition Polytopes

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Technion - Israel Institute of Technology

Hwang Frank - Rothblum Uriel G.

Keywords: combinatorial optimization - linear programming - partitions - polytope - vertex enumeration

We consider the *Shaped Partition Problem* of partitioning n given vectors in real k-space into p parts so as to maximize an objective function which is convex on the sum of vectors in each part. We study the *Shaped Partition Polytope* defined as the convex hull of solutions.

The Shaped Partition Problem easily captures NP-hard problems such as the Traveling Salesperson problem, and the Shaped Partition Polytope may have exponentially many vertices and facets, even when k or p are fixed.

In contrast, we show that when both k and p are fixed, the number of vertices is polynomial in n, and all vertices can be enumerated and the optimization problem solved in strongly polynomial time.

TH2-A-IN2

On the Strength of Inequalities

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Keywords: cutting plane methods - polyhedral theory - valid inequalities

Recently, Michel Goemans suggested an indicator to compare classes of linear inequalities with respect to their potential effectiveness in a cutting plane algorithm, geared on optimizing linear objective functions over a polyhedron. He showed that this indicator has a nice interpretation in case the polyhedron is of blocking type and the objective is to minimize a linear function with nonnegative coefficients.

In this presentation we will show that the indicator has a similar interpretation for maximizing any linear objective function in case the description in the origin is identical for a relaxation polytope, and its strengthenings, that is: the polytopes resulting from intersecting the relaxation polytope with the halfspaces induced by the respective families of valid inequalities. Some examples are added to illustrate the result.

MO3-I-CM200

Solving inverse Spanning Tree Problems Through Network Flow Techniques

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MIT

Ahuja R. K. - Sokkalingam Palaniswamy

Keywords: assignment problems - inverse optimization - minimum cost flow problem - spanning tree

Given a solution x^* and an a priori estimated cost vector c, the inverse optimization problem is to identify another cost vector d so that x^* is optimal with respect to the cost vector d and the deviation of d from c is minimum. In this paper, we consider the inverse spanning tree problem on an undirected graph $G = (N, A)$ with n nodes and m arcs, and where the deviation between c and d has been defined by the rectilinear distance between the two vectors. We show that the inverse spanning tree problem can be formulated as the dual of an assignment problem on a bipartite network with $O(m)$ nodes and $O(nm)$ arcs. This assignment problem has two special structures: (i) the nodes on one side of the bipartite network are much smaller than the nodes on the other side; (ii) arc costs can be factored (that is, each arc cost $c(i,j) = u(i) + v(j)$ for some vector u and v).

Using the first special strucure of the assignment problem, we develop a specific implementation of the successive shortest path problem that solves the inverse spanning tree problem in $O(n^3)$ time. Next, using the second special structure, we show that the inverse spanning tree problem can be solved in $O(n^2 \log n)$ time. We also consider the inverse spanning tree problems with weighted rectilinear distances and minimax distances.

TH1-I-CM120

Solving Inverse Optimization Problems in Polynomial Time

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Ahuja R. K.

Keywords: inverse optimization - linear programming - polynomial time

Given a non-optimal solution x* for an optimization problem, the "inverse" optimization problem is to perturb the cost data by a minimum amount so that x* is optimal for the perturbed problem. The inverse problem has connections to sensitivity analysis. Moreover, the inverse problem is a natural perspective from which to view errors in the case that the cost data to the problem is not known with high precision. We consider inverse optimization problems for a large number of network and combinatorial optimization problems. We show that the inverse problem is solvable in polynomial time whenever the original problem is solvable in polynomial time. We also show how to efficiently solve the inverse problem for network flow problems as well as other combinatorial optimization problems.

TH1-I-CM120

Determining K-Route Flows Efficiently

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Keywords: maximum flow - network flow

Let G = (N, A) be a network with a designated source node s, a designated sink node t, and a finite integral capacity u(i,j) in U on each arc (i,j) in A. An elementary K-flow is a flow of K units from s to t such that the flow on each arc is 0 or 1. A K-route flow is a flow from s to t that may be expressed as a non-negative linear sum of elementary K-flows. We show how to determine a maximum K-route flow as a sequence of O(minlog KU, K) minimum cut problems plus a single maximum flow problem. This improves upon the algorithm by Kishimoto, who solves this problem as a sequence of K minimum cut problems plus a maximum flow problem. In addition, we have simplified and extended some of the basic theory.

FR2-B-CO10

Globalization of the $\mathcal{U}$-Newton Algorithm to Minimise the Maximum Eigenvalue Function

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Keywords: eigenvalue optimization - nonsmooth optimization - semidefinite programming

Many optimization problems arising in engineering sciences (combinatorial optimization, control engineering, structural design ...) can be reduced to minimize the maximum eigenvalue function $\lambda(\cdot)$ over an affine subspace of the space $\mathcal{S}_n$ of symmetric $n \times n$ matrices. This problem is convex but not smooth. We start with a presentation of a local algorithm called the *$\mathcal{U}$-Newton algorithm*; we obtain the quadratic convergence of the iterate. The key idea of the globalization is to introduce a "good approximation" of the approximate subdifferential of $\lambda(\cdot)$: for $\varepsilon \geq 0$ we define the indices of ε-largest eigenvalues $I_\varepsilon(A) := \{i \in [1, \ldots, n] : \lambda_i(A) > \lambda(A) - \varepsilon\}$, the ε-first-multiplicity $r_\varepsilon := \#I_\varepsilon$ and the ε-first eigenspace $E_\varepsilon(A) := \oplus_{i \in I_\varepsilon(A)} E_i(A)$, where $E_i(A)$ is the eigenspace of A associated with the ith eigenvalue $\lambda_i(A)$. Taking an $n \times r_\varepsilon$ matrix Q_ε whose columns form an orthonormal basis of $E_\varepsilon(A)$, we set $\delta_\varepsilon \lambda(A) := \{Q_\varepsilon Z Q_\varepsilon^T : Z \succeq 0,\ \mathrm{tr}\, Z = 1\}$. This set satisfies $\partial\lambda(A) \subset \delta_\varepsilon\lambda(A) \subset \partial_\varepsilon\lambda(A)$ and enables us to get $\delta(\varepsilon)$-descent directions where $\delta(\varepsilon)$ is proportional to $\lambda_{r_\varepsilon}(A) - \lambda_{r_\varepsilon+1}(A)$. Then at each iteration we choose ε such that $\lambda_{r_\varepsilon}(A) - \lambda_{r_\varepsilon+1}(A) > \eta > 0$ (for a given $\eta > 0$); this implies the global convergence. We also show how to extend the algorithm to semidefinite programming and to solve **large scale problems**. Finally we present several numerical applications from robust control (Popov stability problem) and from combinatorial optimization (Lovasz Θ function and Quadratic Assignment Problem).

TH3-D-CO123

A Global and Superlinear Algorithm to Minimise the Maximum Eigenvalue Function

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Keywords: eigenvalue optimization - nonsmooth optimization - semidefinite programming

Many optimization problems arising in engineering sciences (combinatorial optimization, control engineering, structural design ...) can be reduced to minimizing the maximum eigenvalue function over an affine subspace of the space of symmetric n-by-n matrices. This problem is convex but not smooth. We start with a presentation of a first-order method: using convex analysis, we simplify and develop further an algorithm due to J. Cullum, W. E. Donath and P. Wolfe in 1975. The key idea of this algorithm consists in introducing an enlargement of the subdifferential: the convex hull of so-called approximate eigenvectors. We show that this enlargement enables us to generate "good" descent directions. The global convergence is thereby established. Then we explain how to use this algorithm to globalize the second-order algorithm developed by M. L. Overton in the eighties and recently revisited in the U-Lagrangian theory framework. The quadratic rate of convergence of the iterate is preserved. Finally we present several numerical applications from robust control (Popov stability problem) and from combinatorial optimization (Lovasz prob-

lem and Quadratic Assignment Problem).

TH2-E-CO21

On a Special Class of Equilibrium Problems

Outrata Jiri Vladimir

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Keywords: Newton method - bundle methods - generalized equation - regularity

The paper deals with equilibria described by a paremeter-dependent generalized equation and an algebraic equation. In this way one can model implicit complementarity problems, quasi-variational inequalities or fixed points of so-called extremal mappings, but the class is much wider. The aim is to propose some nonsmooth numerical approaches to the computation of these equilibria. In particular, we convert this problem to a mathematical program with equilibrium constraints and examine the conditions, under which it can be treated by the so-called implicit programming approach. We describe also some applications and give results of preliminary numerical tests.

TH3-C-CO3

Optimality Conditions for a Class of Mathematical Programs with Equilibrium Constraints

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Keywords: coderivative - generalized equation - strong regularity - subdifferential

The paper deals with mathematical programs, where parameter-dependent nonlinear complementarity problems arise as side constraints. Using the generalized differential calculus for nonsmooth and set-valued mappings due to B.Mordukhovich, we derive new 1st-order necessary optimality conditions. They attain an easy form, provided the complementarity problem is strongly regular at the solution. In this case the optimality conditions are generally sharper (more selective) than the conditions derived using the generalized Jacobians of Clarke.

TU1-U-IN10

On Video Placement in a Video–On–Demand Network

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Keywords: video placement - video-on-demand

In the past, educational and entertainment programs are delivered at fixed times to users by television. Users cannot control the programs they watch and cannot schedule the watching time of programs to suit their preferences. Besides, if users want to look for the programs they are interestes in, they must subscribe to all the channels which may broadcast this program. Hence, they have to bear the extra cost for subscribing to a large number of channels, but also tolerate a tremendous overload of irrelevant information. As the digital audio, video, and computing are integrated, the entertainment sector is witnessing a radical shift from conventional broadcast mode of services to an video on Demand (VOD) mode of services.

VOD is a service that provides a set of video to the users through the network. The users can select any video programs they like, and then after a short set up time, they will watch the video transmitted from the network. Like watching the video tape, they have greater flexibility in scheduling the watching time and have fine control : they can pause, resume, fast rewind and fast forward the video. This kind of services is like the rental store of video tapes, but the customer need not go to the rental stores to look for the video tapes which are available or not. The only thing they should do is to connect to the network they have registered and search the video they want. The services providers will renew the videos and delete the unpopular ones. All those features make VOD an attractive services.

To provide VOD service, we need video servers to store the digitized and compressed video material, and broadband networks to transmit the video from the server to the subscriber. The issue we treat here is the trade–off between storage cost and communication cost in VOD networks. Namely, if we have many storage places in the distribution network, the mean distance between the customers and the video will be small, and therefore the communication costs will be small too. However, the storage costs will be high. Conversely, if we have few storage places, we have high link costs and low storage costs. In between, there is is an optimum total cost.

Assuming we have an existing broadband network with fixed storge and transmission resources and some forecast information of user demands on video programs. This paper is to study where to place different video programs such that the total cost of providing the service is minimized. We have developed an heuristic to solve this problem and our preliminary results show that our solution is quite close to the optimal cost, but the computational complexity is greatly reduced compared to the optimal method.

WE1-B-CO10

Eigenvalue Optimization for Nonsymmetric Matrices

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Burke James V..

Keywords: non-Lipschitz - nonconvex - spectral abscissa - subdifferential

Eigenvalue optimization for symmetric (or Hermitian) matrices has received a lot of attention recently. In this talk we consider eigenvalue optimization problems for nonsymmetric real (or non-Hermitian complex) matrices. Ths issues are quite different: the eigenvalues are not Lipschitz functions in general, and perturbation results even for an affine matrix function of one variable are quite complicated. Nevertheless, a lot is known about this problem. We define a directional derivative for certain eigenvalue functions of a matrix (for example the spectral abscissa or the spectral radius), and we give lower bounds for the directional derivative at a given point A in a

direction D, assuming the Jordan form of A is known. We also give conditions under which the bounds are attained. When the directional derivative is positive in all directions, it follows that the point A is a local minimizer. This is not true for the ordinary directional derivative. Finally we discuss the relationship of the directional derivative to certain non-convex subdifferentials which have been proposed in the literature for general non-Lipschitz functions.

TU4-D-CO123

SDPPACK: A Package for Semidefinite Programming

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Keywords: MATLAB - Mehrotra - degeneracy - primal-dual

SDPpack is a package of Matlab files designed to solve semidefinite programs (SDP). SDP is a generalization of linear programming to the space of block diagonal, symmetric, positive semidefinite matrices. The main routine implements a primal–dual Mehrotra predictor–corrector scheme based on the XZ+ZX (AHO) search direction. We also provide certain specialized routines, one to solve SDP's with only diagonal constraints, and one to compute the Lovász θ function of a graph, using the XZ (H..K..M) search direction. Routines are also provided to determine whether an SDP is primal or dual degenerate, and to compute the condition number of an SDP. The code optionally uses MEX files for improved performance; binaries are available for several platforms. Benchmarks show that the codes provide highly accurate solutions to a wide variety of problems. Time permitting we shall also discuss updated versions of SDPPACK for mixed SDP-QCQP problems.

MO3-N-CO15

GIDEN: A Graphical Environment for Network Optimization

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Coullard Collette R. - Dilworth David S.

Keywords: animation - java - network optimization - teaching

We describe and demonstrate our software environment for network optimization, GIDEN: A Graphical Implementation Development Environment for Networks. Giden features interactive graphical display and basic algorithm animation for network optimization problems. The environment has proven to be useful for teaching, implementing, and developing network optimization algorithms.

TU1-A-IN2

Solving Mixed-Integer Linear Programs with General Integer Variables

Owen Jonathan Hutchison

Northwestern University

Mehrotra Sanjay

Keywords: mixed integer programming

Recently, advances have been made for solving generic mixed integer linear programs with binary variables using disjunctive programming. We present work towards developing a similar solution approach for generic mixed integer linear programs with general integer variables. We compare the performance of 0-1 formulations of these problems with a direct approach for solving them.

WE3-T-CO22

A Generalized Divisor Method for the Political Apportionment Problem

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For more than 200 years the political apportionment problem has been extensively studied and debated by both mathematicians and politicians. The problem can be stated very simply: given a house size H, and state populations $p_1, \ldots, p_n$, find an allocation $h_1, \ldots, h_n$ of house seats to states, where $\sum_{i=1}^{n} h_i = H$ and $h_1, \ldots, h_n$ are nonnegative integers. Many apportionment methods have been proposed and various desirable properties for them have been suggested. However, debate still continues about the relative merits of various approaches.

One of the most frequently discussed and applied solution procedures for apportionment has been the class of divisor methods, which can be implemented in various forms. Throughout most of the history of the U.S., one divisor method or another has been used for apportionment of Congressional seats to states.

We propose a general parametric divisor function (GPDF) which generalizes the class of divisor methods. This approach contains all the divisor methods that have been used for the U.S. Congress, as well as many others. We describe both global and local optimization criteria that are optimized by the GPDF. We discuss rank functions and local measures of inequity for the GPDF. We also investigate conditions under which the GPDF provides allocations that satisfy the quota property, in the sense that each state's allocation is within the lower and upper integers obtained by rounding its exact fair share.

We perform a numerical study using data from Japan's House of Representatives. The study demonstrates that the GPDF offers advantages over traditional apportionment methods, when measured by unbiasedness and satisfaction of the quota property. Finally, we discuss the possibility that the GPDF will be accepted by our society in the future.

TU3-P-IN201

Nondominated Schedules for a Job Shop with Two Competing Users

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Keywords: job shop - nondominated schedules - nonregular objective functions

When two jobs compete for a set of resources (for example, machines), then a need arises to

1. schedule the operations of the two jobs on the given resources so that a given cost function is minimized, or
2. schedule the two jobs so that a set of given objectives functions, one for each job, are "appropriately" considered.

In the second case there are two users, each having to perform one job on the common set of resources. In this case it is beneficial to determine a set of *nondominated* schedules, to allow the two users to negotiate among the nondominated schedules to achieve a compromise schedule.

The initial motivation for this research was the following: two major companies were proposing a joint venture to construct a modern flexible manufacturing system to manufacture their respective (large, expensive) products (they both produced a similar family of products). Discussion with these companies indicated that a decision support system that allows the two parties to negotiate the use of, and hence their respective schedules on the new manufacturing system would in fact be extremely useful.

In this talk we present a polynomial algorithm to:

– characterize all the nondominated schedules when the cost functions associated with each of the two jobs are general quasi-convex (hence, non-regular) functions of the completion times.

– find an optimum schedule in the case of a *single user* who wishes to minimize the *sum* of the overall costs, and the cost functions associated with each of the two jobs are convex.

The non-regular functions correspond to the fact that each job should not be completed too early or too late.

These results generalize well-known results for the job shop problem with two jobs, in which cost functions are regular.

WE-am-CO1

Facets, Rank of Integer Polyhedra and Other Topics

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An integer polyhedron is any polyhedron in the n-dimensional space that has integer-valued extreme points only. We discuss several general methods to obtain all facets of integer polyhedra of "small" dimension and propose criteria for their classification. In particular, a meaningful notion of the "rank" of the facets is sought. For the travelling salesman polytope we have performed pertaining experiments and we discuss some of the insights gained by this numerical work.

WE2-U-IN10

Set Covering Problem: an Approach Based on Column Generation and State Space Relaxation

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Keywords: dynamic programming - network optimization - set covering - shortest path - state space relaxation

State space relaxation (SSR), has been used as a technique to reduce the dimension of the state space associated with a dynamic programming formulation for the set covering problem (SCP). Set covering models have been widely used for modeling crew scheduling instances. For such instances the expected number of feasible columns (schedules) is normally large. In order to avoid considering the whole column set explicitly, the state space relaxation may be solved by using a column generation technique. The columns correspond to paths in an adequate network and the pricing for the variables is obtained from the state costs produced by the SSR. Column duplication is ruled out by using a technique proposed by Martins [84] for finding the k-shortest paths in a network. Feasible solutions may be built upon the SSR solutions yielding an upper bound on the optimum. Computational experience carried out with real life test problems is reported.

FR1-L-CM201

A Superlinearly and Globally Convergent Algorithm for Large Scale Trust Region Problems

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Lucidi Stefano

Keywords: trust region problems

In this paper we consider the problem of minimizing a (possibly nonconvex) quadratic function with a quadratic constraint in the case that the number of variables is large. We propose a new class of algorithms for locating the global solution of large scale trust region problems based on the unconstrained reformulation of the trust region problem via an exact penalty function. The algorithm is global convergent and shows a superlinear rate of convergence. At every iteration only the approximate solution of a linear system of dimension $n-1$ is required; this solution can be obtained by means of a conjugate gradient method that require only matrix by vector products. Hence our approach is well suited for large scale problems. Preliminary numerical results are reported.

WE3-B-CO10

Minimal Pairs of Convex Compact Sets

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Urbanski Ryszard

Keywords: convex analysis - pairs of convex sets - quasidifferential calculus

Let $X = (X, \tau)$ be a topological vector space and $\mathcal{B}(X)$ (resp. $\mathcal{K}(X)$) the family of all nonempty bounded closed (resp. compact) convex subsets of X. For nonempty $A, B \subset X: \quad A + B$ denotes the algebraic Minkowski and $A \dot{+} B$ the closure of $A + B$. For $A, B \in \mathcal{K}(X): \quad A \dot{+} B = A + B$. Since $\mathcal{B}(X)$ satisfies the order cancellation law, i.e, for $A, B, C \in \mathcal{B}(X)$ the inclusion $A \dot{+} B \subset B \dot{+} C$ implies $A \subset C$, the set $\mathcal{B}(X)$ endowed with the sum $\dot{+}$ and $\mathcal{K}(X)$ with the Minkowski sum are commutative semigroups with cancellation property.

A equivalence relation on $\mathcal{B}^2(X) = \mathcal{B}(X) \times \mathcal{B}(X)$ is given by $(A, B) \sim (C, D)$ iff $A \dot{+} D = B \dot{+} C$ and a partial ordering by the relation: $(A, B) \leq (C, D)$ iff $A \subset C$ and $B \subset D$. With $[A, B]$ the eqivalence class of (A, B) is denoted.
A pair $(A, B) \in \mathcal{B}^2(X)$ is called *minimal* if there exists no pair $(C, D) \in [A, B]$ with $(C, D) < (A, B)$. For any $(A, B) \in \mathcal{K}^2(X)$ exists a minimal pair $(A_0, B_0) \in [A, B]$, but this is not true for $\mathcal{B}^2(X)$. There exists a class $[A, B] \in \mathcal{B}^2(c_0)$ which contains no minimal element, where c_0 is the Banach space of all real sequences which converge to zero.
For the 2-dimensional case, equivalent minimal pairs of compact convex sets are uniquely determined up to translation. For the 3-dimensional case, this is not true.

Let $A, B, S \in \mathcal{K}(X)$, then we say that S *separates* the sets A and B if for every $a \in A$ and $b \in B$ we have $[a, b] \cap S \neq \emptyset$. The following statements are equivalent:
$i)$ $A \cup B$ is convex, $ii)$ $A \cap B$ separates A and B, $iii)$ $A \vee B = conv(A \cup B)$ is a summand of $A + B$.

We consider conditional minimality: A pair $(A, B) \in \mathcal{K}^2(X)$ is called *convex* if $A \cup B$ is a convex set and a convex pair $(A, B) \in \mathcal{K}^2(X)$ is called *minimal convex* if for any convex pair $(C, D) \in [A, B]$ the relation $(C, D) \leq (A, B)$ implies that $(A, B) = (C, D)$.
It is possible to consider the problem pairs of convex sets in the more general frame of a commutative semigroup S which is ordered by a relation $\leq$ and which satifies the condition: if $as \leq bs$ for some $s \in S$, then $a \leq b$. Then $(a, b) \in S^2 = S \times S$ corresponds to a *fraction* $a/b \in S^2$ and *minimality* to a relative prime representation of $a/b \in S^2$.

TH1-A-IN1

A Basis-Deficiency-Allowing Variation of the Simplex Method for Linear Programming

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As one of the most important and foundational concepts in the simplex methodology, *basis* is restricted to having a number of columns exactly equal to that of rows of the coefficient matrix. This might have been the source of too many zero steps, taken by simplex methods in solving real-world highly degenerate linear programming problems. In this paper, the basis is first generalized to include the deficient case, characterized as one that has columns fewer than rows of the coefficient matrix. Using such a basis, a variation of the simplex method is then made, where the number of basis' columns varies dynamically in the process until optimality is achieved. Generally speaking, the more degenerate a problem to be handled is, the fewer columns the basis will have. Consequently, this offers the possibility of greatly reducing computational effort required per iteration, and of efficiently solving highly degenerate problems. We also show the distinctive and remarkable behavior of the proposed method by reporting results obtained from our computational trials.

WE4-E-CO21

New Models for Discretized Adhesive Contact Problems

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Keywords: adhesive contact - hemivariational inequalities - unilateral contact

In the present paper we study adhesive contact problems for discretized continua. For these problems hemivariational inequalities as variational formulations are obtained, which express the principle of virtual work in inequality form due to the nonconvex energy functionals which describe the adhesive effects. The adhesive contact problems introduce nonmonotone, possibly multivalued laws between reactions and displacements thus giving rise to hemivariational inequalities. The multivaluedness holds in the sense of mathematics, i.e. the corresponding law contains complete vertical branches: a stress and strain state can lie on this vertical branch at the position of equilibrium. This kind of laws appear in several mechanical problems. We mention here the well-known friction law of Coulomb and its nonmonotone variants. Similar is the situation with the adhesive contact law and the sawtooth stress-strain laws for compression in fibre reinforced materials. The same effects may appear at the interface of sandwich beams and plates (delamination effects), as well as in reinforced concrete in tension (Scanlon's diagram) and in composite materials, and in the corresponding contact problems with this type of structures.

The discrete adhesive contact problems studied here give rise to the following hemivariational inequality for C a closed star shaped set and T_C its tangent cone.
Problem P. Find $u \in C$ such that

$$< Mu - q, v > \geq 0, \quad \forall v \in T_C(u),$$

where q is fixed in R^N.

A theoretical study of this problem can be found in (Goeleven et al, 1996), and they are based on the results of (Naniewicz and Panagiotopoulos, 1995) for the continuous problem. After the derivation of necessary and sufficient conditions for the existence of equilibrium positions we give some numerical application based on Mistakidis and (Panagiotopoulos, 1997).

TH-pm-CO2+3

Error Bounds in Mathematical Programming

Pang Jong-Shi

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Originated from the practical implementation and numerical considerations of iterative methods for solving mathematical programs, the study of error bounds has grown and proliferated in many interesting areas within mathematical programming. This paper gives a comprehensive, state-of-the-art survey of the extensive theory and rich applications of error bounds for inequality and optimization systems and solution sets of equilibrium problems.

WE3-E-CO21

A Unified Approach to Frictional Contact Problems

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Stewart David E.

Keywords: contact mechanics - existence theorem - friction - homotopy

We present a unified treatment of discrete or discretized contact problems with Coulomb friction that include quasistatic and dynamic problems involving rigid or elastic bodies undergoing small or large displacements. A general existence theorem is established under broad assumptions that are easily satisfied by many special models. The proof is based on a homotopy argument. This result extends many existence results known to date for discrete contact problems.

TU1-A-IN1

Pivoting Algorithms Generating tow Paths

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UNIVERSITY OF MACEDONIA

Beraldi Patrizia

Keywords: exterior point algorithms - interior point methods - linear programming - pivoting algorithm - primal-dual algorithms

Pivoting algorithms solving general linear programming problem (glp), $min\{cx : Ax = b, x \geq 0\}$, and generating two paths to the optimal solution are presented. One of the paths is of simplex type while the other, the non-simplex path, is feasible to glp. Three algorithms are presented; an Exterior Point Simplex Algorithm (EPSA), Primal-Dual Algorithm (PDA) and a Hybrid Algorithm (HA). region of glp, while the non-simplex path consists of consecutive line segments, the end points of which lie on the boundary of the feasible region. These end points are not vertices of the polyhedron. The simplex type paths of the PDA and HA are feasible to the dual problem of glp. The non-simplex path generated by PDA is very similar to that generated by EPSA. The non-simplex path of HA is generated by an Interior Point Algorithm (IPA). HA can be interpreted as a dual simplex algorithm in which the leaving variable, is determined by an IPA. The dual simplex algorithm of HA can be seen as a purification procedure. However, contrary to the known purification procedures which are only applied after the construction of an approximate optimal solution, ours can be applied at any time. Computational results will also be presented.

WE2-C-CO3

Lagrange Multipliers in Vector Optimization

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The paper presents an approach to stationarity and Lagrange multipliers in vector optimization based on separation and alternative theorems. The key point of the approach is a generalization to vector case of the famous Abadie's Linearization Lemma.

We believe, in fact, that many applied problems formulated with scalar optimization models could have a better interpretation with a multiobjective function. For this reason we think that Vector Optimization Theory must continue to receive a great development. In these last years, in fact, many papers appeared in literature in this field. Among all the topics of Vector Optimization, stationarity plays a key role because it represents the starting point for establishing necessary optimality conditions, duality theorems and methods of resolution. Here we propose a scheme for treating stationarity and Lagrange multipliers passing through separation and alternative theorems and we start with the case in which the objective and the constraining functions admit convex directional derivative. A first generalization consists in removing the assumption of directional differentiability by considering upper sublinear estimates of the Dini derivatives.

Strictly connected with this problem is the introduction of the concept of semistationarity of the Lagrangian. When, in fact, the assumption of directional differentiability is removed we need to introduce a generalized concept of stationarity.

The purpose of this note is to deliver this approach which can be generalized and also applied to the study of vector variational inequalities.

TH4-C-CO122

Continuous Characterization of Graph Coloring

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UNIVERSITY OF FLORIDA

Keywords: combinatorial optimization - global optimization - graph coloring

In this talk, we present different global optimization formulations of the graph coloring problem and study their properties. Based on these formulations, a generator of graphs with known chromatic number is presented.

TU1-C-CO3

A GRASP For The MultiTarget MultiSensor Tracking Problem

Pardalos Panos M.

UNIVERSITY OF FLORIDA

Murphey Rob A. - Pitsoulis Leonidas S.

Keywords: GRASP - data association problem - nonlinear assignment problems

A Greedy Randomized Adaptive Search Procedure (GRASP) is presented for computing approximate solutions to the MultiTarget MultiSensor Tracking (MTMST) problem. The MTMST problem may be described as follows: Given a large number of sensors, each with some error, reporting a large number of closely spaced objects at discrete intervals in time, determine trajectory estimates for any targets that may be present. At any single interval in time, the MTMST is shown to be a MultiDimensional Assignment Problem (MAP). Since the objective is to select a target hypothesis and partition of the measurements that is "most likely" to occur, a likelihood cost function and partitioning constraint set are developed. Filtering techniques are established which promise to dramatically decrease the cardinality of the feasible partition space, enabling a GRASP heuristic to be applied effectively. Computational results on test problems will be presented using a recursive algorithm coded in FORTRAN.

MO4-R-IN203

Unified Experimental Analysis of Metaheuristics for the Vehicle Routing Problem, Especially Concerning Neighborhood Search and Geometric Structure

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Imai Hiroshi - Nishimura Shigeki

Keywords: meta-heuristics - neighborhood search - tabu search - vehicle routing

The vehicle routing problem (VRP) is one of NP-hard problems, and has important applications in real world. The VRP is regarded as a kind of the set partitioning problem, and includes the traveling salesman problem. For these problems, which are difficult to solve strictly, metaheuristics, frameworks of approximate algorithms, seem to be useful. Especially, neighborhood search approaches like tabu search have been considered effective for the VRP. Recently the algorithms that combine neighborhood search and genetic construction have been shown to be more successful. But there are few researches of designing and analyzing neighborhoods and their performance, in spite of their importance.

First, we describe several designs of neighborhood, including our original successful designs. For these designs, we implement algorithms with tabu search, and analyze their performance by thorough experiments with respect to quality of solution, speed and robustness. Detailed implementations of metaheuristics, tabu search and iterated local search, for the VRP are given, which enhances the efficiency of the framework as much as possible. These implementations reveal that the successful approaches based on neighborhood search become essentially similar in their behavior and performance. From these computational results, we show guidelines for designing efficient algorithms for VRP.

We also consider the utilization of geometric structure. Geometric information helps to limit the area of neighborhood to search, and speed up the search. We show how to utilize geometric structure combining with metaheuristic strategies. Our techniques make it possible to apply neighbor search to large-scale problems.

TH1-I-CM4

A Branch-and-Price Algorithm for the Targeting Problem

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Kwon Ojeong - Lee Kyungsik

Keywords: branch and price - integer programming - targeting problem

We consider the problem of asigning weapons to targets so that the total cost is minimized while satisfyng varoius tactical and operational constraints. Given a set of weapon systems and a set of targets, we need to assign weapons to targets and determine the number of rounds that each weapon system fires on the targets.A target may be fired on by more than one weapon system and a weapon may fire on more than one target. The constraints include the desired destroy level on each target, the amount of ammunition available for each weapon, and restriction on the number of targets that a weapon system can fire. The problem can be modeled as a nonlinear integer programming problem, which can be transformed into a linear integer programming problem by linearizing the nonlinear constraints. Unlike 0-1 integer programming problems, there have been little progresses in solving general integer programming problems. We try to solve the problem by reformulating it and using the branch-and-price approach. We reformulate the model by introducing impact configuration variables. The reformulated model includes exponentially many variables. Therefore, the linear programming relaxation is solved using the delayed column generation technique. When the linear programming relaxation does not provide an integral solution,we need to branch. We devise a branching scheme that works in the space of original variables and implemented in the space of the target configuration variables. The procedure to generate columns after branching is also given. We provide computational experiences on randomly generated data for both models. Computatonal experiences show the branch-and-price approach gives quite satisfactory results.The results suggest that the branch-and-price approach may be used successfully to solve the general integer programming problems which have some special structures.

MO4-A-IN2

Computing the Hilbert Basis

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Keywords: Hilbert basis

An algorithm to compute the Hilbert basis S of the semigroup of nonnegative solutions of a system of linear Diophantine equations $Ax = 0$ is presented. It is derived from the R. Stanley's polyhedral interpretation of the Elliot-McMahon algorithm for computing the generating function of the semigroup ring of S.

The algorithm differs from the known ones, namely the Groebner basis-like algorithms due to R. Thomas et al., as well as from an algorithm due to M. Henk and R. Weismantel, as it is able to solve "truncated" problems (e.g. compute the elements of S satisfying $x_i <= B_i$ for a given vector B) in an efficient way. The latter permits on-the-fly checking whether $x \in S$ without browsing the subset of S computed so far.

FR1-A-IN2

Radial DEA Models Without Inputs or Without Outputs

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Keywords: DEA - models without inputs or with a single input

In this paper we consider radial DEA models without inputs (or without outputs), and radial DEA models with a single input (or with a single output). We demonstrate that (i) a CCR model without inputs (or without outputs) is meaninless; (ii) a CCR model with a single constant input (or with a single constant output) coincides with the corresponding BCC model; (iii) a BCC model with a single constant input (or a single constant output) collapses to a BCC model without inputs (or without outputs); and (iv) all BCC models, including those without inputs (or without outputs), can be condensed to models having one less varialbe (the radial efficiency score) and one less constraint (the convexity constraint).

WE1-B-CO10

The Provable Nonsmoothness of Spectral Functions

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Lewis Adrian

Keywords: basic solutions - eigenvalue optimization - nonsmooth optimization - spectral functions

A phenomenon of central interest in optimizing spectral functions is the clustering of eigenvalues at optimal solutions. Clustering (that is several eigenvalues being equal) causes the non-differentiability of the function at the solution point, making the optimization of spectral functions a "model problem" of nonsmooth optimization.

We consider the model problem of minimizing a convex spectral function subject to m linear equality constraints. For a large class, including practically each spectral function arising in applications, we show that when m is sufficiently small, the function will necessarily be nonsmooth at extreme points of the solution set. Moreover, at these points there is a lower bound on the dimension of the subdifferential; the bound is a function of m.

We also show that - somewhat surprisingly - the value of m in order to have a subdifferential of a given dimension (or larger) can be computed just by looking at the special case, when the function is defined on diagonal matrices.

TU3-D-CO123

The Geometry of Convex Programs: Basic Solutions, Nondegeneracy and Strict Complementarity

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Keywords: basic solutions - conic formulation - convex programming - facial structure - nondegeneracy - strict complementarity

We study convex programming problems expressed as a linear program with a cone constraint, and give simple and intuitive extensions of the definitions and results on basic solutions, nondegeneracy and strict complementarity in linear programs. Our work also generalizes and simplifies the results of Shapiro and Fan, of Alizadeh, Haeberly and Overton on nondegeneracy, and of the author on extreme solutions in semidefinite programs.

A basic solution of a cone-lp is defined as an extreme point of the feasible set. We give a simple characterization of basic solutions that depends only on the minimal face of the cone containing x.

Nondegeneracy of a solution and strict complementarity of a solution-pair is defined by using the complementary face in the polar cone. We show that most results well-known from linear programming admit a simple, and natural generalization in the setting of cone-lp's.

We illustrate our results by specializing them for the three classes of cone-lp's most studied in the literature: ordinary linear programs, semidefinite programs and the conic formulation of convex quadratic programs.

TH4-A-IN2

If You Can Branch, You Can Cut: Disjunctive Cuts for Mixed Integer Programs

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Keywords: disjunctive programming - integer programming - mixed integer models - software - valid inequalities

A disjunctive constraint (a disjuction for short) for a mixed integer program specifies that at least one constraint set among several be satisfied. The simplest one states that a variable be either 0 or 1. Disjunctions are a natural tool to divide the problem into subproblems, as done in branch-and-bound. In our work we use disjunctions to generate strong cutting planes for mixed integer programs, building on the theory developed by Balas in the seventies. We focus on disjunctions that tend to perform well as branching rules: our computational results show that they also provide strong cuts. Among other settings, this approach proved to be successful on set-partitioning problems using the Ryan-Foster branching rule.

TH1-U-IN10

Traffic Management Through Link Tolls : New Developments

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Keywords: Lagrange multipliers - MPEC - Stackelberg games - side constrained traffic equilibrium

We consider a mathematical model for achieving a set of traffic management goals through the use of link tolls. The model, which is a simplified version of a general MPEC model for the traffic management problem, can be viewed and solved as a sequence of two models: the first one, which is used to derive a set of link flows satisfying the goals and a tentative set of link tolls, is a side constrained traffic equilibrium problem; the second one is to find, over the (only implicitly known) set of link tolls that achieve the goals, an optimal set of link tolls with respect to some secondary criterion (such as the toll revenue). We characterize this set and illustrate some of its properties, both for a fixed demand and an elastic demand traffic model. We then outline an algorithm for the solution of the toll optimization problem, and present some recent numerical results taken from medium-scale traffic networks with traffic management goals described as link flow capacities.

TU3-I-CM4

(n,e)-Graphs with Maximum Sum of Squares of Degrees

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Petreschi Rossella - Sterbini Andrea

Keywords: sum of squares of degrees - threshold graphs

Among all simple graphs on n vertices and e edges, which have the largest sum of squares of the vertex degrees? It is easy to see that they must be threshold graphs, but not every threshold graph is optimal. We specify a general threshold graph in the form $G_1(a,b,c,d,\ldots) = K_a + (S_b \cup (K_c + (S_d \cup \cdots)$ or its complement $G_2(a,b,c,d,\ldots)$, where K and S indicate complete and edgeless graphs, $\cup$ indicates disjoint union and $+$ indicates complete disjoint join. Boesch et al. showed that for given n and e there exists exactly one $G_1(a,b,1,d)$ and exactly one $G_2(a,b,1,d)$ and that one of them is optimal. We show that *every* optimal graph has the form $G_1(a,b,c,d)$ or $G_2(a,b,c,d)$ with one of b,c,d at most 1.

WE3-I-CM4

On the Structure of Universal Realization Graphs of Degree Sequences

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Arikati Srinivasa Rao

Keywords: degree-sequence

An alternating 4-cycle of a graph is a configuration (a,b,c,d) consisting of distinct vertices a,b,c,d such that a is adjacent to b, c is adjacent to d, a is not adjacent to c, and b is not adjacent to d. A cycle exchange along an alternating 4-cycle (a,b,c,d) consists of deleting the edges ab, cd and adding the edges ac, bd. The universal realization graph of a degree sequence is defined as follows: The vertices are the realizations of the sequence, and two vertices are adjacent if one can be obtained from the other by performing a cycle exchange. We present some results on the structure of universal realization graphs.

TU2-J-IN202

On the Distance to Infeasibility

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Keywords: condition number - convex optimization - perturbation theory

We discuss some properties of the distance to infeasibility of a conic linear system: $Ax = b, x \in C$ where C is a closed convex cone.

Some interesting connections between this concept and the solution of certain optimization problems are established. Such connections provide insight into the estimation of the distance to infeasibility and the explicit computation of infeasible perturbations of a given system. We also investigate the properties of the distance to infeasibility assuming that the perturbations are restricted to have a particular structure.

WE3-I-CM200

On Integrality, Stability and Composition of Dicycle Packings and Covers

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Keywords: $K_{3,3}$-free digraphs - 3-connected components - algorithms - composition - graph - integral dicycle covers and packings

Given a digraph D, the minimum integral dicycle cover problem (known also as the minimum feedback arc set problem) is to find a minimum set of arcs that intersects every dicycle; the maximum integral dicycle packing problem is to find a maximum set of pairwise arc disjoint dicycles. These two problems are NP-complete.

Assume D has a 2-vertex cut. We show how to derive minimum dicycle covers (maximum dicycle packings) for D, by composing certain covers (packings) of the pieces. The composition of the covers is simple and was partially considered in the literature before. Our main contribution is related to the packing problem. We show that simple compositions, similar to the cover one, are in general not valid for the packing. However, if the pieces satisfy, what we call, the stability property, then a simple composition do work. We also observe that if $\nu = \nu^*$ holds for each piece, where ν^* (ν) is the value of a maximum (integral) dicycle packing, then the stability property holds as well. Further, we use the stability property to prove that if $\nu = \nu^*$ holds for each piece, then $\nu = \nu^*$ holds for D as well.

In particular, we use the methods obtained to extend an $O(n^3)$ algorithm for finding a minimum integral dicycle cover and an $O(n^4)$ algorithm for finding a maximum integral dicycle packing from planar digraphs to $K_{3,3}$-free digraphs (i.e., digraphs not containing any subdivision of $K_{3,3}$).

FR3-C-CO2

Optimality Conditions in Mathematical Programming with General Constraints

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Optimality conditions for mathematical programming problems with polyhedral constraints are well-known. Here we focus our attention on problems for which the constraints are not necessarily polyhedral. Among such problems are semidefinite programming and semi-infinite programming problems. New necessary conditions and new sufficient conditions for optimization problems with explicit or implicit constraints are examined and compared to some previously known optimality conditions.

WE4-C-CO2

Duality for Anticonvex Problems

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Keywords: convexity - generalized convexity - quasiconvexity - reverse convexity

We consider problems of two types: the maximization of a convex function on a convex set and the minimization of a convex function over the complement of a convex subset. Both problems are known to be difficult problems. We establish a correspondence between the two problems and give conditions in order to have a zero duality gap. Our main tools are conjugacies of the type studied by Atteia-Elqortobi and Thach. These conjugacies are shown to be of the classical Fenchel-Moreau type and are symmetric.

WE4-E-CO11

A Generalized Potential Approach to Averaging for Solving Variational Inequalities and Fxed Point Problems

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Keywords: fixed point problems - variational inequalities

We consider a general dynamic averaging framework for solving fixed point and variational inequality problems. Our scheme averages the underlying fixed point map with the identity map. This approach permits us to consider fixed point maps that are nonexpansive and weakly nonexpansive with respect to a generalized potential. Our goals in developing this framework are to (i) develop schemes under weak conditions, (ii) understand and develop convergence results for well-known schemes such as the Frank-Wolfe algorithm, (iii) develop convergence results that are more efficient than classical ones, (iv) unify several convergence results from the fixed point and variational inequality literature.

TH4-E-CO21

On the Convergence of Quasi-Newton Methods for Nonlinear Complementary Problems

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Keywords: minimum and Fischer functions - nonlinear complementary problems - nonsmooth equations - quasi-Newton methods

A family of Least Change Secant Update methods for solving Nonlinear Complementary Problems based on Nonsmooth Systems of Equations is introduced. Local and superlinear convergence results for the algorithms are proved. Two different reformulations of the Nonlinear Complementary Problem as a nonsmooth system are compared, both from the theoretical and the practical point of view. We present an hybrid global algorithm to solver the Nonliner Complementary Problem; it combines the local behaivor of the minimun function and the global behaivor the Fischer function.

TH2-F-IN203

Collision Avoidance as a Differential Game: Real-Time Approximation of Optimal Strategies using Higher Derivatives of the Value Function

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Keywords: differential games - optimal strategies - real time

Collision avoidance problem arise in connection with nearly all kinds of moving craft, e.g. cars, ships and aeroplanes. A worst case approach based on pursuit-evasion differential games is investigated. The precomputed representation of an optimal strategy for the evader at many points of the state space is used to approximate a collision avoidance strategy globally and in real time. For this purpose additional information yielded by the Hessian of the value function is exploited. The precomputational phase requires the solution of complicated multi-point boundary value problems involving the state vector, the gradient and the Hessian of the value function. As illustrative example serves the freeway wrong driver scenario: On a freeway, a normal driver is faced with a wrong driver using the same lane in the opposite direction. The normal driver's goal is to avoid a collision against all possible maneuvers of the wrong driver. Examples of simulations with the developed method prove satisfactory performance against various typical maneuvers of wrong drivers.

WE1-T-CO22

A DEAlike Linear Model to Distribute Resources

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Keywords: data envelopment analysis - resource allocation

A resource allocation problem is considered. A central authority fixes the goals to be reached in a future observation period by some decisional making units (DMUs). Then, the DMUs are initially asked to propose a resource allocation strategy, and, finally, the central authority mediates a final resource allocation plan taking into account the DMUs' performances in the past. The present paper proposes a DEAlike approach enabling the DMUs to define their optimal initial bargaining positions with the central authority.

For this problem, different models are presented and discussed, leading to a two–step procedure: first the optimal input and output weights are determined, then, keeping fixed such values, the optimal resource allocation is determined.

An application of the provided models is discussed in the final part of the paper.

TH1-C-CO3

Parameter Identification Algorithms for Approximating Positive Sums of Exponentials to Empirical Data

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Keywords: curve fitting - exponential sum - initial value al-

gorithms - nonlinear least squares - onlinear estimation

In this paper we discuss algorithms to approximate positive sums of exponentials, $\sum_{i=1}^{p} \alpha_i \exp(-\lambda_i t)$, with constraints $\alpha_i \geq 0$, $\lambda_1 < \lambda_2 < ... < \lambda_p$, to empirical data $y(t_j), j = 1, .., m$. The number of terms p is determined by an information criterion and the parameters (α_i, λ_i) are determined minimizing a weighted least squares criterion.

As this parameter identification problem is strongly nonlinear and ill conditioned it is important to have good initial values. Thus the algorithm for the parameter estimation consists of first finding initial values and then making further adjustment by a least squares method.

For the first part of our algorithm we use a variant of ML-criterion for $p = 1$, and for $p = 2, 3$ we use expressions based upon geometrical sums.

For the second part of the algorithm, we compare results from standard software for least squares problems with our new implementations of a sub space minimization Fletcher-Xu hybrid method, a sub space minimization Al-Baali-Fletcher hybrid method, Huschens totally structured secant method (TSSM) with linesearch and a sub space minimization Gauss-Newton method with Hessian corrections. The general least squares approach is also compared to a separable nonlinear least squares formulation.

TH2-H-CO22

Parametrical Identification of Linear Models of Multifactor Estimation

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Keywords: comparative identification - decision taker - linear model - multifactor estimation

Informally, the process of the multifactor choice can be described as follows. A decision taker (DT) considers N > 1 alternatives, each being characterized by n natural numbers. DT prefers one alternative out of the displayed set. The problem is to identify the model of this mental process of choice.

At present methods and algorithms of parametrical identification are described for linear models of multifactor estimation. They are based on the proposed theory of comparative identification. The individual preference matrix of DT is desined with the help of LP theory.

TU2-I-CM120

Approximation Algorithms for Cardinality Constrained Bin Packing Problems

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Keywords: bin packing - cardinality constraints - worst case analysis

We consider bin packing problems where the number of items, which can be put into one bin, is bounded by a given constant k. This cardinality constraint changes the original problem considerably because also small items play a significant role in the new problem.

In 1975 Krause et al. (JACM) analyzed several heuristics for the problem (e.g. First-Fit-Decreasing) and showed that they all have an asymptotic worst-case ratio of only 2. No better algorithms have been found so far.

In this contribution we present a new algorithm with $O(n \log n)$ running time, which takes the cardinality constraint more explicitly into account. Its worst–case ratio can be bounded by 3/2. It is based on the computation of a lower bound LB and a packing procedure using $3/2 \cdot LB$ bins.

Several open problems and related questions will also be pointed out.

MO4-G-IN11

Branch and Bound Methods for Global Stochastic Optimization

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Keywords: branch and bound - global optimization - stochastic programming

This is a joint work with A.Ruszczynski, V. Norkin and W. Gutjahr.

A stochastic version of the branch and bound method is proposed for solving stochastic global optimization problems. To guide the partitioning process the method uses stochastic upper and lower bounds instead of the usual deterministic bounds. Almost sure convergence of the method is proved and random accuracy estimates are derived. Methods for constructing random bounds for global optimization problems are discussed. The theoretical considerations are illustrated with two practical examples: The first is a facility location problem and the second a scheduling problem (the stochastic single-machine tardiness problem). In both cases the algorithm works quite well.

FR1-C-CO3

D.C. (Difference of Convex Functions) Optimization: Theory, Algorithms and Applications

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Le Thi Hoai An

D.c. program is of the form

$$\alpha = \inf\{f(x) - h(x) : x \in I\!R^n\} \qquad (P)$$

where g, h are convex, lower semicontinuous and proper on $I\!R^n$. The function f is called d.c. function and g, h its d.c. components. We present the theory of d.c. programming: d.c. duality, local & global optimality conditions and stability of Lagrangian duality. D.c. programming marks the passage from convex optimization to nonconvex optimization. This extension is large enough to cover most real-life problems but not too much for still being allowed to use the convex analysis tools.

We give the description of DCA (D.c. Algorithm) (based on the d.c. duality and the local optimality conditions) and its general convergence, in particular the finite convergence of

DCA in d.c. polyhedral programming (i.e. when g or h is polyhedral convex). D.c. objective function has infinitely many d.c. decompositions which may have an important influence on the qualities (robustness, stability, rate of convergence and globality of sought solutions) of DCA. In pratice regularization techniques using the kernel $(\lambda)/2\|.\|^2$ and inf-convolution may provide interesting d.c. decompositions of objective functions for DCA. In general DCA converges to a local solution however we observe that it converges quite often to a global one. So it is particularly interesting to combine DCA and Branch-and-Bound method for globally solving large-scale nonconvex programs. D.c. approach to solving Trust Region subproblems, Multidimensional Scaling problem, Nonconvex quadratic programs, Mixed 0-1 quadratic programming in image restoration processing, Optimization over the Efficient Set problem, minimum cost multicommodity flow problem with step increasing cost functions... will be presented in Sessions D.c. programming I & II

FR4-C-CO3

D.C. Programming Approach for Solving the Multidimensional Scaling Problem

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Keywords: d.c. algorithm (DCA) - d.c. duality - d.c. programming - finite convergence of dca - global and local optimality - metric multidimensional scaling problem - polyhedral d.c. programming - regularization techniques - stability of Lagrangian duality

The paper is devoted to d.c (difference of convex functions) programming, Lagrangian duality without gap relative to the maximization of a finite gauge over the unit ball of another gauge (in particular the metric Euclidean Multidimensional Scaling Problem (MDS) formulated by de Leeuw) and to the solution of MDS problem by d.c. algorithm (DCA). We present convergence result of DCA which is based on d.c. duality and local optimality conditions for d.c. programming and the finite convergence of DCA in polyhedral d.c. programming. Different regularization techniques are studied in order to improve the qualities (robustness, stability, convergence rate and globality of computed solutions) of DCA. Lagrangian duality without gap permits to state interesting equivalent forms of MDS problem and the very simple expression of the dual objective function can be used for checking globality of solutions computed by DCA. Semidefinite programming problems have been formulated by multidimensional and clustering techniques as the metric Euclidean MDS problem can be regarded as a parametrized trust region problem. DCA (with and without regularization techniques) is described for solving both MDS problems and the relationship between DCA and the reference majorization method by de Leeuw is given. Moreover DCA (which globally solves trust region problem) is presented in its parametrized version to deal with the metric Euclidean MDS problem. Finally many numerical simulations are reported which prove the robustness and the efficiency of DCA for solving the metric Euclidean MDS problem, especially in the large-scale setting. They also showed the globality of computed solutions in the case where the dissimilarities are the Euclidean distances between the objects.

FR4-C-CO3

Sufficient Optimality Conditions and Duality for Problems with invex-convelike functions

Phan Quoc Khanh

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WE2-T-CO22

Hydro-Electric Unit Commitment Subject to Uncertain Demand

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Keywords: electric power scheduling - stochastic integer programming

We consider the problem of scheduling daily electricity generation in a set of eight hydro-electric stations located along the Waikato River in New Zealand. Each station has a number of turbines which incur fixed charges on startup and have a generation efficiency which varies nonlinearly with flow. With appropriate approximations the problem of determining what turbine units to commit in each half hour of the day can be formulated as a large mixed-integer linear programming problem. In practice the generation required from this group of stations in each half hour is often different from that forecast. We investigate the impact of this uncertainty on the unit commitment by using an optimization-based heuristic to give an approximate solution to the stochastic problem.

WE4-T-CO22

Optimizing the Velocity of an America's Cup Yacht

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Jackson Peter

Keywords: SQP - design optimization - performance modelling

Computer programs which predict the velocity of sailing boats from their design parameters are becoming increasingly popular with yacht designers and those who are responsible for determining handicapping rules for yacht racing. These programs have been instrumental in producing winning designs in the last three America's Cup regattas. We report here on the application of mathematical programming software to a computer model of a sailing vessel giving a velocity prediction program with which optimization can be carried out. The results of applying this program to International America's Cup Class yachts will be presented.

WE4-F-IN203

Flows as Dual Solutions of Control Problems with Multiple Indegrals

Pickenhain Sabine

Technische Universität Cottbus

Keywords: maximum prinziple - multiple integrals - neces-

sary and sufficient optimality conditions

This paper deals with free and fixed boundary value problems of optimal control with multiple integrals of Dieudonne-Rashevski-Type. It can be shown that a Maximum Principle holds for these problems with canonical variables in $[C^{0,nm}]^*$. Interpreted as flows, these canonical variables are at the same time solutions of a dual problem.

TU1-E-CO21

A New Smoothing Method for the Solution of Nonlinear Complementarity Problems based on the Fischer-Function

Pieper Heiko

University of Hamburg

Kanzow Christian

Keywords: global convergence - nonlinear complementarity problems - quadratic convergence - smoothing method

In this talk we will present a new smoothing method for the solution of nonlinear comlementarity problems based on the Fischer-Burmeister function. We use the gradient of the natural merit function associated with the nonsmooth reformulation to globalize a smoothing Newton method and reduce the smoothing parameter depending on the distance of the Jacobian of the smoothing function to a set of generalized Jacobians of the nonsmooth Fischer-Burmeister operator. The resulting smoothing method is superlinearly convergent and has better global convergence properties than existing superlinearly convergent smoothing methods. Numerical results, which will be presented, show very good performance on standard test problems.

TU2-B-CO11

Continuation Methods for Chebyshev Solution of Overdetermined Linear Systems

Pınar Mustafa Celebi

Bilkent University

Keywords: Chebyshev estimation - continuation method - overdetermined linear systems

Finite continuation algorithms for the Chebyshev solution of overdetermined linear systems will be discussed. The first algorithm is based on applying a quadratic penalty function to the primal LP formulation of the problem. The algorithm generates piecewise linear non-interior solution paths to the optimal set. The second algorithm is obtained by smoothing a piecewise linear nondifferentiable primal reformulation of the Chebyshev problem. We use one-sided Huber functions to smooth the kink points. This algorithm also generates a family of piecewise linear solution paths and terminates finitely. Computational results and comparisons with the Barrodale-Phillips simplex code and the predictor-corrector interior point algorithm will be given.

TH3-C-CO2

Optimality and Duality Results for a New Class of Generalized Convex Functions

Pini Rita

Universita degli Studi di Milano

Singh Chanchal

Keywords: Fritz John conditions - Kuhn-Tucker conditions - generalized convexity - nonlinear programming - weak and strong duality

Convexity of a function and of a set are generalized. The new class introduced includes many well known classes as its subclasses. Some properties are studied with or without differentiability: in the differentiable case, first and second order conditions are stated. The new concept is applied to develop optimality conditions of Fritz John type and Kuhn–Tucker type under differentiability for a minimization problem with real valued objective and inequality constraints. A dual of the Mond–Weir type is considered and a number of weak and strong duality results are established. Weak and strong duality theorems are also given in the framework of Wolfe duality.

FR1-W-CO15

Model Management and Solver Systems in Global Optimization

Pinter Janos D.

Dalhousie University

Global optimization (GO) is aimed at finding the best solution of nonlinear decision models, in the (possible) presence of multiple local solutions. In this talk, a concise overview of several GO model management and program systems is presented. As an example, LGO - a model development and solver system for continuous and Lipschitz problems - is demonstrated. Several recent LGO application areas will also be highlighted.

TH4-I-CM200

Exact Solution of Large Scale Quadratic Knapsack Problems

Pisinger David

DIKU, University of Copenhagen

Caprara Alberto - Toth Paolo

Keywords: 0-1 quadratic programming - Lagrangean relaxation - branch and bound - knapsack problem

The *Quadratic Knapsack Problem* (QKP) calls for maximizing a quadratic objective function subject to a knapsack constraint, where all coefficients are assumed to be nonnegative and all variables are binary. The problem has applications in location and hydrology, and generalizes the problem of checking whether a graph contains a clique of a given size. We propose an exact branch-and-bound algorithm for the problem, where upper bounds are computed by considering a Lagrangian relaxation which is solvable through a number of (continuous) knapsack problems. Suboptimal Lagrangian multipliers are derived by using subgradient optimization. We also discuss the relationship between our relaxation and other relaxations presented in the literature. Heuristics, reductions and branching schemes are finally addressed. Computational results are reported for instances with up to 400 binary variables, i.e. almost one order of magnitude larger than those solvable by the previous approaches. The key point of this improvement is that the upper bounds we obtain are typically within 1% of the optimum, but can still be derived effectively. We also show that our algorithm is capable of solving large

maximum clique instances from the literature.

FR4-I-CM120

The three-Dimensional Bin Packing Problem

Pisinger David

DIKU, University of Copenhagen

Martello Silvano - Vigo Daniele

Keywords: bin packing - branch and bound - combinatorial optimization - loading

We adress the problem of orthogonally packing a given set of rectangular-shaped boxes into the minimum number of rectangular bins. The problem is strongly NP-Hard and extremely difficult to solve in practice. Lower bounds are discussed, and it is proved that the asymptotical worst-case performance of the continuous lower bound is 1/8. An exact algorithm for filling a single bin is developed, leading to the definition of an exact branch-and-bound algorithm for the three-dimensional bin packing problem, which also incorporates original approximation algorithms. Extensive computational results, involving instances with up to 60 boxes, are presented: it is shown that many instances can be solved to optimality within a reasonable time limit.

MO4-I-CM200

Dynamic Programming and Tight Bounds for the 0-1 Knapsack Problem

Pisinger David

DIKU, University of Copenhagen

Martello Silvano - Toth Paolo

Keywords: dynamic programming - knapsack problem - surrogate relaxation

We present a new approach to the exact solution of the 0-1 Knapsack Problem which combines dynamic programming and tight upper bounds into an overall robust algorithm. It is shown how additional constraints may be generated and surrogate relaxed. The solution of the relaxed problem gives a tight upper bound, and in many situations also an optimal lower bound.

The enumeration is based on dynamic programming, which ensures pseudo-polynomial worst-case solution times. The algorithm does not use the classical approach to *core* problems. Instead of choosing a core as a collection of items with profit-to-weight ratios close to those of the break item, we use some heuristic rules to find a collection of items which fit well together. These are used as an initial core, which is gradually expanded according to some greedy principles.

The algorithm has excellent solution times, being able to solve very large instances with bounded coefficients within less than one second. There is basically no difference in the solution times of “easy” and “hard” instances found in the literature.

TU1-R-IN203

Recent Progress on the Greedy Flip Algorithm

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École Normale Supérieure

Keywords: arrangement of lines - greedy flip algorithm - topological sweep method - topological walk method - visibility graphs

In their seminal paper 'Topologically Sweeping an Arrangement' Edelsbrunner and Guibas (JCSS89) designed an optimal time and linear (working) space algorithm to sweep an arrangement of lines in the plane by a topological line. They introduced the so-called horizon trees in order to discover where in a cut an elementary step can be applied. This tricky notion of horizon trees has been reused by Asano, Guibas and Tokuyama (IJCGA94) to design an efficient algorithm — the Topological Walk Method — to sweep the region of an arrangement of lines bounded by a convex polygon, and more recently by Rivière (Doctorat, Grenoble 97) to design an optimal time and linear space output sensitive algorithm to compute the visibility graph of a collection of line segments. I will show that the Greedy Flip Algorithm of Vegter and myself (DCG96) — an algorithm to compute the tangent visibility graph of a collection of convex sets in the plane — can be used as an alternative to the three previous mentioned algorithms, and I will relate, in a precise sense, the notion of horizon tree to the notion of greedy pseudo-triangulation. A byproduct of this study is a new method to implement the flip operation of the Greedy Flip Algorithm that uses only primitive data structures.

WE2-A-IN2

Mixing Mixed-Integer Valid Inequalities

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CORE and IAG, Université Catholique de Louvain

Günlük Oktay

Keywords: integer programming - mixed integer models - mixed integer rounding - valid inequalities

In the design of cutting plane or branch and cut algorithms for solving mixed-integer programming problems, one important step is the polyhedral study of the feasible set in order to identify classes of strong valid inequalities.

Such valid inequalities are often defined by applying general procedures to simple substructures embedded in the formulation, or to simple relaxations of the original formulation. One important example is the mixed-integer rounding (MIR) procedure. It is defined for the simplest or "basic" mixed-integer structure and, despite its simplicity, it has or can been used on many mixed-integer sets to produce classes of strong and computationally effective valid inequalities. Another example is the well known lifting procedure.

Our objective in this paper is to develop a procedure for generating new valid inequalities for a mixed-integer region S. In particular, we are interested in the case where it is easy to identify a collection of valid "base" inequalities for S. The starting point of our procedure is to consider the MIR inequality related with each base inequality. For any subset of the base inequalities, we generate two new inequalities by combining or "mixing" the MIR inequalities related with the base inequalities. These new inequalities are shown to be strong in the sense that they describe the convex hull of the region Q defined by the collection of base inequalities.

We next study some extensions of this mixing procedure, and show how it can be used to obtain new classes of strong valid

inequalities for mixed-integer programming problems. In particular, we present examples for production planning , capacitated facility location, capacitated network design, and multiple knapsack problems.

TH4-I-CM5

A Lifting View of the Traveling Salesman Polytope

Pochet Yves W.

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Naddef Denis Joseph

Keywords: TSP - combinatorial optimization - integer programming - lifting procedure - valid inequalities

We consider the convex hull of feasible solutions of the Traveling Salesman Problem (TSP). The linear description of this polytope has received a great deal of attention because of its central role in the exact solution procedures for the TSP. Many papers have appeared which give more and more complex valid inequalities for this polytope. Unfortunately, except for the so-called subtour elimination inequalities, no intuitive idea on why these inequalities are valid has ever been given.

We give here a tour of this polytope, focussing on inequalities that can be defined on sets. The most known inequalities are all of this type. We give an intuition into the validity of such inequalities. We start by giving a unifying way of defining these inequalities through a sequential lifting procedure. This procedure is based on lifting the slack (integer) variables associated with subtour elimination constraints defined on sets of nodes (called teeth). This intuitive approach will not in general be a proof of validity, but, we hope, will help in understanding these inequalities.

We apply this procedure to some known classes of valid inequalities for the TSP, respectively Comb, Brushes, Star and Path, Bipartition inequalities. It is shown that these inequalities can be generated by the lifting procedure. From this intuitive explanation, we derive a direct and non inductive proof of validity for Comb, Star and Bipartition inequalities.

In the above examples, the lifting coefficients are sequence independent. We also give an example where a facet defining inequality is derived from the lifting procedure, but where the lifting coefficients are sequence dependent.

We finally study the Ladder Inequalities and show that they can be generated by an extension of the sequential lifting procedure. The lifted variables are here different from the slacks of subtour elimination constraints.

FR3-A-IN2

An Algebraic-Enumerative Algorithm for Nonlinear 0-1 Programming

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Catholic University of Rio de Janeiro

Parreira Anderson

Keywords: branch and bound - partial k-trees - penalties - vertex elimination

Algebraic methods can explore partial k-tree structure in the co-occurrence graph associated to an instance of a nonlinear 0-1 maximization problem. This kind of algorithm have linear time complexity for fixed k, but performs poorly if k is large. We propose a hybrid algebraic-enumerative approach which consists of a branch-and-bound that may call the algebraic algorithm to solve the sub-instance at a given node, i.e. branch-and-solve.

We report experiments with different strategies such as having an a priori variable fixation sequence that leads to linear time instances (for different k-tree width) or the standard choice of variable to fix based on penalties. For the latter, since we work on the compact representation of nonlinear 0-1 programming which allows complemented variables, we present an extension of Hansen's penalties for this representation.

Finally, we present a comparison with both pure approaches, algebraic and enumerative.

TU4-A-IN2

The "gamma"-Connected Assignment Problem

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Catholic University of Rio de Janeiro

Uchoa Eduardo

Keywords: branch and cut - branch and price - clustering - mixed integer programming

Given a graph and costs of assigning each vertex one of K different colors, find a minimum cost assignment such that no color induces a subgraph with more than "gamma" connected components. This problem arises in the context of contiguity-constrained clustering, but also has a number of other possible applications.

We propose a mixed-integer programming formulation for this problem that leads to a branch-and-cut algorithm. In order to get a stronger formulation, we apply a Dantzig-Wolfe decomposition to this formulation, followed by an integralization of the subproblems. The resulting formulation has a large number of variables, and leads to a branch-and-price algorithm. We report computational experiments on both approaches.

In order to get even stronger formulations, we introduce new classes of valid inequalities. We present some theoretical results that support the idea that these inequalities are strong, and facet defining for some special cases. The general separation problem for these inequalities is NP-hard, although important particular cases can be solved in polynomial time. We report some computational experiences with an improved branch-and-cut that uses some of these inequalities.

MO3-C-CO122

Image Denoising Using Interior-Point and Bundle Methods

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Sagastizábal Claudia

Keywords: bundle methods - image denoising - infeasible interior point methods - predictor-corrector methods - variable-metric proximal-point methods

Let z be a noisy image described by $m := n \times n$ pixels. Its values correspond to a black-and-white unknown image x^*, corrupted by a random (uniformly distributed) noise: $z_i = x_i^* + \eta_i$. To recover an image $\bar{x}$ as close to the original image x^* as possible, we solve an optimization problem.

Consider separatedly pixels by rows and columns in the image-space. They define interfaces, each one of measure $1/n$, with coordinates i, j, $i, j = 1, \dots n$. Then, given an arbitrary image x reshaped as a square matrix X, its total variation in gray levels corresponds to the sum of both the vertical and the horizontal variations:

$$TV(x) = \sum_{i=1}^{n}\sum_{j=1}^{n-1}\frac{1}{n}|X_{i,j} - X_{i,j+1}| + \sum_{j=1}^{n}\sum_{i=1}^{n-1}\frac{1}{n}|X_{i,j} - X_{i+1,j}|$$

Equivalently, $TV(x)$ can be expressed as

$$TV(x) = \|Ax\|_1\,, \quad \text{with} \quad A = \frac{1}{n}\begin{pmatrix} I & \otimes & M \\ M & \otimes & I \end{pmatrix}$$

where $\otimes$ denotes the Kronecker product, I is the $n \times n$ identity matrix and M is the $(n-1) \times n$ matrix given by

$$M = \begin{pmatrix} 1 & -1 & 0 & \dots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & 1 & -1 \end{pmatrix}.$$

Altogether, the optimization problem (P) to be solved is

$$\begin{aligned} & \min_{x\in\Re^m} \tfrac{\alpha}{2m}\|x - z\|_2^2 + TV(x) \\ = \quad & \min_{x\in\Re^m} \tfrac{\alpha}{2m}x^T x + \tfrac{\alpha}{m}z^T x + \|Ax\|_1 \end{aligned}$$

Clearly, (P) is a nonsmooth optimization problem. It can also be written as a quadratic program (P1) :

$$\left\{ \begin{array}{ll} \min\limits_{(x,u,v)\in\Re^{m+r+r}} & \frac{\alpha}{2m}x^T x + \frac{\alpha}{m}z^T x + e^T(u+v), \\ Ax - u + v = 0 & \\ u, v \geq 0 & \end{array} \right.$$

where we denote $r = 2n(n-1)$ and $e = (1, \dots, 1)^T \in \Re^r$.

We present an infeasible predictor-corrector algorithm (PCIP) taking advantage of the underlying structure in (P1). We give some convergence results and show that it also has good computational properties. Finally, we give numerical results comparing PCIP's performances to those obtained using a proximal variable-metric bundle algorithm for solving (P).

TH2-E-CO21

Structural Optimization with Reliability Constraints

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Kirjner-Neto Carlos - der Kiureghian Armen

Keywords: reformulation techniques - reliability constraints - semi-infinite optimization

We present a new formulation of the problem of minimizing the initial cost of a structure subject to a minimum reliability requirement, expressed in terms of the so-called "design points" of the first-order reliability theory, i.e., points on limit-state surfaces that are nearest to the origin in a transformed standard normal space, as well as other deterministic constraints. Our formulation makes it possible to use outer approximations algorithms for the solution of such optimal design problems, eliminating some of the major objections associated with treating them as bilevel optimization problems. A numerical example illustrates the reliability and efficiency of the algorithm.

WE2-C-CO3

On the Transcription of Optimization Problems with MAXMIN Constraints into Standard Nonlinear Programming Problems

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Kirjner-Neto Carlos

Keywords: disjunctive optimization - maxmin constraints - nonlinear programming - path-planning

We consider the problem of minimizing a real-valued function $f^0(x)$ subject to maxmin constraints, i.e., constraints of the form $maxsubkmemberboldr \quad minsubj \in qsubk \quad fsubksupj(x)le0$. Problems with this kind of constraint arise in a variety of applications, such as design of electronic circuits subject to manufacturing tolerances and post-manufacturing tuning and optimal steering of mobile robots in the presence of obstacles.

An optimization problem with maxmin constraints is equivalent to a collection of optimization problems with smooth inequality constraints. This collection can be very large, and hence solving an optimization problem with maxmin constraints by solving each member of the collection can be exorbitantly expensive. We present a transcription of problems of this type into a single inequality constrained nonlinear programming problem with smooth constraints, which can be solved using readily available software. The transcription is based on the fact that a set of real numbers contains a nonpositive element, if and only if its convex hull contains a nonpositive element. While this fact is fairly obvious, establishing a correspondence between the global and local minimizers of the original problem and those of the problem resulting from our transcription turned out to be quite difficult.

The significant advantages of using our transcription are demonstrated by the numerical examples that are included in the paper to illustrate the effectiveness of our approach.

FR3-W-CO15

Algebraic Description of Discrete Event Simulation Models

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Technion

Keywords: modeling language - simulated annealing - simulation - third party transportation

Recently Geoffrion introduced a comprehensive modeling language called SML (Structured Modeling Language) for description of analytic models in the management and decision sciences. The aim of this presentation is to show a way how SML could support discrete event system simulation as far as any widely used language such as GPSS does.

Simulation has always been treated in procedural terms (simi-

lar to such programming languages as FORTRAN, C or Lisp) which is an antithesis of declarative paradigm of SML. We propose hereby a solution for writing simulation decleratively. We want to discuss extensions to SML which enable to write simulations that are expressive (i.e., any situation can be modeled), short, natural, general (i.e., there is a clear distinction between the model on one hand and its instance and analysis of its running, on the other hand), easy to understand and logical. The proposed supplements to SML try to minimize introduction of new elements to it and keep its spirit as far as possible.

We propose to add to the usual domains of real, integer and logical variables also the domain of "ordered set of natural numbers" representing the various transaction entities in simulations. Furthermore, we need functions of time (we call term "containers") which are constant except for a finite number of points where they are continuous only from the right (similar to distribution functions of discrete random variables) and its differences for infinitesimally small time intervals (similar to probability masses at discrete points) which are referred as "event chains". Introducing functions and operators into SML which may have containers and event chains as arguments or results, provides a system which can describe discrete event system simulation as well as any well established simulation language and fulfills the above desiderata.

FR2-C-CO3

Nonlinear Rescaling vs. SUMT in Constrained Optimization (Exterior-Interior Point Methods)

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1. Rescaling the objective function and/or constraints of a given inequality constrained optimization problem into an equivalent one and applying the Classical Lagrangean (CL) to the equivalent problem for both theoretical analysis and numerical methods forms the Nonlinear Rescaling Principle (NRP). The NR method consists in sequential unconstrained minimization of the Lagrangean for the equivalent problem in primal space followed by explicit formulas for the Lagrange multipliers update. The scaling parameter can be fixed or updated from step to step.

2. The NR method is an alternative to SUMT (Fiacco, McCormick, 1990). Practically, for each SUMT method one can find a NR equivalent. Various classes of Exterior Nonquadratic Augmented Lagrangeans (AL) including Exponential AL and class P_1, which are particular cases of NR, have been known for a long time (Bertsekas, 1982). The NRP offers a unified framework to analyze both Exterior and Interior AL, known as Modified Barrier and Modified Distance Functions (Polyak 1981, 1992).

3. We will consider general conditions on the nonlinear transformations which guarantee convergence of NR methods under mild assumptions on the problem data for any fixed positive scaling parameter and any fixed center. Convergence due to the Lagrange multipliers update allows to eliminate the ill conditioning which is typical for SUMT, contributes to the rate of convergence and allows to discover the "hot start" phenomenon for nondegenerate constrained optimization (Polyak 1992).

4. We will show that for such problems the general NR methods converge with Q-linear rate under fixed, but large enough scaling parameter. The fundamental role of the condition number for the rate of convergence and "hot start" will be discussed.

5. The recently discovered equivalence of the NR method to Prox-method with Entropy-like Distance for solving the dual problem show that NR methods are Exterior-Interior point methods (Polyak, Teboulle 1997). Being Interior-Prox methods for the dual problem the NR methods allow to eliminate the combinatorial nature of the constrained optimization in both prime and dual spaces.

We will illustrate it on recently developed Log-Sigmoid method, which is equivalent to an Interior Prox with the Entropy-like Distance, that is based on FermiDirac distribution (Polyak 1997).

FR1-D-CO124

Acceleration of the Affine Scaling Method Convergence for Optimisation Problems of Thermodynamics

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Keywords: acceleration of convergence - affine scaling - dual variables - entropy - free Gibbs energy function - interior point methods

The paper presents and studies algorithms of searching for optimal and feasible solutions. Consideration is given to classical extremal problems of thermodynamics: minimization of the free Gibbs energy function and maximization of entropy. These interesting problems can be solved by the suggested algorithms of the affine scaling method. Here the vector of dual variables, that have an informal interpretation in both problems under investigation, is assigned to each interior feasible point.
The authors have revealed reliable convergence of a sequence of dual variables to the dual problem solution. This experimental fact forms the base for devising and realization of effective ways to speed up convergence. The suggested simple formulas to improve an approximate solution allow the feasible solution and dual variables satisfying optimality conditions within a high range of accuracy to be obtained in a small number of iterations. The affine scaling method efficiency is demonstrated on the examples.

TU4-A-IN2

Recognizing Interval Matrices through PQR-Trees

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Keywords: PQR-trees - interval matrices - network matrices

A binary matrix is called an *Interval Matrix* when its rows can be permuted so that in each of its columns the 1's appear consecutively. Interval matrices are known to be *Network Matrices.* We study the recognition problem for these matrices and we give a compact representation of all valid permutations of an interval matrix. We recast the problem using collections of sets, developing a new theory for it. This leads to the extension of the notion of *PQ-Tree* to the notion of *PQR-Tree* and to a new algorithm for constructing such a tree given a binary matrix.

TU2-D-CO124

An Efficient Implementation of an Interior Point Method for Multicommodity Network Flows

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Resende Mauricio G. C. - Veiga Geraldo

Keywords: decomposition - interior point methods - multicommodity flow

We present an efficient implementation of the truncated primal-infeasible dual-feasible interior point algorithm for linear programming to solve large instances of multicommodity network flow problems. The implementation uses a preconditioned conjugate gradient algorithm to determine an approximate search direction. We describe the preconditioners and show how the code performs on large test problems.

WE2-E-CO21

Secant Methods for Semismooth Equations

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Qi Liqun - Sun Defeng

Keywords: secant method - semismooth equation - superlinear convergence

Some generalizations of the secant method to semismooth equations are presented. In the one-dimensional case the superlinear convergence of the classical secant method for general semismooth equations is proved. Moreover a new quadratically convergent method is proposed that requires two function values per iteration. For the n-dimensional cases, we discuss secant methods for two classes of composite semismooth equations. Most often studied semismooth equations are of such form.

FR3-H-CO22

A New Value for Games in Partition Function Form

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Keywords: axiomatic approach - shapley value

The games in partition function form have been introduced by W.F.Lucas and R.Thrall (1963). Values for such games have been introduced by Myerson (1977), Bolger (1986) and Feldman (1994); all of them are in some way extensions of the Shapley value for cooperative transferable utility games. In this paper, we discuss another Shapley-type value for games in partition function form. We use the axiomatic method in which we impose the regular Shapley-type axioms and also a new axiom that we call "coalitional symmetry". A formula for the new value is obtained and the uniqueness proof is given. Several examples show that our valueis different from the previously defined values of the authors mentioned above. Besides regular ideas used in Shapley's proof, new ones are introduced, based upon some combinatorial arguments, and even the regular concepts like null pla- yer had to be modified.

WE3-A-IN1

Computation of Hilbert bases

Pottier Loic

INRIA

Keywords: Graver bases - Hilbert basis - toric ideals

We will present an algorithm which is a natural extension in dimension n of Euclide algorithm computing the greatest common divisor of two integers.

Let H be a sub-group of Z^n, given by a system of generators. This algorithm computes the Graver basis of H, which is the union of (Hilbert) bases of all monoids obtained as intersection of H with the 2^n orthants of Z^n.

This is a *completion* algorithm, i.e. similar to Buchberger algorithm (Grobner bases), and to Knuth-Bendix algorithm (canonical rewriting systems), also parent with Euclide algorithm. It works like a Grobner basis computation on binomials, but with a modified version of division, which is more restrictive than the usual division of monomials. Important notions of completions algorithms like critical pairs, elimination criterion have a natural interpretation in this context, and allow to have efficient implementations.

After R.Stanley, we will also show how Eliott/MacMahon algorithm on generating series of solutions of Diophantine systems can be seen as the ancestor of many algebraic approaches to integer programming.

We will show that many applications of this algorithm are possible, in particular in integer linear programming: minimal solutions of linear Diophantine systems, integer points of a rational simplicial convex cone or of a rational polytope, small size theorems in geometric theorem proving, Ehrart polynomial of a polytope, shortest vector of a lattice.

We will also review existing upper bounds on the size of Hilbert bases.

FR2-P-IN201

Scheduling a Batching Machine

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Keywords: batching machine - complexity - dynamic programming - scheduling

We address the problem of scheduling n jobs on a batching machine to minimize regular scheduling criteria that are non-

decreasing in the job completion times. A batching machine is a machine that can handle up to b jobs simultaneously. The jobs that are processed together form a batch, and all jobs in a batch start and complete at the same time. The processing time of a batch is equal to the largest processing time of any job in the batch. We analyze two variants: the unbounded model, where $b \geq n$; and the bounded model, where $b < n$.

For the unbounded model, we give a characterization of a class of optimal schedules, which leads to a generic dynamic programming algorithm that solves the problem of minimizing an arbitrary regular cost function in pseudopolynomial time. The characterization leads to more efficient dynamic programming algorithms for specific cost functions: a polynomial algorithm for minimizing the maximum cost, an $O(n^3)$ time algorithm for minimizing the number of tardy jobs, an $O(n^2)$ time algorithm for minimizing the maximum lateness, and an $O(n \log n)$ time algorithm for minimizing the total weighted completion time. Furthermore, we prove that minimizing the weighted number of tardy jobs and the total weighted tardiness are NP-hard problems.

For the bounded model, we derive an $O(n^{b(b-1)})$ time dynamic programming algorithm for minimizing total completion time when $b > 1$; for the case with m different processing times, we give a dynamic programming algorithm that requires $O(b^2m^22^m)$ time. Moreover, we prove that due-date based scheduling criteria give rise to NP-hard problems. Finally, we show that an arbitrary regular cost function can be minimized in polynomial time for a fixed number of batches.

TH3-H-CO22

Approximations in Dynamic Zero-Sum Games

Pourtallier Odile

INRIA

Altman Eitan - Tidball Mabel

Keywords: approximation algorithms - pursuit evasion games - stochastic game - zero-sum games

We study approximations of values and ϵ-saddle-point policies in dynamic zero-sum games. After extending a general theorem for approximation, we study zero-sum stochastic games with countable state space, and unbounded immediate reward. We focus on the expected average payoff criterion. We use some tools developed in the first paper, to obtain the convergence of the values as well as the convergence of the ϵ saddle-point policies in various approximation problems. We consider several schemes of truncation of the state space (e.g. finite state approximation) and approximations of games with discount factor close to one for the game with expected average cost. We use the extension of the general Theorem for approximation to study approximations in stochastic games with complete information. We finally consider the problem of approximating the sets of policies. We obtain some general results that we apply to a pursuit evasion differential game.

WE2-A-IN1

On the Convergence of Variable Metric Algorithms for Unconstrained Optimization

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University of Cambridge

The encouragement of Phil Wolfe was vital to the author's first proof of the convergence of variable metric algorithms when the objective function is convex and exact line searches are used, but inexact line searches occur in practice and there is no convexity in many applications. Therefore our knowledge of convergence properties in these cases will be surveyed, assuming that the values of the variables remain finite and that the objective function has continuous second derivatives. An example shows that lack of convexity can cause the calculated first derivatives to be bounded away from zero.

TH2-A-IN1

Kantorovich's Hidden Duality

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London School of Economics

Kantorovich formulated a production planning model for use in a planned economy, he also proposed a solution algorithm that used 'resolving multipliers' to test for optimality. Vajda formulated a liner program to represent the Kantorovich model. Based on that linear program this paper demonstrates that Kantorovich's resolving multipliers are directly related to dual variables. A numerical example will be given.

TH2-G-IN11

Application of Discrete Moment Problems in Stochastic Programming

Prékopa András

Rutgers University

A Multivariate discrete moment problem (MDMP) is an LP, where the right hand side values are moments, of order up to a given number, of a discrete random vector, and we minimize or maximize a linear function on the unknown probability distrbution. The optimum values can be used to derive sharp lower and upper bounds for expectations and probabilities connected with the random vector. Earlier results concerning sharp Bonferroni inequalities have been recognized as discrete moment problems, and this allowed for various generalizations and improvements on these bounds. An MDMP has a special structure which can be exploited in the solution algorithm of the LP, and, if the order of the available moments is low, the bounds can be presented in closed forms. In the presentation first we outline the underlying theory of the MDMP's and clarify its relationship to Boole's probability approximation scheme. Then we show, how MDMP's can sufficiently be incorporated into probabilistic constrained and simple recourse stochastic programming problems. Special algorithms will be outlined for the solution of the new problems.

TH4-I-CM4

A Computational Study of Shortest Hyperpath Algorithms

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Università di Camerino

Nguyen Sang

Keywords: directed hypergraphs - hyperpaths - shortest path

The shortest hyperpath problem in directed hypergraphs is an extension of the well known shortest path problem in graphs. In this paper, we consider shortest hyperpaths for different classes of cost functions. We restrict ourselves to those tractable cases for which efficient algorithms can be obtained by suitably modifying some well known shortest path algorithms. We discuss the theoretical complexity as well as the practical efficiency of these algorithm. We also investigate the “all shortest hyperpaths” problem, and contrast it with the “all shortest paths” problem in graphs. Issues related to the experimental design are discussed and extensive computational results are reported.

FR3-I-CM4

Distance and Eccentricity Approximating Spanning Trees

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Keywords: distance - graph - spanning tree

Certain ‘tree-like’graphs allow spanning trees resembling more or less the distance pattern of the graph. More precisely, we shall deal with two sorts of spanning trees T: If for every pair of vertices the distance in T and in G differs by at most k, then we call T *distance k-approximating.* If for every vertex x the maximum distance from x to any other vertex (the so-called *eccentricity* in T or G differs by at most k, then T is called *eccentricity k-approximating.*

The existence of such distance- or eccenticity k-approximating spanning trees is closely related to other properties revealing that the graphs behaves more or less like a tree. Surprisingly, these properties have nothing to do with the well-known treewidth.

In this talk it is shown that every block graph, distance-hereditary graph, interval graph, or cocomparability graph allows some distance 1-,2-,3-, or 4-approximating spanning tree, which can be found rather quickly. Although for every k there is some chordal graph without distance k-approximating spanning tree, one can quickly find an *eccentricity* 4-approximating spanning tree in every chordal graph.

MO4-I-CM120

Strengthening to Survivability in the Plane

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University of North Carolina

Keywords: 2-connected - Euclidean - network design - survivability

Given connected network $\mathcal{N}$ in the plane, it is desired to “strengthen” $\mathcal{N}$ to withstand any single line break, by adding the minimum length set of additional edges that will make $\mathcal{N}$ 2*-edge-connected.* Two important special cases are the *Euclidean case*, when any set of straight lines can be added with costs proportional to Euclidean length, and the *graphical case*, where the edges must be chosen from an existing weighted graph G. We give a polynomial algorithm to solve this problem in the graphical case when G is planar, and show how this algorithm can be extended to give a fully-polynomial approximation scheme in the Euclidean case.

This involves joint work is joint with Roger Burk of Science Applications International Corporation, Chantilly, VA and Emily Larson of UNC-Chapel Hill (USA).

FR3-I-CM120

Traveling Salesman Problem: New Heuristics and Domination Analysis

Punnen Abraham

University of New Brunswick

Keywords: combinatorial optimization - heuristics - traveling salesman problem

We identify new heuristic approaches for the traveling salesman problem (TSP) with interesting consequences. The performance of these heuristics is examined using domination analysis, a measure that links the problem solving effort of an algorithm with the number of solutions that are guranteed to be dominated by the solution produced.

FR2-I-CM200

On a Cyclic Supervision Problem

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Universidad de Santiago

Keywords: combinatorial optimization - computational complexity - cyclic supervisor problem - dynamic programming - lot sizing - scheduling

We define a new optimization problem of a rather elementary nature and engage in a first exploration of its computational complexity.

Assume an idealized supervisor that is overseeing operations at n locations. For each location i, a positive integer bound a(i) is placed on the time interval between a departure of the supervisor from this location and his next arrival to it. The supervisor’s displacements take place instantly, and his stay at a place may have any nonnegative length, including zero.

In order to organize his task, we wish to assign the supervisor a schedule consisting of a yet undetermined number q of cyclically ordered steps. Each step k must specify one of the locations, l(k), visited by the supervisor at this step and a nonnegative real duration d(k), from the supervisor’s arrival to location l(k) to his departure from this location. For a schedule to be optimal, we wish it to maximize the duration of the whole cycle divided by the number of displacements of the supervisor, that is, we wish it to minimize the average number of displacements per time unit.

It can be proven than optimal cycles do always exist, but their lengths are not polynomially bounded in the length of the data.

The problem of finding an optimal schedule, called ‘Cyclic Supervisor Problem’ by this author, seems to be very hard for even small values of n if we try to solve it by traditional integer programming approaches.

Two algorithms related to this problem are presented. The first algorithm completely solves the problem for an arbitrary number of locations, but not in polynomial time.

The second algorithm is more limited, for it applies only to the case of 3 locations, and the optimality of its solutions has only experimentally (though very extensively) been established by comparison with the first algorithm. However, it takes a polynomially bounded time to find both the conjectured optimal value and a polynomial description of an associated supervision cycle.

FR1-U-IN10

Combinatorial Multiple-Target Tracking

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Cornell University

Keywords: generalized assignment problem - integer programming - set packing - tracking

Multiple-Target Tracking is a well-known application of information processing commonly encountered in aerospace engineering. At the heart of it lies a combinatorial data association phase which is generally handled by well-established deferred logic association methods. In light of the tremendous speed boost that off-the-shelf LP solvers have achieved within the last ten years, it is of interest to consider anew the combinatorial aspect of data association through a study of applications which at present lie beyond the reach of conventional tracking methods. This talk will focus on one such application in High Energy Physics.

In the combinatorial approach proposed here, regional constraints imposed on observations define set packing and generalized assignment types of polytopes. As none but the smallest instances of generated IPs can be handled by black-box integer programming solvers, the key to the success of this approach is to apply a decomposition heuristic which is based on the degree of correlation between dense data clusters. A full implementation of this method in the reconstruction code of a major High Energy Physics experiment has revealed improvements in track resolution routinely reaching up to seventy percents. In the general case, this approach can be seen as an interesting alternative to centroid tracking as the density of observations gets large.

TH2-C-CO3

Constant Positive Linear Independence, KKT Points and Convergence of Feasible SQP Methods

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Wei Zengxin

Keywords: KKT points - constrained optimization - constraint qualification - feasible SQP method - global convergence - superlinear convergence

In this paper, we introduce a constant positive linear independent condition (CPLIC) for a constrained nonlinear programming problem. This condition is weaker than the Mangasarian-Fromovitz constraint qualification (MFCQ) and the constant rank constraint qualification (CRCQ). We show that a limiting point of an approximate Karush-Kuhn-Tucker (KKT) point sequence is a KKT point if the CPLIC holds there. We then show that a KKT point satisfying the CPLIC and the strong second-order sufficiency conditions (SSOSC), is an isolated KKT point. Finally, we apply these results to convergence analysis for the feasible sequential quadratical programming (SQP) method proposed by Panier and Tits in 1993 for inequality constrained optimization problems. We establish its global convergence under the MFCQ and the SSOSC, and superlinear convergence of a modified version of this algorithm under the MFCQ, the CRCQ and the SSOSC. This significantly reduces its original convergence conditions which include the linear independence constraint qualification and the strict complementarity.

TU2-E-CO21

Regular Pseudo-smooth NCP and BVIP functions and globally and quadratically convergent generalized Newton method for complementarity and variational inequality problems

Qi Liqun

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TU4-E-CO21

A Variable Metric Proximal Point Algorithm for Monotone Operators

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Math. Dept., California State University, Fullerton

Burke James V..

Keywords: global convergence - maximal monotone operator - proximal point methods - superlinear convergence - veriable metric

The Proximal Point Algorithm (PPA) is a method for solving inclusions of the form $0 \in T(z)$ where T is a monotone operator on a Hilbert space. The algorithm is one of the most powerful and versatile solution techniques for solving variational inequalities, convex programs, and convex–concave mini–max programs. In the context of convex programming, where the operator T is the subdifferential of the essential objective function, the PPA can be viewed as an implementation of the method of steepest descent applied to the Moreau-Yosida regularization of the objective function. Motivated by this interpretation, we consider a variabl e metric implementation of the method and study conditions under which such an implementation accelerates convergence. In this talk, we describe both the global and local convergence properties of the variable metric proximal point algorithm and provide conditions under which the Broyden and BFGS updating strategies ensure local super-linear convergence.

FR1-P-IN201

Decompositions, Network Flows and a Precedence Constrained Single Machine Scheduling Problem

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University of British Columbia, Faculty of Commerce

Margot François - Wang Yaoguang

Keywords: decompositions - network flow - single machine scheduling

We present an in-depth theoretical, algorithmic and computational study of a linear programming relaxation to the precedence constrained single machine scheduling problem $1|\text{prec}|\sum_j w_j C_j$ to minimize a weighted sum of job completion times. On the theoretical side, we study the structure of tight parallel inequalities in the LP relaxation and show that *every* permutation schedule which is consistent with Sidney's decomposition has total cost no more than twice the optimum. On the algorithmic side, we provide a parametric extension to Sidney's decomposition and show that a finest decomposition can be obtained by essentially solving a parametric minimum cut problem. Finally, we report results obtained by an algorithm based on these developments on randomly generated instances with up to 2,000 jobs.

MO3-U-IN10

A Nonlinear Assignment Problem in Nuclear Reactor Fuel Management

Quist Arie J.

Delft University of Technology

van Geemert R. - Hoogenboom J.E. - Illés Tibor - de Jong A.J. - de Klerk Etienne - Roos Cornelis - Terlaky Tamás

Keywords: mixed integer nonlinear optimization - nonlinear assignment problems - nuclear power plants

In the core of a nuclear power plant, there is a number of uranium fuel bundles placed. About once a year, a subset of these bundles is discharged and new bundles are introduced. So the core consists of bundles with different ages. Even bundles of the same age may have different burn-up levels, which depend on their previous positions in the core. The available bundles must be arranged in such a way that the yield is maximized, while safety limitations and operational constraints are satisfied.

A nuclear fission produces neutrons, that flow through the reactor and may cause a new fission at another place. Therefore, one of the most important equations involved in computing the yield for a given pattern is a diffusion equation. To obtain stationary solutions from this equation, it is converted to an eigenvalue equation.

To get accurate results with finite difference model, a grid of about 10 by 10 grid points per fuel bundle is needed. Solving such a model is very time-consuming. This is undesirable, especially in an optimization context. Therefore, a simplified heuristic model is used, with only one grid point per fuel bundle. The diffusion equation is then replaced by a nonlinear matrix eigenvalue equation.

Many heuristics have been applied to the problem, such as simulated annealing, pairwise interchange algorithms and genetic algorithms, with varying succes. Because one percent improvement can save (at least theoretically) several millions of dollars per year, obtaining very good solutions is important. In our work, we state the problem as a mixed integer nonlinear optimization problem. This is solved using branch and bound, linear approximation techniques (DICOPT) and the generalized reduced gradient method. The first results indicate that this approach, eventually combined with local improvement heuristics, may lead to better assignments, found in a much shorter time.

FR1-C-CO122

A Simplicial Branch-and-Bound Method for Solving Nonconvex All-Quadratic Programs

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Keywords: branch and bound - global optimization - indefinite all-quadratic programs

In this paper we will present an algorithm for solving nonconvex quadratically constrained quadratic programs. The method is based on a simpicial branch-and-bound scheme involving mainly linear programming subproblems. Under the assumption that a feasible point of the all-quadratic program is known, the algorithm guarantees an ϵ-approximate optimal solution in a finite number of iterations. Computational experiments with an implementation of the procedure are reported on randomly generated test problems. The presented algorithm often outperforms a comparable rectangle branch-and-bound method.

WE4-T-CO22

The Readiness Problem: Scheduling Training for Emergency Organizations

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University of Chicago, Graduate School of Business

An Army tank battalion schedules training events over an ongoing peacetime horizon and a potential emergency horizon. The objective is to minimize the makespan in the emergency horizon, subject to a budget in the peacetime horizon. We model readiness measurement and trade-offs using dynamic programming and column generation. Though we focus on an Army tank battalion, this work has applicability and policy implications for other emergency organizations, such asthe Red Cross.

TH1-E-CO21

Active Sets for Nonlinear Programs under a Constant Rank Assumption

Ralph Danny

University of Melbourne

Qi Liqun

Keywords: active set - c-derivative - constant rank condition - nonlinear programming - semiderivative - semismooth gradient - superlinear convergence

We examine nonlinear constrained optimization problems with semismooth or smooth derivatives, under a constant rank assumption. The constant rank assumption means that if we are near the solution then we have some hope of determining which constraints will be active at the solution, and some properties their gradients, which is suggestive of algorithms. Determining an active set is akin to selecting a (semi)smooth system of equations, specifying some first-order conditions, that we wish to solve. We discuss the connection between this and the recent ideas of semiderivatives and C-derivatives in Newton methods for nonsmooth equations.

FR3-C-CO3

A Survey of Quadratic Programs with

Equilibrium Constraints (QPEC)

Ralph Danny

University of Melbourne

Jiang Houyuan - Pang Jong-Shi

Keywords: bilevel programming - convergence - implementation - numerical methods - quadratic programs with equilibrium constraints

A survey is made of recent progress on quadratic programs with equilibrium constraints (QPECs), which are an important class of mathematical programs with equilibrium constraints (MPECs), from the point of view of local minimization. QPECs arise from several interesting engineering applications such as the identification of parameters in structural engineering, origin-destination estimation in traffic assignment, strategic gaming in electric power networks, and optimal design of mechanical structures. Some fundamental results regarding first and second order optimality conditions, exact penalty results, and existence of feasible and optimal solutions, are presented. Local and global convergence of some computational methods are included. Numerical implementations of these methods have been tested on a set of realistic test problems that arise from applications.

MO4-C-CO3

Stability or Regularity of Nonsmooth Feasibility Problems

Ralph Danny

University of Melbourne

Keywords: Aubin continuity - metric regularity - nonsmooth - piecewise smooth - stability - strong perturbation

We consider strong approximation of a nonsmooth feasibility system, and discuss the stability or (metric) regularity properties of each of these systems. This is directly motivated by the classical stability results of Graves-Lyusternik and Robinson which deal with smooth feasibility systems. A potential application is stationarity conditions for mathematical programs with equilibrium constraints, similar to bilevel programs. We contrast this with recent work of Scholtes and Stohr which achieves stability in the sense of exact penalty results but avoids strong approximation.

TH4-L-CM201

Parallel Branch-and-Cut for Capacitated Vehicle Routing

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Cornell University

Pulleyblank William - Trotter Leslie Earl

Keywords: branch and cut - parallel computation - vehicle routing

By inserting a copy of the "depot" for each vehicle in the (fixed) delivery fleet, we model the capacitated vehicle routing problem (VRP) as a TSP with side constraints (the capacity restrictions). The subfamily of TSP tours which satisfy capacity restrictions defines a VRP polytope which lies within the TSP tour polytope. We examine a branch-and-cut algorithm for optimizing over this inner polytope. When TSP separation technology fails, we seek a violated capacity constraint by attempting to express the current LP solution as a convex combination of tour incidence vectors from a "tour pool." If successful, the LP solution lies within the TSP polytope and we examine the tours in this representation for a violated capacity constraint, which must exist provided the LP solution violates a capacity restriction. If unsucessful, an application of the Farkas Theorem yields a TSP whose optimum solution displays either a violated valid inequality (separation is accomplished) or a new entry for the tour pool, and the process iterates. For practical VRP instances, this TSP subproblem is only of modest size.

We present computational results obtained from a rudimentary implementation of this algorithm using COMPSys on the IBM SP2 of the Cornell Theory Center. These results indicate that the algorithm provides a promising means of separation for VRP capacity restrictions.

TU4-U-IN10

An Application of Quadratic Assignment Problem to ATM Switch Design

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Borst Sem

Keywords: cell scheduling quadratic assignment - template

Quadratic Assignment Problem (QAP) has been the subject of active research for many years. In this talk, we present a real-world application of QAP arising in a template-driven mechanism for scheduling cells in a Asynchronous Transfer Mode (ATM) switch. Our work was motivated by the need to design optimal templates for multiplexing cell streams in the switch fabric. The objective of the template-driven scheduling is to reduce cell jitter (variance in cell delay). Thus the performance of the template mechanism critically depends on the regularity properties of the template.

The regularity measure we propose dictates that the slots assigned to a given class be as equally spaced as possible. The mathematical formulation of this regularity measure is a *constrained QAP* .

We solve the constrained QAP using a LP-relaxation-based Branch-and- bound algorithm, similar in spirit to the work by Pardalos, Ramakrishnan, and Resende, but modified because of the additional constraints. The presence of the additional constraints makes it infeasible to compute upper bounds using heuristic techniques such as GRASP. We have computed the upper bounds for the QAP using heuristics designed for polling systems. We have solved problems of size up to 16 corresponding to template length of 16. Larger template sizes in the thousands are coming into vogue in ATM switches. Exact solution of the QAP formulation is infeasible in these large instances. However, we can use the LP-relaxation to compute lower bounds for the problem which can guide the quality of solutions obtained by other heuristics.

Our methodology has been used for cell scheduling in the Lucent Technologies' Voyager ATM switch.

TH2-A-IN2

A Posteriori Bounds for Variable Aggrega-

tion in Integer Programming

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Universidade Estadual Paulista - UNESP

Litvinchev Igor S.

Keywords: aggregation - cutting plane methods - integer programming

When an aggregated problem has been solved, it is necessary to estimate the accuracy loss due to the fact, that a simpler problem than the original one has been solved. One way of measuring this loss in accuracy is the difference in objective function values. To get the bounds for this difference it is usually assumed that a simple (knapsack-type inequality) localization of an original optimal solution is known. A method to compute the bounds for variable aggregation in convex problem is proposed, which posses to deal with general localization of the original solution. A localization for integer programming problems is obtained by generating valid inequalities to cut off the aggreated solution. Examples are given to illustrate the main constructions.

FR3-U-IN1

Bilevel Models in Worst-Case and Topology Problems in Structural Design

Rao Jagannatha

University of Houston

Keywords: eigenvalue optimization - structural topology - worst case design

In this presentation, we will discuss certain special classes of bilevel problems that arise in mechanical design optimization. In particular, the focus is on worst-case design of structures under load uncertainty and topology optimization of structures under static, dynamic and thermal loads.

TU3-I-CM4

Recognizing Cobithreshold Graphs in Linear Time

Raschle Thomas

ETH Zürich

Sterbini Andrea

A cobithreshold graph G is a graph that can be written as the (edge-)union of two threshold graphs T_1 and T_2 such that every clique of G is also a clique of T_1 or T_2. In this paper, we give a linear time algorithm to recognize cobithreshold graphs.

TH2-C-CO122

A New Global Optimization Technique Using Slopes

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Keywords: global optimization - interval branch-and-bound - interval slopes

This paper introduces a new pruning technique based on slopes in the context of interval branch-and-bound methods for global optimization. We show that it is possible to replace the frequently used monotonicity test by a new pruning step, and we demonstrate the theoretical and practical effect of this pruning step within a first-order model algorithm for one-dimensional global optimization. It is underlined how the new technique provides considerable improvement in efficiency for our model algorithm. For this reason, we compare the required CPU time, the number of function and derivative or slope evaluations, and the necessary storage space when solving several global optimization problems with two variants of the model algorithm, i.e. equipped with the monotonicity test and the pruning step, respectively.

TU2-C-CO122

Efficient Random Algorithms for Constrained Global and Convex Optimization

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Keywords: Markov chains - Monte Carlo approximations - random search - simulated annealing

Global optimization problems may often prove difficult to solve by deterministic means due to the presence of many local optima. We present a stochastic approach to solving such problems based on the concept of sampling candidate solutions via a biased random walk. For convex programming, we demonstrate three random optimization algorithms that enjoy polynomial complexity. Coupling the random walks with a Lagrangian relaxation procedure, we extend these algorithms to yield an efficient simulated annealing algorithm for constrained global optimization. Finally, we present empirical results for the simulated annealing algorithm when applied to a difficult automotive design problem.

WE2-D-CO124

Perturbed Path Following Interior Point Algorithms

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INRIA Rocquencourt

Bonnans Frédéric - Pola Cecilia

Keywords: decomposition - infeasible algorithms - interior point methods - large scale optimization - linear complementarity problem - linear programming - parallel computation - perturbation - polynomial complexity - predictor-corrector methods

The path following algorithms of predictor corrector type have proved to be very effective for solving linear optimization problems. However, the assumption that the Newton direction (corresponding to a centering or affine step) is computed exactly is unrealistic. Indeed, for large scale problems, one may need to use iterative algorithms for computing the Newton step.

In this paper, we study algorithms in which the computed direction is the solution of the usual linear system with an error in the right-hand-side. We give precise and explicit estimates of the error under which the computational complexity is the same as for the standard case. We also give explicit estimates that guarantee an asymptotic linear convergence at

an arbitrary rate. Because our results are in the framework of monotone linear complementarity problems, our results apply to convex quadratic optimization as well.

MO4-I-CM200

On the Exact Resolution of the Bin Packing Problem

Rebetez Vianney

Université Libre de Bruxelles

Bourjolly Jean-Marie

Keywords: bin packing - branch and bound - reduction procedure

In this talk, we will examine the Martello & Toth solution for the BPP. We will cover their lower bound procedure, their dominance criteria, their reduction procedure and the branching scheme of their branch and bound algorithm. We will present a generalisation of the reduction procedure and an improvement of the lower bound procedure. We will also propose a different brancing scheme for a branch and bound algorithm and finally present the results of our algorithm. We will analyse the results presented and see it is globally more performant than the Martello & Toth algorithm.

TH3-C-CO122

Towards a Fundamental Theorem of Calculus for Nondifferentiable Functions

Recht Peter

University of Dortmund

Keywords: generalized tangent space - lemma of Poincaré - nondifferentiability

Of central meaning in the treatment of nondifferentiable functions is the concept of directional differentiability . This concept allows the construction of *generalized gradients* for d.d. functions, based on a development of the directional derivative into spheric harmonic polynomials. Using this special representation we will attack the problem of finding a *primitive funtion* for a given directional derivative:

we consider a subset $U \subset \mathbf{R^n}$ on which we assume that at every point $x \in U$ a *generalized gradient* is given. Then a natural question is, which are the conditions that for such a generalized *"gradient-field* ω*"* a (not necessary differentiable, but) Lipschitz-continuous, directionally differentiable function F exists, whose *directional derivative* dF coincides with ω *at every point* of U. In the classical theory of differentiable functions, the general answer is just given by the fundamental theorem of calculus.

In the talk we will show, that for the non-differentiable case the special representation of the directional derivative (using the generalized gradient) allows an suitable approach for attacking the problem. The procedure and the results are very similar to classical theorems (among them the well-known *Lemma of Poincaré*).

TH3-I-CM5

Channel Routing in the Dogleg-Free Multilayer Manhattan Model

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Keywords: VLSI design - combinatorial optimization - matroid - scheduling

Let l_H and l_V denote the number of layers reserved for horizontal (vertical, respectively) wire segments in the multilayer dogleg-free Manhattan model. $[d/l_H]$ is a lower bound for the minimum width for routing a channel of density d where $[x]$ denotes the upper integer part of x. A greedy interval packing algorithm realizes width $[d/(l_V-1)]$ in linear time if $l_V \geq 2$. This is clearly best possible if $l_V = l_H + 1$. We prove that it is **NP**-complete to decide whether the lower bound can be reached if $l_V = l_H$ or if $l_V = 1$ and $l_H = 2$. Then we suggest quick heuristic solutions: in the former case a quick superpolynomial algorithm is given. In the latter case the problem is reduced to a scheduling problem and a polynomial time algorithm using matroidal methods essentially due to Marcotte and Trotter, leads to stronger lower bounds of the minimum width.

TH1-B-CO10

Filter Design in the Frequency Domain by Semi-Infinite Programming

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Technische Universität Cottbus

Potchinkov Alexander W.

Keywords: complex approximation - digital filter design - nonrecursive filters - semi-infinite programming

The four central design problems for digital filters in the frequency domain are the problems of approximating a given ideal frequency response resp. a magnitude response and the problems of simultaneously approximating a magnitude and phase response resp. a magnitude response and group delay by the corresponding quantities of a digital filter. Additional requests with respect to the properties of a filter can often be expressed by equality and/or inequality constraints on the filter coefficients. The normally used distance measures for the approximation are the least square norm and the maximum norm.

In this talk primarily the design of nonrecursive digital filters is considered. The four design problems for such filters are stated in a suitable mathematical way, and results on the existence of solutions and the convergence of the approximation errors are given. Concerning the numerical solution of these problems, it is advised to approach the respective equivalent semi-infinite programs, where the state of the development of numerical methods for such programs suggests to replace some of the nonlinear design problems by a proper convex approximation. At last several computed designs of filters are presented.

WE2-S-IN202

A Polyhedral Approach for RNA Secondary Structure Alignment

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Lenhof Hans-Peter - Mutzel Petra - Vingron Martin

Keywords: combinatorial optimization - computational biol-

ogy - secondary structure

Ribonucleic acid (RNA) sequences are strings over a four letter alphabet which represent the four nucleic acids. Such molecules fold in space and form bonds between pairs of nucleic acids. While the sequence alone is called the molecule's primary structure, the sequence together with the pairing information is called the secondary structure. The biological function of an RNA molecule is determined to a large extent by its secondary structure and in many cases it is the secondary structure that is conserved in evolution.

Traditionally, similarity between two nucleic acid sequences is determined using sequence alignment algorithms. Most of these algorithms can only account for the primary structure of the sequences. In this paper we address the problem of optimally aligning a given RNA sequence with unknown secondary structure to one with known sequence and structure. We phrase the problem as an integer linear programming problem and then solve the problem using methods from polyhedral combinatorics.

FR4-U-IN1

A New Model for Stochastic Optimization of Weekly Generation Schedules

Renaud Arnaud

Électricté de France

Brignol Sandrine

Due to uncertainty on the demand, in France, the optimization of weekly generation schedules is inherently a stochastic problem: because of electric heating, a variation of one degree Celsius in the average winter temperature leads to a load variation of more than 1GW (compared to a peak load ranging around 70GW). To deal with this type of problem, a stochastic decomposition approach has been proposed in. It may be considered as a generalization of a Lagrangian Relaxation method, which is now usually applied to solve Unit Commitment problems, to a stochastic framework. Randoms are modeled as scenario trees. Prices are attached to each node of the scenario tree and are updated at the coordination level. At each iteration, for each generation unit, a subproblem has to be solved which consists in minimizing the average generation cost over a scenario tree of prices.

This decomposition strategy has been chosen by EDF to design a new model for the optimization of weekly start-up schedules and of water values. In this model, hydro-valleys, thermal units, nuclear plants, exchanges management and demand side management are represented. This presentation is devoted to the description of this new model.

First, the stochastic decomposition framework which is used is outlined. Secondly, the modelings of the generation units and of the random events are presented. The algorithms which have been applied to solve the subproblems are then described and the bundle coordination technique is briefly outlined. Finally, numerical tests over the French generation mix are presented.

TU2-D-CO123

Semidefinite Programming using Eigenvalue Optimization

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Helmberg Christoph

Keywords: max-cut - semidefinite programming

We consider solving large scale instances of the Max-Cut problem. We use a semidefinite relaxation of the problem, where all the constraints are sparse and highly structured. Since the primal problem is both time and space consuming for larger sized problems, say for graphs on several hundred of nodes, we approximate the dual as eigenvalue optimization problem. We use an inner approximation of the subdifferential to get a descent direction and present computational results for medium sized instances of the Max-Cut library.We consider solving large scale instances of the Max-Cut problem. We use a semidefinite relaxation of the problem, where all the constraints are sparse and highly structured. Since the primal problem is both time and space consuming for larger sized problems, say for graphs on several hundred of nodes, we approximate the dual as eigenvalue optimization problem. We use an inner approximation of the subdifferential to get a descent direction and present computational results for medium sized instances of the Max-Cut library.

FR1-I-CM4

Max-Cut Approximations in Graphs with Triangles

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Keywords: approximation algorithms - max-cut

We consider the Goemans- Williamson approximation approach for Max-Cut for graphs having many triangles. By constraining the semidefinite relaxation of the problem to satisfy all the triangle constraints, we show that Max-Cut can be approximated with multiplicative error of at most .912, provided that the cost function is contained in the cone generated by incidence vectors of triangles. We also indicate possible extensions and limitations of this approach.

MO4-D-CO124

A Branch and Bound Algorithm for the Quadratic Assignment Problem using Lower Bounds Based on Linear Programming

Resende Mauricio G. C.

AT&T Labs - Research

Ramakrishnan K. G. - Pardalos Panos M.

Keywords: branch and bound - interior point methods - quadratic assignment problem

In this paper, we study a branch and bound algorithm for the quadratic assignment problem (QAP) that uses lower bound based on the linear programming (LP) relaxations of integer programming formulations of the QAP. We report on computational experience with the branch and bound algorithm on numerous QAP test problems. The linear programming relaxations are solved with an implementation of an interior point algorithm that uses a preconditioned conjugate gradient algorithm to compute directions. The branch and bound algorithm is compared with a similar branch and bound algorithm that uses the Gilmore-Lawler lower bound (GLB) instead of the LP-based bound. The LP-based algorithm examines a small portion of the nodes explored by the GLB-based algorithm. Extensions to the implementation are discussed.

TH4-I-CM121

Approximate Solution of Weighted MAX-SAT Problems using GRASP

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AT&T Labs - Research

Pitsoulis Leonidas S. - Pardalos Panos M.

Computing the optimal solution to an instance of the weighted maximum satisfiability problem (MAX-SAT) is difficult even when each clause contains at most two literals. In this talk, we describe a greedy randomized adaptive search procedure (GRASP) for computing approximate solutions of weighted MAX-SAT problems. The heuristic is tested on a large set of test instances. Computational experience with serial and parallel implementations of this heuristic indicates the suitability of GRASP for this class of problems.

TH2-K-CM106

A Framework for the Development of Local Search Based Heuristics for Combinatorial Optimization Problems

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Catholic University of Rio de Janeiro, Brazil

Andreatta Alexandre - Carvalho Sergio

Keywords: combinatorial optimization - heuristics - local search - tabu search

In the study of heuristics for combinatorial problems, it is often important to develop and compare, in a systematic way, different algorithms, strategies, and parameters for the same problem. The central issue in this paper is that, by modeling (using the object-oriented programming paradigm) in separate classes the different aspects involved in local search based methods, and by relating these classes in a framework, we increase our ability to construct and compare heuristics, independently of their implementations.

The main goal of this work is to provide an architectural basis for the implementation and comparison of different local search heuristics. Frameworks are essentially prototypical architectures for related systems, or systems in the same application domain. The proposed framework, described using design patterns, encapsulates, in abstract classes, different aspects involved in local search heuristics, such as algorithms for the construction of initial solutions, methods for neighborhood generation, and movement selection criteria. It also makes easier the use of dynamic neighborhood models, due to type variation support offered by the object-oriented methodology. Encapsulation and abstraction allow unbiased comparisons between different heuristics, code reuse, and easy extensions.

The classification of different aspects of heuristics simplifies their implementations, and invites new extensions, in the form of subclasses. Code reuse, accomplished by the implementation of common aspects of a family of heuristics, allows a better platform for comparison, since a large part of the code is common to all members of the family.

We are using this framework to develop and compare heuristics for the phylogeny problem under the parsimony criterion, which is one of the main problems in comparative biology. The instantiation of the proposed framework to the phylogeny problem allowed the development of a family of local search methods, and a fair comparison in terms of solution quality and computational times.

TU3-K-CM106

A Grasp for a Matrix Decomposition Problem in Traffic Assignment

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Prais Marcelo

Keywords: GRASP - heuristics - local search

We consider a traffic assignment problem arising in the context of TDMA satellite systems, consisting in finding an optimal schedule of traffic demands to satellite channels, so as to minimize the overall transmission time. Given a traffic matrix, we search for its decomposition into a sum of matrices with at most one element per row and per column, such that the sum of the largest element of each matrix appearing in the decomposition is minimized.

This problem can be formulated as a very large set partitioning problem. A very fast greedy heuristic consists in forming the matrices appearing in the decomposition by successively selecting the largest element in the traffic matrix, eliminating its row and column, and repeating the above steps, until no further elements can be placed in the current commutation mode matrix. The procedure is re-applied to the remaining non-assigned elements, until all entries of the original matrix are assigned to exactly one commutation mode matrix.

We propose a greedy randomized adaptive search procedure (GRASP) to this matrix decomposition problem. Each GRASP iteration consists of two phases: construction and local search. The construction phase builds a feasible solution, whose neighborhood is explored by local search. The best solution over all iterations is retained. In the construction phase we use a randomized version of the above described greedy heuristic. At each step, instead of selecting the largest nonselected entry, we build a list containing the largest nonselected entries and randomly select one of them to be placed in the commutation mode matrix currently under construction.

The local search phase is based on a specific kind of neighborhood devised for this problem. The neighborhood definition is based on the insetion/elimination of some elements appearing in one the matrices, followed by the reconstruction of a new decomposition. Computational results with different strategies for the implementation of the local search phase are presented.

TU1-U-IN10

A Home Health Care Scheduling Problem

Rich Jennifer Lynn

Rice University

Cheng Eddie

Keywords: heuristics - mixed integer programming - vehicle

routing

Consider the problem of routing a set of nurses from each individual nurse's home to a set of patients and back home again. Each patient must be visited by a single "feasible" nurse during its time window. Essentially, this is a multi-depot vehicle routing problem with time windows with additional feasibility restrictions on which nurses can visit which patients. This problem is $\mathcal{NP}$-Hard. We give a mixed-integer-linear programming formulation of this problem and a heuristic for finding a good solution.

WE4-I-CM200

Realization Spaces of 4-Polytopes are Universal

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Keywords: NP - existential theory of the reals - polytope - universality

The attempt to structure the set of all polytopes of a fixed dimension leads to two major lines of study:

- to list all possible combinatorial types of polytopes, and
- to describe the set of all realizations of a given combinatorial type.

In the case of 3-dimensional polytopes, a classical result by Steinitz, 1922 — his "Fundamentalsatz der konvexen Typen" — provides complete solutions to these problems:

> *A graph is the edge graph of a* 3*-polytope if and only if it is planar and* 3*-connected, then the polytope is realizable over the integers and the realization space is a topological disk.*

We will prove that such nice results are no longer true for 4-dimensional polytopes. By encoding arbitrary polynomial equations into polytopes we prove:

- There is no local characterization of polytopality of 4-polytopes.
- All algebraic numbers are needed to realize all 4-polytopes.
- The realization space can be arbitrary complicated (i.e. topologically equivalent to any semi-algebraic variety).

All these statements are consequences of a construction that proves that the *polytopality-problem* is polynomially equivalent to the *existence theory of the reals.*

TU3-E-CO21

Solving Maximal Monotone Operator Inclusions by Reformulation

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Keywords: continuation - equilibrium - homotopy - maximal monotone operator - variational inequalities

We consider methods for numerically solving maximal monotone operator inclusions of the form

$$0 \in f(x) + M(x),$$

through reformulation as single-valued, generally nonsmooth, equations. Here f is a function from R^n to R^n that has nice differentiability properties (e.g. it may be smooth, or at least C^2), and M is a maximal monotone operator from R^n to R^n. Such inclusions are also called *generalized equations;* some well known special cases include the pure or mixed (nonlinear) complementarity problem and the more general variational inequality problem. In problems found in applications the operator M is frequently *polyhedral:* that is, its graph is the union of finitely many polyhedral convex sets. The methods we consider here are designed primarily for such problems.

We first illustrate the reformulation approach by considering the normal map for variational inequalities, and outline a considerable amount of theoretical and computational work already done for that case by various authors, including some recent applications to stochastic equilibrium problems. Then we show how the theoretical part of the analysis can be extended to more general maximal monotone operator inclusions. Numerical experiments with these extended problems will be described to the extent that they are available.

TH1-L-CM201

Computing Minimum-Weight Perfect Matchings

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Universität Bonn

Cook William J.

Keywords: matchings - perfect matchings

We make several observations on the implementation of Edmonds' blossom algorithm for solving minimum-weight perfect-matching problems and we present computational results for geometric problem instances ranging in size from 1,000 nodes up to 5,000,000 nodes. As a benchmark of the algorithm's performance, solving a 100,000 node geometric instance on a 200 Mhz Pentium-Pro computer takes approximately 3 minutes.

TH1-L-CM201

A New Approach to Exploiting Negative Curvature Directions in Large Scale Unconstrained Optimization

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Gould Nicholas I. M. - Lucidi Stefano - Toint Philippe L.M.

Keywords: Newton method - large scale unconstrained optimization - negative curvature direction

In this work we consider the definition of new efficient algorithms for solving large scale unconstrained optimization problems by exploiting the local nonconvexity of the objective function. In particular in this new class of algorithms two search directions are computed at each iteration: a Newton-type direction which ensures the global convergence and a fast convergence rate and a negative curvature direction which enables to escape from the region of local nonconvexity. Usually similar algorithms already proposed generate the new trial point by performing a movement along the path obtained by the combined contribution of these two directions. The main difficulty in defining efficient path relies on the fact that these two directions are differently scaled. In the approach that we describe we choose at each iteration only one of these two directions according to a switching rule based on the decrease of the quadratic model of the objection function. The rationale behind this choice is to use as search direction that one which appears more promising. To this aim we investigate robust methods for determining both the directions. Some preliminary results are reported.

TU3-M-IN202

Knowledge Representation for Decision Support System of Optimization 2-D Placement Problems

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Keywords: mathematical models - optimization placement problems

The paper considers knowledge representation for decision support system of solving 2-D optimization placement problems.

Concept to construct the decision support system to solve 2-D optimization placement problems is developed.

A thorough review of 2-D optimization placement problems (namely: layout, packing, cutting, arrangement and so on) are given.

Problems under consideration are NP -hard geometric optimization problems of practical importance.

A unified mathematical model of the problems within geometric design theory is represented.

Peculiarities of the mathematical model as mathematical programming model are analyzed.

A realization of the mathematical model is described by structure (system) of linear (nonlinear) inequalities with linear (nonlinear) objective function.

Each the realization characterized by indications of a stated problem such as shapes (i.e., topological invariants, metrical characteristics and shapes of connected component of frontier) of geometric bodies, technological restrictions (i.e.,minimal (maximal) admissible distance between geometric bodies, periodic, latticed placement, guillotine cuts.) and kind of objective function (i.e. minimum of a length, maximum of filling domain factor, minimum of deviation of object center gravity)

Equivalence relation on a set of realizations of the mathematical model (according to the indications) is defined.

A choice of the solution method is defined by indications of the realization of the mathematical model.

Representation of knowledge based on peculiarities of the unified mathematical model of the problems, whose set of realizations reflect the variety of arising applied or scientific problems and solution methods of global and local optimization.

N-tuples of the problem statement, the mathematical model and solution method constructed. Predicative functions to connect elements of ones are given. Concept of Petry network is used.

FR3-C-CO122

Simulated Annealing for Mixed Integer/Continuous Global Optimization

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Keywords: composite structural design - jamming - mixed integer/continuous optimization - simulated annealing

To reduce the well-known problem of jamming in global optimization algorithms, we propose a new generator for the simulated annealing algorithm based on the idea of reflection. Furthermore, we give conditions under which the sequence of points generated by this simulated annealing algorithm converges in probability to the global optimum for mixed integer/continuous global optimization problems. Finally, we present numerical results on some artificial testproblems as well as a composite structural design problem.

WE1-K-CM106

A Class of Generalized Greedy Algorithms for the Generalized Assignment Problem

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Erasmus University

Romeijn H. Edwin

Keywords: generalized assignment problem - greedy heuristics - probabilistic analysis

The Generalized Assignment Problem (GAP) examines the minimal cost assignment of tasks to agents such that each task is assigned to exactly one agent subject to capacity restrictions on the agents. A class of generalized greedy algorithms is proposed for the GAP. Given weights for each agent, a measure is defined representing the desirability of assigning each task to each agent. The obtained solution depends on the choice of weights. A relation with the partial solution given by the LP relaxation of the GAP is found. We derive conditions under which the heuristic is asymptotically optimal in the probabilistic sense.

MO4-G-IN11

Quantitative Stability of Stochastic Programs

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Keywords: dynamic stochastic programs - empirical approximation - probability metric - stability

We consider a convex stochastic optimization model, where the objective is given as an expectation functional and the constraint set is fixed. We study quantitative stability properties of its optimal value and (ε-) solution set when the underlying probability distribution varies in some metric space of probability measures. Two types of results are presented. The first result establishes Lipschitzian stability for general perturbations of the original probability distribution with respect to a Fortet-Mourier type probability metric. The metric is adapted to the continuity properties of the integrand. In the second result we consider, in particular, empirical estimates of the original distribution and derive convergence rates under weak polynomial moment conditions for the integrand. Here we utilize a specific ideal probability metric. The general results are used to derive stability properties of multistage stochastic programs with linear (fixed) recourse.

TU2-U-IN10

Solving Capacitated Facility Location Problems with Single Sourcing Using a Lagrangean Heuristic, Repeated Matching and Branch-and-Bound

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Holmberg Kaj - Yuan Di

Keywords: Lagrangean heuristics - branch and bound - facility location - integer programming - mathematical programming

Facility location problems are often encountered in many areas such as distribution, transportation and telecommunication. We describe a new solution approach for the capacitated facility location problem in which each customer is served by a single facility. An important class of heuristic solution methods for these problems are Lagrangean heuristics which have been shown to produce high quality solutions and at the same time be quite robust. A primal heuristic, based on a repeated matching algorithm which essentially solves a series of matching problems until certain convergence criteria are satisfied, is incorporated into the Lagrangean heuristic. Finally, a branch-and-bound method, based on the Lagrangean heuristic is developed, and compared computationally to the commercial code CPLEX. The computational results indicate that the proposed method is very efficient.

MO4-A-IN1

An Exponential Example for the Least-Index-Pivot Variant of the Criss-Cross Method

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Keywords: criss-cross method - exponential example - linear optimization

In 1985 Terlaky proposed a pivoting rule for a variant of the criss-cross method of Zionts (1979) which prevents cycling. Thus, with this so-called least-index-pivot rule the criss-cross method terminates after finitely many iterations. Our aim is to show that on the famous Klee-Minty polytope the number of iterations may be as large as $2^n - 1$.

WE1-D-CO123

An Exact Polynomial-Time Solution Method for the Self-Dual Linear Optimization Problem

Roos Cornelis

Delft University of Technology

Terlaky Tamás - Vial Jean-Philippe

Keywords: linear optimization - polynomial time method - rounding procedure - self-dual model

Tucker (1956) already observed that any given linear optimization (LO) problem (P) can be embedded in a self-dual problem (SP) such that a strictly complementary solution of (SP) either yields a strictly complementary solution of (P) or decides that (P) has no optimal solution, which means that (P) is infeasible or unbounded. We deal with a simple interior-point method for solving (SP). First we embed (SP) in another self-dual model (ESP) that satisfies the interior-point condition (IPC). We give a new proof of the known fact that the IPC implies the existence of the central path and we show that without loss of generality it may be assumed that a point on the central path of (ESP) is available. Then we present a simple central-path-following method for solving (ESP), which includes a rounding procedure from an interior solution to a strictly complementary (exact) solution. In this way the given LO problem (P) can be solved in $7\sqrt{n+m}L$ iterations, where n denotes the number of variables and m the number of constraints and L the binary input size of (P).

TH4-V-CM106

Applications of Scenario Optimization for Hedging and Estimating Implied Parameters

Rosen Dan

Algorithmics

Dembo Ron

Keywords: financial optimization - risk management - stochastic programming

Scenario optimization is a powerful tool for financial modelling. Applications of this robust technique include asset and capital allocation, pricing and hedging in complete and incomplete markets, risk-reward analysis, and estimation of implied interest rate curves and option volatilities. We discuss several real-world applications, including static hedging of complex derivatives and portfolios, hedging basis risk of fixed income portfolios, and computation of implied probabilities in option pricing.

WE2-T-CO22

Optimization Modeling for Airlift Mobility

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Naval Postgraduate School

Baker Steven F. - Melody Laura J. - Morton David P.

We will highlight the structure and features of a new LP model called NRMO (The NPS/RAND Mobility Optimizer), designed to help efficiently transport equipment, supplies and personnel by air during military contingencies. NRMO determines the maximum on-time throughput of cargo and passengers that can be transported with a given aircraft fleet over a given network, subject to appropriate physical and policy constraints. The optimization model has helped the US Air Force answer questions about selecting airlift assets and about investing or divesting in airfield infrastructure.

MO4-I-CM121

Clustering Problems on the Line and on Trees

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Keywords: clustering - maximum cut

Given a set of n points on the line, we want to partition them into two parts V_1 and V_2 such that the total sum of all distances between pairs of points in the same part are minimized. (This can be formulated as a max-cut problem.) We show that in an optimal solution, there is one of the sets V_1 and V_2 which has no point of the other set between any two of its points. This is true even if the desired cluster sizes $|V_1|$ and $|V_2|$ are specified, extending a result of Boros and Hammer (1989).

If the given points are vertices of a *tree* and inter-point distances are measured by path lengths in the tree, it has been conjectured that the same separability property holds. We give some experimental evidence in support if this conjecture, but we show that separability is not guaranteed if the cluster sizes are specified. In any case, the optimal clustering can be found in $O(n^3)$ time by a dynamic programming approach.

TU1-D-CO123

Polynomial Time Root Computation of Parametric Polynomials with Newton's Polygon Process

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Eaves B. Curtis

Given a ground field a parametric polynomial is regarded as a polynomial with coefficients in the extension field of semi-terminating formal fractional power series. Roots of parametric polynomials are in the extension field and are termed parametric roots. Using a refinement of the Newton Polygon Process, a complete set of approximate parametric roots are computed in parallel. Elements in the complete set are truncations of the exact parametric roots, are accurate to prescribed accuracy, and are dense in the set of all approximate roots. A complexity analysis over the ground field of arithmetic operations, storage, required time, required number of parallel processors and requested roots of polynomials is provided; polynomial bounds are established in the degree of the parametric polynomial and the prescribed target accuracy.

FR2-I-CM4

Strategic Behavior in Matching Markets with Lack of Information, in Search of Practical Advice for Participants

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Roth Alvin E.

We consider the strategic options facing workers in labor markets with centralized market clearing mechanisms such as those in the entry level labor markets of a number of professions. If workers do not have detailed information about the preferences of other workers and firms, the scope of potentially profitable strategic behavior is considerably reduced, although not entirely eliminated. This gives some insight into the successful operation of these market mechanisms.

MO3-C-CO2

Convex-Along-Rays Functions and Star-Shaped Sets

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Vladimirov Alexander

Keywords: abstract convexity - convexity-along-rays - global optimization - star-shaped sets

Let H be the set of all functions defined on the space $\mathbb{R}^n$ by the formula $h(x) = \min_{i=1,\dots,n+1}[\ell_i, x] - c$ with $\ell_i \in \mathbb{R}^n$ and $c \in \mathbb{R}$. We study abstract convex functions with respect to the set H. That is functions which can be represented as the upper envelope of subsets of H. A function f is called convex-along-rays (CAR(X)) if its restriction to each ray starting from zero is a convex function of one variable. Clearly an abstract convex function with respect to H is lower semicontinuous and CAR(X). We give an example showing that the reverse assertion is not, in general, true. Nevertheless, it holds under some very mild additional assumptions. We also give conditions guaranteeing that a CAR(X) function is subdifferentiable in the sense of abstract convex analysis. Some applications to the study of problems of global optimization will be outlined. The connection with the theory of star-shaped sets will also be discussed.

MO3-C-CO2

Increasing Convex-Along-Rays Functions with Applications

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Glover Bevil Milton (Barney)

Keywords: abstract convexity - convexity-along-rays - global optimization

A function defined on the positive orthant of R^n is called convex-along-rays (CAR(X)) if its restriction to each ray starting from zero is a convex function of one variable. A function f is increasing and CAR(X) if and only if it is abstract convex with respect to the set H of all functions of the form $h(x) = \langle \ell, x\rangle - c$ where c is a constant, $\ell \in R^n_+$, and $\langle \ell, x\rangle = \min_{i:\ell_i \neq 0} \ell_i x_i$. Abstract convexity of f means that the function can be represented as the upper envelope of a subset of H. The class of increasing CAR(X) functions is very broad, it contains, for example, all polynomials with nonnegative co-efficients. We shall give a description of the subdifferential (in the sense of abstract convex analysis) of strictly increasing CAR(X) functions and study the properties of the subdifferential. These properties are applied to describe the maximal elements of the support set of a coercive increasing CAR(X) function f (the support set is the set of all $h \in H$ minorized by f). The results obtained are applied to the study of some problems of global optimization involving increasing CAR(X) data. We also consider increasing concave-along-rays

(CAR(V)) functions and related applications.

WE1-E-CO21

Reformulation of Economic eEquilibria Problems

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Glover Bevil Milton (Barney)

Keywords: continuous approximation - economic equilibria - nonsmooth analysis

We study the reformulation of some economic equilibria problems into equivalent optimization problems which are involve the minimization of differences of special nonsmooth marginal functions over very simple constraints. This approach allows us to define a family of generalized equilibria if the usual equilibrium does not exist. We study some properties of the objective function and discuss some approaches for finding a solution of the extremal problems under consideration.

WE2-C-CO2

On a Multiplicative Analogue of Infimal Convolution with Application to Penalization

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University of Ballarat

Yang Xiao Qi - Glover Bevil Milton (Barney)

Keywords: abstract convexity - exact penalization - homogeneous functions - increasing positively - infimal convolution

We define and study a multiplicative analogue of infimal convolution for decreasing functions defined on the cone of vectors with positive coordinates. The main tool we use is a representatation of increasing positively homogeneous functions as abstract convex functions with respect to the class of min-type functions. The results are applied to the study of modified penalty functions for continuous mathematical programming problems.

TH1-B-CO10

One-Parameter-Families of Feasible Sets in Semi-infinite Optimization

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Keywords: Mangasarian-Fromovitz constraint qualification - bifurcation point - feasible set - parametric family - semi-infinite optimization

Feasible sets in semi-infinite optimization are defined by a finite number of equality constraints and (perhaps) an infinite number of inequality constraints. We consider one-parametric families of such sets. In particular, all defining functions - including those defining the index set of the inequality constraints - will depend on a parameter. For a quite natural class of mappings we discuss the change of the topological structure of the corresponding feasible set as the parameter varies. As long as the index set (-mapping) of the inequality constraints is lower semicontinuous, all appearing changes in topology are those which generically appear in one-parametric sets defined by finitely many constraints. However, in case that some component of the mentioned index set is born (or disappears), the topological change is of global nature and is not controllable. In fact, the change might be as drastic as that when adding or deleting an (arbitrary) inequality constraint. The lecture is based on a recently published joint paper together with H. Th. Jongen (Aachen, Germany).

FR1-A-IN2

A Statistical Test for Detecting Influential Observations in DEA

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Sirvent Inmaculada - Pastor Jesús T.

Keywords: data envelopment analysis - linear programming - nonparametric statistics

This paper deals with the problem of detecting influential observations in radial DEA models. In the first part of the work, which is deterministic, we define a new measure of the influence of a DMU on the radial efficiency of any of the remaining units. This measure has the property of being an efficiency score. In the second part, we model the problem from a statistical point of view, suggesting a statistical test to determine the magnitude of the influence of the DMU being analized as well as the number of affected DMUs. Hence, after solving this test we will have some useful information to decide whether this unit is influential or not.

MO-pm-SPO

Decomposition Methods in Stochastic Programming

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Keywords: decomposition - stochastic programming

Stochastic programming problems have very large dimension and special structures which are tractable by decomposition. We review basic ideas of cutting plane methods, augmented Lagrangian and splitting methods, and stochastic decomposition methods for convex polyhedral multi-stage stochastic programming problems.

TH3-G-IN11

A Stochastic Branch-and-Bound Method

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Norkin Vladimir I. - Pflug Georg Ch.

Keywords: stochastic global optimization - stochastic integer programming

We present a novel methodology for solving stochastic integer or global optimization problems: a stochastic branch-and-bound method. At each step a certain partition of the feasible set is considered, and for each subset stochastic estimates of lower and upper bounds for the best objective value are calculated. They are used to construct a new partition, for which

new estimates are generated, etc. The method is convergent with probability one.

We discuss various ways of calculating stochastic bounds, using multiple observations, estimating the accuracy of the solution, and deleting non-prospective subsets.

We present also an application of the new methodology to a problem of water quality management.

WE2-I-CM4

Patching: A Technique for Constructing Facets

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Keywords: facets - patching - polyhedral combinatorics

Many interesting, and usually NP-hard, combinatorial optimization problems can be formulated as a 0,1-programming problem. One of the major problems in solving these integer programs is to find a good linear description of the set of feasible solutions, i.e. to find facets of the polytope corresponding to the problem at hand (this polytope is the convex hull of all solutions to the integer progam). Patching is a technique to construct new valid inequalities by combining the support of two or more known valid inequalities. Under certain conditions these new valid inequalities define facets. In this presentation we explain how and why patching works, and we give some examples, including the traveling salesman polytope, the stable set polytope, and the clique partitioning polytope.

MO4-I-CM5

An Optimization Model and Solution Method for Standby Crew Selection

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Meyer Jeff

Keywords: airlines crew scheduling - optimization - set partitioning

Crew scheduling in the airline industry involves first the construction of tours of duty (or pairings) which are then rostered (or allocated) to individual crew members to form a crew roster over some roster period of say twenty eight days. Standby lines, typically of twenty eight days duration and involving alternating periods of standby (or on-call) duties and rest, are also allocated to crew in the roster to provide additional staff resource who can be called out to work when, for some reason, a rostered crew member is unable to perform an allocated tour of duty in their roster line. In longhaul airline operations the selection of standby crew is an operational problem which demands careful attention.

When a standby crew member is called out from their standby line to cover a tour of duty of say fourteen days duration, the standby duties they would have been “performing” during those fourteen days will be undercovered by one person and it is easy, over a period of some days and after a number of crew have been called out independently, to end up with standby duties in which all the planned standby coverage has been eliminated and no standby crew are available. The undercoverage of a standby duty is referred to as a *hole* in the standby coverage. The optimization model described in this paper selects individual crew to be called out so that *holes* in the future standby coverage are minimized and the standby lines for crews who are returning from a standby call out are recreated to to fill in holes which are appearing. The model is based on a generalised set partitioning form.

MO3-T-CO22

Optimization Methods in Food Processing

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Universität Trier

Kleis Detlev

Keywords: SQP - heat equation - optimal control

Mathematical methods gain significant importance in the field of food processing in recent years. The modelling of food sterilisation is much improved and the technology is available to make strategies developped with optimization methods applicable in the food industry. The authors formulate several problems from industry in mathematical terms as optimization problems which grew out of cooperation with industry. As an example we consider the optimal control of heating for maximal retention of vitamines under the fulfilment of sterilization. This leads to an optimal control problem which itself lends to a large scale optimization problem when discretized properly. We show how SQP methods can be applied in this context and interpret the final results for the model in terms of the industrial application.

WE2-L-CM201

A Class of Augmented Lagrangian Algorithms for Infinite Dimensional Optimization with Equality Constraints

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Universität Trier

Sartenaer Annick, M. A. V.

Keywords: augmented Lagrangian - constrained optimization - infinite-dimensional optimization

A class of augmented Lagrangian algorithms for the solution of optimization problems posed in an *infinite dimensional* setting is presented. This class is derived from finite dimensions, by extending the class of augmented Lagrangian algorithms to the solution of infinite dimensional problems. In this class, the iteration consists of solving a sequence of subproblems in which the augmented Lagrangian is *approximately* minimized – i.e. each subproblem is terminated as soon as a stopping condition is satisfied. Global and local convergence results are outlined. A study of the behaviour of the extended class of algorithms is further presented when the sequence of approximately solved infinite dimensional subproblems is replaced by a sequence of finite dimensional subproblems obtained by a more and more refined discretization of their infinite dimensional counterpart.

WE3-T-CO22

Using Low Quality Water for Irrigation

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Center for Technological Education, Department of Technology Management

Because of limited supply of good water, there is an increasing usage of low quality water in agriculture. A given amount of low quality water includes higher rates of dissolved chlorides. A system of equations modeling the interactions among soil, plants and water, under presence of irrigation with low quality water is developed. The developed model includes variables describing yield levels, soil water content, salinity of soil water content, evaporation, transpiration and drainage. A mathematical programming approach is used to solve the system of equations. The ability of soil to hold water are additional constraints. Managerial assumptions such as minimizing water usage or maximizing yield are the objective functions.

The model is applied to field crops using different functional forms of yield response to water and salinity stress. The model can be used to estimate parameters from experiment data. Validation of the model is done with respect to real world and experiment data. The results can be used for economic and financial analyses, scientific research, and policy consequences of using low quality water.

TH2-B-CO10

$\mathcal{VU}$-Decomposition Derivatives for Convex Max-Functions. Part I

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Mifflin Robert

Keywords: $\mathcal{U}$-Lagrangian - convex optimization - max-functions - second order derivatives

We consider minimax problems of the form

$$\min_{x\in\Re^N} f(x) \quad \text{where } f(x) = \max\{f_i(x) : i = 0, \cdots, m\} \qquad \text{(P)}$$

The composite function f is convex and, hence, is differentiable almost everywhere, with the points of nondifferentiability being ones where more than one underlying function f_i realizes the maximum. Typically, such is the case at a solution $\bar{x}$ of (P). Solving the problem via a straightforward application of a Newton-type method is not possible.

A major concern in devising a superlinearly convergent algorithm consists of identifying near $\bar{x}$ a subspace on which the graph of f is "V-shaped", i.e., where f's nonsmoothness is concentrated. When identified, a Newton process can be used in its orthogonal complement, where f is differentiable and its graph is "U-shaped", to follow a smooth trajectory leading to $\bar{x}$. The V-U-theory developed by C. Lemaréchal, F. Oustry and C. Sagastizábal in "The U-Lagrangian of a convex function", formalizes these concepts for general convex programs.

We prove, under weak assumptions and for a general convex function, the superlinear convergence of a conceptual algorithm for minimizing f using V-U-decomposition derivatives. Then we apply the U-theory to our max-function, to show that the subspace V is spanned by differences of gradients of functions active at $\bar{x}$. Moreover, we show the existence of second-order derivatives of the U-Lagrangian when strong second order sufficient conditions for optimality are satisfied.

TU4-C-CO122

Computing Global Solutions of Nonconvex NLPs via Branch-and-Reduce

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Keywords: finiteness - global optimization - software

The branch-and-reduce optimization framework for solving nonconvex NLPs comprises: (a) duality-based and interval arithmetic-based range contraction techniques aiming at strengthening conventional lower bounds; (b) finite, as opposed to the typical convergent, branching schemes; (c) a general purpose computational system.

This talk will concentrate mostly on finiteness issues. Computational results will be presented for several classes of structured NLPs including bilinear programs, fixed-charge programs, multiplicative programs, indefinite quadratic programs and separable concave programs.

FR1-D-CO123

Semidefinite Programming and the Quadratic Assignment Problem

Saigal Romesh

The University of Michigan

Lin Chih-Jen

Keywords: preconditioned conjugate gradient method - predictor-corrector methods - primal-dual methods - quadratic assignment problem - semidefinite programming

In this talk we will present the experience of solving very large semidefinite programs that arise from the relaxation of quadratic assignment problems. In this application, the primal semidefinite program has no interior while the dual has, and thus the primal solution is not attained. The algorithm used to solve the semidefinite program is an infeasible start primal-dual predictor-corrector method as proposed by Lin and Saigal. In all instances, the algorithm did find a dual feasible solution, which then generated a lower bound to the quadratic assignment problem. Solving the larger instances when the number of plants is more than 20, requires a large memory for the direct methods. Thus we solved instances of up to 30 plants using a preconditioned conjugate gradient method on a workstation with a modest amount of memory.

WE2-W-CO15

Embedding a Modeling Language System in Specialized Application Software

Saigal Sanjay

Compass Modeling Solutions, Inc.

Keywords: decision support systems - modeling language

Modeling languages are great prototyping tools, but how do they help modelers build applications that can be turned over to users? We describe several possibilities, with emphasis on the design of a procedural interface that lets a run-time version of an algebraic model be "hidden" inside a custom-built user interface.

TH1-W-CO15

Models and Algorithms for Statistical Disclosure Control of Tabular Data

Salazar Juan Jose

D.E.I.O.C. - Fac.Matematicas - Universidad de La Laguna

Fischetti Matteo

We address the problem of protecting sensitive data in a statistical multi-dimensional table with marginals. In particular, we study the NP- hard problem known in the literature as the secondary Cell Suppression Problem (CSP). For the case of 2-dimensional tables, we introduce a new 0-1 linear programming model based on capacity conditions on a suitably-defined network. The basic model is enhanced by means of several classes of additional inequalities. A connection with the problem of finding a minimum-weight bridgless subgraph of a given graph is also established. We present a branch-and-cut algorithm for the exact solution of the model, based on exact/heuristic separation procedures. Extensive computational results are presented, showing that instances with several thousands of table entries can be solved in a few minutes, even on a PC. Finally, we discuss an extension of our model to tables of any dimensions. The algorithms are part of the SDC package tau-ARGUS.

FR1-E-CO21

A Family of Perturbed Forward-Backward Methods for Solving Variational Inequalities

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University of Namur

Nguyen Van Hien - Strodiot Jean-Jacques

Keywords: auxiliary problem principle - barrier methods - co-coercivity - epiconvergence - forward-backward splitting method - variational inequalities

Like other decomposition methods, the forward-backward method allows to iteratively solve variational inequalities by taking advantage of their particular structure. In this talk, we consider variational inequalities of type $0 \in F(x)+T(x)$ where F is a single-valued monotone operator on the n-dimensional Euclidean space and T is the subdifferential of a closed proper convex function f. For solving this problem, we propose to combine the forward-backward method both with an extension of the Auxiliary Problem Principle and the epiconvergence theory in order to get a general family of perturbation methods. The idea to couple variational convergence with iterative methods for solving convex optimization problems or monotone variational inequalities has already been extensively used to perturb the proximal point algorithm and the Tikhonov algorithm. Here we replace the function f by a sequence of functions (f_k) that epiconverges to f. Each iteration of the proposed algorithm consists in solving a strongly convex optimization subproblem that admits a unique solution.

When the auxiliary function is fixed, we prove that, if F is co-coercive and the sequence (f_k) epiconverges sufficiently fast to f, then the sequence generated by the algorithm converges to some solution of the problem. This framework allows us to consider barrier functions and interior approximations of feasible domains. When the auxiliary function changes at each iteration, the previous result can be generalized either by imposing conditions only on the auxiliary functions or by assuming the same kind of assumptions on F and the auxiliary functions as Pang and Chan do when there is no perturbation on f. Finally a local version of this last result is provided. It allows us to find again the classical convergence theorems of the Newton method (without perturbation on f) for variational inequalities.

WE3-T-CO22

Forest Age Classes and Rotation Periods in Continuous Time Models for Nonindustrial Private Forest Owners in the Presence of in Situ Values

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Tahvonen Olli

Keywords: amenity values - even-aged management - forest rotation - timber supply

The purpose of this project is to develop models in which a forest owner decides an optimal rotation pattern for a forest consisting of any number of even-aged stands. The study is motivated by empirical findings suggesting that timber supply depends on variables that are absent from the original Faustmann-Pressler-Ohlin formulation. It is shown that in situ preferences may even prevent all future harvestings.

TH3-I-CM4

Some Results on a Conjecture of Chvatal

Sanchez-Arroyo Abdon

Banco de Mexico

Keywords: perfect graph - skew partition conjecture

In 1985 V. Chvatal conjectured that no minimal imperfect graph G contains a skew cutset (a cutset that induces a disconnected graph in the complement of G). In this talk, we will comment on the known results about this conjecture and present some results stating the conjecture for small skew cutsets.

MO4-A-IN1

External Pivoting Revisited: Finding Good Directions

Sandblom Carl-Louis

Dalhousie University

In external pivoting for linear programming, we introduce linear combinations of pivot eligible columns into the basis. The selection of the weights for creating these linear combinations is of crucial importance if we want to quickly approach an optimal solution. We discuss this selection problem.

WE2-B-CO10

A Hybrid Algorithm for Solving Linear Semi-Infinite Programming Problems

Sanmatías Susana

Universidad de Valencia

León Teresa - Vercher Enriqueta

Keywords: feasible directions - linear programming - pivoting rules

In this talk we describe a primal algorithm for solving Semi-infinite Linear Programming problems with a set of several inequality constraints, being each constraint index set a closed interval in the real line.

The method is based on the theoretical statements of Linear Programming in infinite-dimensional spaces and deals with feasible solutions. It uses both a simplex-type strategy and a feasible directions approach together with a purification algorithm. To generate the improving feasible directions involves the solution of certain small size linear subproblems.

Numerical results illustrating the efficiency of the method are given.

WE4-I-CM200

Bistellar Flips in Triangulations of Point Configurations

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Keywords: polytope - triangulations

A triangulation of a finite point configuration $A \in \mathbf{R}^d$ is a geometrically realized simplicial complex which covers the convex hull of A and uses (perhaps not all) the points of A as vertices. Bistellar flips provide a natural notion of adjacency between different triangulations of the same point configuration which generalizes the usual edge-flips in planar triangulations.

For applications in optimization problems, it would be very useful to know that the collection of triangulations of a point configuration is connected under bistellar flips. No counter-example to this is known, but connectivity has only been proved in a few cases: dimension 2, cyclic polytopes, regular (or coherent) triangulations, $n \leq d+3$ (where n is the number of points and d the dimension), ... It is worth mentioning that in all these cases any triangulation admits at least $n-d-1$ flips.

We think that there are configurations with disconnected space of triangulations. Evidence for this assertion comes from the fact that in the natural generalization of the problem to (perhaps non-realizable) oriented matroids, triangulations with no flips are known. As additional evidence, we construct triangulations with very few bistellar flips in dimensions 3 and 4:

- In dimension 3, all the triangulations of point configurations in convex position have at least $n-4$ flips, but there are configurations in non-convex position with 8 vertices and only 3 flips. Also, for arbitrary n, triangulations with $5n$ points and only $3n-2$ flips can be constructed.

- In dimension 4, there are triangulations of 10 and 14 points in convex position with 4 and 6 flips respectively and triangulations in non-convex position with arbitrarily many vertices and a bounded number of geometric bistellar flips.

WE4-B-CO10

Augmented Lagrangians with adaptive precision control for quadratic programming with simple bounds and equality constraints (I.Theory)

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Dostal Zdenek

Keywords: adaptive precision control - augmented Lagrangian - equality constraints and simple bounds - quadratic programming

In this work we introduce an augmented Lagrangian type algorithm, specifically for strictly convex quadratic programming problems with simple bounds and equality constraints. The main feature of the proposed algorithm is the precision control of the auxiliary problems. As a consequence, the known results on rate of convergence are improved. Global convergence and boundedness of the penalty parameter are proved.

WE3-W-CO15

New Algorithms for L_1 Penalized Regression

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Bruce Andrew G. - Tseng Paul Yun

Keywords: basis pursuit - block coordinate relaxation - regression - wavelet

Penalized regression methodology, such as ridge regression, plays a prominent role in statistical prediction. Ridge regression computes an estimate $\hat{y} = W\hat{\alpha}$ where $\hat{\alpha}$ minimizes the functional $\frac{1}{2}\|y - W\alpha\|_2^2 + \lambda\|\alpha\|_2^2$. Recently, considerable attention has focused on the use of an L_1 penalty term instead of L_2 measures, and solving for $\hat{\alpha}$ which satisfies $\min_\alpha \frac{1}{2}\|y - W\alpha\|_2^2 + \lambda|\alpha|_1$. Of particular note is the "basis pursuit" procedure of Chen, Donoho, and Saunders for nonparameteric signal de-noising using over-complete adaptive waveform bases. A key contribution of basis pursuit is a novel application of primal-dual log-barrier interior-point optimization techniques. Their optimization algorithm provides a way to solve the L_1 penalized regression problem in nearly-linear time, and can be applied on problems of high dimension where the number of basis functions is much larger than the number of data values. In this paper, we investigate an alternative optimization approach based on "block coordinate relaxation" (BCR) techniques for a special class of problems. BCR is a general method for nonlinear function optimization, and works by successively optimizing for coordinate blocks. In the signal de-noising problem, BCR can be applied whenever the overcomplete set of basis functions is the union of sets of orthogonal basis functions. Examples of when BCR can be applied include translation invariant wavelets, wavelet packets, and cosine packets. We study two approaches towards block selection: cyclical rules and optimal descent rules (Gauss-Southwell). For the optimal descent rules, the best basis algorithm is used to find the best block. We show that BCR is globally convergent, and empirically, BCR is faster than interior point methods for a variety of signal de-noising problems.

WE4-D-CO124

An Infeasible-Interior-Point Algorithm for Degenerate LCPs with Q-Subquadratic

Convergence

Sargent Roger W.H.

Imperial College

The paper describes a relaxation of the usual "centering condition" for interior-point algorithms and a technique for dealing with degenerate variable-pairs, which are incorporated in a simple infeasible-interior-point algorithm for solving a generalized monotone linear complementarity problem.

The algorithm requires only one factorization per iteration, and has global weakly linear convergence from an arbitrary initial point. Its final convergence rate is Q-subquadratic, even for degenerate problems with no feasible interior point or strictly complementary solution.

WE3-U-IN10

Optimal Joint Syntheses of Base and Spare Telecommunication Networks

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Vial Jean-Philippe - Lisser Abdel

Keywords: cutting plane methods - decomposition - interior point methods - survivability in telecommunication networks

A telecommunication network is survivable if, following an arc failure, the interrupted traffic can be redirected through the network via existing excess capacity. The standard survivability problem cinvestmentonsists in finding the least cost investment in spare capacity to allow rerouting of a given base traffic. In this paper we consider the more involved problem of simultaneously designing the base traffic and the spare capacity investment. If the investment costs are linear, the problem can be formulated as a large scale structured linear program that we solve using different decomposition techniques, including the analytic center cutting plane method.

The global analysis is performed under the assumption of local rerouting of the traffic, i.e., the interrupted traffic creates a local demand between the end points of the broken edge. More sophisticated telecommunication network management allows to break down the interrupted traffic into its individual demand components. We do not treat the simultaneous design of the base traffic and the spare capacity under a global rerouting strategy. We propose a two-step procedure. We determine first the base traffic and the spare capacity under the local rerouting strategy. We then compute the necessary spare capacity to secure the base traffic under the global rerouting strategy.

Our solution techniques are tested on a set of realistic problems.

WE3-I-CM200

Polyhedral and Disjunctive Cutting Planes for the p-Median Problem

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Università di Roma "La Sapienza"

Avella Pasquale

Keywords: disjunctive cutting planes - p-Median - polyhedral cutting planes

The p-Median problem is a discrete location problem which consists of choosing p nodes in an undirected graph with the property that the total distance from all the remaining nodes is minimized. In this talk we investigate the polyhedral structure of the convex hull of the feasible solutions of the p-Median problem (*p-Median Polytope*). In particular, we introduce two classes of valid inequalities for the p-Median Polytope and for both of them we describe heuristic separation algorithms. In addition, we show how to combine polyhedral analysis and the disjunctive paradigm to produce effective cutting planes.

Finally, we describe a branch and cut algorithm, based both on polyhedral and disjunctive cuts, and we briefly discuss its performances in the solution of hard instances of the p-Median problem.

MO3-I-CM120

A Dual Ascent Procedure with Valid inequalities for the Multi Level Concentrator Location Problem

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Murthy Ishwar

Keywords: dual ascent - network design - telecommunications - valid inequalities

The Multi Level Concentrator Location Problem (MCLP) is a well known problem in computer communication network design. Several remote terminals or user nodes have to be connected to a central processing unit or root node. Concentrator devices that facilitate sharing of high capacity lines among several terminals are used to route traffic from terminals to the central unit. These concentrators have capacity limitations and each user node or concentrator is connected to at most one concentrator with higher capacity, introducing levels or hierarchy among concentrators. The MCLP problem determines the most economic way of connecting user nodes to the root node using concentrators.
The capacitated Steiner tree problem is similar to the MCLP. It is well known that for the uncapacitated Steiner tree problem, the LP relaxation of the disaggregated multicommodity formulation gives very tight bounds and the dual ascent procedure gives good results (Wong 1984). However, for the capacitated version, LP bounds are known to be poor and standard dual ascent procedures do not peform well. For the MCLP, we introduce two classes of strong valid inequalities, and develop a fast dual ascent type of procedure where these inequalities are introduced as additional columns in the dual. Unlike standard cutting plane based procedures, we solve the separation problem and reoptimize the LP relaxation entirely in the dual space. This procedure allows us to obtain faster solutions at each iteration. Computational results based on this solution method are also presented.

FR3-P-IN11

Valid Inequalities and Facets for Multi Item Lot Sizing With Changeover Costs

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Magnanti Thomas L.

Keywords: facets - lot sizing - scheduling

Several researchers have studied the polyhedral structure of various versions of the single item production lot-sizing problem. However, the polyhedral structure of the multi item problem, except as embodied in trivial generalizations of single item inequalities, remains essentially unknown. In this paper, we describe several classes of valid inequalities and facets for the multi item capacitated problem with start-up and set-up costs. It is also possible to generalize these inequalities to other versions of the multi item lot-sizing problem.

WE3-C-CO2

Embedded Algorithms, Complexity and Linear Bilevel Programming

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Keywords: bilevel programming - branch and bound - complexity - embedded algorithm

This paper proposes a way to compare algorithms which process different optimization problems. Such a comparison differs from traditional ones used in complexity theory in the sense that polynomial reformulation from one problem to another is not required. Hence it allows, at least in theory, to study embedding of algorithms defined for any pair of optimization problems. These concepts are applied to the linear bilevel problems (BLP) and the mixed-integer problems (MIP). In particular, we show that the branch-and-bound algorithm of Beale and Small for MIP is embedded in the Hansen, Jaumard and Savard algorithm for BLP through a reformulation of MIP to BLP. The mapping from MIP to BLP is simple, i.e., it does not involve any large unknown constant, and moreover, it is a reformulation (given an optimal solution of a reformulated instance of MIP, one can obtain an optimal solution of the instance within a polynomial amount of time). This suggests that BLP is at least as difficult as MIP. As an aside, these results lead to a generalization of a test from MIP to BLP.

The interest of the embedded algorithm concept will be discussed in terms of algorithm development, complexity and inherent structure. Systematic study of embedding of algorithms could reveal a structure for relative difficulty among NP-complete and NP-hard problems. Using this structure, one might study how tests for algorithms for specific problems can be generalized or specialized. In time, this might lead to many new tests and algorithms, and to a better understanding and organization of them.

TH2-L-CM201

PARINO, A PARallel INteger Optimizer

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Perumalla Kalyan - Linderoth Jeffrey Todd - Ramachandran Umakishore

Keywords: integer programming - parallel computing

We describe the design and implementation of PARINO, a parallel mixed integer optimizer. PARINO is portable across any message-passing parallel computing platform. It is written in C++ and developed using an "entity-FSM"-based structure that greatly facilitates the modularity and extensibility of the functionality of the system and its portability to any message-passing interface. The current version of PARINO has been used on an 8-node IBM SP2 multicomputer. The implementation is based on a distributed version of the traditional linear programming based branch-and-bound approach for mixed integer programs. In addition, several state-of-the-art techniques are incorporated, such as preprocessing, global reduced-cost fixing, primal heuristics, SOS-branching and various types of cutting planes. Cut management is an important factor that can influence the performance of parallel mixed integer optimization. A key contribution of our work is the development of a novel architecture and associated techniques for distributed cut management, and addressing the issues arising in its implementation.

TH1-A-IN2

MINTO, A Mixed INTeger Optimizer

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Nemhauser George

Keywords: branch and cut - integer programming - software

MINTO is a software system that solves mixed-integer linear programs by a branch-and-bound algorithm with linear programming relaxations. It also provides automatic constraint classification, preprocessing, primal heuristics and constraint generation. Moreover, the user can enrich the basic algorithm by providing a variety of specialized application routines that can customize MINTO to achieve maximum efficiency for a problem class.

WE3-A-IN2

A Polyhedral Approach to the Cardinality Constrained Cycle Problem

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Georgia Institute of Technology

Bauer Petra M. - Linderoth Jeffrey Todd

Keywords: branch and cut - clique - cutting plane methods - polyhedron

In the Cardinality Constrained Circuit Problem (CCCP) the objective is to find a maximum weight circuit in a graph with a length of at most k. We have analyzed the polyhedral structure of the set of feasible solutions and we have identified several classes facet inducing inequalities. Subsequently, we have studied the complexity of the separation problem associated with each class of facet inducing inequalities and we have implemented a branch-and-cut algorithm based on the identified classes of inequalities. Our initial computational results are encouraging.

TU3-G-IN11

Automatically Estimating Data Uncertainties for Robust Optimization

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COLORADO SCHOOL OF MINES

van Wyk Kasper - Navidi William

Keywords: data errors - least squares - robust optimization

In geophysical inverse problems an estimate of data uncertainties is required in order to avoid over-fitting the data. In practice this issue is often ignored in favor of a simple model of error distribution. Our goal is to develop rigorous optimization procedures that estimate data uncertainties automatically from the data. Our assumption will be that the distribution of data uncertainties is constant over geographical sub-sets. In each sub-set the data is weighted with its locally computed variance. An approximation of the data misfit function will lead to a better distinction between data uncertainties and the effects of local physical features. This information has been implemented in the optimization algorithm so that we can diminish the influence of systematic errors on the model. Since outliers are common in geophysical data, we will compare the results of regularized least squares methods with robust methods such as iterative least squares inversion (IRLS). We will show an application of these methods to a large-scale geophysical survey.

WE-pm-SPO

Test Sets for Integer Programs

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YALE UNIVERSITY

In this paper I discuss various properties of the simplicial complex of maximal lattice free bodies associated with a matrix A. If the matrix satisfies some mild conditions, and is **generic,** the edges of the complex form the minimal test set for the family of integer programs obtained by selecting a particular row of A as the objective function, and using the remaining rows to impose constraints on the integer variables.

TU1-K-CM106

Scatter Search in a Hybrid Method for General Integer Problems

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LAMSADE - UNIVERSITÉ PARIS IX DAUPHINE,

Msilti Halim - Tolla Pierre

Keywords: economic cuts - general integer programming - genetic algorithms - interior point methods - scatter search - simulated annealing

The hybrid method proposed in this paper combines interior point method, genetic algorithm and cut generation. The continuous optimization techniques quickly find points named "anchor points". The genetic algorithm or simulated annealing explores the integer-solution space around the anchor points in order to find "satisfactory" solutions. However, precedents experiments shows limits of these probabilistic methods; therefore, the use of the scatter method, poposed by Glover, is evaluated in this paper. Cuts enable one to determine "centered anchor points" inside the feasible space.

TU1-C-CO2

Generalized Monotonicity in Equilibrium Problems I (scalar case)

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UNIVERSITY OF CALIFORNIA

Bianchi Monica - Hadjisavvas Nicolas

Keywords: equilibrium problems - pseudomonotonicity - quasimonotonicity - variational inequality problems

In recent years there has been a shift of focus from generalized convex functions to generalized monotone maps. The analysis of generalized convex optimization problems has been extended to a study of generalized monotone variational inequality problems, and very recently beyond that to a study of equilibrium problems involving generalized monotone bifunctions. Following a brief survey of various research directions in generalized monotonicity, we report on existence results for quasimonotone and pseudomonotone equilibrium problems. In addition to the results for quasimonotone variational inequality problems (Hadjisavvas/Schaible 1996), we present their extensions to quasimonotone equilibrium problems (Bianchi/Schaible 1996). In this work bifunctions are assumed to be real-valued. The talk also provides the background for N.Hadjisavvas lecture on "Generalized Monotonicity in Equilibrium Problems II (vector case)".

FR3-C-CO2

Mathematical Program with a Generalized Equilibrium Constraint

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Morales Gudelia - Arica Jose

Keywords: generalized bi-level problem - hierarchical programs - nondifferentiable optimization - optimality conditions

In this work we introduce the optimization problem (MPGEC), where the objective function is locally Lipschitz and one of the constraints is a parametric generalized variational inequality, defined by a maximal monotone operator and has smooth convex constraints. Our formulation is an extension of the bi-level program when the second problem has a convex and nondifferentiable objective function. It also generalizes the mathematical program with an equilibrium constraint given by a point-to-point operator. We obtain a Karush-Kuhn-Tucker type of necessary locally optimality conditions, under a constraint qualification property. In order to derive them, we reformulate the MPGEC as a classical bi-level problem which involves a dual gap function. We establish some properties about the subdifferential of this gap function, using the Rockafellar's subderivatives of optimal value functions.

TU4-I-CM200

A New Approach for the Multi-Container Loading Problem

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The Multi-Container Loading Problem (MCLP) consists of finding the minimal number of containers (and corresponding packing patterns) needed to pack a given consignment of smaller boxes. In the paper a new efficient solution approach is presented to cope with instances of practical interest regarding a number of additional restrictions. Especially, some details will be discussed how the patterns are generated and how the optimality of a solution can be verified. New heuristics and an LP-based lower bound will be given.

TU4-C-CO122

The NOP-2 Modeling Language for Nonlinear Programming

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Institut für Mathematik

Dallwig Stefan - Neumaier Arnold

Keywords: global optimization - large scale optimization - modeling language - nonlinear programming

We present the modeling language NOP-2 for specifying general optimization problems, including constrained local or global nonlinear programs and constrained single and multistage (stochastic) programs. The language is specifically designed to represent the internal (separable, repetitive) structure of the problem, and serves as an interface to the our global optimization program GLOPT-2. NOP-2 provides named variables, parameters, indexing, loops, relational operators, extensive set operations, matrices and tensors, and parameter arithmetic. Due to these features the language is comparable to other modeling languages such as AMPL and GAMS and allows the user to define a wide range of problems arising in real life applications.

TU3-R-IN203

Timing Analysis and Optimization based on Physical Design Information

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Keywords: delay optimization - static timing analysis

All steps during the design of a VLSI chip are targeted to the minimization of cycle time (maximizing the frequency). The cycle time defines the maximum time to be spent for evaluating any boolean function of a integrated circuit. Furthermore the design process itself must be as short as possible forcing to move actions taken to correct timing violations from synthesis tools into placement and wiring based program. In this talk an optimization scheme is presented, used to optimize an integrated circuit for different design tasks, based on the result of a static timing analysis. The crucial input of the analysis (capacity of nets and RC delay) used to determine the timing and judge the optimization alternatives is derived from a given placement using the same routing heuristics as wiring tools do. After presenting the basic ideas of a static timing analysis the optimization scheme is presented by explaning the removal of *late-mode* problems.

TH1-I-CM200

A Probabilistic Cost Analysis of Simulated Annealing for TSP's

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Eindhoven University of Technology

Ten Eikelder Huub

Keywords: TSP - local search - probabilistic analysis

Given a cooling schedule for simulated annealing (SA) and a probability distribution over the set of n-city TSP instances, we consider the following experiment: select a random problem instance, run SA on it and stop SA after k iterations. We want to find the distribution of the cost of the current solution of SA.

It is well known that the operation of SA on a given problem instance of size n can be modeled as a Markov chain on the set of solutions. For many combinatorial optimization problems, the set of solutions is of exponential size. Hence, calculations involving this chain are practically impossible. We construct a Markov chain on the set of real number that approximates the cost behavior of SA on a random instance. Its behavior can be calculated numerically.

A possible application is to determine whether a given cooling schedule strikes the right balance, in the sense that it is neither too fast nor too slow.

TU3-G-IN11

Numerical Solution of Parameter Estimation Problems based on One-dimensional Time-dependent PDE's

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Keywords: least squares - parameter estimation - partial differential equations - performance evaluation - software

We present an approach to estimate parameters in dynamic models based on one-dimensional time-dependent partial differential equations. By using the line method, the PDE is transformed into a large system of usually stiff ordinary differential equations and solved by standard methods. Several least squares algorithms are implemented and coupled to the ODE-solver of the discretized system. Numerical results are presented to show the feasibility and efficiency of the approach, moreover to compare the optimization algorithms proceeding from a collection of 20 different test cases. The dynamic models selected, cover a braoad area of different disciplines, e.g. chemical engineering, pharmaceutics, geology, mechanical and electrical engineering, biology, where measurements are either simulated or are available from experiments.

FR2-G-IN11

Cash-Management with Stochastic Programming

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Keywords: cash management - structural properties

The problem of investing positive and financing negative cashflows suffers from the lack of synchronization between cash inflows and outflows. The financial manager has to decide periodically how to manage cashflows in order to minimize total costs taking into account refinancing and opportunity costs. A stochastic program is presented which considers stochastic cashflows and transaction costs for optimizing the cash-

amount. The cash-positions are decomposed into money market instruments, the non-cash positions are represented by capital and stock market. We discuss structural properties of the stochastic program and report on its numerical solvability and the gained experience.

TH1-T-CO22

Global Optimization Methods for Protein Folding Problems

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Azmi Aqil - Byrd Richard H. - Eskow Elizabeth - Shao Chung-Shang

Keywords: global optimization - molecular chemistry

The problem of finding the configuration that a chemical macro-molecule assumes in nature is a very important problem, that includes the well-known protein-folding problem. The naturally occurring structure is believed to be the structure that minimizes the potential energy function of the macromolecule. Finding this structure turns out to be a very challenging global optimization problem, with large numbers of variables and minimizers. This talk will discuss our research in developing new large-scale global optimization methods and applying them to molecular configuration problems, in the context of protein-folding problems. Our approach combines new stochastic-perturbation global optimization techniques and smoothing techniques. The stochastic-perturbation approach enables the method to move from low to even lower local minimizers by varying a few parameters at once. It is combined with a smoothing strategy that replaces the energy function with a smoother surface that has a reduced number of local minimizers, and then traces these back to the minimizers of the original function. The novel features of our smoothing approach include a new, analytic smoothing function, and the application of our stochastic-perturbation global optimization approach at each level of smoothing. The combination of smoothing and the stochastic/perturbation global optimization approach has been very successful on the proteins we have tried so far. This has included locating an optimal, folded structure for poly-L-alanine with 58 amino acids that had not been determined previously.

MO3-B-CO11

Existence and Discovery of Average Optimal Solutions in Deterministic Infinite Horizon Optimization

Schochetman Irwin Ernest

Oakland University

Smith Robert L.

We consider the problem of making a sequence of decisions, each chosen from a finite action set over an infinite horizon, so as to minimize the associated average cost. Both the feasibility and cost of a decision are allowed to depend upon all of the decisions made prior to that decision; in particular, time-varying costs and constraints are allowed. The concept of a dynamic programming state is formalized within this general framework, as is the associated concept of an efficient solution. A feasible solution is *efficient* if it reaches each of the states through which it passes at minimum cost. A principle result of the paper is that, under a state reachability condition, an average optimal solution exists and, without loss of optimality, is efficient. Exploiting this characterization of efficiency via a solution's short run (as opposed to long run) behavior, a forward algorithm is constructed which recursively discovers the first, second, and subsequent decisions of an efficient, and hence average optimal, infinite horizon solution.

TU2-C-CO122

Variable Threshold Methods for Global Optimization

Schoen Fabio

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Keywords: global optimization - stochastic algorithm

In this talk we will present some recent developments in the analysis of stochastic algorithms for global optimization. In particular we will be concerned with threshold methods in which, during a sequential uniform random sampling over the objective function domain, the decision whether to start or not a local search from a sampled point is based upon the comparison between the nearest neighbor distance and a variable threshold. Convergence, finiteness, finiteness of the total number of local searches, can be obtained under suitable conditions on the threshold. In this talk we will analyze threshold functions which depend also on the distance of iterate from the boundary. This dependence enables to better tune the behaviour of the optimization method as the dimension of the problem increases. Theoretical as well as experimental results will be presented which show the numerical feasibility of such an approach, at least for moderately sized (under 100 variables) multimodal optimization problems.

FR3-E-CO21

Mathematical Programs with Equilibrium Constraints: Stationarity, Optimality, and Sensitivity

Scholtes Stefan

University of Cambridge, Department of Engineering

Scheel Holger

Keywords: equilibrium constraints - optimality conditions - piecewise smooth - sensitivity analysis

We consider mathematical programs with equilibrium constraints in the form of stationarity conditions which we assume to be reformulated as piecewise smooth equations. Starting point is the observation that, in contrast to smooth nonlinear programming, Lagrange multipliers may exist even if there is a first order descent direction, i.e. the primal and dual stationarity concepts differ in the presence of equilibrium constraints.

We explain this phenomenon and study the relation between the two stationarity concepts. In particular, we show how they can be combined to extend the Fiacco-McCormick second order conditions to equilibrium constrained programs.

After reformulating the dual stationarity condition as a nonsmooth equation, we are able to extend Kojima's strong stability theorem to mathematical programs with equilibrium constraints. Our approach neither assumes that the equilibrium

point in the lower level problem is locally a unique function of the parameter nor that strict complementarity holds at the equilibrium point.

TH3-C-CO3

Exact Penalization of Mathematical Programs with Equilibrium Constraints

Scholtes Stefan

University of Cambridge, Department of Engineering

Stöhr Michael Alexander

Keywords: bilevel programming - equilibrium constraints - error bounds - exact penalization - nonsmooth trust region method - piecewise smooth

We extend Robinson's result that the constraint set of a smooth nonlinear program admits a stable local error bound at a feasible point if the Mangasarian-Fromovitz constraint qualification is satisfied at that point to piecewise smooth programs. A specification to piecewise smooth formulations of mathematical programs with complementarity or normal equation constraints yields conditions which guarantee locally the existence of an exact piecewise smooth penalty function.

By extending the recently proposed nonsmooth trust region framework of Dennis, Li, and Tapia to functions which are not necessarily regular in the sense of Clarke, and incorporating an approximation scheme for composite piecewise smooth functions due to Fletcher and Womersley, we obtain a globally convergent trust region method for the piecewise smooth penalty functions arising from mathematical programs with equilibrium constraints.

WE1-G-IN11

Unit Commitment Under Uncertainty via Two-Stage Stochastic Integer Programming

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Konrad-Zuse-Zentrum für Informationstechnik Berlin

Caroe Claus C. - Ruszczyński Andrzej

Keywords: mixed integer linear programming - optimization in energy systems - stochastic integer programming

The unit commitment problem in electricity production consists in finding a fuel cost optimal scheduling of start-up/shutdown decisions and operation levels for generation units in a power system over some time horizon. Mathematically, unit commitment leads to mixed-integer optimization problems of quite substantial size. In the talk, we consider unit commitment under uncertainty of the electrical load that has to be covered by the power system. We elaborate a two-stage stochastic program with mixed-integer recourse that can be seen as a large-scale mixed-integer linear program with block-angular structure. For this class of problems we developed a novel scenario decomposition method involving Lagrangian relaxation (see talk of Claus C. Caroe for details). We report about the application of this method to real-life unit commitment models that were derived from the hydro-thermal power system of the utility VEAG Vereinigte Energiewerke AG Berlin.

MO3-A-IN2

An Optimization Problem is Nine Problems

Schulz Andreas S.

Fachbereich Mathematik, Technische Universität Berlin

Weismantel Robert - Ziegler Günter M.

Keywords: combinatorial optimization - computational complexity - integer programming - local search - test sets

Test sets is an old, but important (theoretical) concept in integer linear programming; local search is another old and important (algorithmic) concept in combinatorial optimization; both concepts can be seen as the two sides of the same coin. Yet, only since a few years there is a quite productive interaction of more theoretically oriented people and more algorithmically oriented people aiming with some success for both a better understanding of integer linear programming problems and new tools for tackling them.

This stimulating interrelation has not only led to quite a few new interesting questions, but has also raised again seemingly lost old problems. Only one question among the latter ones is the following (which is phrased in local search terminology). Assume that there is an exact local search algorithm for a combinatorial optimization problem with neighborhoods that can be searched in polynomial time. Does this guarantee the existence of a polynomial-time algorithm for the optimization problem itself? In this talk, we not only give an affirmative answer to this problem, but also show that altogether nine quite different problems related to 0/1-integer programming are strongly polynomial time equivalent; among them are the maximum mean augmentation problem, the verification (or sub-optimality) problem, and the component determination problem. Though these results are not too difficult to prove (and we actually present some proofs in the talk), some of them are perhaps surprising.

TH2-P-IN201

Scheduling-LPs Bear Probabilities

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Fachbereich Mathematik, Technische Universität Berlin

Skutella Martin

Keywords: approximation algorithms - linear programming relaxations - performance guarantees - randomized algorithms - scheduling

In the past two years, there has been a considerable amount of work on proving performance guarantees for approximation algorithms using linear programming or randomization, particularly for scheduling problems in which the objective is to minimize the average weighted completion time. In this talk, we present a new class of randomized approximation algorithms by directly interpreting solutions to so-called time-indexed LPs as probabilities. This not only leads to the best known performance guarantees in several settings, but also sheds new light on some of the previous algorithms.

WE4-I-CM200

Combining a Pack of Polytopes: The Transitive Packing Polytope

Schulz Andreas S.

Fachbereich Mathematik, Technische Universität Berlin

Keywords: Chvátal-Gomory cuts - combinatorial optimization - independence systems - polyhedral combinatorics - quality of relaxations

The last decades have witnessed the success and the importance of the polyhedral approach to better understand and solve several combinatorial optimization problems. Most work in this vein, however, has focused on quite special problems and their associated polyhedra. To unify the knowledge and the study of many of those polyhedra and their associated optimization problems, we utilize the concept of transitive packings and survey the class of transitive packing polytopes.

Specifically, this talk tries to give a better understanding of the facial structure of previously separately investigated polyhedra by studying transitive packing polytopes. We not only show that generalized cycle, generalized clique, generalized antihole, generalized antiweb, generalized web, and odd partition inequalities subsume several known classes of valid inequalities for several of the special cases, but also give quite a few new inequalities for several others. We will illustrate that this new point of view quite often leads to elucidating insights.

In addition, for some of the classes we not only prove a nontrivial lower bound on their Chvátal rank, but we also point out a relation between their respective cutting-plane proofs and their strength. The strength of an LP relaxation measures how well this relaxation approximates a polyhedron in comparison to another weaker relaxation.

Polytopes that are special cases of the transitive packing polytope are, among others, the node packing polytope, the acyclic subdigraph polytope, the bipartite subgraph polytope, the planar subgraph polytope, the (clique) partitioning polytope, the transitive acyclic subdigraph polytope, the interval order polytope, the relatively transitive subgraph polytope, and the cut polytope.

MO4-P-IN201

The Two-Stage Multiprocessor Open Shop Scheduling Problem

Schuurman Petra

Eindhoven University of Technology

Woeginger Gerhard J.

Keywords: approximation algorithms - open shop - scheduling - worst case analysis

We study the two-stage multiprocessor open shop scheduling problem. In this variant of the open shop model, there are two stages, each consisting of a number of parallel identical machines. Each job consists of two operations, one for each stage, that can be executed in any order. The objective is to minimize the makespan.

The complexity of this problem has not been resolved yet; it is only known to be NP-hard in the ordinary sense. In case the number of machines at both stages is fixed, the result of Woeginger and Sevastianov on the standard open shop model can be extended and leads to a polynomial approximation scheme. We consider the case that the number of machines at both stages is part of the input. We present a $\frac{3}{2}+\varepsilon$-approximation scheme for this problem.

WE1-L-CM201

A Partitioning Strategy for Solving Large Nonsymmetric Systems of Equations by Row Projection Methods

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Echebest Nelida Ester - Vacchino Maria Cristina - Guardarucci Maria Teresa

Keywords: estimation of condition numbers - large nonsymmetric systems - row partition strategies - row projection methods

The efficiency of the row projection methods for solving large nonsymmetric systems of equations depends upon the row partitioning strategy used for splitting the matrix into blocks. According to Bramley and Sameh [Row Projection Methods for Large Nonsymmetric Linear Systems, SIAM J. Sci. Stat. Comput., 13, 1, January 1992] the row partitioning goals are: First, the projections must be efficiently computable. Second, storage efficiency. Third, a bound of the condition number of the submatrices induced by the projections should be given. And fourth, the number of projections should be kept as small as possible and independent of the dimension of the matrix. The algorithm presented in this paper aims at obtaining a block partition satisfying those conditions. This is done by means of a sequential estimation of the condition numbers of the submatrices involved in the projections using updates of the decomposition $L_k D_k {L_k}^t$. We present numerical results using this row partitioning strategy in conjunction with row projection algorithms.

TH1-I-CM121

Binary Metrics, Multiflows and Clutters I

Sebő András

CNRS-Leibniz

Novick Beth Ann

Keywords: binary matroids - clutters - ideal - max-flow-min-cut property - metric - multiflow - packing

Multiflows in binary matroids, especially those in which the “Cut Condition” is sufficient for the existence of a flow are well-known from celebrated papers of Seymour. When the Cut Condition is not sufficient some more general metrics provide necessary and sufficient conditions as shown in some earlier work (common with W. Schwärzler and Karina Marcus).

Binary clutters are closely related to these multiflow problems and the graph theoretical applications also include T-join packings (related to edge-colorings), or integer packings of one sided paths embedded in non-orientable surfaces. Metrics in binary matroids, as in graphs, constitute the ”polar” notion of multiflows, but have been studied less.

We would like to show in this talk some basic facts and problems about metrics in binary matroids. After an introduction with improved and simplified versions of earlier results, we discuss recent developments on multiflows and metric packings beyond the "cut condition". We relate the results that have been shown to a conjecture of Seymour on minimal non-ideal binary clutters and to Lehman's theorem, constituting a bridge between our results on multiflows and recent work with Beth Novick on minimal non-ideal binary clutters (see the next talk).

TH3-W-CO15

Generic Approach to Problem Specification for Mathematical Models

Sekiguchi Yasuki

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Keywords: entity-relationship - generic approach - model management - unification

After survey of problem specification methods in decision support systems and model management areas, we discuss necessity of a new problem specification method which treat problem specification independent of mathematical model. Then, we argue that although existing methods based on the entity-relationship model which describes mainly numerical attributes are good at describing structure of numerical data, problem specification which defines a set of numerical problem instances (i. e., problem type) requires to represent qualitative and structural attributes as well as numerical attributes. The Generic Entity-Relationship Model (GERM) proposed by the author of this paper is the entity-relationship model with augmented description of qualitative and structural attributes. As a mechanism to combine a problem description to its mathematical model, we propose unification condition which collates numerical attributes in a problem description with symbols in the corresponding mathematical model. Finally, some favorable properties of the GERM-based problem specification are iscussed: expandability/flexibility/preciseness, coexistence with executable modeling languages, applicability to problems which are better formulated as simulation models than mathmatical models, prototypical implementation of GERM in developing a case-base.

TH2-G-IN11

A Stochastic Scenario Decomposition Algorithm for Multi-stage Stochastic Linear Programming

Sen Suvrajeet

University of Arizona

Higle Julia Lynne - Rayco Brenda

Keywords: computational methods - sampling - stochastic programming

In this paper, we propose a stochastic cutting plane algorithm for multi-stage stochastic programming. We will begin the presentation with the development of dual problems which form the basis for the method. It turns out that the structure of the dual problem in the multi-stage case happens to posses a structure that is very similar to that obtained in the two stage case. We use this observation to motivate cutting plane algorithms that incorporate sampling within the process. We discuss several aspects of these algorithms, including the structure of master and subproblems, parallelizability, asymptotic results and the development of stopping rules. Finally, we report our preliminary computational results with this method.

TH4-F-IN203

Some Insights into Near-Optimal Plans for Stochastic Manufacturing Systems

Sethi Suresh P.

University of Toronto

Keywords: hierarchical controls - manufacturing systems - production planning

We present some insights obtained from the considerable research that has accumulated in proving that a hierarchical decomposition based on the frequencies of occurence of different types of events in the system results in near-optimal decisions as the rates of some events become large compared to those of others. In the simple context of dynamic two-machine flowshops, we observe a capacity loss phenomenon which must be accounted for in any construction of a near-optimal decision. We also show that a threshold type control known as the Kanban control is nearly optimal in some cases and not in others.

MO4-D-CO123

Interior Point Methods for Nonconvex Quadratic Programming

Shanno David Francis

Rutgers University

The talk examines the application of logarithmic barrier functions to nonconvex quadratic programming problems. Both modified barrier methods and primal dual varients of the classical logarithmic barrier method are studied. In particular, the talk discusses convergence conditions for the primal dual method, and compares the two methods from various starting points.

WE1-B-CO10

Second Order Analysis of Nonlinear Semidefinite Programs

Shapiro Alexander

Georgia Institute of Technology

Keywords: duality - second order optimality conditions - stability and sensitivity analysis

We discuss nonlinear semidefinite programs in a framework of optimization problems subject to cone constraints. Second order necessary and sufficient conditions for such problems are presented. Second order sufficient conditions are based on a concept of "second order regularity", which always holds in the case of semidefinite programming. Second order analysis is implied to an investigation of stability and sensitivity of optimal solutions of semidefinite programs

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TH3-G-IN11

Simulation Based Optimization, Theory and Algorithms

Shapiro Alexander

Georgia Institute of Technology

Keywords: simulation - stochastic counterpart method - stochastic programming - two stage stochastic programming with recourse

Consider an optimization problem of minimization of an expected value function over a feasible region. Suppose that the expected value function cannot be calculated explicitly and should be estimated, say by a Monte Carlo simulation. That is, a sequence of random (or rather pseudorandom) functions is generated and the expected value function is approximated by their averages . Then one can try to solve the original optimization problem by using the obtained estimates of the expected value function. There are basically two available approaches to such an optimization, namely the stochastic approximation (SA) method and the stochastic counterpart (SC) (sample path) optimization. In the SC method a large sample is generated and consequently the obtained sample-average function is minimized by (deterministic) techniques of nonlinear programming.

In this talk we mainly discuss the SC approach. We discuss statistical inference of such an approach and argue that it can be incorporated into numerical algorithms. This allows an estimation of the involved stochastic error, which in turn leads to an iterative update of the sample size, efficient stopping rules and variance reduction techniques. Two stage stochastic programming with recourse is discussed as an example.

TU3-I-CM121

On Submodular and Bisubmodular functions having non zero values on empty sets

Sharma Prabha

Indian Institute of Technology

Rajesh Srinivasan

Keywords: bisubmodular functions - empty sets - greedy algorithm - non-zero values - submodular

We show that for submodular and bisubmodular functions with negative values on empty sets, for the associated polyhedron p(f), the nestedness property of tight constraints at an extreme point of P(f) may not hold. We thus show that the greedy algorithm may fail to solve the linear programming problems defined over polyhedra associated with submodular and bisubmodular functions having negative values on empty sets. We give an efficient algorithms for solving this class of linear programming problems by using an algorithm for minimizing a submodular function as a subroutine. Some of the existing theory for submodular and bisubmodular functions assumed to have zero value on empty sets is extended to such functions having negative value on empty sets.

WE2-I-CM200

A Linear Bound on Stalling in the Network Simplex Algorithm

Sharma Prabha

Indian Institute of Technology

Sokkalingam Palaniswamy

Keywords: bound - networks - simplex - stalling

In this paper, we obtain an $O(n)$ bound on stalling in the network simplex algorithm. This pivot rule requires that a negative cycle is available. Performing simplex pivots on the arcs in this cycle in a sequential order and maintaining strongly feasible basis, we show that the network simplex method performs a nondegenerate pivot within at most n consecutive degenerate pivots. At present, the best available time bound on stalling is $O(n^2)$.

TH4-U-IN10

A Unified Limited Column Generation Approach for Facility Location Peroblems on Trees

Shaw Dong

School of Industrial Engineering, Purdue University

Keywords: facility location - limited column generation - tree algorithms

In this paper, we show that several well-known facility location problems on trees, including the Uncapacitated Facility Location Problem (UFLP), the Facility Constrained Covering Problem (FCCP), the Customer Constrained Covering Problem, the Round-Trip Covering Problem (RTCP), p-Center Problem, and p-Median Problem, can be formulated uniformly into a special structured Tree Partitioning Problem (TPP). Then, we develop a generic algorithm to solve all these facility location problems. Although our algorithm is a generic algorithm, our time-complexity for solving each of these problems matches the best time-complexity of the "dedicated" algorithm.

Our approach is based on the Limited Column Generation technique for solving the TPP, which can be formulated into a linear program with an exponential number of columns. Then, we show that this linear program can be solved in just n pivots by adopting a special column generation procedure, where n is the number of rows of the linear program. We believe our approach has shown much insight of the location problems on trees.

TH3-B-CO10

A Combined Entropic Regularization and Path Following Method for Some Minimax Problems with Infinitely Many Linear Constraints

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Wu Soon-Yi - Liu J.C.

Keywords: entropic regularization - path following - semi-infinite programming

Consider the problem of minimizing the max function of q smooth convex functions on a domain specified by infinitely many linear constraints. The entropic regularization technique is used to overcome the problem of non-differentiability and the path following approach is used to create an interior trajectory in the feasible domain. A convergence proof is given. This extends interior point methods to non-smooth optimization problems.

WE2-C-CO122

A Global Optimization Method for Minimum Maximal Flow Problem

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School of Management, Science University of Tokyo

Yamamoto Yoshitsugu

Keywords: bipartite graphs - cutting plane methods - global optimization - matchings - maximal flow

In this paper, we present two approaches for solving an $\mathcal{NP}$-hard problem: minimum maximal flow problem, i.e., $\min\{\text{val}\,\xi \,|\, \xi \text{ is a maximal flow}\}$. We introduce lower bounds on flow, and cast the problem into a minimization of a concave function over a convex set. We solve the problem by a global optimization method. As an application, we consider the minimum maximal matching problem. Some numerical experiments are reported.

TU4-D-CO124

Existence of Central Trajectory to Monotone Semidefinite Complementarity Problem and its Newton Direction

Shida Masayuki

Kanagawa University

Kojima Masakazu - Shindoh Susumu

Let $\mathcal{S}^n$, $\mathcal{S}^n_+$ be the class of $n \times n$ symmetric matrices and the class of $n \times n$ symmetric and positive semidefinite matrices. Let $\mathcal{F}$ be a maximal monotone (affine) subset of $\mathcal{S}^n \times \mathcal{S}^n$. We deal with a monotone semidefinite (linear) complementarity problem (SD(L)CP);

$$\begin{array}{ll} \text{Find an} & (\mathbf{X}, \mathbf{Y}) \in \mathcal{F} \cap (\mathcal{S}^{\mathbf{n}}_+ \times \mathcal{S}^{\mathbf{n}}_+) \\ \text{such that} & \mathbf{X} \cdot \mathbf{Y} := \mathrm{tr}(\mathbf{XY}) = \mathbf{0}. \end{array}$$

We show the existence of the central trajectory, which is characterized as the intersection of the maximal monotone subset $\mathcal{F}$ and the set $\{(\mathbf{X}, \mathbf{Y}) \in \mathcal{S}^{\mathbf{n}}_+ \times \mathcal{S}^{\mathbf{n}}_+ : \mathbf{XY} = \mathbf{aI}\ (\mathbf{a} > \mathbf{0})\}$ which is maximal and strictly antitone. This fact leads to the following observation. The Newton directions, each of which is known for its unique existence, in interior-point-algorithms for the SD(L)CP are the intersection of the maximal monotone affine subspace $\mathcal{F}$ and the maximal and strictly antitone affine subspace which is a suitable linear approximation of the centrality condition. This is the reason for the unique existence of these Newton directions.

TH3-E-CO11

LocalConvergence Analysis of Some Interior-Point Methods for the SDP and the Monotone SDLCP

Shindoh Susumu

The National Defense Academy

Shida Masayuki - Kojima Masakazu

Keywords: predictor-corrector infeasible-interior-point methods - quadratic convergence - strict complementarity - superlinear convergence

The purpose of this talk is to demonstrate the local superlinear or quadratic convergence of some predictor-corrector infeasible-interior-point methods for the SDP and the monotone SDLCP with certain search directions, under the strict complementarity condition.

FR4-I-CM121

Minimization of M-convex function

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Keywords: base polyhedron - convex function - minimization - valuated matroid

M-convex function, introduced by Murota (1995), is an extension of valuated matroid of Dress–Wenzel (1990) as well as a quantitative generalization of the set of integral points in an integral base polyhedron. M-convexity is quite a natural concept appearing in many situations, and enjoys several nice properties which are sufficient to be regarded as convexity in combinatorial optimization.

In this talk, we study the minimization of an M-convex function. Since the local optimality is equal to the global optimality, an optimal solution can be found by a descent method, which does not necessarily run in polynomial time. Instead, we propose an efficient algorithm for the minimization. Each iteration finds a 'center' of the current domain, and divides the domain so that the 'center' and an optimal solution are separated. These procedures can be done efficiently and the size of the domain reduces in a certain ratio iteratively, which leads to a weakly-polynomial time algorithm.

We also discuss the layer structure of an M-convex function and the minimization in each layer, where the layer is the restriction of the function to $\{x \in \mathbf{Z}^V \mid x(W) = k\}$ for $W \subseteq V, k \in \mathbf{Z}$. We reveal that each layer has a nice structure such as M-convexity, and that the minimizers in consecutive layers are closely related. Exploiting these properties, we can solve the minimization problems in successive layers efficiently.

FR4-B-CO10

Using of Nonsmooth Optimization Methods for Solving Quasiblock Structured Problems of Semidefinite Programming

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Institute for Cybernetics of Ukrainian National Academy of Sciences

Keywords: nonsmooth optimization - quasiblock structured problems - semidefinite programming

Let $E^n = E^{n_1} \times E^{n_2} \ldots \times E^{n_k}$ be n-dimensional Eucleadean space, represented as prime product of Eucleadean spaces E^{n_i},

$$n = \sum_{i=1}^{k} n_k.$$

Consider quasiblock semidefinite programming problem of the form:

$$\text{find } \inf \sum_{i=1}^{k} l_0(x_i) \qquad (P)$$

under constraints:

$$\begin{aligned} \sum_{i=1}^{k} l_{ij}(x_j) &\leq 0, \; j = 1, \ldots, r \\ K_i(x_i) &\succeq 0, \; i = 1, \ldots, k, \end{aligned}$$

where subvectors $x_i \in E^{n_i}$, $l_{ij}(x_j)$-convex functions, $K_i(x_i)$-symmetric matrices $n_i \times n_i$, $i = 1, \ldots, k$, $j = 1, \ldots, r$, entries of K_i are linearly depended of x_i, "$\succeq$" is the symbol of positive semidefiniteness. We propose for solving problem (P) the decomposition scheme solving at each step the inner problem of minimization

$$L(x, u) = \sum_{i=1}^{k} \left[l_0(x_i) + \sum_{j=1}^{r} u_j l_{ij}(x_i) \right], \; u = \{u_1, \ldots, u_r\}$$

under constraints:

$$K_i(x_i) \quad \succeq \quad 0, \; i = 1, \ldots, k.$$

Let $\psi(u) = \sup_x L(x, u)$, $\psi^* = \sup_{u \geq 0} \psi(u)$. We propose algorithms, based on subgradient-type methods with space transformation for solving the inner problem of finding $\inf_u L(x, u)$ and for outer coordinate problem of obtaining $\sup_u \psi(u)$. The results of numerical experiments are described.

TH4-G-IN11

Mean-Variance Analysis in a Multiperiod Setting

Siede Heiko

Institut für Unternehmensforschung

In finance, a widely accepted and applied measure of risk in portfolio optimization is the volatility of a chosen portfolio. The classical one-period Markowitz approach determines efficient portfolios with respect to estimated returns and covariances. Clearly this model depends essentially on the goodness of the estimated input data.

Similar to the one-period approach one may apply a mean-variance criterion to a multiperiod setting taking into account rebalancing activities and the dynamic evolvement of returns and covariances to obtain efficient portfolios. Based on the dynamics of asset prices a stochastic return process and corresponding covariances provide the input in a probabilistic way. The numerical solvability of the underlying optimization problem is achieved through discretization of the stochastic process with respect to time and space. This amounts to solving a stochastic multistage program.

In this talk modelling aspects of the optimization problem and characteristic features of the scenario tree are reported. Furthermore, the structural properties of the optimal solution and its relation to the classical one-period approach are investigated.

MO3-C-CO122

Sufficient Conditions of Optimality for Nonsmooth Continuous Time Optimization Problems

Silva Geraldo Nunes

UNESP

Rojas-Medar Marko

We consider continuous-time nonlinear programming problem (CNP). In a companion paper, we provided first-order necessary conditions of optimality of both Fritz-John and Karush-Kuhn-Tucker types and also invex duality results under nonsmooth assumptions.

In this work, we discuss nonconvex sufficient conditions of global optimality for problem CNP. We first prove the sufficiency of Fritz-John and Karush-Kuhn-Tucker conditions in the Lipschitz case using the notion of invex functions. The proof given here makes use of the generalized Gordan's Theorem for continuous time programming problems. Later, we get more precise results under both Clarke regularity and generalized convexity hypotheses. Finally, by using a generalized Hessian, introduced by Cominetti and Correa, we provide second-order sufficient conditions of optimality.

The best previous results on sufficient optimality conditions for CNP have been proved for smooth data. In our case, we allow functions on the data to be only Lipschitz on the second variable. We also point out that the notion of invex functions has been used for the first time in order to garantee global sufficient optimality conditions for problem CNP.

FR3-B-CO10

Proximal Point Methods and Separators

Silva Paulo José da Silva e

University of Sao Paulo

Humes Junior Carlos

Keywords: proximal point methods

In this work, we use the concept of Eaves and Zangwill's separators functions to discuss the convergence of proximal point methods. This is done equating bounds on the decrease of the objective function with a separator. In doing so, we obtain a wider class of regularization functions. Typically, instead of the classical $\| \cdot - x^k \|_2^2$ regularization, we show that we can use any regularization of the form $\phi(\cdot - x^k)$, where $\phi(\cdot)$ is a strictly convex function such that $\{0\} \equiv \partial\phi(0)$.

Using these results, we also present how to generate a wide class of Augmented Lagrangians Methods that, in some preliminary tests, converge in fewer iterations than the usual Augmented Lagrangian.

TU2-P-IN201

Supply-Chain Management: Integrating Inventory and Transportation

Simchi-Levi David

Northwestern University, Dept of IE/MS

Chan Lap Mui Ann - Muriel Ana

Keywords: inventory - supply-chain - transportation

In this paper we analyze the problem faced by companies that rely on third parties, such as LTL carriers, for the distribution of products across their supply chain. In this case, the timing and routing of shipments need to be coordinated so as to minimize total system costs, including inventory, transportation and shortage costs, by taking advantage of economies of scale offered by the carriers. We model this problem using a set-partitioning approach and characterize structural properties of the resulting formulation. These properties are used to suggest an efficient algorithm.

TH2-P-IN201

Parallel Machine Scheduling, Linear Pro-

gramming and Parameter List Scheduling Heuristics

Simchi-Levi David

Northwestern University, Dept of IE/MS

Chan Lap Mui Ann - Muriel Ana

In this paper we consider a class of parallel machine scheduling problems and their associated set-partitioning formulations. We show that the tightness of the linear programming relaxation of these formulations is directly related to the performance of a class of heuristics called parameter list scheduling heuristics. This makes it possible to characterize the worst possible gap between optimal solutions for the scheduling problems and the corresponding linear programming relaxations. In case of the classical parallel machine weighted completion time model we also show that the solution to the linear programming relaxation of the set-partitioning formulation is asymptotically optimal under mild assumptions on the distribution of job weights and processing times. Finally, we extend some of the results to the time-discretized formulation of machine scheduling problems.

TH4-P-IN201

A Linear Time Algorithm for One-Machine Scheduling with Set Up Times and Time Windows

Simonetti Neil

Carnegie Mellon University

Balas Egon - Vazacopoulos Alkis

We discuss a dynamic programming approach to solve the one machine scheduling problem with setup times. The procedure can incorporate release times and delivery times or due dates, as well as handle different objective functions, including minimum makespan and the sum of weighted completion times.

TH4-C-CO2

Abstract Convex Analysis

Singer Ivan

Institute of Mathematics

It is well known that one of the fields of applications of usual convex analysis is the theory of convex optimization. Here we want to present ABSTRACT CONVEX ANALYSIS,a collection of tools (such as generalized convex sets,generalized convex functions,conjugations, subdifferentials) for the development of a theory of non-convex optimization. We show some ideas of our book on this subject (in print).

FR3-V-CM106

Static and Dynamic Modeling of International Financial Equilibrium with Hedging

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University of Massachusetts

Nagurney Anna

Keywords: hedging - international finance - networks - projected dynamical - systems - variational inequalities

In this paper, we develop international financial equilibrium models with hedging in the form of futures and options, utilizing variational inequality theory for the analysis of the statics and projected dynamical systems for the study of the dynamics and disequilibrium behavior. We identify the network structure of the individual sector's optimization problems and then reveal the network structure of the financial economy in equilibrium which is attained through the proposed dynamic adjustment process. We discuss qualitative properties of the equilibrium asset, liability, and price pattern, in terms of existence and uniqueness, as well as provide stability analysis results. Finally, we present computational procedures for the determination of the equilibrium pattern and for the discrete time approximation of the trajectories of the assets, liabilities, and prices.

FR1-A-IN2

A New Global Efficiency DEA Measure

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Keywords: data envelopment analysis - fractional programming - linear programming

In this work we propose a new efficiency measure for the evaluation of the performance of a set of DMUs We start with a nonlinear programminng problem and succeed in linearizing it. The new measure, unlike the measures obtained from radial DEA models, accounts for all sources of inefficiency. In addition, it has some advantages over the already known global efficiency measures, which are mainly based on additive-type models. Thus, we propose a new measure, which can be considered as a new efficiency score, obtained from a new defined DEA model.

TU4-P-IN201

Showing Schedules in Slow Motion

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Schulz Andreas S.

Keywords: approximation algorithms - lp lower bounds - randomization - scheduling

Three characteristics encountered frequently in real-world machine scheduling are jobs released over time, precedence constraints between jobs, and average performance optimization. The general constrained one-machine scheduling problem to minimize the average weighted completion time not only captures these features but is also an important building block for more complex problems.

In this context, the conversion of preemptive to non-preemptive schedules has been established as a strong and useful tool for the design of approximation algorithms. If already the preemptive problem is NP–hard, generating preemptive schedules from LP relaxations in time-indexed variables has been proved to be a promising contribution. However, a straightforward combination of these two building blocks does not directly lead to improved approximations. By showing schedules in slow motion we introduce a new point of view on this procedure which also enables us to give a better analysis.

This leads to a randomized approximation algorithm for the general constrained one-machine scheduling problem with performance guarantee e. This improves upon the best previously known worst-case bound of 3. In the process, we also give randomized algorithms for related problems involving precedences that asymptotically match the best previously known performance guarantees.

FR1-H-CO22

Aggregation-Disaggregation Approach to Preference Modelling in Multi-Criteria Sorting

Slowinski Roman

Poznan University of Technology

Mousseau Vincent

Aggregation-disaggregation approach to preference modelling tend to infer parameters of a preference model from examples of comprehensive decisions dupplied by an expert. This is a typical way of knowledge acquisition in artificial intelligence. We adapt this approach to a multi-criteria sorting problem which concerns an assignment of each alternative from a finite set to one pre-defined categories. In particular, we are interested in the inference of parameters for the preference model used by the existing ELECTRE TRI method. This method requires the following parameters: weights of criteria, indifference, preference and veto thresholds, an category limits. In order to infer these parameters from assignment examples supplied by an expert, we need to solve a non linear programming problem. In fact, this problem is to be solved in an interactive way because the quality of the final solution (parameters) depends on many different features. The methodology will be illustrated by an example of practical application.

FR2-C-CO3

Determination of Sensitivity of Nonregular Optimum Solutions in Nonlinear Programming

Smaoui Hichem

ENIT

Bessi Fourati Radhia

The computation of directional derivatives of optimum solutions of parametric nonlinear programming problems has been studied by many authors. In the present work the determination of the optimum solution sensitivity is considered in the case of a local optimum lying at a nonregular point, that is at a solution such that the gradients of the active constraints are linearly dependent. This includes problems such that the optimum solution remains nonregular while the parameter varies in some neighborhood. Under specified assumptions, including the strong second order sufficiency condition, the problem of finding the desired sensitivity is formulated as a saddle point problem for judiciously constructed function.

TU1-I-CM120

Computing Lower Bounds for Steiner Trees in E^3 is a Hard Problem

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Weiss Rich

Keywords: Steiner minimal trees - algorithms - lower bounds

The problem of computing Euclidean Steiner Minimal Trees in E^3 is well-known to be an NP-Hard Optimzation Problem. We show that the problem of computing even a lower bound on the ESMT problem is a difficult optimization problem from a transformation to the Euclidean Graph Embedding Problem (EGEP). This transformation is facilitated by a Dual Geometric Construction of the ESMT problem which provides a lower bound on the ESMT problem. Thus, polynomial running time heuristics for lower bound constructions are appropriate.

TH4-A-IN2

Generating Disjunctive cuts for mixed 0-1 programs

Soares Joao

Ceria Sebastián

In this talk we analyze some structural properties of the mathematical programs that need to solved in order to generate disjunctive cuts, also called lift-and-project cuts, for a mixed 0-1 program. We show that there is a natural dual program associated with the separation program. Different normalization constraints originate different pairs of dual programs. The duality results give rise to a new geometric interpretation of the separation problems.

MO3-D-CO123

Interior Point Methods for 3-Dimensional PET Reconstructions

Sofer Ariela

George Mason University

Johnson Calvin A.

Positron Emission Tomography (PET) is a medical imaging technique that quantifies the distribution of a radioactively labelled compound in the subject of interest. Maximum likelihood reconstructions of PET images from data sets with poor counting statistics have improved resolution over nonstatistical reconstructions. Yet maximum likelihood reconstructions are considered to be too expensive, due to their high computational requirement.The problem is especially severe in the case of 3-D reconstruction, where 10^6 or more variables are estimated from 10^8 or more reconstructions. This talk investigates the solution of the maximum likelihood reconstruction problem via a stabilized barrier algorithm that includes a truncated-Newton method for unconstrained optimization. We discuss a variety of computational issues such as data structures, preconditioning techniques, scaling of variables and the line search, and present computational results.

MO3-K-CM106

Applications of Outer Approximation Techniques to Machine Learning

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Instituto de Matematica Pura e Aplicada

Zavriev Sergei

Keywords: neural networks - outer approximation

We describe an application of outer approximation techniques for optimization problems with an infinite number of constraints to machine learning. Outer approximation approach consists of solving at each step a problem with a finite number of constraints, followed by adding relevant and dropping irrelevant constraints. In the context of a separation problem in machine learning, this corresponds to the following. At every major iteration, a neural network is trained on a (relatively small) subset of training samples. After this, only samples which are essential (or relevant) to defining the separating surface are kept. Irrelevant samples are removed from the working training set, and some of those new samples are added which are miscalassified by the current separator.

TU3-I-CM200

Computing the Nucleolus of an Essential Permutation Game

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Keywords: computation - cooperative games - nucleolus

Permutation games are closely related to assignment games and, from another aspect, to balanced linearly connected games. For these games fast nucleolus computing algorithms are known. Key factors for the efficiency of these algorithms are the balancedness of the games, and the existence of a small collection of coalitions containing all essential ones. Permutation games are also balanced, however, there are examples in which all coalitions are essential, so to find their nucleolus efficiently, other specialties of such games must be utilizied.

We present a partial answer to this problem. For permutation games in which the grand coalition is essential, the determination of the nucleolus can be translated to another lexicographic optimization problem for which a modified version of the assignment nucleolus algorithm can be applied. This way the nucleolus of an n-person essential permutation game can be computed directly from the data matrix in $O(n**4)$ time.

FR2-I-CM4

Existence of Stable Outcomes for a Unified Matching Market

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MATH AND STAT DEPT., APPLIED MATH. DEPT., UNIVERSITY OF SAO PAULO

Roth Alvin E.

This paper establishes the existence of stable matchings in a matching market consisting of "mixed economy" in which some firms compete by means of salary, others by means of level of appointment (each of which comes with a fixed salary), and others have no flexibility over terms of appointment. A common existence proof is used, which unifies the traditional discrete and continuous cases, namely the marriage and assignment models.

FR4-U-IN1

Nonlinear Least Squares and Electron Paramagnetic Resonance

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COMMISSARIAT À L'ÉNERGIE ATOMIQUE

Chachaty Claude

Keywords: Brownian diffusion motion - EPR spectroscopy - Levenberg-Marquardt algorithm - nonlinear least squares

Electron paramagnetic resonance (EPR) spectroscopy relies on the interaction between a magnetic field and an atomic magnetic moment, discovered in atomic spectroscopy and branded Zeeman effect. First achieved by Zavoisky in 1944, EPR spectroscopy applies to materials in which "unpaired electrons" are present. It provides information on the Zeeman interaction as well as on the interaction between electronic spins and the neighbouring nuclear spins. EPR may be applied to solids, liquids, amorphous and glassy materials, biological vesicles and membranes, etc. Once an adequate model of a system is available, its EPR spectrum may be predicted for any set of the relevant spectroscopic parameters. However, given an experimental spectrum, the determination of the unknown parameters, which is an "inverse problem", is aimed at. Nonlinear least squares optimization is the tool of choice to solve it. While the nonlinear simplex of Nelder and Mead is of common use among EPR spectroscopists, we have resorted to the Levenberg-Marquardt algorithm, which proved much more efficient. We will describe the mathematical features relevant to a particular system, which is a polymer containing a transition metal ion (vanadyl VO++) which was investigated experimentally at a very low temperature such that the system is rigid. A visual inspection of the spectrum enables to obtain crude estimates of the unknown parameters which enter the model. A nonlinear least squares fit is then applied to obtain the best values of these parameters. At a higher temperature, the system undergoes a motion at a time scale characteristic of EPR. We will describe the algorithm used to simulate a spectrum within the frame of a model in which the paramagnetic species undergoes infinitesimal rotations (Brownian diffusion). The simulation involves all the parameters which were previously determined at low temperature, plus two additional parameters, associated to the motion.

FR4-I-CM5

Locomotive Assignment with Heterogeneous Consists

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GERAD, ÉCOLE POLYTECHNIQUE

Ziarati Koorush - Desrosiers Jacques

Keywords: column generation - locomotive assignment - multicommodity

We consider the problem of assigning locomotives to train segments. The power required to pull a train is determined according to train's weight and length as well as the route segment on which it must travel. This problem has been modeled as a multi commodity flow problem with supplementary constraints. It is solved by using a branch-and-bound procedure which integrates a Dantzig-Wolfe decomposition approach and several cutting plane strategies. Numerical experiments have been conducted on a very large scale scheduling problem (some 1300 locomotives and 2000 trains in one week). Our results indicate a 9% improvement over the current solution in effect at the company.

TH4-I-CM200

A New Upper-Bound and an Exact Algorithm for the 0-1 Quadratic Knapsack Problem

Soutif Eric

CEDRIC - Institut d'Informatique d'Entreprise

Billionnet Alain - Faye Alain

Keywords: Lagrangean decomposition - bounds - branch and bound - computational experiments - knapsack problem - quadratic 0-1 optimization

We consider in this talk the 0-1 quadratic knapsack problem (QKP) which consists in maximizing a positive quadratic pseudo-Boolean function subject to a linear capacity constraint. This problem is interesting because it can be viewed as the simplest integer nonlinear programming problem and it may represent many practical situations. Moreover it appears as a subproblem of other more complex combinatorial optimization problems.

We present a branch and bound algorithm for (QKP). At each node of the search tree, we compute an upper bound by a new method based on Lagrangean decomposition. The aim of this method is to find a good decomposition of the objective function into sub-functions relatively easy to optimize, since it can be done by solving series of continuous linear knapsack problems.

Computational experiments show the sharpness of this new bound. We take advantage of this result by reducing the size of the initial problem : a three steps procedure tries to fix simultaneously several variables before starting the branch and bound algorithm.

We report two kinds of results. The first ones concern the exact algorithm, which allows us to solve very large instances of (QKP), up to 130 variables, when the best algorithms of the literature don't solve instances involving more than 100 variables. The second ones concern the quality of the new upper bound : for instances up to 500 variables we find approximate solutions with a relative error less than one percent within sixty minutes of CPU running time on a HP9000 workstation.

A future research direction will be to generalize the method to the maximization of a 0-1 quadratic function subject to a set of linear constraints.

WE3-I-CM121

What Implication Implies

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Institut für Informatik, Universität zu Köln

Heusch Peter

In this talk formulas are considered formed by the implication operator and variables and nothing else. We show that these formulas have a nice characterization. Moreover they do not only offer a different point of view at the satisfiability/ falsifiability problem of boolean formulas but this perspective helps detecting new subclasses of Boolean functions for which satisfiability/ falsifiability can be determined efficiently.

TU3-P-IN201

The Assembly of Printed Circuit Boards: a Case with Multiple Machines and Multiple Board Types

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University of Limburg, Department of Mathematics

Crama Yves - Flippo Olav - van de Klundert Joris

Keywords: PCB-assembly - heuristics

A typical situation arising in the assembly of printed circuit boards is investigated. The planning problem we face is how to assemble boards of different types using a single line of placement machines. From a practical viewpoint, the multiplicity of board types adds significantly to the complexity of the problem, which is already very hard to solve in the case of a single board type. In addition, relatively few studies deal with the multiple board type case.We propose a solution procedure based on a hierarchical decomposition of the planning problem. An important subproblem in this decomposition is the so-called *feeder rack assignment problem*. By taking into account as much as possible the individual board type characteristics (as well as the machine characteristics) we heuristically solve this problem. The remaining subproblems are solved using constructive heuristics and local search methods. The solution procedure is tested on real-life instances. It turns out that, in terms of the makespan, we can substantially improve the current solutions.

TH2-I-CM200

Polyhedral Results for the Clique Partitioning Problem

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University of Limburg, Department of Mathematics

Bandelt Hans-Juergen - Oosten Maarten - Rutten Jeroen H.G.C.

Keywords: polyhedral combinatorics

A wide variety of clustering problems can be formulated as a clique partitioning problem We present facet-defining inequalities for this polytope, provide a characterization of all facet-defining inequalities with right-hand side 1 or 2, and prove two lifting theorems.

FR1-E-CO11

Lipschitzian Q_0-Matrices

Sriparna Bandyopadhyay

I.S.I Hostel

Let $A \in R^{n\times n}$. Say A satisfy (*) property if A (as well as every principal pivotal transform of A) satisfies the condition that the rows corresponding to nonpositive diagonal entries of A (every principal transform of A) are nonpositive. In this talk we will demonstrate how lipschitzian Q_0 matrices are completely characterized by (*) property.

FR1-I-CM200

Combinatorial Optimization Based on

Coupled Selection Equations

Starke Jens

University of Heidelberg, Institute of Applied Mathematics

Keywords: assignment problems - combinatorial optimization - dynamical systems - selection equations

A new approach for combinatorial optimization problems based on coupled selection equations will be introduced. This method works with a specifically constructed nonlinear dynamical system with suitable stable points and suitable basins of attraction. The idea will be explained using the example of assignment problems.

The choice between several decisions of the combinatorial optimization problem is mapped to the competition between stable points, i.e. to the stay in one of the basins of attraction of the dynamical system. There exists a bijective mapping from the set of feasible solutions to the set of stable points. Additional constraints can easily be considered by extending the dynamical system. To obtain the necessary adaption, specific coupling terms are used to result in a suitable selection of decisions and feasible solutions as stable points.

In comparison to many other methods this approach has the advantage that even complicated additional constraints of the optimization problem can easily be considered. Furthermore, parallel hardware realizations of this approach are possible because of the similarity to models of complex physical and chemical systems.

WE4-E-CO21

Structured Nonconvex Modelling in Nonsmooth Mechanics

Stavroulakis Georgios E.

Technical University of Braunschweig, Inst. Appl. Mechanics

Keywords: difference convex functions - nonconvexity - nonsmooth mechanics - quasidifferentiability

Several attempts to use structured nonconvex modelling in computational mechanics will be discussed in this talk. First general material or boundary laws can be generated by means of difference convex or in general quasidifferentiable potentials. Nonconvexity accounts for local instabilities. Further the linear or nonlinear kinematics of the structural analysis problem are introduced and the previous convex-concave structure is followed up to the level of the structure. Recall that nonlinear transformations destroy convexity. Applications on adhesive and frictional interface modelling and on elastoplasticity problems are discussed.

FR3-C-CO3

Numerical Experiments with Multilevel Optimization Techniques

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Keywords: computational mechanics - multilevel optimization - optimal design - structural analysis

A number of optimal structural design and inverse problems in mechanics are formulated and solved by multilevel optimization techniques. This multilevel splitting where the structural analysis solver, possibly enhanced with sensitivity analysis, is used within one level of the solution technique, has certain advantages concerning the reusability of existing software tools. Depending on the complexity of the problem the optimization level can be treated by smooth or nonsmooth numerical optimization tools, by optimality criteria iterations (such as the classical fully stressed design techniques) or even by soft (neural) computing techniques. A short discussion of these approaches and our restricted numerical experience on several examples solved with finite element and boundary element methods will be presented.

TU4-B-CO10

Convex Separable Minimization Problem with a Linear Inequality Constraint and Bounds on the Variables

Stefanov Stefan Minev

Department of Mathematics Neofit Rilski University

Keywords: algorithms - convex programming - separable programming - singly constrained program

In this paper we consider a minimization problem with convex and separable objective function over a feasible region defined by a single linear inequality constraint of the form "great equal" and bounds on the variables. A sufficient condition is proved for a feasible solution to be an optimal solution to this problem. A subsidiary problem is discussed and analysed. An iterative algorithm of polynomial complexity for solving the problem under consideration is suggested and the convergence of this algorithm is proved. Some important forms of convex functions and computational results are given in the Appendix.

FR2-B-CO10

Approximations with Respect to l_1 and l_∞ Norms: An Application of Convex Nonsmooth Programming

Stefanov Stefan Minev

Department of Mathematics Neofit Rilski University

Keywords: approximation algorithms - inconsistent linear systems - least squares - nonsmooth optimization - subgradient methods

In this paper we consider the problem for approximation a function of many variables given by a table of values and problem for "solving" a system of inconsistent linear equations. A traditional approach for solving these two problems is the least squares method which is based on l_2-norm. We suggest an alternative approach: with each of these problems we associate a nonsmooth unconstrained minimization problem for which the objective function is based on l_1 and/or l_∞-norm, that is, we use these norms as proximity criteria in the approach suggested. Some computational results obtained by an appropriate iterative method for these problems are given at the end of the paper. The results are compared with ones obtained by the iterative "smooth" method applied for corresponding least squares problems.

WE2-D-CO123

Deteriorating Convergence for Asynchronous Methods on Linear Least Squares Problems

Steihaug Trond

Department of Informatics, University of Bergen

Yalcinkya Yasemin

Keywords: large scale optimization - least squares - parallel algorithms - primal-dual interior point methods

A block iterative method is used for solving linear least squares problems. The subproblems are solved asynchronously on a distributed memory multiprocessor. It is observed that an increased number of processors results in deteriorating rate of convergence. This deteriorating convergence is illustrated by numerical experiments. The deterioration of the convergence can be explained by contamination of the residual. Our purpose is to show that the residual is contaminated by old information. The issues investigated here are the effect of the number of processors, the role of essential neighbors, and synchronization. The characterization of old information remains an open problem.

FR4-U-IN10

Approaches for Solving the Cable Management Problem

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Niggemann Oliver - Suermann Michael

Keywords: cable management - configuration of computer networks - min-cost-flow algorithm - shortest path

Local area networks (LANs) form the basis for worldwide data communication, and, during the last years, performance and size of these networks has been continuously increasing. Inevitably, the configuration of these networks became an important and sophisticated job.

This paper presents solutions for the cable management problem, which is a central part of the network configuration process. Among others we show the following: 1. The simplified cable management problem (without bundling resctriction) is an instance of the minimum-cost-flow problem. 2. The standard cable management problem (with bundling resctriction) is NP-complete.

From an applicational viewpoint, the central contribution of this paper is the development of a heuristic algorithm that tackles the standard cable management problem. Our approach produces sufficiently exact results in the network configuration domain, and it is much more efficient than exact algorithms that solve the weaker minimum-cost-flow problem.

TU2-I-CM4

Beautiful and Fast: New Minimum Cut Algorithms

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Goldberg Andrew V. - Chekuri Chandra - Karger David - Levine Matt

Keywords: minimum cuts

Recently, exciting new algorithms have been developed for the minimum cut problem. The new algorithms include those by Nagamochi and Ibaraki, Hao and Orlin, Karger and Stein, and Karger. These algorithms are different from the earlier ones and from each other and substantially improve the worst-case time bounds for the problem. However, only one of the algorithms has been implemented before our study, and nothing was known about relative performance of these algorithms in practice.

We conduct an experimental evaluation of relative performance of these algorithms. In the process, we develop heuristics and data structures that substantially improve their practical performance. We also develop problem families for testing minimum cut algorithms. Our work leads to a better understanding of the practical performance of the minimum cut algorithms and produces very efficient codes for the problem.

TH4-G-IN11

Solving Portfolio Management Problems with Optimal Complexity

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Keywords: portfolio management - recursive multistage factorization

Portfolio optimization over a finite, discrete planning horizon leads to a multistage mean-variance model when applying the Markowitz approach and stochastic programming. The dynamic evolvement of variance-covariance matrices and expected rates of return on the scenario tree induce a specific block-sparse structure in the Karush-Kuhn-Tucker matrix of the equivalent deterministic convex quadratic program. We present a highly efficient solution algorithm with strictly linear complexity in the number of nodes of the scenario tree. The algorithm applies a direct recursive factorization, based on a simple variable transformation and a fixed block elimination scheme. All block operations are local to the nodes, and no (heuristic) reordering is needed. Computational results will be presented.

FR4-V-CM106

Defining Universal Portfolios via Stochastic Programming

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Gaivoronski Alexei A.

Keywords: portfolio management - stochastic programming - universal portfolio

We deal here with the problem of optimal portfolio selection on the stock market. Such markets are often characterized by high changeability of statistical properties of the stocks involved. Universal portfolios were introduced in financial literature in order to describe portfolios which are constructed directly from observations of stocks behavior without any assumptions about statistical properties of stocks. It was shown by Cover that one can construct universal portfolio using only observations of the past stock prices which generates the same rate of growth of logarithmic wealth as the best constant rebalanced portfolio constructed with the full knowledge of the future stock behavior.

We use here ideas of nonstationary stochastic optimization for computing universal portfolios. Our simplest portfolio is obtained by computing before each trading period the constant rebalanced portfolio for the elapsed trading periods using past observations. This portfolio is applied for the current trading period. For the next trading period the problem is reformulated and resolved incorporating the new observation of stock prices. More involved techniques is developed for stabilizing our portfolios during the first trading periods.

We develop stochastic programming approach also for nonstationary markets and incorporate trading costs.

Numerical experiments on the real data from New York stock exchange show superior performance of our portfolios compared to results reported in the literature. Theoretical studies show that they possess also superior asymptotic behavior.

In this talk we concentrate on applied side of our work. Relevant theoretical results on nonstationary stochastic optimization are reported in accompanying talk in session G001.

WE3-I-CM4

An $O(n^3)$ Recognition Algorithm for Threshold Dimension 2 Graphs

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Raschle Thomas

Keywords: threshold dimension - threshold graphs

Threshold dimension 2 graphs are the (edge-)intersection of two threshold graphs T_1 and T_2. Moreover they are the intersection graphs of points, axially parallel line segments and rectangles in the first quadrant of the Euclidean plane subject to the following constraints: (1) line segments have one endpoint on one of the axes, (2) the lower left corner of a rectangle is the origin and (3) except for the above, every point, endpoint of a line segment and corner of a rectangle has unique x and y coordinates. The above intersection graph, called rectangle model, can be constructed in $O(n^3)$ providing the set of vertices that corresponds to the rectangles is known.

In this paper, we show that there always exists a rectangle model in which the rectangles correspond to the vertices common to all maximum cliques. As the maximum cliques of a threshold dimension 2 graph can found in $O(n^3)$, the overall running time of our recognition algorithm is $O(n^3)$ which compares favorably to the previous approaches with complexity $O(n^4)$ and $O(m^2)$ respectively.

TH3-E-CO21

Time-Stepping for Rigid Body Dynamics and Complementarity Problems

Stewart David E.

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Keywords: Coulomb friction - contact mechanics - nonlinear complementarity problems

Time-stepping formulations of rigid body dynamics problems with contact have been developed using nonlinear complementarity problems. These formulations avoid Painlevé's paradoxes, and have solutions for each time-step. This work is related to recent work with Jong-Shi Pang.

FR2-U-IN10

An Application of Murty's k-best assignment method to Reid's Multiple Hypothesis Tracking Algorithm

Stone Harold

NEC Research Institute

Cox Ingemar J. - Miller Matt

Keywords: bipartite graphs - k-best - multiple hypothesis tracking

Reid's multiple hypothesis tracking (MHT) algorithm is an optimal solution to the motion correspondence or data association problem that occurs in the context of multi-target tracking. However, the exponential growth of the hypothesis tree has precluded practical applications. A number of approximations have been implemented that aim to restrict this growth. Several algorithms have attempted to determine the k-best hypotheses at each iteration of the MHT, but these algorithms, while significantly slowing the rate of growth of the hypothesis tree, still have exponential worst case running time. However, because each legal hypothesis is a bipartite graph matching, Murty's algorithm for determining the k-best matchings can be applied. The computation time for Murty's algorithm grows only linearly in k, but for bipartite matchings, the worst-case time grows cubicly in N, the number of tracks. We describe several optimizations that we incorporated into Murty's algorithm to reduce the computation time to an average time linear growth in both k and N for randomly generated problems. The result is a very efficient implementation of Reid's MHT algorithm. Two of the optimizations are well-known in the literature, and the third, ordering of subproblem generation by lower bounds, is a novel way to force the best solutions into small subproblems where the cost of discovery is much less than if they were in large subproblems.

FR1-E-CO11

Lipschitzian Matrices and Nondegenerate INS-Matrices

Stone Richard E.

Northwest Airlines

Keywords: linear complementarity problem

We show that a Lipschitzian matrix must be a nondegenerate *INS*-matrix. We then define the concept of a set in R^n being Lipschitz path-connected and show that if $\operatorname{int} K(M)$ is Lipschitz path-connected, for $M \in R^{n\times n}$, then M is Lipschitzian if and only if M is a nondegenerate *INS*-matrix.

TH1-G-IN11

Computational Complexity of Stochastic Programming Problems

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Dyer Martin

Keywords: computational complexity - stochastic programming

Stochastic programming is the subfield of mathematical programming that considers optimization in the presence of uncertainty. During the last four decades a vast amount of literature on the subject has appeared. The researchers in the field have never ceased to emphasize the inherent complications in solving stochastic programming problems, without ever giving a theoretical justification of this common feeling. Recent developments in the theory of computational complexity allow us to establish the theoretical complexity of several stochastic programming models studied in the literature. Our results confirm the general feelings alluded to above.

FR4-C-CO122

On Global Optimality Conditions for D.C.-programming

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Keywords: global optimality - global optimization

The paper is devoted to Global Optimality Conditions (GOC) for the non-convex optimization problems, where the objective function or some constraints are given by the functions, which can be presented as the difference of two convex functions (d.c.-functions).

In general such non-convex problems posses a huge number of applications.

Further in these problems there are a set of local extremums or even stationary points which differ from global solutions.

Besides such non-convex problems as the convex maximization and reverse convex problems are particular cases of d.c.-programming. In order to solve the problems globally we propose Global Optimality Conditions for a point to be a global solutions to d.c.-problems.

On one hand this theory is connected with classical local optimality conditions.

On the other hand GOC developed earlier for convex maximization and reverse convex problems are particular cases of constructed theory.

In addition these GOC can be interpreted as a linearization following a level surface of convex functions, which generate the principal non-convexity in the problems under study.

Several examples demonstrating the possibility to escape from a stationary point with the help of GOC are given. Finally, a Global Search Algorithm based on GOC is developed and successfully tested.

TU3-P-IN201

Scheduling for Parallel Dedicated Machines with a Single Server

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Keywords: complexity - flow shop - heuristics - open shop - parallel dedicated machines - scheduling - setup - single server - worst case performance

We study machine scheduling problems in which a single robot, attendant or piece of equipment is required for the setup phase of each operation of a job. The objective is to minimize makespan.

For the processing system consisting of two parallel dedicated machines we prove that the problem of finding an optimal schedule is NP−hard in the strong sense even if either all setup times are equal or all processing times are equal. For the case of m parallel dedicated machines, a simple greedy algorithm is shown to create a schedule with the makespan that is at most twice the optimum value. For the two–machine case, an improved heuristic guarantees a tight worst–case ratio of 3/2. We also describe several polynomially solvable cases of the two–machine problem.

The flow shop and the open shop problems with a single server are also shown to be NP−hard in the strong sense even in the two–machine case. We apply Gilmore–Gomory algorithm for the travelling salesman problem to solve the two–machine flow shop no–wait problem with a single server in polynomial time

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FR3-D-CO124

Error Bounds for Semidefinite Programming

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Econometric Institute EUR

Keywords: semidefinite programming

Consider the semidefinite feasibility problem

$$\text{find } X \text{ such that } X \in (B + \mathcal{A}) \cap \mathcal{S}_+,$$

where $\mathcal{S}_+$ is the cone of semidefinite matrices, $\mathcal{A}$ is a linear subspace and B is some fixed symmetric matrix. We show that for any bounded sequence $X(\epsilon)$, $\epsilon \downarrow 0$, with

$$\text{dist}(X(\epsilon), B + \mathcal{A}) + \text{dist}(X(\epsilon), \mathcal{S}_+) \leq \epsilon,$$

there holds

$$\text{dist}(X(\epsilon), (B + \mathcal{A}) \cap \mathcal{S}_+) = O(\epsilon^{2^L}),$$

where L is called the irregularity level of the problem; for strongly feasible problems there holds $L = 0$. Applying the result to the iterative sequence generated by path–following methods for semidefinite programming, we demonstrate that the rate of linear convergence for this sequence can be significantly slower than for the corresponding duality gap sequence. This discrepancy will show up in the absence of strict complementarity (and otherwise it won't). Furthermore, a surprising connection to Ramana's duality theory will be revealed.

FR3-E-CO21

A Hybrid Projection-Proximal Point Algorithm

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Instituto de Matematica Pura e Aplicada

Solodov Michael V.

Keywords: maximal monotone operator - projection method - proximal point methods

We propose a modification of the classical proximal point algorithm for finding zeroes of a maximal monotone operator in a Hilbert space. In particular, an approximate proximal point iteration is used to construct a hyperplane which strictly separates the current iterate from the solution set of the problem. This step is then followed by a projection of the current iterate onto the separating hyperplane. All information required for this projection operation is readily available at the end of the approximate proximal step, and therefore this projection entails no additional computational cost. The new algorithm allows significant relaxation of tolerance requirements imposed on the solution of proximal point subproblems, which yields a more practical framework. Weak global convergence and local linear rate of convergence are established under suitable assumptions.

TH2-D-CO123

Optimal Truss Topology, Semidefinite Programming, and a Method Based on Conservative Approximations

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Brännlund Ulf G.

Keywords: compliance constraints - conservative approximations - minimum weight - semidefinite programming - truss topology

The problem of minimizing the weight of a truss structure subject to stiffness constraints under multiple load conditions is considered. Design variables are the cross section areas of a large set of bars in a so called ground structure. In an optimal solution, the majority of these areas are typically zero, while the non-zero areas define the optimal topology among possible substructures of the given ground structure. It is shown that this problem can be formulated as a semidefinite programming problem in which the structural stiffness matrix and the given load vectors appear in a surprisingly natural way. Further, some theoretical results concerning duality relations and ε-perturbed problems of the above problem are presented. Finally, an iterative method, based on explicit conservative approximations of the constraints, is theoretically analyzed and numerically tested.

TH1-K-CM106

An Approximation Algorithm for the Uncapacitated Facility Location Problem

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Sobolev Institute of Mathematics

Ageev Alexander A.

Keywords: approximation algorithms - facility location - hardness of approximation

The uncapacitated facility location problem in the following formulation is considered:

$$\max_{S\subseteq I} \quad z(S)=\sum_{j\in J}\max_{i\in S} b_{ij}-\sum_{i\in S}c_i,$$

where I and J are finite sets, and b_{ij} and c_i are real numbers. Let z^* denote the optimal value of the problem and $z_R=\sum_{j\in J}\min_{i\in I} b_{ij}-\sum_{i\in I}c_i$. Cornuejols, Nemhauser and Wolsey (1977) prove that a simple greedy algorithm finds a solution S such that $(z(S)-z_R)/(z^*-z_R)\geq 1-e^{-1}\approx 0,632$. We suggest a polynomial-time approximation algorithm for this problem based on the idea of randomized rounding due to Goemans and Williamson (1994). It is proved that the algorithm delivers a solution S such that $(z(S)-z_R)/(z^*-z_R)\geq 2(\sqrt{2}-1)\approx 0,828$. We also show that there exists $\varepsilon>0$ such that it is NP-hard to find an approximate solution S with $(z(S)-z_R)/(z^*-z_R)\geq 1-\varepsilon$.

WE2-G-IN11

Solving Subproblems in Two Stage Stochastic Programming with a Penalty-Based Simplex Optimizer

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Keywords: decomposition methods - exact penalty - stochastic programming

Decomposition methods used for solution of stochastic problems typically employ some iterative algorithm which solves a (possibly large) number of similar subproblems. Thus a need to solve them in shortest possible time.

Regularized Decompostion method for two stage stochastic linear problems is one example of such method, in which a number of linear programs is solved at each major iteration. The author has found out how a primal simplex optimizer using exact penalty for handling infeasible starting points is capable of offering both computational efficiency and considerable modelling freedom.

The main focus of the presentation will be on the impact of exact penalty on (a) the restart procedure, (b) generation of cuts (the information returned to the higher level) and (c) the choice of information flow scheme.

Numerical evidence will be used to support the claims of high efficiency of the method in question.

FR2-I-CM200

On Extremal GTT Matrices

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A GTT(n) matrix is a matrix $\{x_{ij}\}$ such that for all $i,\ j,\ k\in\{1,2,...,n\}$

(1) $x_{ij}\geq 0$
(2) $x_{ii}=0$
(3) $x_{ij}+x_{ji}=1,\ i\neq j$
(4) $x_{ij}+x_{jk}+x_{ki}\geq 1,\ i,j,k$ distinct.

An extremal GTT(n) matrix is an extremal point of the polytope defined by (1)-(4). We characterize extremal and non-extremal GTT(n) matrices by systems of linear equations and special kinds of digraphs and give a new proof that all GTT(5) matrices are $\{0,1\}$ matrices.

FR2-W-CO15

The Hilbert Class Library: Abstract Base Classes for Optimization and Inversion

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Gockenbach Mark

Keywords: object oriented numerics

The Hilbert Class Library (HCL) is a collection of C++ classes designed for implementing numerical optimization in Hilbert Space. HCL includes base classes defining vector spaces, vectors, operators, and functions with the features necessary to write optimization algorithms. It also includes classes specifying a growing list of algorithms, as well as several concrete vector classes useful in many contexts. A central principle of HCL design is maximal abstraction: for example the most abstract vector class defines the operations of linear algebra, but not access to coordinates (reserved to subclasses). This feature differentiates HCL from many other similar libraries, and is essential in its application to very large problems. The talk will survey the library design, and provide several examples of its use in solving design and inverse problems.

FR1-G-IN11

Probabilistic Constrained Programming with Different Multivariate Probability Distributions

Szántai Tamás

Institute of Mathematics, Technical University of Budapest

Keywords: software - stochastic programming

The effect of different multivariate probability distributions on the optimum value of probabilistic constrained programming problems will be investigated.

After András Prékopa developed the general theory of log-concave measures in the early 70-ies the solution of stochastic programming problems with joint probabilistic constraints became possible from theoretical point of view. On the practical side one had to solve the following problems.

The first problem in solving joint probabilistic constrained programming problems is the efficient calculation of probabilities according to the probability distributions with given marginals involved in the problem. The second problem is the calculation of the derivatives of these probabilities according to the decision variables and finally the last problem is the application of an appropriate nonlinear programming problem solver.

All of these problems were solved before by many authors. This talk will be about the solution by the author called PCSP (Probalistic Constrained Stochastic Programming) code and as a new element the possibility of application of a new multivariate probability distribution, the multivariate Student's t-distribution will also be investigated.

WE3-E-CO11

Some Stability Aspects of the Linear Complementarity Problem and its Generalizations

Sznajder Roman

Bowie State University

Keywords: directional stability - linear complementarity problem - strict Pareto minimum

In this talk we discuss solvability of the perturbed linear complementarity problem $(M+\varepsilon I, q+\varepsilon p)$ when M is a P_0-matrix and $\varepsilon > 0$. Among other results, we show that if the solution set of the problem (M, q) is nonempty and bounded, then any accumulation point of the sequence of solutions of the above perturbed problems solves the original problem (M, q). We also show that for a PSD matrix M such that (M, q) has a nonempty solution set, the sequence of solutions of the above perturbed problems converges to the element x^*, a solution of the problem (M, q) such that the l_2-norm of $x^* + p$ is the least among those of $u + p$, where u solves the problem (M, q). In turn, when M is a P_0-matrix, any accumulation point of the sequence of solutions corresponding to the problem $(M+\varepsilon I, q)$ is a *strict Pareto minimum* with respect to its supporting space. We also present some results in the context of the vertical linear complementarity problem.

FR3-I-CM4

On Clique Graphs of Some Classes of Graphs

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Universidade Federal do Rio de Janeiro

Keywords: intersection graphs

A **clique graph** of an undirected graph G is the intersection graph of the maximal cliques of G. It is an open problem to determine the complexity of recognizing clique graphs. We present a brief survey of results about clique graphs of specific classes of graphs, with emphasys on subclasses of chordal graphs.

WE2-K-CM106

Ant Hybrid for the Quadratic Assignment Problem

Taillard Eric

IDSIA

Gambardella Luca Maria - Dorigo Marco

Keywords: ant system - combinatorial optimization - metaheuristics

This presentation discuss an implementation of an ant system for finding good solutions to quadratic assignment problems. This system is hybridized with a fast local search and numerical results show that it is particularly efficient on structured problems.

MO4-R-IN203

Solving Airline Crew Scheduling Problem with Many Irregular Flights

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Misono Shinji

Keywords: column generation - crew scheduling - irregular

flights - set partitioning problems

We address the air-crew scheduling problem involving many irregular flights that are scheduled only on a certain dates in a given period of time. The crew scheduling problem itself has been investigated for over twenty years. Previous studies have assumed that every flight is available every day, and coped with irregular flights by minor post-process operations. Airlines are, however, increasing the number of irregular flights to satisfy the passengers' requirements. Thus, irregular flights should be handled explicitly in the crew scheduling problem, if we consider the actual feasibility and optimality of assigning crews to the schedule.

The crew scheduling can be formulated as set partitioning problem(SPP). A straight forward approach to handle many irregular flights would be to solve the SPP defined over the full range of the given scheduling period, or a month in most cases. The full-sized SPP becomes very large in size, and it is practically impossible to solve it. On the other hand, separating regular and irregular flights results in an inefficient schedule.

This article presents a new approach that reduces the total number of man-days in pilots' round-trip flight patterns (called crew pairings) that cover all the regular and irregular flights. Our approach is based on column generation method, where a candidate pairing (column) is generated by patching multiple one-day paths that are enumerated in advance. We first generate a schedule (set of pairings) for regular flights, then insert irregular flights into the pairings so that they still satisfy given working regulations. For irregular flights which were not inserted, the full-sized SPP is solved. We also facilitate the insertion by modifying the costs of candidates of regular pairings so that they reflect the potential of including irregular flights.

The approach is validated by using real-world datasets provided by an airline company. The output schedule of our prototype system outperformed that of experienced engineers in the airline company in both the total number of man-days in pairings and the total expense.

TU3-E-CO11

Computation of Robust Stationary Points on Polytopes

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van der Laan Gerard - Yang Zaifu

Keywords: robustness - simplicial algorithm - stationary points

Nonlinear stationary point problems are studied from a view point of stability and a new solution concept is proposed. The new concept is called robust stationary point and is a refinement of the concept of stationary points. It is shown that every continuous function on a polytope has at least one robust stationary point. Also a simplicial algorithm is introduced to compute approximate robust stationary points of a continuous function on polytopes. Starting with an arbitrarily chosen interior point of the polytope, the algorithm generates a piecewise linear path of points in the polytope. That path leads to an approximate robust stationary point of any accuracy within a finite number of iterations.

WE2-I-CM200

A Maximum b-Matching Problem Arising from Median Location Models with Applications to the Roommates Problem

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TEL AVIV UNIVERSITY, MATHEMATICAL SCIENCES

Mitchell Joseph S.B.

Keywords: b-matchings - median location problems - roommates problem

We consider maximum b-matching problems where the nodes of the graph represent points in a metric space, and the weight of an edge is the distance between the respective pair of points. We show that if the space is either the rectilinear plane, or the metric space induced by a tree network, then the b-matching problem is the dual of the (single) median location problem with respect to the given set of points. This result does not hold for the Euclidean plane. However, we show that in this case the b-matching problem is the dual of a median location problem with respect to the given set of points, in some extended metric space. We then extend this latter result to any geodesic metric in the plane. The above results imply that the respective fractional b-matching problems have integer optimal solutions. We use these duality results to prove the nonemptiness of the core of a cooperative game defined on the roommate problem corresponding to the above matching model.

TU1-I-CM4

The Generalized Stable Set Problem for Bidirected Graphs and Polynomial Time Solvability for Perfect Cases

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Keywords: bidirected graphs - perfect graph - stable set problem

Bidirected graphs are a generalization of undirected graphs. For bidirected graphs, we can consider a problem which is a natural extension of the maximum weighted stable set problem for undirected graphs. Here we call this problem the generalized stable set problem. It is well known that the maximum weighted stable set problem is solvable in polynomial time for perfect undirected graphs. Perfectness is naturally extended to bidirected graphs in terms of polytopes. Furthermore, it has been proved that a bidirected graph is perfect if and only if its underlying graph is perfect. We show that the problem for any bidirected graph is reducible to the maximum weighted stable set problem for a certain undirected graph in time polynomial in the number of vertices, and moreover, prove that this reduction preserves perfectness. Hence, the generalized stable set problem for perfect bidirected graphs can be solved in polynomial time.

TH4-P-IN201

Single Machine Scheduling with Positional Due and Release Dates

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NTT LABORATORIES

Vlach Milan

Keywords: due dates - release dates - scheduling

In 1986, N. G. Hall introduced a new type of due dates called generalized (also called generic or positional) due dates. Each of positional due dates is not given for a particular job, but they are given for a set of jobs. It does not matter which job is completed by each positional due date. The first positional due date indicates the time by which at least one of the jobs should be completed, the second one gives the time by which at least two of the jobs should be completed, and so on. In this paper, first, we briefly survey the recent results on single machine scheduling problems involving positional due dates. Then, we consider scheduling problems with a new type of release dates, called positional release dates. They are related to traditional release dates in similar way as positional due dates to traditional ones. Each of positional release dates is not given for a particular job, but they are given for a set of jobs. It does not matter which job becomes available for processing by each positional release date. The first positional release date indicates the time at which one job becomes available for processing, the second one gives the time at which another job becomes available, and so on. Particular, we consider the problem to minimize the sum of completion times with positional release dates which have constant intervals. The strong NP-hardness is proved for this problem. This extends a previously known results on a flowshop problem. We also consider basic problems in the presence of positional release dates.

TU3-C-CO2

Computational Issues Related to Interior-Point Methods for Nonlinear Programming

Tapia Richard Alfred

Rice University, Dept of CAAM

Argaez Miguel - Parada Zeferino

Keywords: Newton method - interior point methods - nonlinear programming

In this talk the speaker will discuss various computational and implementational issues related to the primal-dual Newton interior-point method for both linear and nonlinear programming. A main focus will be centrality conditions, their use, their form, and their value. Relationships between the primal-dual Newton interior-point method and the logarithmic barrier function method will be included. Several choices of merit functions will be presented. Finally, many of the claims will be supported by numerical experimentation.

MO3-I-CM121

Minimizing Submodular Functions on Finite Sublattices of Product Spaces

Tardella Fabio

Fac. of Economics, Univ. of Rome

Queyranne Maurice

Keywords: integer programming - lattice theory - location theory - submodularity

We present a characterization of sublattices and sublattice hulls in product spaces. Based on this characterization we propose an encoding for finite sublattices and we show that its length is, in a sense, the shortest possible. We then present an algorithm for minimizing a submodular function on a finite sublattice and show that its complexity is polynomial in the length of its encoding. This polynomiality result encompasses and extends several known results in location theory, computational geometry and integer programming.

MO-pm-CO1

Routing in Networks

Tardos Eva

Cornell University, Dept. Computer Science

In this talk we will consider the disjoint paths problem. This problem is one of the basic algorithmic problems underlying the management of high-speed communication networks, and is also one of the oldest and most the basic algorithmic questions, it is one of Karp's original NP-complete problems. Given a graph and a set of node-pairs that would like to be connected by disjoint paths, we can ask a number of natural questions: How many of the disjoint paths are simultaneously realizable? How many rounds are required to satisfy all connection requests, when all paths assigned in a single round must be disjoint? All these questions are NP-hard, and hence we cannot expect to have efficient algorithms for them. In this talk we will consider approximation algorithms for these questions in different classes of graphs. We will discuss efficient algorithms that are guaranteed to provide solutions close to optimal.

FR2-P-IN201

On the Complexity of Shop Scheduling Problems with Batching Machines

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Otto-von-Güricke University Magdeburg

Potts Chris N. - Strusevich Vitaly A.

Keywords: batching - complexity - flow shop - job shop - open shop - scheduling

We consider the problem of scheduling n independent jobs on two machines in the case of open shop, flow shop and job shop. The machines are batch machines, i.e. several jobs can be combined to a batch and processed on a machine in parallel. Such a situation may occur for instance if machine parts are placed together on a palette in an oven to burn in paint. We consider both machines with unlimited batch size and machines which can process only a bounded number of jobs in one batch. For most of the possible combinations of restrictions, we establish the complexity status of the problem.

FR1-I-CM121

Pseudo-Weightings for Classes of Boolean Functions

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Department of Mathematics, Union College

Zwicker William S.

If f(x1, . . . , xn) is a threshold function, then weights can be assigned to input vectors in a completely additive way – the weight of (x1, . . . , xn) is Sigma-wixi – and so that the weight of every false vector is strictly less than the weight of every true vector. Such additive weightings provide a structural explanation for why many properties hold for threshold functions. For example, every threshold function is a regular Boolean function (there are no cycles in the natural strict ordering of the variables). We seek similar structural explanations for nonthreshold functions, and we find these by weakening additivity in several ways so as to characterize classes of Boolean functions (like the regular ones) as precisely those that carry certain kinds of pseudoweightings.

TU1-P-IN201

Scheduling Orders with Release Times and Decreasing Revenues

Tayur Sridhar

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Keskinocak Pinar

Keywords: release times - scheduling

We discuss complexity results, off-line and on-line algorithms for the following problem: Customer orders arrive over time, where r_j is the *release time*, w_j is the weight and p_j is the processing time of order j. Our goal is to maximize revenue given by $R_j(d) = (l_j - d)w_j$ for $d < l_j$, if the processing of order j is completed at $r_j + p_j + d$, and zero otherwise. We have the option of rejecting an order, but if an order j is accepted, it must be processed without preemption and its processing must be started before $r_j + l_j$.

WE2-A-IN2

XPRESS-EMOSL: A Combined Modeller and Optimiser for Algorithm Development

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University of Buckingham, Department of Management

Daniel Robert

The purpose of XPRESS-EMOSL is to enable the algorithm developer to access entities expressed in the modeller's notation from a high level programming language. Currently, most algorithm development takes place at the internal in-core form of the matrix, or at best, at the MPS level. But both of these wantonly throw away the structure that the human modeller has so carefully constructed. We show that the ability to refer to generic model entities (e.g., data tables, parameters, subscripted variable and constraint names, Special Ordered Sets, etc.) greatly facilitates rapid algorithm development by means of several examples drawn from real life applications. These include the generation of "model cuts", some heuristics for a variant of the unit commitment problem and the extraction of alternative decomposition structures from an existing model.

Containing both modelling and optimisation abilities, XPRESS-EMOSL allows the user to work with whichever representation is most convenient. Thus the user can take a base model, add or delete components, optimise, inspect solution values, change the model, re-optimise, etc., etc.

WE2-E-CO11

Lagrangian Multiplier Methods for Semidefinite Programming

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Tel-Aviv University, School of Mathematical Sciences

Doljanski Moshe

Keywords: Lagrangian methods - proximal algorithms - semidefinite optimization

Non-quadratic proximal methods are central to develop and analyze smooth Lagrangians multiplier methods for standard convex programs. In this talk we extend the notion of non-quadratic proximal maps to semidefinite optimization and propose a general scheme for developing interior proximal algorithms and Lagrangian multipliers methods for semidefinite programs. We outline the basic properties and convergence results of the proposed algorithms. Special cases of the general scheme including exponential and log-barrier multiplier algorithms for semidefinite programming problems will used to illustrate the approach.

FR1-H-CO22

Bicriteria Assignement Problem

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Keywords: assignment problems - multiobjective optimization

Until recently, multi-objective combinatorial optimization (MOCO) did not receive much attention in spite of its potential applications. The reason is probably due to specific difficulties of MOCO models as pointed out in a recent survey concerning this field.

The aim of this paper is to present for a partticular MOCO problem,the bicriteria linear assignement problem,
- two exact methods to generate the set of efficient solutions
- an heuristic procedure to approximate this set.

WE2-I-CM120

An Arc Design Formulation for the Two-Level Network Design Problem

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Faculdade de Ciencias da Universidade de Lisboa

Gouveia Luis E. N.

The two-level network design (TLND) problem was first introduced by CURRENT,J.R.;REVELLE,C.S.;COHON,J.L. (1986) and consists of an extension of the classical shortest spanning tree problem with two different types of nodes and arcs. As shown by BALAKRISHNAN,A.;MAGNANTI,T.L.;MIRCHANDANI,P. (1994), the TLND problem can be seen as a Steiner tree on a spanning tree. Therefore, we present a formulation which combines together a Steiner tree model by KHOURY,B.N.;PARDALOS,P.M.;HEARN,D.W. (1993) with a well-known packing for the spanning tree problem. The LP relaxation is weaker than the LP relaxation of the network flow model by BALAKRISHNAN,A.;MAGNANTI,T.L.; MIRCHANDANI,P. (1994). However, we describe the so-called generalized cut constraints which considerably strength the LP relaxation of our original model. Some computational results are presented based on some variations used with different proportions and position of primary nodes.

TH-pm-CO1

Criss-Cross Methods: A Fresh View on Pivot Algorithms

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Delft University of Technology

Fukuda Komei

Keywords: criss-cross method - cycling - linear complementarity problem - linear programming - oriented matroids - pivot rules - quadratic programming - recursion

Criss-cross methods are pivot algorithms that solve linear programming problems in one phase starting with any basic solution. The first finite criss-cross method was invented by Chang, Terlaky and Wang independently. Unlike the simplex method that follows a monotonic edge path on the feasible region, the trace of a criss-cross method is neither monotonic (with respect to the objective function) nor feasibility preserving. The main purpose of this paper is to present mathematical ideas and proof techniques behind finite criss-cross pivot methods. A recent result on the existence of a short admissible pivot path to an optimal basis is given, indicating shortest pivot paths from any basis might be indeed short for criss-cross type algorithms. The origins and the history of criss-cross methods are also touched upon.

FR3-D-CO124

Initialization in Semidefinite Optimization by Self-Dual Embedding, Central Path, Maximally Complementary Solution

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Delft University of Technology

de Klerk Etienne - Roos Cornelis

Keywords: interior point methods - self-dual embedding - semidefinite optimization

Because of semidefinite programming duality theory is weaker than that of linear programming, only partial information can be obtained in some cases of infeasibility, nonzero optimal duality gaps, etc. A comprehensive treatment of a specific initialization strategy is presented by self-dual embedding, where the original primal and dual problems are embedded in a larger problem with a known interior feasible starting point. This construction provides a framework for infeasible start algorithms with the best obtainable complexity bound. The information that can be obtained in case of infeasibility, unboundedness, etc., is stated clearly.

TU4-I-CM200

New Relaxations for the Cutting Stock Problem

Terno Johannes

University of Technology Dresden

The classical cutting stock problem means that a given order for smaller pieces have to be cut from larger stock material using a minimal number of stock material. Introducing the cutting patterns the corresponding well known integer linear optimization problem (ILP) can be formulated. Based on the definition of proper cutting patterns two new relaxations for the cutting stock problem are considered. The paper reports on theoretical and numerical investigations for the new relaxations.

FR4-C-CO123

Upper Convex Approximation and Convergence of Algorithms to Solve Nonsmooth Optimization Problems

Terpolilli Peppino

Elf Aquitaine Production

Keywords: convergence results - line search - nonsmooth optimization - trust region - upper convex approximation

In our work we introduce a new framework for nonsmooth analysis. Our main objective is to provide convenient tools for the design and the analysis of algorithms to solve optimization problems.

The key point in our work is the introduction of a new kind approximation for nonsmooth objective functions. We call them upper convex approximation. In a rough way we can say that we define some kind of local convex analysis.

Our approach extends considerably the case of convex composite optimization and is related to the work of Levitin Milyutin Osmolovski and Ioffe.

In a first part we show the 'obstruction' ,for generalized subdifferential such as those defined by Clarke ,Penot .., to be upper convex approximation. The results obtained here give motivations for the definitions given for the new approximations. We see also that a lot of useful approximations introduced in numerical optimisation are in fact upper convex approximation.

In this new new framework we study convergence properties of descent algorithms to solve nonsmooth optimization problems.

We first consider algorithms with line search of the Armijo type. We obtain fairly general convergence results which contains those by Pschenichny, Burke Sachs and we compare them with those by Pang Han Rangaraj. We focus on a famous conterexample first given by Demyanov.

We consider then algorithms using trust region strategy and prove convergence results which extends those by Yuan. We compare our results with those by Dennis Li Tapia and Qi Sun.

In both case we consider situations where we actually use approximate models such as done by More for trust region algorithms to solve smooth Problems.

In the conclusion we give some perspectives for future works.

MO4-K-CM106

A Genetic Clustering Method for Multi-Depot Vehicle Routing Problems

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Salhi Said - Rahman Faruq

Keywords: genetic algorithms - heuristics - multiple depot - vehicle routing

We propose a general purpose genetic clustering method for solving vehicle routing problems based upon route primitives. The genetic clustering method is used to solve the vehicle routing problems with multi-depots for problems obtained from the literature. The clustering method show promising results for a large number of problems.

FR3-C-CO123

On Solving Inverse Multobjective Max-Separable Optimization Problems

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Zimmermann Karel

Keywords: inverse problems - maxmini optimization

In this article we suggest different techniques for solving some inverse problems which are called in the literature max-separable problems and induced from the following problem:

$$\text{Find} \quad x \in M(\hat{A}, b, h, H),$$

where $M \equiv \{x : R(x) = b \;\&\; h \leq x \leq H\}$.

$R(x) = (R_1(x), \ldots, R_n(x))^T$, $R_i(x) \equiv \max\limits_{1 \leq j \leq n} \hat{a}_{ij} - r_{ij}(x_j)$, $\hat{a}_{ij} \wedge r_{ij}(x_j) \equiv \min(\hat{a}_{ij}, r_{ij}(x_j))$, $b \in \mathbf{R}^n$ is a given vector, $h, H \in \mathbf{R}^m$ are given constant vectors, $x \in \mathbf{R}^n$, and the functions $r_{ij} : \mathbf{R} \to \mathbf{R}$ are strictly increasing functions.

These inverse problems concerning the matrix $\hat{A}$, the boundary vectors h, H, where the vector b unchanged. We shall introduce a solution method for the following optimization problem

$$t \to \min \qquad \text{s.t} \qquad M(t) \neq \emptyset.$$

where $M(t) \equiv \{A \in \mathcal{A} :\parallel A - \hat{A} \parallel \leq t\}$, and other problems. The set of matrices $\mathcal{A}$ defined as follows:

$$\mathcal{A} = \{A : \exists x : h \leq x \leq H \;\&\; R(x) = b\},$$

where the norm $\parallel A - \hat{A} \parallel \equiv \max\limits_{i,j} |a_{ij} - \hat{ij}|$.

MO4-B-CO10

Finding A Zero Of The Sum Of Two Maximal Monotone Operators

Théra Michel

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Keywords: Brézis-Crandall-Pazy condition - co-coercive operators - fixed point methods - maximal monotone operator - proximal point algorithm - variational inequalities

In this lecturer we establish the equivalence between variational inclusions and a generalized type of Wiener-Hopf equation is established. This equivalence is then used to suggest and analyze iterative methods in order to find a zero of the sum of two maximal monotone operators. When the problem has a nonempty solution set, a fixed point procedure is proposed and its convergence is established provided that the Brézis-Crandall-Pazy condition holds true. More precisely, it is shown that this allows reaching the element of minimal norm of the solution set

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TH1-A-IN2

ABACUS - A Branch-And-CUt System

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Keywords: branch and cut - combinatorial optimization - integer programming

Branch-and-cut algorithms, branch-and-price algorithms, and their combination turned out to be powerful methods for the solution of combinatorial and mixed integer optimization problems. In order to simplify and speed up the implementation of such an algorithm we developed ABACUS—A Branch-And-CUt System. ABACUS is an object oriented framework in which problem specific functions, e.g., cutting plane generation methods, can be embedded easily. We give on overview on the design of the system, explain its usage, and report on successful applications.

MO4-C-CO2

Branch and Bound Methods for the General Quadratic Programming Problem

Thoai Nguyen van

UNIVERSITY OF TRIER

Keywords: branch and bound - general quadratic problem - global optimization

The branch and bound scheme is one of the most successful approaches in nonconvex global optimization. In this paper we present some new branch and bound algorithms for solving the general quadratic programming problem, in which bounding procedures are established based on convex envelopes of concave functions and the Lagrange duality.

FR1-C-CO122

A Duality Bound Method for the General Quadratic Programming Problem with an Additional Quadratic Constraint

Thoai Nguyen van

UNIVERSITY OF TRIER

Keywords: general quadratic problem - global optimization - quadratic constraints

Consider the general quadratic programming problem with an additional quadratic constraint, which is formulated as follows.

$$\begin{array}{ll} \min & f(x) = xQx + qx \\ \text{s.t.} & Ax + d \leq 0 \\ & xCx + cx \leq 0 \\ & x \in R, \end{array}$$

where Q, C are arbitrary $n \times n$ matrices, A an $m \times n$ matrix, $q, c \in \mathbb{R}^n$, $d \in \mathbb{R}^m$, and R is a box in $\mathbb{R}^n_+$. We show that the above problem can be transformed to an equivalent problem whose Lagrange dual is a linear program. Using this result als a method for computing lower bounds, we obtain a branch and bound algorithm for solving the above problem, which is convergent whenever the corresponding branching procedure is exhaustive in a sense often used in global optimization.

MO4-I-CM120

Rectilinear Steiner Trees with Terminals Constrained to Smooth Curves

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Brazil Marcus - Weng Jia

Keywords: Steiner tree - minimal networks - polynomial algorithm

We show that there is a polynomial time algorithm for solving the rectilinear Steiner problem for the case where the terminals are constrained to lie on a fixed set of disjoint finite-length smooth compact curves. The problem is known to be NP-hard in general.

MO4-A-IN2

Gomory's Group Problem and Groebner Bases

Thomas Rekha Rachel

Texas A & M University

Hosten Serkan

Keywords: Groebner bases - group problem

The group relaxation of an integer program, introduced by Ralph Gomory, has a natural and more general reformulation in the language of Groebner bases theory for integer programming. In this talk I will examine the group problem in this light and present both general and specific results for integer programs that can be obtained this way. The tools used are those of regular triangulations, Groebner bases, and the algebraic operation of localization.

WE4-A-IN1

An Integral Simplex Algorithm for Solving Combinatorial Optimization Problems–A New Paradym?

Thompson Gerald L.

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Keywords: global integral simplex method - local integral simplex method - subproblem search tree

In this paper a local integral simplex method will be described, which, starting with the initial tableau of a set partitioning problem which has an initial basis consisting of (artificial) slack variables having large costs, makes pivots using the pivot on one rule until no more such pivots are possible because a local optimum has been found. If the local optimum is also a global optimum the process stops. Otherwise, a global integral simplex method creates and solves a sub problem search tree consisting of a polynomial number of subproblem, subproblems of subproblems, etc., and the solution to at least one of which is guaranteed to be an optimal solution to the original problem. If that solution has a bounded objective then it is the optimal set partitioning solution of the original problem, but if it has an unbounded objective then the original problem has no feasible solution. It is shown that the total number of pivots required for the global simplex method to solve a set partitioning problem having m rows and n columns, where m is an arbitrary but fixed positive integer, is bounded by a polynomial function of n. Preliminary computational experience is given which indicates that the global integral simplex algorithm has a low order polynomial emperical performance when solving such problems.

TU2-B-CO10

On New Proximal Point Methods for Variational Inequalities with Monotone Operators

Tichatschke Rainer

University of Trier

Kaplan Alexander

Keywords: monotone operators - proximal point methods - variational inequalities

We present methods which couple a successive approximation of the variational inequality with the proximal point approach as well as related methods using a regularization on a subspace or a weak regularization.
The problem under consideration is the following variational inequality:

$$find \;\; u \in K \;\; such \; that \;\; \exists \, y \in \mathcal{T}u : \; \langle y, v-u \rangle \geq 0 \;\; \forall \, v \in K$$

with K a convex, closed subset of a Hilbert space V, $\mathcal{T} : V \to 2^{V'}$ a monotone operator, $D(\mathcal{T}) \equiv \{v \in V : \mathcal{T}v \neq \emptyset\} \supset K$, V' a dual space of V and $\langle \cdot, \cdot \rangle$ the duality pairing between V and V'. It is supposed that H is a given Hilbert space such that V can be continuously embedded in H, V_1 is a given closed subspace of V and $\mathcal{P} : V \to V_1$ is an orthogonal projection operator (orthoprojector). If V_1 is also closed in H then $\mathcal{P}$ can be defined as the orthoprojector according to the norm of H.
In the framework of the approach considered, the solution is obtained by solving approximately the sequence of variational inequalities:

$$u \in K_i : \langle \mathcal{T}_i u, v-u \rangle + \chi_i(\mathcal{P}u - \mathcal{P}u^{i,s-1}, \mathcal{P}v - \mathcal{P}u)_H \geq 0$$

$\forall v \in K_i$; $s = 1, ..., s(i); i = 1, 2, ...$

with $\mathcal{T}_i : V \to V'$ and K_i certain approximations for $\mathcal{T}$ and K, respectively; $(\cdot, \cdot)_H$ the inner product in H; $u^{i,s-1}$ a solution of the previous problem ($u^{i,0} \equiv u^{i-1,s(i-1)}$); $0 < \chi_i \leq \bar{\chi}$.
For example, treating variational problems in mechanics, often K_i is an internal approximation of K constructed by means of a finite element method, and $\mathcal{T}_i$ is the gradient of a smoothened energy functional.
We investigate the convergence of such methods. This permits to consider new applications, in particular, saddle point problems and complementarity problems.

WE3-B-CO10

Convex Input and Output in DEA

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Bogetoft Peter - Tama Joseph M.

Keywords: DEA - data envelopment analysis

The purpose of this presentation is to study two projections of the possibility set.

For a given vector of inputs we shall study the projection into the output space. This defines the production set and consists of all obtainable output vectors.

Similarly, for a given output vector we consider the consumption set consisting of all input vectors that may produce this output.

It is natural to require that the production and consumption sets be convex. This is the case if the possibility set itself is convex. However this is not necessary. The purpose of this presentation is to characterize a minimal possibility set such that the production sets as well as the consumption sets are still convex. The only additional assumption introduced is the requirement of free disposability.

We show how to formulate the minimal, convex production and consumption sets. The formation is obtained by a recursive process that may be either finite or infinite. We give a necessary and sufficient condition for the process to be finite and present an illustrative example for the finite case. We also discuss how to obtain a good approximation of the production and consumption sets in the infinite case.

MO4-N-CO15

An Automatic Differentiation Interface for FFSQP

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Liu Mingyan

Keywords: automatic differentiation - feasibility - sequential quadratic programming - software tools

ADIFFSQP, an interface between automatic-differentiation preprocessor ADIFOR and nonlinear programming software FFSQP is presented.

In the absence of ADIFFSQP, FFSQP users wishing to make use of ADIFOR have to create a "composite file", a "script file", an appropriate main program, and a "driver" subroutine invoking the ADIFOR-generated derivative-evaluation subroutines. The purpose of ADIFFSQP is to save the user the time and hardship associated with creating these. Indeed, with ADIFFSQP available, the user simply must provide a valid input set for FFSQP, and the interface does the rest.

FR1-D-CO124

Accelerating Convergence of a Potential Reduction Method

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Eberhard Andrew C

Keywords: interior point methods - primal-dual potental methods

A a new primal dual potential-reduction algorithm is proposed with good complexity and for which a monotonic gap reduction is assured. The (worst) rate of convergence is global linear in a two-step sense with further scope for improvement if centrality is carefully controlled. It has the added feature of interactively varying a parameter which accelerates gap reductions. This parameter varies the mix of a primal affine descent direction and a dual affine ascent direction. This leads to a true primal-dual potential reduction method which allows for large steps in both the primal and dual iterates.

WE1-D-CO123

Infeasible-Interior-Point Methods for Convex Programming Problems

Todd Michael J.

School of Operations Research, Cornell University

Nesterov Yurii E. - Ye Yinyu

Keywords: conic problems - detecting infeasibility - infeasible interior point methods

We present several infeasible-interior-point primal-dual methods for convex programming problems in conic form. The algorithms seek to find either near-optimal solutions or strong-infeasibility detectors in polynomial time, and are based on looking for a recession direction in a certain convex set by minimizing a barrier function.

TU4-D-CO123

Properties of Search Directions for Semidefinite Programming

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Keywords: interior point methods - search directions - semidefinite programming

We discuss several desirable properties for the search directions in semidefinite programming to satisfy. Then we investigate whether these properties hold for certain known search directions and families of search directions, as well as some new ones based on matrix geometric means.

TU-am-SPO

Recent Progress in Unconstrained Nonlinear Optimization without Derivatives

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Facultés Universitaires Notre Dame de la Paix - Dépt de Mathématique

Conn Andrew Roger - Scheinberg Katya

Keywords: algorithms - derivative free methods - trust region

We present an introduction to a new class of derivative free methods for unconstrained optimization. We start by discussing the motivation for such methods and why they are in high demand by practitioners. We then review the past developments in this field, before introducing the features that characterize the newer algorithms. In the context of a trust region framework, we focus on techniques that ensure a suitable "geometric quality" of the considered models. We then outline the class of algorithms based on these techniques, as well as their respective merits. We finally conclude the paper with a discussion of open questions and perspectives.

WE1-R-IN203

An Analysis on Learning Optimized Regions in Application to Data Mining

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IBM Tokyo Research Laboratory

Takeshi Fukuda - Morimoto Yasuhiko - Morishita Shininch - Yoda Kunikazu

Keywords: computational geometry - data mining

We consider the following region finding problem: Let G be an $N \times N$ grid in the square region $[0,1] \times [0,1]$ of the plane, and let μ be a distribution on G. $\mu(i,j)$ denotes for the measure of the (i,j)-th pixel with respect to μ. For a grid region R, we define $\mu(R) = \sum_{(i,j)\in R} \mu(i,j)$. Let $\mathcal{R}$ be a family of grid regions, and we would like to find the optimized region R_{opt}, which has at most $\mu(G)$ pixels, and maximizes $\mu(R)$.

This problem has been considered in application to database mining, in which the optimized region is sometimes called the *maximum confidence region*. However, in database mining, we are not given the distribution μ, but only sample data which obey the distribution. Hence, the sampling error causes distortion of the optimized region learned from the sample data. It can be observed by experiment that the distortion highly dependent on the family of regions.

In this talk, we compare "x-monotone regions" and "rectilinear convex regions", each of which has infinite VC dimensions, and demonstrates that learning optimized region in rectilinear convex regions is useful in both theory and practice.

TH3-U-IN10

Modelling in Distributed Telecommunications Networks

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Norwegian Univ. of Sciences and Techn., Section of Manag. Economics and OR

Dye Shane - Wallace Stein W. - Audestad Jan A. - Stougie Leen - Van der Vlerk Maarten H.

Keywords: distributed networks - optimization - services - stochastic integer programming - stochastic modelling - stochastic programming - telecommunications

The purpose of this talk is to formally describe new optimization models for distributed telecommunications networks. Modern distributed networks put more focus on the processing of information and less on the actual transportation of data than we are traditionally used to in telecommunications. The models presented here treat some of the new problems facing service and network providers. We look at resource allocations to services in the short term and investment in and location of resources in the long term.

Underlying assumptions come from the Telecommunications Information Networking Architecture Consortium (TINA-C) documentation. One of the main advantages of this distributed framework is its inherent flexibility, which enables us to do dynamic planning and to consider uncertainty when decisions are made. When we present the models, emphasis is placed on the modelling discussions around the shift of focus towards processing, the new technological aspects, and how to utilize flexibility to cope with uncertainty.

Uncertainty and decisions are treated in the setting of stochastic integer programming. More specificly the models presented here have binary first stage variables and continuous second stage decisions.

WE4-W-CO15

Web-Based Tools for the Optimization Subroutine Library

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IBM Almaden Research Centre

Jensen David

Keywords: optimization software - world wide web

We discuss web based tools for using the Optimization Subroutine Laibrary (OSL). This will include a description of the OSL benchmark server as well as more recent developments.

WE1-T-CO22

Some Mathematical Programming Aspects of DEA

Tone Kaoru

Graduate School of Policy Science Saitama University

Keywords: DEA - uniqueness - zero data

The following subjects will be discussed: (1) Equivalence of fractional and linear programs in DEA in the presence of zero data. (2) Uniqueness issues of the primal and the dual optimal solutions in DEA.

TU2-T-CO22

Robust Derivative-Free Methods for Linearly Constrained Minimization

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College of William and Mary

Lewis Robert Michael

Keywords: bound constrained optimization - direct search methods - linear inequality constraints - pattern search methods

Despite their simplicity, pattern search algorithms continue to be popular for solving difficult nonlinear optimization problems for which derivatives are either unavailable or unreliable. Most of the original pattern search methods were designed by practitioners—statisticians and engineers—trying to solve difficult optimization problems. Our investigation of pattern search methods and their extension to bound and linearly constrained minimization was itself motivated by a variety of problems from engineering design (e.g., helicopter rotor blade design) and parameter estimation.

We will discuss the extension of pattern search methods to bound and linearly constrained minimization. We will present the admissible classes of algorithms and the attendant convergence analysis, with an emphasis on the practical import of this work. The convergence results are comparable to those for projected gradient methods, despite the fact that we have no explicit information about the gradient and its projection onto the feasible region. To the best of our knowledge, this is the first such analysis for direct search methods applied to problems with constraints.

In the special case of bound constraints, global convergence for many classical pattern search methods originally motivated by simple heuristics can be proven with little or no modification to the original techniques. In the case of general linear inequality constraints, we introduce new classes of pattern search methods that cope with the less predictable geometry of the constraints.

WE2-P-IN201

Schedule Revision by Graph Coloring Method

Toyama Haruhiko

TOSHIBA Corp, Research & Dev. Center, Systems and Software Lab.

Araki Dai

Keywords: combinatorial optimization - graph coloring - scheduling - tabu search

This paper proposes a new schedule revision method for resource assignment problems based on graph coloring technologies, and also shows its evaluation results through an application to a practical schedule revision problems which is a reassigning problem of train vehicles to each train schedules.

An accident causes some changes on the original schedule. For the changes, it needs the schedule revisions to satisfy the given constraints . On the revision, less scheduling changes are required. By "less changes", we mean (A) less days in which the schedules are changed, and (B) less influences on the resources unchanged by the accident. This problem is formulated as a resource reassignment problem.

The features of the proposed method are that the constraints of this problem are translated into Graph Coloring Problem(GCP), and that the less scheduling changes are accomplished by a local search method for the coloring with the original schedule initial data. The GCP has been used for the constraints satification problem. However, the GCP itself has no applications for any optimization problems such as "less changes". The local search with the original schedule initial data is our solution of this problem. The less changes corresponds to the closer to initial data, and local search methods can find out a solution closer to intial data.

We apply this method to a practical train vehicle schedule revision problem, and we could get schedules revised with less changes than that revised manually.

MO4-D-CO124

Stochastic Interior Point Techniques for Global Optimization and Applications to Artificial Neural Network Training

Trafalis Theodore

University of Oklahoma

Keywords: global optimization - interior point methods - neural network training - stochastic optimization

Interior point techniques applied to the general nonlinear optimization problem are local approaches. Reaching a global minimum is only possible if one considers convexity assumptions about the objective function and the constraints. To overcome this limitation, we propose to combine the local interior point search framework with a global stochastic search technique. Specifically we consider nonconvex objective functions with convex constraints. Borrowing ideas from simulated annealing, we introduce a random noise to a barrier objective function and slowly remove it as we approach the optimal solution. This increases the chance of reaching a global optimum. The main motivation of our approach comes from the idea of combining efficient local optimization techniques with stochastic optimiza- tion methods to solve neural network training optimization problems. Connections with mean-field theory in statistical physics are also investigated.

WE1-C-CO122

An Incremental Primal-Dual Technique for Nonlinear Programming and Applications to Artificial Neural Network Training

Trafalis Theodore

University of Oklahoma

Couellan Nicolas P.

Keywords: incremental method - nonlinear least squares - nonlinear programming - primal-dual methods

We propose a new class of incremental primal-dual techniques for nonlinear programming. The technique is applicable to problems where the objective function is a sum of independent terms corresponding to data blocks and where a set of constraints is given for each data block. The algorithm solves the Karush-Kuhn-Tucker (KKT) optimality conditions of the subproblems for each data block. The system of KKT conditions is linearized with the Newton method. The solution of the system generates a direction of move for each subproblem. The variables are updated in an incremental manner so as to converge to a KKT point of the original problem. Constrained least square problems with the above special structure are investigated. We show that the incremental primal-dual algorithm can be nicely applied to the online artificial neural network (ANN) training problem.

WE2-G-IN11

Solving Stochastic Linear Programs with Restricted Recourse Using Interior Point Methods

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Università della Calabria - D.E.I.S.

Musmanno Roberto - Beraldi Patrizia

Keywords: restricted recourse - stochastic linear programming

We present a specialized version of an interior point algorithm for solving the two-stage stochastic program with restricted recourse. The model is a classical two-stage stochastic programming problem that includes constraints to enforce the robustness in recourse decisions. The need of having robust solutions that remain close to the optimal even in presence of changes in input data, is particularly required in those real-world applications for which changes in the solutions are often difficult or very expensive to realize (problems of capacity planning, manufacturing, etc..).

The proposed algorithm takes full advantage of both the block-angular structure of the constraint matrix and the special structure of the second-stage matrices involved in the model. Exstensive computational experiments have been conducted with the aim to evaluate the performance of the code. The results show that our code is faster than ROBOpT and competitive with the state-of-the-art optimization solver.

MO3-P-IN201

Optimal Timing of Partially Ordered Jobs for Early-Tardy Scheduling

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DEI Politecnico di Milano

Della Croce Federico

Keywords: early-tardy - parallel machines - polynomial algorithm - precedence constraints - scheduling

In this work, we consider a partially ordered set of jobs to be scheduled on m parallel machines with idle time permitted. Given the sequence on each machine, we want to minimize an early-tardy function of the completion times subject to the precedence constraints among the jobs of the ordered set which are sequenced on different machines. This problem is a generalization of the optimal idle time insertion problem for a given sequence in single machine early-tardy scheduling which was tackled by Garey-Tarjan-Wilfgong (1988) and more recently by Davis-Kanet (1993) and Szwarc-Mukhopadyay (1995). We propose a polynomial procedure based on repeated solutions of maximum matching problems on a bipartite graph if the earliness and tardiness penalties are equal. In case of different earliness and tardiness penalties, a polynomial procedure is proposed based on repeated solutions of max flow problems.

WE1-U-IN10

Solving Large Fleet Assignment Problems

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Keywords: airline scheduling - combinatorial optimization - fleet assignment - heuristics - integer programming

The fleet assignment problem is one of a series of optimization problems occuring in airline industry operations, beginning with market modelling and flight scheduling followed by fleet assigment, crew pairing and crew rostering. The fleet assignment has usually to be done 3 month before day of operation and is planned on a weekly basis.

It is not unusual that a large internationally operating airline offers more than 100.000 possible itineraries on 10.000 legs a week working with more than 200 aircrafts of 20 different subtypes (fleets) on 150 airports. There are a lot of hard and soft constraints. A fleet assignment is only valid if the aircrafts are assigned on round-trips. Additional restrictions are the passanger capacity, range of the aircrafts, maintainace periods, crew restrictions, take-off and landing time-slots etc.

Our approach has two phases, firstly generating rotational elements and secondly assigning an aircraft type to every rotational element guaranteeing rotations for the whole planning period. We maximize the profit instead of minimizing costs. The difference is that number of passengers on a certain leg is not independent of the passenger capacity, i.e. if passengers are rejected (the number of estimated passengers is higher than the aircraft capacity) this has impact on the revenue of other legs because passengers will look for alternative flights (spill-off and recover model). We tested our algorithm on real world data (8000 legs, 250 aircrafts, 200.000 itinararies) provided by a large german airline.

WE3-D-CO123

Search Directions for and Convergence Analysis of Some Infeasible Path-Following Methods for the Monotone Semi-Definite LCP

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Keywords: infeasible path-following methods - search directions - semidefinite lcp

We consider two infeasible predictor-corrector path-following methods for the monotone semi-definite LCP, with the predictor and corrector steps used either in series (similar to the Mizuno-Todd-Ye method) or in parallel (similar to Mizuno et al./McShane's method). We study the issues of search directions, central-path neighborhood, and global/local convergence rate.

FR3-E-CO21

Analysis of Some Continuation Methods for Complementarity Problems

Tseng Paul Yun

University of Washington

TU2-B-CO10

Decomposition Methods Based on Alternating Projection-Proximal Steps

Tseng Paul Yun

University of Washington

Keywords: maximal monotone operator - projection method - proximal point algorithm

We consider a mixed problem comprising in part of finding a zero of a maximal monotone operator and in part of solving a monotone variational inequality problem. We consider solution methods for this problem that alternate between a proximal step and a projection-type step. These methods, extending a method of Chen and Teboulle, have nice features for problem decomposition in convex programming and variational inequalities.

FR4-I-CM120

On Continuous Approach to Knapsack Problem with Several Constraints

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Irkutsk State University

Strekalovsky Alexander - Kuznetsova Antonina

Keywords: global optimality - global search algorithm - global solution - local minimizer

We consider a combinatorial optimization problem that is the well- known knapsack problem with several constraints. It can be expressed as global optimization problem. There are many continuous methods for solving such problems. We propose other approach based on necessary and sufficient global optimality conditions. These conditions have been obtained by Strekalovsky. The knapsack problem can be stated as follows

$$\left.\begin{array}{c} \langle c,x\rangle \to \max, \\ \left\langle a^j,x\right\rangle \le \beta_j, \quad j=1,...,m, \\ x\in\{0,1\}^n \end{array}\right\} \tag{1}$$

where $c_i > 0, a_i^j > 0, b_i > 0$ for $i = 1,..,n, \quad j = 1,..,m$. The problem (1) is encountered in several practical applications. We convert this problem into equivalent continuous one:

$$\left.\begin{array}{c} f(x) = -\langle c,x\rangle \to \min, \\ \left\langle a^j,x\right\rangle \le \beta_j, \;\; j=1,..,m, \\ g(x)\ge 0, \\ x\in\Pi=\{x\in R^n /\;\; 0\le x_i\le 1, \quad i=1,..,n\}, \end{array}\right\} \tag{PR}$$

where

$$g(x) = \left\| x - \frac{e}{2} \right\|^2 - \frac{n}{4}, \quad e = (1,...,1)^\top \in R^n,$$

It is easy to see that the function $g(x)$ is convex, hence the constraint $g(x) \ge 0$ is reverse convex. The difficulty of the problem (PR) consists in that it have many local minima, which differ from global solutions.

For solving the reverse convex problems so-called $\Re$-algorithm has been developed [2] on the basis of the conditions mantoined above. We used $\Re$-algorithm for finding a global optimum to Problem (PR). The algorithm has been coded and a number of computational results are reported.

Analysing obtained results we can conclude that in practice we can find a solution of Problem (PR) of rather high dimension with a reasonable computational effort. Moreover the $\Re$-algorithm solves the problem (PR) in polynomial time.

To sum up, one can say, that $\Re$-algorithm possesses a robustness w.r.t. the number of constraints, the problems size (till 500) and a choice of initial point.(using PC/AT 486)

WE2-D-CO124

Polynomiality of Primal-Dual Path Following Algorithms for SDP and SDLCP using the Kojima-Shindoh-Hara Search Directions

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The Institute of Statistical Mathematics

Monteiro Renato D. C.

Keywords: primal-dual path following algorithm - semidefinite complementarity problem - semidefinite programming

Kojima, Shindoh and Hara proposed a family of search directions for the semidefinite linear complementarity problem (SDLCP) and established polynomial convergence of a feasible short-step path-following algorithm based on a particular direction of their family. The question of whether polynomiality could be established for any direction of their family thus remained an open problem. This paper answers this question in the affirmative by establishing the polynomiality of primal-dual interior-point algorithms for SDLCP based on any direction of the Kojima, Shindoh and Hara family of search directions. We show that the polynomial iteration-complexity bounds of two well-known algorithms for linear programming, namely the short-step path-following algorithm of Kojima et al. and Monteiro and Adler, and the predictor-corrector algorithm of Mizuno et al., carry over to the context of SDLCP.

TU2-I-CM4

Minimax Programs

Tucker Paul A.

University of California, San Diego

Hu T.C. - Shing Mantak

Keywords: min cuts

I will present some recent research on this topic.

TH1-D-CO123

Desired Properties of Interior-Point Algorithms for Convex Optimization Problems

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Combinatorics and Optimization, University of Waterloo

Keywords: barrier functions - interior point methods - self-concordance

Ability to take long steps, small worst case iteration bound, scale-invariance, primal-dual symmetry are among the many desired attributes of an interior-point algorithm. In this talk, we study these properties in the framework of self-concordant barrier functions. The theory of self-concordant barriers allows us to formulate these attributes as related properties of the underlying barrier function. These problems themselves are optimization (or feasibility) problems over the set of convex barriers. We will show the solutions of some of these problems.

Parts of this talk are based on the joint work with O. Guler and on the joint work with Y. Nesterov.

TU1-A-IN1

Generalized Transformation of Gauss and Gram-Schmidt and Simplex Method Development

Tuniev Albert Daniel

Institute for Informatics and Automation Problems

Tuniev proposed to choose simultaneously k elements - the pivot vector of length k - instead of the pivot element in Gauss transformation, where k=1,...,n, and n is the number of columns of matrix A. This idea leads to a parametric linear transformation depending on k, which in geometrical terms is a realization of the idea of partial orthogonalization and in algebraic terms it is a "convex" combination of Gauss transformation (k = 1) and Gram-Schmidt transformation of the orthogonalization process (k =n). In other words, this transformation, on the one hand, is a development of Gauss transformation (for k ¿ 1), and on the other hand, is a development of Gram-Schmidt transformation (for k ¡ n).

Using this transformation the elimination methods, the LU-decomposition and the orthogonal decomposition (of the orthogonalization process) were generalized. Besides, new concept of partially inverse matrix was obtained, which is the analogy of the inverse and the Moore-Penrose inverse. On this base was obtained the new optimality criterion of the feasible solution, which is between the Dantzig's optimality criterion and the Kantorovich's optimality criterion. It was shown that in the context of the new parametric linear transformation the Dantzig's simplex method, bound with Gauss transformation, contains considerable hidden possibilities in the sense of its development.

In this paper one variant of the development of the simplex method is proposed. The essence of the development is the following. In the each s -th step the pivot vector of length k is selected, that permits to move to the improved feasible solution after step of the generalized method of Gauss-Jordan elimination. The pivot vector (rule) is selected in such way that the movement to the optimal point takes place over the interior points. In other words, we obtain "simplex method" of the interior points. This method is finite. Using the concept of partially inverse matrix we obtain modified "simplex method" of the interior points.

FR2-E-CO11

Infeasible-Interior-Point Algorithms for the LCP

Tutuncu Reha Husnu

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Keywords: infeasible interior point methods - potential reduction methods

Theoretical developments in infeasible-interior-point methods for linear programming have recently been extended to linear complementarity problems. As in the case of LPs, these developments are often limited to path-following methods. We survey some of these recent results, then introduce a new infeasible-point potential function and a potential-reduction algorithm based on this function. We study the convergence properties of this algorithm.

WE2-C-CO122

Global Optimality Conditions for General Quadratic Optimization Problems

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Keywords: copositivity - optimality conditions - quadratic programming

In the case of quadratic functions with linear constraints, necessary and sufficient second-order conditions for global optimality of x^* can be reformulated into copositivity conditions (positivity of a quadratic form over a polyhedron). Copositivity conditions can be checked by a recursive procedure, which gives in the negative case (x^* is not a global optimum) at least an improving direction.

TH4-C-CO3

Global Convergence of Trust-Region Interior-Point Algorithms for Infinite-Dimensional Nonconvex Minimization Subject to Pointwise Bounds

Ulbrich Michael

Technische Universität München

Ulbrich Stefan - Heinkenschloss Matthias

Keywords: affine scaling - bound constraints - global convergence - infinite-dimensional optimization - interior point methods - nonlinear programming - optimal control - trust region method

We introduce and analyze a globally convergent class of interior-point trust-region algorithms for infinite-dimensional optimization subject to pointwise bounds in function space. The methods are based on an affine-scaling formulation of the first-order necessary optimality conditions. They allow for very general affine scalings and scalings of the trust-region. The methods are generalizations of the algorithms presented by Coleman and Li for finite-dimensional problems. We show that all first- and second-order convergence results that are available for the finite-dimensional setting can be extended to our infinite- dimensional L^p-Banach space framework. The lack of the equivalence of norms requires new proof techniques which are also valuable from the finite-dimensional point of view because they provide a convergence theory which is almost independent of the problem dimension. Important applications for our methods arise from optimal control problems with bound-constrained L^p-control.

TH3-F-IN203

Superlinear Convergence of Affine-Scaling Interior-Point Newton Methods for Infinite-Dimensional Nonlinear Problems with Pointwise Bounds

Ulbrich Stefan

Technische Universität München

Ulbrich Michael

Keywords: affine scaling - bound constraints - infinite-dimensional optimization - interior point methods - nonlinear programming - optimal control - superlinear convergence - trust region method

In this talk we will present results on the local convergence rate of affine-scaling interior-point Newton methods for problems in L^p-space with pointwise bounds.
The fact that under the usual strict complementarity condition the active set can only be identified outside a residual set of small measure requires algorithmic changes to ensure fast local convergence of affine-scaling interior-point methods in the infinite-dimensional framework. This difficulty carries over to the discretized problem since the strict complementarity is typically very weak for some components. Hence, the available finite-dimensional convergence results are only applicable very close to the solution. The building block of our algorithm is a Newton-like iteration for an affine-scaling formulation of the KKT-condition as proposed by Coleman and Li for the finite-dimensional case. We will give an example that a stepsize-rule to obtain a strict feasible iterate may require very small stepsizes even arbitrarily close to a nondegenerate solution. Using a pointwise projection instead we show that

the algorithm converges superlinearly under a weak strict complementarity condition and with Q-rate > 1 under a slightly stronger complementarity condition if a post-smoothing step is available. An application of the algorithm to the control of a heating process shows the improved local convergence rate of our algorithm.

TH2-I-CM120

A Fast Enumerating Algorithm for all Directed Spanning Trees in a Directed Graph

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Keywords: directed spanning tree - enumeration

A directed spanning tree in a directed graph $G = (V, A)$ is a spanning tree such that no two arcs share their tails. The problem of enumerating all directed spanning trees in a given directed graph have been studied and some algorithms have been proposed. The smallest time complexity among them is $O(|A| + |V|N)$. In this talk, we propose an improved algorithm for this problem. Its time and space complexities are $O(|A| + N\mathrm{D}(|V|, |A|))$ and $O(|A| + \mathrm{DS}(|V|, |A|))$, where $\mathrm{D}(|V|, |A|)$ and $\mathrm{DS}(|V|, |A|)$ are the time and space complexities of the data structure for updating the minimum spanning tree in an undirected graph with $|V|$ vertices and $|A|$ edges. Here N denotes the number of directed spanning trees in G. The current best time complexity for this updating is $O(|V|^{1/2})$, and our algorithm terminates in shorter time than them.

MO3-A-IN2

Decomposition of Integer Programs and of Generating Sets

Urbaniak Regina

KONRAD-ZUSE-ZENTRUM FÜR INFORMATIONSTECHNIK BERLIN

Cornuejols Gerard - Weismantel Robert - Wolsey Laurence Alexander

From the geometrical point of view it is possible to reduce integer programming to the problem of computing bases of a lattice or Hilbert bases of various cones. So far there is no algorithm known that can handle large integer programming problems via generating sets. One step into this direction is the study of composition and decomposition techniques for matrices and generating sets. These techniques combined with methods for scaling the data lead to a considerable improvement for several integer programming problems. We demonstrate on various examples the effectiveness of this approach.

FR3-I-CM120

A Decomposition algorithm for the Complete Crew Scheduling Problem

Vale Rego Cesar Augusto

PORTUCALENSE UNIVERSITY - DEPARTEMENT OF COMPUTER SCIENCE

Gomes Marta - Cavique Luis - Themido Isabel

The traditional Crew Scheduling Problem (CSP) is formulated as the minimum number of duties necessary to cover a predefined timetable. The solution to this problem provides information about the driving periods of each duty. The definition of the timetable of the duties, including report time, clear time and break time, is usually done using some simple rules of thumb. We refer to this later problem as the Crew Time Tabling Problem (CTTP). This paper reports part of a decision support system developed for the Lisbon Metro Company. A decomposition algorithm is proposed is proposed for the solution of the Complete Crew Scheduling Problem (CCSP) which deals with the resolution of the CSP and the CTTP.

WE3-P-IN201

Integer Binpacking Problems

Valério de Carvalho José Manuel

DEPT PRODUCAO E SISTEMAS UNIVERSIDADE DO MINHO

Keywords: bin packing - branch and price - column generation

The one-dimensional binpacking problem can be modelled using an arc flow formulation with side constraints. The model has a set of flow conservation constraints and a set of constraints that force the appropriate number of items to be included in the packing. Formulations based on arc flows are usually denoted as "original formulations", whilst the formulations that use the deferred column generation of paths are denoted as "path formulations". In this setting, the arc flow formulation can be seen as an "original formulation" of the classical model of Gilmore-Gomory for the cutting-stock problem, which is well known for its strength.

The arc flow formulation provides insights that can be used for developing LP based approaches that use branch-and-price. We describe a solution strategy that uses the path formulation to solve the restricted master problem, while the branching constraint are imposed on the flow variables of the original formulation. The subproblem has a pseudopolynomial number of variables, and its structure does not change during the branch-and-bound phase.

This is done in a framework where the structure of the columns that are added to the restricted master problem changes, as, besides the elements pertaining to the demand, they have nonnegative integer coefficients in the branching constraints. The change in structure can be justified from compatibility issues between the master problem and the subproblem.

The model uses general integer variables (not restricted to be binary), and is used to solve integer binpacking problems. Economies of scale may be obtained from grouping several items of same size into the same demand group.

FR3-P-IN201

Scheduling in Robotic Flow Shops

van de Klundert Joris

MAASTRICHT UNIVERSITY

Crama Yves

Keywords: automated manufacturing - complexity - scheduling

We consider a robotic flow shop model in which a single robot

is responsible for the transportation of parts between machines and the amount of time that a part spends on a machine must be comprised in some predefined interval. The objective is to find a feasible schedule with minimal cycle time. We describe some recent results concerning the complexity of this problem and the role played by so-called 1-unit cyles, i.e. production sequences in which the robot repeatedly performs a fixed cycle of activities resulting in the production of exactly one part.

TH3-A-IN2

Lifting Valid Inequalities for the Precedence Constrained Knapsack Problem

van de Leensel Robert

MAASTRICHT UNIVERSITY

Van Hoesel Stan - van de Klundert Joris

Keywords: cover inequalities - knapsack problem - lifting - valid inequalities

This paper considers the precedence constrained knapsack problem. More specifically, we are interested in classes of valid inequalities which are facet-defining for the precedence constrained knapsack polytope. We study the complexity of obtaining these facets using the standard sequential lifting procedure. Applying this procedure requires solving a combinatorial problem. For valid inequalities arising from minimal induced covers, we identify a class of lifting coefficients for which this problem can be solved in polynomial time, by using a supermodular function, and for which the values of the lifting coefficients have a combinatorial interpretation. For the remaining lifting coefficients it is shown that this optimization problem is strongly NP-hard. The same lifting procedure can be applied to (1,k)-configurations, although in this case, the same combinatorial interpretation no longer applies. We also consider K-covers, to which the same procedure need not apply in general. We show that facets of the polytope can still be generated using a similar lifting technique. For tree knapsack problems, we observe that all lifting coefficients can be obtained in polynomial time. Computational experiments indicate that these facets significantly strengthen the LP-relaxation.

TH2-P-IN201

New Lower Bounds for Minimizing Total Completion In the Two-Machine Flow Shop Problem

van de Velde Steef L.

ROTTERDAM SCHOOL OF MANAGEMENT, ERASMUS UNIVERSITY

Hoogeveen Han

We present a series of powerful bounds based on a combination of Lagrangian relaxation and linear programming.

MO3-E-CO21

On the Transition of Mixed Economies to Market Economies

van der Laan Gerard

DEPARTMENT OF ECONOMETRICS, FREE UNIVERSITY

Vasilev Valeri - Venniker Richard

Keywords: adjustment process - general equilibrium - simplicial algorithm

In this paper a continuous time price adjustment process is considered for the transformation of an equilibrium of a mixed economy to a Walrasian equilibrium. The specific feature of the mixed economy model is the presence of dual markets. On the first market prices are set by the central agency, on the secondary market prices are free. Initially, the process only adjusts the free prices untill an equilibrium of the mixed economy given the fixed state prices has been reached. This part of the process is of the tatonnement type, since markets are out of equilibrium and no trade is assumed to occur. The process proceeeds by adjusting simultaneously the prices on both the state and secondary markets, such that at any moment an equilibrium for the mixed economy with respect to the actual state prices results. It will be shown that eventually a Walrasian equilibrium for the mixed economy will be reached. Using a simplicial algorithm, a path is generated that yields an approximation of the desired adjustment process, where the inaccuracy of the approximation can be made arbitrarily small.

WE4-I-CM5

Sequencing with Job-Groups: Some Solvable Cases of the TSP

Van der Veen Jack A.A.

NIJENRODE UNIVERSITY - THE NETHERLANDS BUSINESS SCHOOL

Keywords: traveling salesman problem

In this paper we will consider several scheduling problems where the jobs are divided into a limited number of groups and there are sequence-dependent change-over times. These problems include hierarchical scheduling on a single machine and minimizing makespan on a single or parallel machines. For the problems considered it is possible to reformulate them as a special case of the Traveling Salesman Problem (TSP). It will be shown that the assumptions made on the structure of the scheduling problem allow algorithms that solve the problems in polynomial time.

TH1-G-IN11

Convex Approximations for Simple Integer Recourse Models

Van der Vlerk Maarten H.

UNIVERSITY OF GRONINGEN

Klein Haneveld Willem K. - Stougie Leen

Keywords: convex approximations - simple integer recourse

We consider a class of convex approximations, named α-approximations, for the objective function of a simple recourse problem with fixed technology matrix and integer second-stage variables. These α-approximations are obtained by replacing the distribution of each right-hand side parameter by a distribution with a probability density function which is constant on unit intervals. A uniform bound on the error of the approximation is known.

In this talk we extend these results in the following ways. First, we study convex combinations of α-approximations, and show that this leads to improvement of the uniform error bound by

a factor two. Secondly, we discuss optimal choices for the parameter α, both when the objective is to minimize the maximal error and from the optimization point of view.

TU3-E-CO11

Simplicial Algorithms for Linear Integer Programming

van Maaren Hans

Delft University of Technology

Dang Chuangyin

Keywords: integer programming - triangulations

We present an arbitrary starting, variable dimension simplicial pivoting algorithm which, in a finite number of pivots, finds an integral solution in a simplex, or establishes the fact that no solution exists. This method, allthough not proven polynomial, has rather effectice performance in cases where solutions are present. The simplicial approach can be seen as a third new attempt , after cutting planes and branch and bound, to tackle linear integer programming problems. The method uses a unimodular transformation. This transformation seems the most consuming part, although it can be done in polynomial time!

TU3-E-CO11

Simplicial Methods for Non Linear Integer Programming

van Maaren Hans

Delft University of Technology

Odijk Michiel A.

Keywords: Diophantine equations - shortest lattice vectors

After the succes of the simplicial method for integer linear programming we look for possible applications for the non-linear case. We shall present some first experiments and thoughts on this matter. A typical application seems those situations where theory provides bounds for possible solutions (as is the case with some Diophantine equations, shortest non zero lattice points,...) and where triangulations can be used fruitfully to perform the actual search in an efficient manner.

FR4-L-CM201

Network Design Problems is Rail and Air Freignt Applications

Vance Pamela H.

Auburn University

Barnhart Cynthia - Kim Daeki - Jin Hong - Newton Harry

Keywords: integer programming - network design - transportation

We consider two freight transportation applications - railroad blocking, and express package service design. We model both problems as network design problems. We present algorithmic strategies for approaching these large-scale applications and discuss our computational experience.

MO3-I-CM121

Finding a Maximum Vector in a 2-lattice Polyhedron

Vande Vate John H.

Georgia Institute of Technology

Chang Shiow-yun - Llewellyn Donna

Although there are a number of polynomial algorithms for finding a maximum cardinality matching in a representable matroid, there can be no efficient algorithm for the problem in general matroids that relies on an oracle to determine ranks. The distinction in the tractability of these two problems does not carry over to their natural relaxations via 2-lattice polyhedra. We present an efficient extreme point algorithm for finding a vector with maximum sum of components in a 2-lattice relaxation of the general matroid matching problem. Our algorithm generalizes augmenting path algorithms for finding a maximum cardinality intersection in two matroids, although the possibility of half-integral components makes it more complicated. It also provides a combinatorial extreme point method for finding a maximum cardinality vector in a fractional matching polytope.

FR3-P-IN11

Lot-sizing with Start-up Times

Vanderbeck Francois

University of Cambridge, The Judge Institute of Management Studies

Keywords: branch and price - column generation - dynamic programming - integer programming - lot sizing

Many practical applications of lot-sizing and scheduling problems involve start-up times. The operations research literature contains but a few studies of lot-sizing models that take start-up times explicitly into account. Here, we review some of these studies, discuss the models and their complexity, and we propose further models. In particular, we consider a single-stage single-mode multi-item lot-sizing model with continuous set-ups and sequence independent start-up times, which we solve using an integer programming column generation algorithm and we develop a dynamic programming procedure for the single-item subproblem that treats the initial stock as a decision variable. We also use cutting planes developed by Constantino for the multi-item polyhedra. By combining column and cut generation, the lower bounds that we obtain before branching are on average less than 2% away from the optimum solution. Our algorithm solves instances with 3 to 5 items and 24 periods in an average of 50 seconds on a modern workstation, and problems with 36 periods in an average of 750 seconds. Solutions that are guaranteed to be within 2% of optimality are obtained in less than 75% of these times.

TU3-B-CO10

Solving Large-Scale Convex Optimization Problems with LOQO/AMPL

Vanderbei Robert J.

Princeton University

Keywords: convex programming - large scale optimization

A typical interior-point method for convex optimization can be described briefly as follows. First, use some heuristic to produce an initial guess at the solution, which need not be feasible. Then, at each iteration, the current non-optimal solution is used to form a quadratic approximation to the problem, which is then used to compute step directions, which are in turn used to move to a new solution. Given a quadratic approximation, step directions based on interior-point methodology are computed using any interior-point code that can handle quadratic objective functions, such as the author's LOQO. Computing the quadratic approximation requires evaluating each convex function, its gradient, and its Hessian. While for any specific problem, one can write subroutines to do this, it is desirable to have a system to do it automatically.

AMPL is a math programming language that can express most convex optimization problems very compactly. Such a math programming language is a natural choice for a system to automatically compute function values, gradients, etc. But, until recently AMPL only provided a solver with function and gradient information—no Hessian information was available. However, the latest release of AMPL (actually, the AMPL/SOLVER interface) provides tools for easily evaluating functions, gradients, and Hessians (sparsely).

Using this new AMPL/SOLVER interface and exploiting the fact that LOQO solves problems exactly as given, we were able to easily hook LOQO to AMPL and can now solve large scale convex optimization problems in a very user-friendly, yet efficient, environment. In this talk, we shall describe the environment and present computational results from several areas including topolgy optimization, trajectory optimization, constrained facility location, utility optimization, image deblurring, and semidefinite programming.

FR1-E-CO11

An Algorithm for the Block Z-Matrix GLCP

Venkateswaran Venkat

ATT Labs

Keywords: linear complementarity

For the GLP with a block Z-matrix, we develop a bisection algorithm. We show that the algorithm will process the problem in O(log(m)**n) pivots, where m is the block size (all blocks of equal size) and n the number of blocks.

WE4-I-CM120

Hierarchical Euclidean Path Planning

Verbarg Knut

University of Würzburg

Hensel Andre

We investigate the problem of constructing an Euclidean shortest path between two configurations in the plane cluttered with n (intersecting) convex polygonal obstacles of constant complexity. We develop two hierarchical motion-planning techniques based on a spatial data structure and the visibility graph, which are shown to be more efficient in scenes of low object density. A shortest path can then be constructed in time $O(l^4 \log l + n \log l)$, if a shortest path of length l exists. The dependency on n can be further reduced by the use of a spatial data structure to $O(l^4 \log l + l^2 \log l \log n)$. If l is not small compared to the diameter D of the scene or no path exists at all, then the algorithm still respects an $O(n^2(\log n + min\{\log D, n\}))$ upper bound. Our methods are complete planners. As far as we know, this is the first "output"-sensitive algorithm in terms of the length of a shortest path. Experimental results verify the efficiency of the methods.

TH4-D-CO123

A Software Package for Polynomial Homotopy Continuation

Verschelde Jan

Katholieke Universiteit Leuven, Dept. of Computer Science

Keywords: homotopy continuation - polynomial system - root count - software

In this talk the structure of a software package for polynomial homotopy continuation will be presented. Useful information will be given on solving polynomial systems by homotopy continuation methods, especially on various root counting techniques and the construction of appropriate start systems. An overview of our database of benchmark problems will be presented.

WE2-R-IN203

A Criterion for Points Influencing the Mixed Volume

Verschelde Jan

Katholieke Universiteit Leuven, Dept. of Computer Science

Wang Xiaoshen

Keywords: mixed volume - normal cone - sparse polynomial systems

The problem addressed is how to check efficiently the influence of a point on the mixed volume of a tuple of polytopes. The first aim is to provide an efficient pre-processor to the mixed-volume computation. Secondly, we want to construct sparse start systems, because the sparser the system is, the easier it can be solved. A simple criterion by inclusion of normal cones is presented first. By elaborating facial mixed volumes, we obtain an exhaustive criterion. Applications illustrate the usefulness of our approach.

TH2-D-CO124

Homogeneous Analytic Center Cutting Plane Method for Variational Inequalities and Constrained Minimization

Vial Jean-Philippe

University of Geneva

Nesterov Yurii E.

Keywords: analytic centers - convex minimization - cutting plane methods - variational inequalities

We propose a new homogeneous analytic center cutting plane method that allows to derive an efficiency estimate in a simple way. The estimate is independent of the dimension of the space and is of the form $O(1/\epsilon^2)$. It is thus optimal for problems with a large number of variables. By using a conic embedding, we can apply the method to three classical problems: finding a point in a convex set, solving variational inequalities on a convex set and minimizing a convex function over a convex set. For the variational inequality and the minimization problems, the constraints are handled via a self-concordant barrier. The resultsare new. In particular, the approach handles the case of a boundary solution.

TH3-D-CO124

Very Deep Cuts and two Cuts in the Analytic Center Cutting Plane Method

Vial Jean-Philippe

University of Geneva

Goffin Jean-Louis

Keywords: analytic centers - convex minimization - cutting plane methods - variational inequalities

We propose two extensions of the basic analytic center cutting plane method, and provide complexity estimates for the two cases. The standard method assumes that a new cut either passes through the analytic center, or intersects the Dikin ellipsoid. If the oracle generates a cut that goes beyond the Dikin ellipsoid, the cutting plane is shifted backward, a procedure that is liable to slow down the method in practice. We show that it is possible to put directly the cut at the right place, and still achieve the same complexity estimate as before. The second extension concerns the simultaneous introduction of two cuts through the analytic center. We provide a new feasibility restoring direction, and prove convergence with the same complexity estimate as in the single cut scheme.

MO3-T-CO22

Properties and Applications of the Marginal Function for a Trust-Region Problem

Vicente Luis N.

Universidade de Coimbra, Departamento de Matematica

Andrews David

Keywords: marginal or value function - perturbation or sensitivity analysis - statistics - trust region

This talk addresses the smoothness and curvature of a marginal function for a trust-region problem. In this problem, a quadratic function is minimized over an ellipsoid. The marginal, or value, function considered is obtained by perturbing the trust radius, i.e., by changing the size of the ellipsoidal constraint. The values of the marginal function and of its first and second derivatives are explicitly calculated in all possible scenarios. A complete study of the smoothness and curvature of this marginal function is given. The main motivation for this work arises from an application in Statistics.

FR1-I-CM120

A Granular Tabu Search Heuristic for Constrained Arborescence Problems

Vigo Daniele

D.E.I.S. - University of Bologna

Toth Paolo

We consider two variants of the Shortest Spanning Arborescence Problem (SSA), known as the Capacitated SSA (CSSA) and the Distance constrained SSA (DSSA). Both problems are NP-hard in the strong sense and find practical applications in network design. We propose a new version of the Tabu Search heuristic using an effective diversification/intensification tool which is a variant of the candidate list concept. The method is based on the use of restricted (called granular) neighborhoods which do not contain the moves involving arcs which are not likely to belong to good feasible solutions. The use and the efficient examination of granular neighborhoods for the solution of constrained SSA problems is studied and the results of an extensive computational testing of the proposed heuristic are discussed.

TU4-I-CM200

Exact Solution of Two-Dimensional Bin Packing Problems

Vigo Daniele

D.E.I.S. - University of Bologna

Martello Silvano

Given a set of rectangular pieces to be cut from an unlimited number of rectangular bins, the Two-Dimensional Bin Packing Problem is to determine the minimum number of cutting patterns that provide all the pieces. We consider both the case where no piece rotation is allowed and the case where the pieces can rotate by 90 degrees. We propose new lower bounds which are used within branch-and-bound algorithms for the exact solution of the problems. Extensive computational testing shows the effectiveness of the proposed approach.

FR4-I-CM120

Exact Method for Orthogonal Two-Dimensional Cutting Problem

Vigo Daniele

D.E.I.S. - University of Bologna

Boschetti Marco - Mingozzi Aristide - Hadjiconstantinou Eleni

Keywords: cutting plane methods - mixed 0-1 programming - two-dimensional cutting problem

We consider the orthogonal two-dimensional cutting problem, in which a number of rectangular pieces must be cut from a single large rectangle so as to maximise the value of the pieces cut. We describe an exact method based on a mixed 0-1 formulation. Valid upper bound is obtained by means of cutting plane procedure for strengthening the usual LP-relaxation. We incorporate general cutting planes for 0-1 programs into a branch and cut framework. Preliminary computational results show the effectiveness of the proposed method.

TH2-U-IN10

Lower and Upper Bounds for the Traveling Salesman Problem with Pickup and Delivery

Vigo Daniele

D.E.I.S. - University of Bologna

Gendreau Michel - Laporte Gilbert

We consider the Traveling Salesman Problem with Pickup and Delivery (TSPPD), an extension of the well-known Traveling Salesman Problem where each vertex, or customer, to be served is associated with two quantities of goods to be collected and delivered, respectively. A vehicle with given capacity starts at a depot and must visit once each customer. The vehicle capacity must not be exceeded and the total length of the tour must be minimized. We describe different lower and upper bounds for TSPPD and analyze their average performance through extensive computational experiments. The worst-case performance of some of the proposed bounds is also discussed.

WE3-S-IN202

Sequence Alignment and Phylogeny

Vingron Martin

Deutsches Krebsforschungszentrum

Keywords: alignment - computational biology - phylogeny

Sequence alignment and phylogeny

Multiple alignment of biological sequences and the reconstruction of phylogenetic trees from sequences are two prominent problems in computational molecular biology. The task in multiple sequence alignment is to find out which positions in different though similar sequences correspond to each other. Tree construction attempts to reconstruct the evolutionary history of a set of sequences. Most multiple sequence alignment programs in practical use rely on a phylogenetic tree in order to speed up the computation. To generate a good initial tree, however, one would need to know the multiple alignment ahead of time.

We are following two lines of research in an attempt to break this circle. The first procedure mimicks agglomerative clustering techniques as used for phylogenetic tree construction. A so-called sequence graph is used to store possible ancestral sequences. Only after a tree and a preliminary alignment have been made, is the final choice of ancestral sequences effected. The other approach uses simultaneous alignment of three sets of pre-aligned groups at a time together with a heuristic to compute phylogenetic trees. Assume a tree on k species has been built already. Sequence $k+1$ may now branch off any of the edges of that tree. For each of these possibilities an alignment is computed, yielding a score also for that particular tree topology. The topology that results in the best score wins and decides where the new sequence is inserted. Then this tree becomes the starting point for insertion of the next sequence.

FR1-P-IN201

Classification of FMS Scheduling Problems

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Keywords: flexible manufacturing systems - scheduling

Gaham, Lawler, Lenstra and Rinnoy Kan elaborated a formal system to describe traditional scheduling problems in a compact form. The system is used widely in the scheduling community. The system does not have any tool to deal with the elements specific to flexible manufacturing systems, In scheduling an FMS the capacity of the material handling system, the number of the palettes and and fixtures, the storage capacity including queues must be taken consideration. The present paper makes an attempt to extend the formal system that it becomes to be able to decribe the new scheding problems of FMS's.

TU2-I-CM5

Discrete Optimization Problems in the Airline Industry

Voigt Bernd

Lufthansa Systems Berlin GmbH

A. The basic business processes of a airline will be reviewed:
(1) service planning
(2) flight planning and scheduling
(3) crew-planning
(4) revenue-management and pricing
(5) operational control and crew-control.
The overall purpose is to maximize profitability in the global network of itineraries.
"Network-Management", including state-of-the-art decision support systems, is the approach of competitive airlines.
B. Mathematically speaking, these decision support systems resolve discrete optimization problems. For each of these processes the basic optimization problems will be described.

WE1-K-CM106

A Core Approach to the 0-1 Equality Knapsack Problem

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Marsman Sicco

Keywords: heuristics - integer programming - knapsack problem

For the 0-1 knapsack problem with equality constraint a partitioning procedure is introduced which focuses on the core of the problem. The purpose is to reduce the required preliminary sorting for large problem instances. Computational results are presented for an improved heuristic as well as for a complete (exact) algorithm showing the success of the core approach. Test problems of size up to 15000 are solved within 400 milliseconds on a standard personal computer, i.e., these problems are solved within the time that is needed for sorting the profit / weight ratios in the standard approach. The core approach reduces the solution times with a factor up to 4 for the large problem instances.

FR2-V-CM106

New LowerBounds for the Number of Equilibria in Bimatrix Games

von Stengel Bernhard

ETH Zürich

Keywords: Nash equilibrium - polytope

We present a class of nondegenerate $n \times n$ bimatrix games that have asymptotically more than $2.414^n/\sqrt{n}$ Nash equilibria. These are more equilibria than the $2^n - 1$ equilibria of the game where both players have the identity matrix as payoff matrix. This refutes the Quint–Shubik conjecture that the latter number is an upper bound on the number of equilibria of nondegenerate $n \times n$ games. The first counterexample is a 6×6 game with 75 equilibria. The approach uses concepts from polytope theory, which imply a known upper bound of $2.6^n/\sqrt{n}$.

TH2-F-IN203

Optimal Guidance of Full Car Simulations in Real-Time

von Stryk Oskar

Department of Mathematics, Munich University of Technology

Keywords: nonlinear programming - optimal control - real-time optimization - vehicle dynamics

New active vehicle control systems, such as anti-lock braking systems, become increasingly important in automative engineering in order to assist the driver in control tasks on the stabilization level. The performance of active control systems can be tested in a virtual prototype driven along a course by hardware-in-the-loop (HIL) experiments linked to full car dynamics simulations in real-time. For investigation of optimal car-driveability, optimal guidance of the virtual prototype at its driving limits is of great interest.

We suggest a procedure for (sub-)optimal guidance in real-time consisting of two parts: By solving optimal control problems for suitable reduced car models, optimal set points in terms of position and velocity of the center of gravity of the car are computed on-line for a subsequent real-time control of the full car model linked to the HIL environment. Optimization methods are suggested for a discretization of the continuous problem and a computation of the optimal control for different parts of the course on a multi-processor hardware. The discretized subproblems are solved by tailored nonlinearly constrained optimization methods (SQP).

First results presented in the talk will be illustrated by a videotape.

MO3-R-IN203

Efficient Algorithms for Partitioning and Placement

Vygen Jens

University of Bonn

Keywords: VLSI-placement - combinatorial optimization - partitioning

Placement is one of the main tasks in the physical design of VLSI-Chips. All state-of-the-art algorithms successively partition the set of movable objects to smaller and smaller subsets, each of which corresponds to a region of the chip area. Two kinds of strategies are used: min-cut and netlength minimization.

The netlength minimization approach comprises the solution of large-scale QPs and a partitioning algorithm respecting the resulting positions of the movable objects. This (crucial) partitioning problem has a nice formulation as a combinatorial optimization problem. A new linear-time algorithm solves this problem optimally. Though quite complicated, it is also very efficient in practice and is one reason for the success of the overall placement algorithm using it.

TH2-I-CM4

On Critically and Anticritically Perfect Graphs

Wagler Annegret

Konrad-Zuse-Zentrum für Informationstechnik Berlin

Keywords: extremal perfect graphs - linegraphs of bipartite graphs - perfect graph - preperfect graphs

A well-known technique for understanding a graph property is the investigation of extremal cases with respect to this graph property. Therefore, we introduce as two new classes of extremal perfect graphs critically and anticritically perfect graphs, i.e., perfect graphs that lose their perfectness by the deletion and, respectively, the addition of an arbitrary edge. We give examples of such graphs as well as some basic properties. In investigating the structure of these two graph classes, we are interested in intersections with other subclasses of perfect graphs and in operations preserving critical or anticritical perfectness.

WE1-I-CM5

Routing in Diagonal Grids

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Universität Konstanz

Kuchem Ruth

Keywords: VLSI design - diagonal grids - routing - wiring

An important problem in VLSI-Design is the detailed routing problem. Often the routing problem is solved in two phases, the layout and the wiring. We consider both phases where nets can be routed not only in vertical and horizontal but also in diagonal directions.

For layout problems in different types of grids containing diagonal directions, new solvability criteria are developed. These lead to efficient new layout algorithms. Then a general approach to the wiring problem is considered. For an edge-disjoint layout in the plane respectively in an arbitrary planar layout graph, we give equivalent conditions for the wirability in k layers. Based on these conditions linear-time algorithms are obtained to wire every layout in a tri-hexagonal grid, respectively every layout in a tri-square-hexagonal grid using at most five layers.

WE1-I-CM5

On Mimicking Networks

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Freie Universität Berlin

Chaudhuri Shiva - Subrahmanyam K.V. - Zarogliagis Christos

Keywords: cut - flow - networks

A *mimicking network* for a k-terminal network, N, is one whose realizable external flows are the same as those of N. Let $M(K)$ denote the minimum size of a mimicking network for a k terminal network. We prove the following results (the values in brackets are the previously best known results): $M(4) = 5[2^{16}]$, $M(5) = 6[2^{32}]$. For bounded treewidth networks we show $M(k) = O(k)[2^{2^k}]$, and for outerplanar networks we show $M(k) \leq 10k - 6[k^2 2^{k+2}]$.

FR3-I-CM4

Circuit Covers in Series-Parallel Mixed Graphs

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University of Sao Paulo

Lee Orlando

Keywords: Hilbert basis - circuit cover - mixed graph - series-parallel graph

A mixed graph M is a graph that contains both edges and arcs. Given a weight function p on the edges and arcs of a mixed graph M, we wish to decide whether (M, p) has a *circuit cover*, that is, if there is a list of circuits in M such that every edge (arc) e is contained in exactly $p(e)$ circuits in the list. When M is a directed graph or an undirected graph with no Petersen's graph as a minor, good necessary and sufficient conditions are known for the existence of a circuit cover. For general mixed graphs this problem is known to be NP-complete. We provide necessary and sufficient conditions for the existence of a circuit cover of (M, p) when M is a *series-parallel* mixed graph, that is, the underlying graph of M does not have a subgraph homeomorphic to K_4. We also describe a polynomial time algorithm to find such a circuit cover, when it exists. Further, we show that p can be written as a nonnegative integer linear combination of at most m incidence vectors of circuits of M, where m is the number of edges and arcs. Other results on the fractional circuit cover and the circuit double cover problem are discussed.

TH2-A-IN2

An Implementation of the Generalized Basis Reduction Algorithm for Convex Integer Programming

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Keywords: branch and bound - integer programming - reduced basis

Branch and bound methods, which are used in most commercial codes for integer programming are not particularly suited for problems involving general integer variables. Although general integer programming and 0-1 integer programming are both NP-Complete, they are quite different when we consider their computational complexities for a fixed number of integer variables. For 0-1 problems, branch and bound methods terminate in polynomial time when the number of integer variables is fixed. However, for general integer problems, the running time of branch and bound methods is exponential in the size of the input even when the number of integer variables is fixed.

As a major breakthrough in the theory of integer programming, Lenstra obtained an algorithm for general integer programming whose running time is bounded by a polynomial in the size of the input when the number of variables is fixed. One major step in Lenstra's algorithm is the basis reduction algorithm which is used to find a short integer vector for an ellipsoidal distance function. Lovász and Scarf developed the generalized basis reduction algorithm which can find a short integer vector for any symmetric, convex distance function. Cook, Rutherford, Scarf, and Shallcross provided the first implementation of the generalized basis reduction algorithm for integer programming. Their method, like Lenstra's algorithm, is specialized to find an integer point in a given polyhedron. However, in practice, it may have to solve many feasibility problems to find an optimal solution.

In this paper, we present a new implementation of the generalized basis reduction algorithm. Our method generalizes branch and bound algorithms by branching on general linear integral functions rather than the coordinate variables. The generalized basis reduction algorithm is used to determine good integral linear functions that make the number of branches at each node small. Our method, like Lenstra's algorithm, is a polynomial algorithm when the number of variables is fixed. But it preserves all the practical advantages of branch and bound algorithms, in that no ellipsoidal approximation is required in order to determine the branching integral linear functions and repeated feasibility searches are avoided. Our method can also be applied directly to solve general nonlinear convex integer programming problems. We report on the solution of a number of examples.

TH2-I-CM120

A New Exact Algorithm for Geometric Steiner Tree Problems

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System Simulation Solutions, Inc.

Keywords: Steiner tree - branch and bound - branch and cut - constraint generation - integer programming - subtour elimination constraints - subtours

Given a finite set V of points in the plane (called *terminals*), the rectilinear Steiner minimal tree is a shortest network of horizontal and vertical lines connecting all the terminals of V. The decision form of this problem has been shown to be NP-complete.

A new algorithm is presented that computes provably optimal Steiner trees using the "FST concatenation" approach. In the "FST generation" phase, extensive geometric processing is used to identify a set of *full Steiner trees* (FSTs). In the subsequent FST concatenation phase, a Steiner minimal tree is then constructed by a finding a minimal spanning subset of the FSTs. This FST concatenation approach has been more efficient in practice than all other methods currently known.

In previous work the author used problem decomposition methods and a "dumb" backtrack search to concatenate FSTs, solving problem instances with up to 65 terminals. Most 45 point instances could be solved within one CPU day on a workstation. Other more recent results include Martin and Koch (who solve 40 point problems), and Fössmeier and Kaufmann (who solve 55 point problems).

This paper presents a refinement to the Salowe-Warme rectilinear FST generator that reduces its runtime empirically from exponential to $O(n^3)$. In addition, the FST concatenation problem has been formulated as an integer program that is solved via branch-and-cut. Together these innovations have resulted in provably optimal rectilinear Steiner trees for problems with up to 1000 terminals. Using the Euclidean FST generator of Winter and Zachariasen, this branch-and-cut procedure has also obtained optimal Euclidean Steiner trees for problems as large as 2000 terminals.

MO4-D-CO124

A Nonlinear Approach to a Class of Combinatorial Optimization Problems

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DELFT UNIVERSITY OF TECHNOLOGY

Keywords: 0-1 programming - combinatorial optimization - frequency assignment - gradient descent - interior point methods - potential reduction methods

A special class of combinatorial optimization problems is considered.
We develop a compact nonconvex quadratic model for these problems that incorporates all inequality constraints in the objective function, and discuss two algorithms for solving this model. One is inspired by Karmarkar's potential reduction algorithm for solving combinatorial optimization problems; the other is a variant of the reduced gradient method.
The paper concludes with computational results on both real–life and randomly generated instances of the frequency assignment problem. Large problems are satisfactorily solved in reasonable time.

WE4-I-CM121

Elliptic Approximations of Satisfiability Problems

Warners Joost P.

DELFT UNIVERSITY OF TECHNOLOGY

van Maaren Hans

Keywords: branching algorithms - maximum 2-satisfiability - satisfiability

Satisfiability problems can be approximated by an elliptic function. This function can be used to obtain efficient branching rules and powerful probing heuristics. In this talk, we address the (maximum-) 2-satisfiability problem, for which the elliptic approximation is exact, and we discuss a hierarchy of branching rules for the 3SAT problem, based on the elliptic approximations. Computational results are presented, confirming that the approximations contain useful information for solving SAT problems.

FR1-B-CO10

Generalized Semi-Infinite Optimization: on Foundations and Iteration Procedures

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TECHNISCHE HOCHSCHULE DARMSTADT

Pickl Stefan

Keywords: constraint qualification - convergence - generalized semi-infinite optimization - iteration procedures - linear programming - optimal control theory - optimality conditions - problem approximation - problem representation

From different problems in *engineering* and *optimal control theory* we motivate the investigation of a generalized semi-infinite optimization problem: $(\mathcal{P}_{\mathcal{GSI}}(f,h,g,u,v))$

$$\left\{\begin{array}{lcl} \text{Min} \quad f(x) \text{ on } M_{\mathcal{GSI}}[h,g], \quad \text{where} & & \\ M_{\mathcal{GSI}}[h,g] & = & \{\, x \in I\!R^n \mid \ h_i(x)=0 \ \ (i \in I), \\ & & \qquad\qquad g(x,y) \geq 0 \ \ (y \in Y(x))\,\}. \end{array}\right.$$

Hereby, $Y(x) = M_{\mathcal{F}}[u(x,\cdot), v(x,\cdot)]$ $(x \in I\!R^n)$ are feasible sets in the sense of finitely constrained optimization, and all functional data are C^1. In the case of some constraint qualification (LICQ or MFCQ) for $Y(x)$, (locally or globally) in x, we can *represent* $\mathcal{P}_{\mathcal{GSI}}(f,h,g,u,v)$ as an *ordinary* semi-infinite optimization problem, where the index set of inequality constraints becomes independent on x. Hereby, we use two (first) different approaches, whereby in the second one we focus on a subset of the feasible set and assume some stiffness of $Y(x)$.

Based on these representations we give *necessary* or *sufficient first order optimality conditions*. For the sufficient conditions, some convexity-like assumptions are made. Moreover, we indicate *topological properties* of our problem $\mathcal{P}_{\mathcal{GSI}}(f,h,g,u,v)$, under small perturbations of the defining functions.

Now, in the case of compactness of $M_{\mathcal{GSI}}[h,g]$, we can introduce *iteration procedures* for the (local or global) solution of our problem. Then, with the help of those optimality conditions and topological results, we present corresponding *theorems on convergence* of a subsequence to a minimizer or to a candidate for a minimizer. Hereby, we need some sequential continuity assumptions on multivalued functions for the second approach.

In our third approach we overcome a complexity of the first approach. Now, we approximate our problem by means of *linear (finitely constrained) programming problems* and arrive again at a convergence theorem.

Finally, coming back to our different motivations, we consider both some suitable *practical modifications* and the *structural frontiers* of our three approaches on iteration procedures.

FR4-P-IN201

Discrete-Continuous Scheduling - Mean Flow Time Results

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POZNAN UNIVERSITY OF TECHNOLOGY

Jozefowska Joanna

Keywords: discrete-continuous scheduling - scheduling

Problems of scheduling n nonpreemptable, independent jobs on m parallel identical machines are considered. Jobs require for their processing a machine and an amount of a continuous, renewable resource. The processing speed of a job is a continuous, concave nondecreasing function of the amount of the continuous resource allotted to this job at a time. The mean flow time is the optimization criterion. The problem can be decomposed into teo related subproblems: (i) to sequence jobs on machines and (ii) to find an otimal (continuous) resource allocation among jobs already sequenced. For a given feasible sequence the optimal allocation of the continuous resource can be found as a solution of a nonlinear mathematical programming problem. It has been shown that this problem can be solved analytically for a certain class of processing speed vs. resource amount functions. Moreover, for a special class of these functions an optimal sequence can be found in time O(nlogn). Equivalence of some problems has been also shown.

TH3-P-IN201

Scheduling to Provide Good Average Service to Jobs That Arrive Over Time

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Polytechnic University

Keywords: average flow time - average weighted completion time - bicriteria scheduling - online scheduling - polyhedral formulations - scheduling

Recently there has been a great deal of progress in the design of on-line and off-line algorithms, for a wide variety of scheduling models, that approximately optimize the average weighted completion time or other measure of average performance of a set of jobs with release dates. We discuss some recent important results in this area. We also discuss algorithmic and structural extensions to bicriteria scheduling.

WE1-I-CM4

2-Layer Planarization of Bipartite Graphs

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Max-Planck-Institut für Informatik

Mutzel Petra

Keywords: bipartite graphs - graph drawing - planarization

A common method for drawing directed graphs is, as a first step, to partition the vertices into a set of k layers and then, as a second step, to permute the vertices within the layers such that the number of crossings is minimized. We suggest an alternative method for the second step, namely, removing the minimal number of edges such that the resulting graph is k-layer planar. For the final diagram the removed edges are reinserted into a k-layer planar drawing. Hence, instead of considering the k-layer crossing minimization problem, we suggest solving the k-layer planarization problem.

In this talk we address the case $k = 2$. First, we give a motivation for our approach. Then, we address the problem of extracting a 2-layer planar subgraph of maximum weight in a given bipartite graph. This problem is NP-hard. Based on a characterization of 2-layer planar graphs, we give an integer linear programming formulation for the 2-layer planarization problem. Moreover, we define and investigate the polytope 2-LPS(G) associated with the set of all 2-layer planar subgraphs of a given bipartite graph G. We will see that this polytope has full dimension and that the inequalities occuring in the integer linear description are facet-defining for 2-LPS(G). Moreover, we report on new classes of valid and facet-defining inequalities. Furthermore, we present separation routines for some of these classes. These results can be used in an efficient branch-and-cut algorithm for solving practical instances of the 2-layer planarization problem. We report on our extensive computational results.

WE3-A-IN1

Generating Sets for the Knapsack Problem

Weismantel Robert

ZIB-Berlin

Henk Martin

This talk deals with the study of generating sets for the set of all non-neagtive integer solutions of a linear diophantine equation. Such a generating set is a subset of integral vectors such that every difference vector of two integer points that satisfy the linear diophantine equation can be written as the non-negative integer combination of elements from the generating set. A generating set for a linear diophantine equation also defines a test set for the knapsack problem. In this talk we discuss this connection, we derive tight bounds on the norm of elements in the generating set and deal with the question when a discrete version of Caratheodory's theorem applies. Algorithmic questions arising in this context are addressed as well.

TU3-A-IN2

The Intersection of Knapsack Polytopes

Weismantel Robert

ZIB-Berlin

Martin Alexander

This talk discusses a scheme to derive valid inequalities for a general integer program with arbitrary bounds on the variables. We relate this scheme to Gomory cutting planes, clique inequalities for the stable set problem and cover and extended weight inequalities for the knapsack problem. We illustrate that with this scheme one can characterize in special cases the convex hull of all solutions of an integer program by means of inequalities.

WE3-U-IN10

Dimensioning the Backbone Network of E-Plus

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Konrad-Zuse-Zentrum für Informationstechnik Berlin

Alevras Dimitris - Grötschel Martin

Keywords: mixed integer programming - survivability - telecommunication networks

Designing low cost networks that survive certain failure situations is one of the prime tasks in the telecommunications industry. In this talk we describe mathematical models based on various models of survivability that we developed in cooperation with E-Plus Mobilfunk GmbH (E-Plus is one of the three mobile-phone service providers in Germany).

We present mathematical investigations as well as a framework to approach these problems. Moreover, we report on computational results with real world data.

TU4-T-CO22

A Column Generation Approach to the Assembly System Design Problem with Tool Changes: Computational Evaluation

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Keywords: assembly system design - column generation - integer programming - robotic cell - strong formulation

This paper presents an integer program for prescribing optimal solutions to the assembly system design problem with tool changes. The model minimizes total cost, including the fixed costs associated with the machine and tools located at each station and the variable cost of operations assigned to each station. It observes precedence relationships and cycle time restrictions and prescribes the optimal sequence of assembly operations at each station so that tool change costs and times can be addressed. The model is especially relevant to the design of robotic cells. A strong formulation prescribes the optimal integer solution by solving a linear program for which columns are generated by solving specialized subproblems. The approach is evaluated on several classes of test problems.

TH1-W-CO15

mu- and tau-ARGUS: Software for Statistical Disclosure of Control

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Hundepool Anco

In recent years Statistics Netherlands has developed a prototype version of a software package, ARGUS, to protect microdata files against statistical disclosure. The launch of the SDC-project in 1996, within the 4th framework of the European Union, made it possible to make a new start with the development of software for Statistical Disclosure Control (SDC). The prototype has served as a starting point for the development of mu-ARGUS, a software package for the SDC of microdata. This SDC-project however foresees also the development of tau-ARGUS, software devoted to protect tabular data. The development of these software packages benefits also from the research of other partners in this project, in particular at the Eindhoven University of Technology in The Netherlands and the Consorzio Padova Ricerche in Italy. This paper gives an overview of the basic ideas underlying both ARGUS packages, in particular concerning optimality aspects.

WE4-I-CM121

The Dual of a Logical Linear Programme

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Keywords: boolean algebra - duality - linear programming - logic - minimax algebra

A Linear Programme (LP) involves a CONJUNCTION of constraints and has a well defined Dual.It is shown that if we allow a complete set of Boolean connectives .and. , .or. , .not. applied to a set of constraints we get a model known as a Logical Linear Programme (LLP). This also has a well defined Dual preserving most of the properties of LP Duality. Minimax Algebra provides a clear format for representing LLPs and their Duals as well as allowing generalisations of which LP can be regarded as a special case. The relationship with Integer Programming formulations of LLPs will also be discussed.

TU2-A-IN2

Solving Satisfiability Problems using a Hybrid Genetic-Algorithm/Branch-and-Bound Approach

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French Alan - Robinson Andrew

Keywords: branch and bound - genetic algorithms - satisfiability

The satisfiability problem in forms such as 3-sat remains a hard problem. Most successful approaches to solve such problems use a form of systematic tree search. This paper will describe the use of a hybrid algorithm, combining genetic algorithm and integer programming branch and bound approaches, to solve satisfiability problems. Such problems will be formulated as integer programs and solved by a hybrid algorithm implemented within standard mathematical programming software. Computational testing of the algorithm, which mixes heuristic and exact approaches, will be described.

MO4-I-CM120

Large Euclidean Steiner Minimum Trees in an Hour

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Zachariasen Martin

Keywords: Euclidean Steiner minimal tree

The Euclidean Steiner tree problem asks for a shortest network interconnecting a set of terminals in the plane. Over the last decade the maximum problem size solvable within one hour (for randomly generated problem instances) has increased from 10 to approximately 50 terminals. We present a new exact algorithm, called `geosteiner96`. It has several algorithmic modifications which improve both the generation and the concatenation of full Steiner trees. On average, `geosteiner96` solves randomly generated problem instances with 50 terminals in less than 2 minutes, and problem instances with 100 terminals in less than 8 minutes. In addition to computational results for randomly generated problem instances, we present computational results for (perturbed) regular lattice instances and public library instances.

FR1-I-CM3

On-Line Dispatching in Llocal Transport

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Zimmermann Uwe T.

Keywords: discrete optimization - integer programming - transport

Dispatch problems arise when preparing and executing the daily schedule of local transport companies. We consider the daily dispatch of transport vehicles from storage yards (de-

pots). Immediately on arrival, each vehicle entering the storage yard has to be assigned to a location in the depot. Simultaneously, a new round trip of the next schedule period must be chosen for the arriving vehicle. In order to achieve a departure order satisfying the scheduled demand shunting of vehicles may be unavoidable. Since shunting takes time and causes operational cost the number of shunting movements should be minimized with respect to operational constraints.

Since the order of arrival usually differs from the planned schedule the assignment is based on incomplete information.

For the off-line case, we present a linear and a quadratic programming model of the dispatch problem.

We decompose the problem into an arrival and a departure part. Some results for the latter subproblem are presented and discussed with respect to real-time applications.

We compare the behaviour of several on-line heuristics and present computational results for real world data of some storage yards in Germany.

TU4-R-IN203

Linear Programming Techniques for Fitting Circles and Spheres

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NIST

Gass Saul I. - Shier Douglas

Keywords: data fitting - linear programming - spheres

The problem of fitting circles or spheres to a set of data points is of interest for precision mesurements in manufacturing. One approach is to minimize the deviations of data points from the fitted circle/sphere, these deviations being assessed by norms of the residual vector such as L_2 (least squares), L_∞ (Chebychev), L_1 (least absolute values). These optimizations fall into two classes: "algebraic" and "geometric" fitting procedures. In the former, the coefficients of an equation describing the curve/surface are optimized. In the latter, the orthogonal distances are targeted. The talk discusses these various options, their implementations, and geometric interpretations of the respective optimality criteria.

TH3-P-IN201

Approximation Algorithms for Shop Scheduling Problems

Woeginger Gerhard J.

TU Graz, Institut für Mathematik

Keywords: approximation algorithms - scheduling - worst case guerantee

This talk summarizes several recent results on the approximability of the open shop, flow shop, job shop and the assembly line problem, and on the approximability of the multiprocessor versions of these problems. Special emphasis is put on polynomial time approximation schemes; Moreover, the talk will summarize the most important open problems in this area.

TU2-K-CM106

A New Heuristic for the Traveling Salesman Problem with Time Windows

Wolfler Calvo Roberto

Politecnico di Milano

Keywords: heuristics - local search - traveling salesman problem with time window

In this paper we describe a new heuristic algorithm for the Travelling Salesman Problem with Time Windows (TSPTW), based on the solution of the assignment problems (ASP). We show how the assignment problem with a parametric objective function gives a solution that is useful to construct a feasible solution for the TSPTW. Infact the solution obtained is a long main tour which connects the depot and few small subtours. Then we insert all the subtours in the main tour with different criteria. Moreover is given a local search procedure to improve this initial feasible solution. The computational results show the effectiveness of this approach.

TU2-D-CO123

Newton Directions in Primal-Dual Interior-Point Methods for Semidefinite Programming Optimization Problems

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Rendl Franz - Kruk Serge

Keywords: Newton directions - semidefinite programming

Semidefinite Programming (SDP) is a generalization of Linear Programming (LP) in that the nonnegativity constraints on the variables is replaced by a positive semidefinite constraint on matrix variables. Many of the elegant theoretical properties and powerful solution techniques follow through from LP to SDP. In addition, SDP has many important applications to Engineering problems and in Combinatorial Optimization. The combination of important applications with a strong solution technique has currently made SDP one of the hottest areas of research.

In this talk we present an introduction to the applications and solution techniques for SDP. In particular, we concentrate on the elegant primal-dual interior-point approaches to solving SDP. We study the different choices for the Newton direction and compare efficiency and robustness.

TH3-A-IN2

Modelling and Solving Lot-Sizing Problems by Mixed Integer Programming

Wolsey Laurence Alexander

CORE, Université Catholique de Louvain

Belvaux Gaetan

We discuss recent work on the modelling and solution of multi-item, single and multi-level, single and multi-machine lot-sizing models. Emphasis is placed on the modelling of various practical constraints such as start-up and cleaning times, minimum batch sizes, and flexibility in the length of production runs that have arisen in industrial models, and on recent computational experience with a branch-and-cut mixed integer programming code

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FR1-E-CO21

Reformulation Methods for Box Constrained Variational Inequalities

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University of New South Wales

Sun Defeng

Keywords: box constraints - reformulation methods - variational inequalities

This paper looks at reformulation methods for box constrained variational inequalities using an extension of the Fischer-Burmeister function for simple lower and upper bounds. A generalised Gauss-Newton method with global and superlinear convergence for solving box constrained VIs is proposed. Superlinear convergence is established for uniform P-functions. Preliminary numerical results will be presented.

MO4-U-IN10

SONET Ring Network Planning

Wong Richard T.

AT&T Labs

Keywords: network design - telecommunications

SONET (Synchronous Optical Network) ring networks are an important new type of telecommunications network architecture. For these systems, traffic demands are routed across a series of one or more rings (simple cycles of nodes) where within each ring, the traffic can be routed in a clockwise or anti-clockwise direction. SONET networks offer very fast restoration capabilities in the event of a single network element failure. Since ring networks are significantly different from mesh networks (where traffic demands are routed across paths instead of one or more rings), SONET ring network planning offers significant new challenges in mathematical programming modelling and algorithms.

In this talk, we discuss the various components of the SONET ring planning problem including ring selection, ring routing and load balancing, and physical ring design. We give an overview of work related to models and solution algorithms for these various aspects of the ring planning problem.

FR3-C-CO122

How Long Must we Wait ?

Wood Graham Raymond

Central Queensland University

Zabinsky Zelda B. - Kristinsdottr Birna

Keywords: adaptive search - convergence - global optimization - stochastic

Stochastic approaches to global optimisation have sprung into widespread use in the last decade. Simulated annealing, inspired by ideas from statistical mechanics, and genetic algorithms, inspired by evolutionary biology, are amongst the most popular methods. At present the convergence rates of these widely used algorithms are little understood.

Pure Adaptive Search, an idealised stochastic search algorithm, has been thoroughly studied and it's convergence rate described. Such an algorithm, however, does not allow the acceptance of worse objective function values (backtracking), a hallmark of simulated annealing. A stochastic search algorithm termed Hesitant Adaptive Search, allowing not backtracking, but hesitation at any level of the objective function, has recently been introduced.

What is the distribution of the number of iterations until Hesitant Adaptive Search reaches a given level of the objective function ? Some very recent answers to this question will be discussed in this talk.

WE4-K-CM106

Combination of Tabu Search and Exact Methods for MIPs

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UC Davis

Løketangen Arne - Glover Fred

Keywords: branch and bound - mixed integer programming - tabu search

In this paper we examine incorporation of tabu search in branch and bound algorithms. Since meta-heuristics require significant computational resources, a major issue is deciding whether to launch a search from a node in the branch and bound tree. We propose methods for making this decision that make use of sampling and chunking to facilitate metric based tests for novelty. Another set of issues concerns interaction between the branch and bound search and the tabu search. We describe methods along with mathematical motivation for using the information from each part to guide the other. Computational results are reported using XPRESS-MP for the branch and bound processing and an extreme point tabu search with path relinking for 0-1 MIPs.

TU2-T-CO22

The Nelder-Mead Simplex Method: Recent Theory and Practice

Wright Margaret H.

Bell Laboratories

Keywords: Nelder-Mead method - derivative-free optimization - non-derivative optimization - unconstrained optimization

During the past three years, the Nelder-Mead method has been the object of study to determine its convergence (or non-convergence) properties. We first summarize the results known so far and speculate about future prospects. On the practical side, various issues involving reliability and restart strategies will be discussed. Finally, we describe how the Nelder-Mead method has been used successfully to solve nasty unconstrained problems arising from wireless placement.

TU3-C-CO2

Why Ill-Conditioning in Interior Methods Usually Doesn't Hurt

Wright Margaret H.

Bell Laboratories

Keywords: ill-conditioning - interior methods - nonlinear programming - primal-dual methods

Ill-conditioning has long been regarded as a plague on interior methods for nonlinear programming, but its damaging effects have rarely been documented. We offer some insight into this seeming contradiction by analyzing ill-conditioning in a primal-dual method. (A similar analysis applies to the primal barrier method.) Although the full primal-dual system is well conditioned, it is often transformed to a smaller "condensed" system in which the matrix is inherently ill-conditioned. We show that the ill-conditioning in the exact condensed matrix has a structure similar to that already known for the primal barrier Hessian, and then examine how cancellation in the active constraints influences the computed condensed matrix. A detailed backward error analysis leads to the overall conclusion that in most instances ill-conditioning does not noticeably impair the accuracy of the solution.

WE3-D-CO123

Infeasible-Interior-Point Methods for Nonlinear Problems

Wright Stephen J.

ARGONNE NATIONAL LABORATORY

Keywords: interior point methods - nonlinear programming

We discuss extension of infeasible-interior-point techniques for linear programming and linear complementarity to nonlinear problems. We focus on local convergence properties, highlighting the theoretical differences between convergence of pure Newton-based methods and interior-point strategies. We discuss too the practical implications of these differences.

TH3-E-CO11

Local Convergence of SQP for Degenerate Problems

Wright Stephen J.

ARGONNE NATIONAL LABORATORY

Most local analyses of the sequential quadratic programming (SQP) method for nonlinear programming make strong assumptions about independence of the constraints and strict complementarity at the solution. In this talk, we examine closely the behavior of SQP when conditions of this type are not satisfied, and discuss the various modifications to SQP that have been proposed for recovering superlinear convergence. We focus particularly on a stabilization scheme that was derived from interior-point methods for nonlinear complementarity problems.

WE4-W-CO15

The NEOS Guide

Wright Stephen J.

ARGONNE NATIONAL LABORATORY

Czyzyk Joseph

Keywords: NEOS - world wide web

The NEOS Guide `http://www.mcs.anl.gov/home/otc/Guide` is an informational and educational resource for optimization on the Web. It provides information about most existing optimization software packages, interactive case studies to show how optimization can be used to solve practical problems, back-of-the-envelope sketches of algorithms and theory, and a Java applet depicting the simplex method, among other things. In this talk, we outline the Guide and its relationship to the other components of NEOS, and discuss plans for enhancement.

TH3-B-CO10

A New Cutting Plane Method for Convex Quadratic Semi-infinite Programming

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Fang Shu-Cherng

Keywords: convex analysis - quadratic semi-infinite programming

One major computational bottleneck of using traditional cutting plane approach to solve convex quadratic semi-infinite programming problems lies in finding a global maximizer of a nonlinear and nonconcave program for constraint violation. This talk presents a new scheme to relax this requirement. The proposed scheme exhibits the capability of generating an approximate solution to any level of accuracy in finite iterations.

TH1-U-IN10

Bilevel Stochastic Programming for Network Equilibrium Problems

Wynter Laura

PRISM, UNIVERSITÉ DE VERSAILLES

Patriksson Michael

Keywords: bilevel programming - network equilibrium - nonlinear programming - spatial price equilibrium - stochastic programming - traffic

We consider applications and solution methods for a combination of two general models in mathematical programming, two-stage stochastic optimization and generalized bilevel programs. Both of these problems are important in their own right, but their combination allows in particular for the modelling of important hierarchical decision problems that take variability and randomness in the input data explicitly into account; this is particularly important since a failure to take randomness in the data into consideration can be very costly.

We discuss here a particular class of generalized bilevel programming problems with applications to network planning: the toll setting problem for a road network, and the pricing problem in a spatial-price equilibrium context.

This class of problems has important practical applications, but is known to be very difficult to solve, due in a large part to its non-convexity. The introduction of random variables in the problem permits one to add substantial realism to these models, at the price of significantly increased complexity and much larger problem size. We formulate the abovementioned models such that the lower-level right-hand side variables, that is the travel demands, are subject to random variations. Time permitting, we present a descent based local solution algorithm for this class of models.

WE1-E-CO21

Non-Interior Path-Following Methods for the Linear Complementarity Problem

Xu Song

University of Washington, Department of Mathematics

Burke James V..

Keywords: interior point methods - linear complementarity problem - smoothing method

Smoothing methods have recently received considerable attention as an efficient alternative to interior point methods for the linear complementarity problem. In this talk we show how one can borrow path-following techniques from the interior point literature to improve the global convergence properties of smoothing methods. We call these methods non-interior path following methods since they do not require the iterates to remain in the interior of the positive orthant. Some advantages of these methods are (1) they can be initiated at any point in the space, (2) they are globally linearly convergent, and (3) when the iterates are restricted to the positive orthant, the algorithm has polynomial complexity. If time permits, we will illustrate the numerical behavior of the method on a few test problems.

TH1-D-CO124

Decomposition in Large Scale Geometric Programming

Xu Xiaojie

Network Design and Analysis

Yang Xiaoguang

Keywords: decomposition - geometric programming - large scale system - nonlinear

Polynomials have been used to approximate various functions. The good feature when only polynomials are concerned is the ease of computing high order derivatives, which have been frequently employed in efficient optimization methods. Posynomial Geometric Program is a class of Polynomial Constrained Program. It can be reformulated as a convex programming problem.

Recent GP formulations from engineering design and economics application involve typically more than 10000 variables and constraints. For those problems, a relative dense Hessian in the indefinite KKT matrix becomes a big barrier for any algorithms that are based on direct factorization approaches.

In this paper, we propose a new decomposition technique for solving the KKT system, which reduces memory requirment and solving time siginificantly. The code has been incorporated in X_Soft's optimization solver suites. Typically, those large-scale GP problems that used to be solved on mainframe can now be solved on PCs.

FR4-U-IN10

Mixed Integer Programming in Backbone Network Design

Xu Xiaojie

Network Design and Analysis

Keywords: mixed integer programming - network design

A backbone network design involves selecting facility types, allocating capacity, and routing traffic to accommodate demand and performance requirement. As usual, the objective is to minimize the total network cost. A typical MIP formulation with a network of n nodes can have up to n^4 integer variables. Clearly, the problem is characterized by large dimensionality, even when relatively small networks are considered. The presentation discusses feasible approaches for solving this challenging problem. Extensive computational results are reported.

TU4-D-CO124

An Efficient Algorithm for Minimizing a Sum of Euclidean Norms with Applications

Xue Guoliang

University of Vermont, Dept of Computer Science and EE

Ye Yinyu

Keywords: Steiner minimal trees - interior point methods - second order cone

The problem of minimizing a sum of Euclidean norms is studied. This problem is convex but not everywhere differentiable. By transforming the problem into a standard convex programming problem in conic form, we show that an ϵ-optimal solution can be computed efficiently using interior-point algorithms. As applications to this problem, polynomial time algorithms are derived for the Euclidean single facility location problem, the Euclidean multi-facility location problem, and the shortest network under a given tree topology. In particular, by solving the Newton equation in linear time using the Gaussian elimination on leaves of a tree, we present an algorithm which computes an ϵ-optimal solution to the shortest network under a given full Steiner topology interconnecting N regular points, in $O(N\sqrt{N}(\log(\bar{c}/\epsilon)+\log N))$ arithmetic operations where $\bar{c}$ is the largest pair wise distance among the given points. Previous best known result on this problem is a graphical algorithm which requires $O(N^2)$ arithmetic operations under certain conditions.

MO4-C-CO2

Polyhedral Approach for Solving Nonconvex Quadratic Problems with Box Constraints

Yajima Yasutoshi

Tokyo Institute of Technology

Fujie Tetsuya

Keywords: cutting plane methods - linearization technique - nonconvex quadratic problems - valid inequalities

We apply a linearization technique for nonconvex quadratic problems with box constraints. We show that cutting plane algorithms can be designed to solve the equivalent problems which minimize a linear function over a convex region. We propose several classes of valid inequalities of the region which are closely related to Boolean quadric polytope. We also describe heuristic procedures for generating cutting planes. Results of preliminary computational experiments show that our inequal-

ities generate a polytope which is a fairly nice approximation of the region.

FR3-I-CM200

Theory and Methods of Optimization on Euclidean Combinatorial Sets

Yakovlev Sergey V.

University of the Internal Affairs

Keywords: combinatorial optimization - combinatorial polyhedron - convexcontinuanion - quadratic optimization

At present a theory of Euclidean combinatorial sets has been developed, the basic of which is a mapping of these sets into arithmetic Euclidean space. The paper considers the properties of the Euclidean combinatorial sets and functions given at these sets, the equivalent statements of optimization problems and some approaches to their solution are investigated.

Let $A = \{a_1, \ldots, a_n\}$ be a given set of real numbers. A set $\mathbf{P}$, elements of which are the ordered collections from elements of a set A is called Euclidean combinatorial set.

We carry out a biaction of a set $\mathbf{P}$ for a subset E of the arithmetic Euclidean set R^n.

We consider a set of permutations, n-locations with iterations and without iterations the images of which by mapping respectively are denote as $E_n, \tilde{E}_n^k, E_n^k$.

The Euclidean combinatorial sets after mapping in R^n have a number of important properties which are described in detail in the paper.

Denote $M = convE, X = vertM$. We consider the properties of functions $\varphi(x)$ given on X.

Theorem 1. For any function $\varphi : X \to R^1$ there exists a convex function $\hat{\varphi}$:$M \to R^1$ such that $\hat{\varphi}(x) = \varphi(x)$ for all $x \in X$ and $\hat{\varphi} = conv\varphi$.

Theorem 2. For any function $\varphi : X \to R^1$ and for any $\rho > 0$ there exists a strongly convex with a parameter ρ differentiable function $\chi : M \to R^1$ such, that $\chi(x) = \varphi(x)$ for all $x \in X$.

The functions $\varphi(x)$ and $\chi(x)$ are called convex and strongly convex differentiable continuation for a function $\varphi(x)$ respectively .

We note that $E_n = vertconvE_n, \tilde{E}_n^2 = vertconv\tilde{E}_n^2, E_{n-1}^n = vertconvE_{n-1}^n$. So,the sets $E_n, \tilde{E}_n^2, E_{n-1}^n$ coincide with a set of vertices of their convex shells. We note that $convE_n$, $convE_n^k$ are described and called by permutation polyhedron and polyhedron of locations respectively. A convex shell of $\tilde{E}_n^k$ is a hypercube.

In accordance with the theorems 1,2 we may confirm that for any function $\varphi(x)$ given on sets $E_n, \tilde{E}_n^2$ or E_n^{n-1} there exists a convex differentiable continuation to the corresponding polyhedron being a convex shell of the set under study.

Extremal properties of functions, given on vertices of some classes of the combinatorial polyhedrons are proposed in the paper.

The approaches related to problem relaxation and its consequent reduction are a basis of the majority of solution methods for discrete problems of optimization. The peculiarity of the relaxation problem of optimization on the Euclidean combinatorial set is that it may be always stated as a problem of convex programming.

Optimization of convex functions on combinatorial polyhedrons has also a number of peculiarities. The thing is that the standard methods of the conditional gradient and gradient projection suppose the solution of auxiliary problems of optimization of linear and special class of quadratic functions on a combinatorial polyhedron. As it was stated above, due to structures of the Euclidean combinatorial sets such problems are reduced to a problem of ordering.

The properties related to the expansion of the Euclidean combinatorial sets for parallel hyperplanes may be bans of dimension reduction.

At present different schemes of discrete optimization based on a convex function continuation on combinatorial polyhedrons are developed. In particular, methods of quadratic optimization on the permutations set are proposed.

Numerical results for practical and modelling problems are considered.

WE3-L-CM201

A Globally and Superlinearly Convergent Primal-Dual Interior Point Method for Large Scale Nonlinear Optimization

Yamashita Hiroshi

Mathematical Systems, Inc.

Yabe Hiroshi - Tanabe Takahito

Keywords: interior point methods - nonlinear programming - trust region method

We present a primal-dual interior point algorithm for large scale nonlinear optimization that converges globally and superlinearly. Global convergence is attained by minimizing the barrier penalty functions by a trust region method for fixed barrier parameter. Superlinear convergence is attained by controlling the barrier parameter appropriately. The method is implemented and tested with CUTE problems. The code is very efficient for large scale problems as well as small scale ones.

WE4-E-CO11

Some Properties of the Restricted NCP-Functions for the Nonlinear Complementarity Problem

Yamashita Nobuo

Department of Applied Mathematics and Physics

Fukushima Masao

Keywords: bounded level sets - constrained optimization reformulation - merit function - nonlinear complementarity problems - restricted NCP-function

We introduce the notion of a restricted NCP-function which may be used to reformulate the nonlinear complementarity problem as a constrained minimization problem. In this paper, we propose a new restricted NCP-function and also consider two other classes of restricted NCP-functions. We give conditions under which a minimization problem based on a restricted NCP-function enjoys favorable properties, such as the equivalence between a stationary point of the minimization problem and a solution of the nonlinear complementarity problem, the strict complementarity at a solution of the minimization problem, and the boundedness of level sets of the objective function of the minimization problem. We examine those properties for the three restricted NCP-functions and show that the merit function constituted by the restricted NCP-function proposed in this paper enjoys quite favorable properties compared with those based on the other two restricted NCP-functions.

FR2-V-CM106

Portfolio Optimization under Minimax Risk Measure

Yang Xiao Qi

The University of Western Australia

Cai X. - Teo K.L. - Zhou X.Y.

Keywords: Kuhn-Tucker conditions - portfolio optimization - risk aversion measure

In this paper, a new model for portfolio selection is introduced to address the situation where a risk averse investor wants to minimize the maximum individual risk among assets to be invested. The model uses an l_∞ function as a risk aversion measure. This differs from previous studies where either an l_2 function or an l_1 risk function is suggested, which may not model adequately the concern of very cautious investors. We formulate our problem as a bi-criteria piecewise linear program, where one criterion is to minimize the l_∞ risk function while the other is to maxmize the total expected return. An interesting finding is that an optimal investment strategy can be derived analytically. The solution exhibits a simple structure, which selects assets to be invested in accordance with the ratio of the difference in their return rates to their risks.

TU2-J-IN202

How Partial Knowledge Helps to Solve Linear Programs

Ye Yinyu

The University of Iowa

Vavasis Steve

Keywords: complexity - condition number - linear programming

We present results on how partial knowledge helps to solve linear programs. In particular, if a linear system, $Ax = b$ and $x \geq 0$, has an interior feasible point, then we show that finding a feasible point to this system can be done in $O(n^{2.5}c(A))$ iterations by the layered interior-point method, and each iteration solves a least-squares problem, where n is the dimension of vector x and $c(A)$ is the condition number of matrix A defined by Vavasis and Ye. This complexity bound is reduced by a factor n from that when this property does not exists. We also present a result for solving the problem using a little strong knowledge.

WE3-D-CO124

Bounded Error Parameter Estimation: a Sequential Analytic Center Approach

Ye Yinyu

The University of Iowa

Bai Er-Wei

Keywords: analytic centers - column generation - error estimation

A sequential analytic-center approach for bounded error parameter estimation is proposed. The analytic center minimizes the "average" output error and allows an easy-to-compute sequential algorithm, which is presented along with its complexity proof. The complexity of this algorithm in terms of the maximum number of Newton iterations is shown to be linear in the number of observed data points.

WE1-D-CO123

Approximating Quadratic Programming with Quadratic Constraints

Ye Yinyu

The University of Iowa

Keywords: approximation algorithms - quadratic programming - semidefinite programming

We consider the problem of approximating the global maximum of a quadratic program (QP) with n variables subject to bound and simple quadratic constraints. Extending the results of Goemans and Williamson and Nesterov, we show that a 4/7 approximate solution can be obtained in polynomial time.

WE4-U-IN10

Multicommodity Network Flow Problem with Side Constraints on Paths Solved by Column Generation

Yuan Di

Linkoping University

Keywords: column generation - multicommodity - network flow - side constraints

The multicommodity network flow model arises in the areas of transportation, production and communication. The model concerns flow routing of a number of commodities through a capacitated network at minimal cost. In the basic model it is assumed that for each commodity, the flow can be routed on any path connecting its origin and destination. In telecommunication applications, there often are additional time-delay and/or reliability requirements on paths that are used for flow routing. Furthermore, these requirements vary by different communication pairs, represented by different priority classes. In this paper, we extend the basic multicommodity network flow model to include these side constraints on paths. The extended problem is NP-complete with the constrained shortest path problem as a special case. To solve this extended model, we use a column generation approach, in which the solution is built up successively by path generation. The side constraints are efficiently handled in the path generation subproblem. We also discuss various enhancements of this approach. Computational results indicate that the column generation approach provides a quite efficient way for solving the extended model, even for fairly large networks, which makes it interesting to use in practice.

WE4-C-CO3

Some Properties of a Trust Region Sub-

problem
Yuan Ya-xiang

Inst. of Comp. Math. and Sci./Eng. Computing, Chinese Academy of Sciences

Keywords: inexact solutions - nonlinear programming - subspace search - trust region subproblem

Most trust region algorithms for unconstrained optimization require to minimize a quadratic function with two quadratic constraints. This problem, which is called Celis-Dennis-Tapia subproblem, is important both theoretically and practically. In this talk, we consider techniques for computing approximate solutions of the CDT problem, such as by conjugate gradient method and two dimensional subspace searches. Relations between these inexact solutions will be reported and predicted reductions obtained by these techniques are compared with the reduction obtained by the exact solution.

WE1-C-CO3

Practical Global Optimization for Engineering Design
Zabinsky Zelda B.

University of Washington

Tuttle Mark - Neogi Sudipto

Keywords: engineering design - global optimization - random search - simulated annealing

Engineering design problems often involve optimization of functions that are treated as “black box” functions. These functions may be nonconvex, nondifferentiable, and even discontinuous. The functions may be in the constraints, or in the objective function. For example, an engineer may choose to treat a function of strain in the objective, such as minimize strain, or may treat strain in the constraint, such as minimize weight while limiting strain to be below a certain threshold. These functions are usually computationally expensive, and may involve finite element methods.

Engineering design problems often have difficulty finding a feasible solution, let alone an optimal solution. In this talk, we investigate a modified penalty approach that is used in conjunction with a random search algorithm. The penalty approach is compared with a two-phase hierarchical approach, where phase 1 is to find a feasible point, and phase 2 maintains feasbility and works toward optimality. Some numerical results will be presented, including a nonconvex, disconnected feasible region. We use random search methods for this type of problem, and investigate their effectiveness at finding a “good” feasible point when the feasible region is disconnected. We also consider approximations of the constraints to reduce the number of times a finite element analysis is executed. We evaluate the effect of approximating the constraints on the performance of the global optimization algorithms.

TU2-C-CO122

Enhancements to IHR: Improving Hit-and-Run
Zabinsky Zelda B.

University of Washington

Keywords: global optimization - simulated annealing - stochastic optimization

Simulated annealing and other random search methods are finding many applications to practical nonconvex problems. Improving Hit-and-Run (IHR) is a random search method that has been successfully used in several engineering design applications. IHR may be considered a limiting form of a simulated annealing method, as its temperature is always equal to zero. However the Hit-and-Run generator ensures that it is always possible to sample anywhere in the feasible region.

Numerical results are presented that compare the basic IHR algorithm to recent enhancements. The enhancements include changes to the generator, as well as changes to the acceptance probability. The performance results of IHR are also discussed in relation to a theory describing the convergence rate for an adaptive random search algorithm. The theoretical performance is based on the underlying sampling distribution as imposed by the generator and acceptance probability.

TH2-I-CM120

Rectilinear Full Steiner Tree Generation
Zachariasen Martin

University of Copenhagen, Dept. of Computer Science

Keywords: exact algorithms - full Steiner trees - rectilinear Steiner trees

The most efficient exact algorithms for the rectilinear and Euclidean Steiner tree problems in the plane use a two-phase scheme: First a small but sufficient set of full Steiner trees (FSTs) is generated and then a minimum Steiner tree is constructed from this set by using simple backtrack search, dynamic programming or an Integer Programming formulation. FST generation methods can be seen as problem reduction algorithms and are also useful as a first step in providing good upper- and lower-bounds for large instances. In this paper we describe and implement a very efficient algorithm for the rectilinear FST generation problem. We use a number of important rectilinear FST properties, previously not used by FST generating algorithms. The new algorithm uses an FST “growing” approach which is based on information obtained in a preprocessing phase. For randomly generated instances approximately 4n FSTs are generated on average (where n is the number of terminals). The observed running time is quadratic and the FSTs for a 1000 terminal instance can on average be generated within one minute.

TU3-T-CO22

Methods for Improving Efficiency in One-Dimensional Cutting Stock Problem
Zak Eugene J.

Majiq, Inc.

Rennick Christopher Anthony - Johnson Mike

Keywords: linear programming

The cutting stock problem (CSP) remains attractive for many researchers for both theoretical and practical reasons. The complicated combinatorial nature of the problem and the wide variety of techniques involved in a solution method range from knapsack problem algorithms (pattern generation) to traveling salesman problem algorithms (pattern sequencing), and pro-

voke new investigations. The huge potential savings to industry of effective solution methods spur much of R&D activity.

Supplemental environmental and technological factors must be employed in a robust commercial system, like MAJIQTRIM, to extract profit from every opportunity. Some of the most promising factors are listed below. - Help rolls are additional roll sizes borrowed from probable future orders to enrich the set of patterns of the current trim problem. - Intertrimming diameters or grades is also a pattern enrichment strategy where sizes are added from existing orders of different diameters or paper grades. - Multi-machine trimming takes advantage of the unique characteristics of two or more parallel running winders, expanding the set of patterns roughly proportional to the number of unique machine deckles. - Multi-stock width trimming is similar to multi-machine trimming in the sense that source reels of different widths are like different machine deckles. - Rewinder trim exploits a rewinding machine (or rewinder), that allows rewinding/splicing rolls to different diameters as well as cutting large width rolls initially produced on the winder into smaller width rolls. This machine is especially helpful when many small width rolls cause bad trims at the winder due to ?knife starvation.? - Skiver trim also requires special equipment (skiver), but unlike a rewinder a skiver produces wider rolls from narrower rolls.

These factors extend the mathematical model of the classic case, even strengthening its combinatorial nature, while retaining the linear programming approach as the main solution engine for the new CSP problems.

FR1-G-IN11

Inexact Cuts in Benders' Decomposition

Zakeri Golbon

University of Auckland, Dept. of Engineering Science

Philpott Andrew Bryan - Ryan David M.

Keywords: Benders decomposition - inexact cuts - stochastic programming

Benders' decomposition is a well-known technique for solving large linear programs with a special structure. In particular it is a popular technique for solving multi-stage stochastic linear programming problems. Early termination in the subproblems generated during Benders' decomposition (assuming dual feasibility) produces valid cuts which are inexact in the sense that they are not as constraining as cuts derived from an exact solution. We describe an inexact cut algorithm, and prove its convergence under mild assumptions. We concluded with some computational results from applying the algorithm to a class of stochastic programming problems which arise in hydroelectric scheduling.

TH1-L-CM201

Techniques for Solving Large-scale Set Partitioning Problems

Zakeri Golbon

University of Auckland, Dept. of Engineering Science

Ryan David M. - Philpott Andrew Bryan

Keywords: integer programming - interior point methods - set partitioning problems

We will describe solution techniques for solving large-scale set-partitioning problems. These are zero-one integer programming problems, arising from crew rostering, which are typically solved using the simplex method and branch-and-bound techniques.
We will present results of using interior-point LP solvers in place of simplex solvers. We will describe a technique for warm starting the interior point algorithm once a constraint branch is imposed and *columns are removed.*

TH3-I-CM4

Minimally Imperfect Graphs and Cutsets

Zemirline Abdallah

Lab SPO,Département Informatique, Université de Bretagne occidentale

Keywords: cutset - minimally imperfect graph - perfect graph

A graph G is perfect if for every induced subgraph H of G, the chromatic number of H equals the size of a largest clique of H. A graph is minimally imperfect if all its proper induced subgraphs are perfect but it is not. In a graph G a cutset is a nonempty set C of vertices such that G - C is disconnected. This talk will deal with minimally imperfect graphs and their cutsets. We will describe some properties that a cutset of a minimally imperfect graph must not satisfy. These results generalize more particularly the star-cutset lemma.

WE2-E-CO21

Globally Convergent Generalized Inexact Newton Methods for Non-Twice Differentiable Optimization Problems

Zhang Jianzhong

City University of Hong Kong

Pu Dingguo

Keywords: c-differentiability - generalized Newton method - global convergence - inexact Newton method - nonsmooth optimization - superlinear rate

We propose two types of globally convergent inexact generalized Newton methods to solve unconstrained optimization problems in which objective functions are not twice differentiable, but second order C-differentiable. The first type makes the norm of the gradient decreasing whereas the second one monotonically reduces the objective value. These methods are implementable and globally convergent. We prove that the algorithms have superlinear convergence rates when the objective functions are C-convex.

TH4-C-CO3

A Scaled Optimal Path Trust Region Algorithm

Zhang Jianzhong

City University of Hong Kong

Xu Chengxian

Keywords: Bunch-Parlett factorization - curvilinear search -

superlinear convergence - trust region

Optimal path trust algorithm intends to determine a trajectory along which the solution to a trust region subproblem at a given point with any trust region radius is located. Although its idea is attractive, the existing optimal path method seems impractical because it requires, in addition to a factorization, the calculation of full eigensystem of the working matrix. We propose a scaled optimal path trust region algorithm which finds a solution of the subproblem in full dimensional space by just one Bunch-Parlett factorization for working matrix at each iteration and by using the resulting unit lower triangular factor to scale the variables in the problem. A scaled optimal path can then be formed easily. The algorithm has good convergence properties under commonly used conditions. Computational results are presented to show that this algorithm is robust and effective.

MO3-A-IN1

New Variants of Finite Criss-Cross Pivot Algorithm for Linear Programming

Zhang Shuzhong

Erasmus University Rotterdam

Keywords: criss-cross pivot method - linear programming

In this paper we generalize the so called first-in-first-out pivot rule and the most-often-selected pivot rule to the criss-cross pivot setting. The finiteness of the new criss-cross variants is proven.

TH3-D-CO124

The Analytic Central Path and some Sensitivity Issues for sSemidefinite Programming

Zhang Shuzhong

Erasmus University Rotterdam

Sturm Jos F.

Keywords: interior point methods - semidefinite programming

Sensitivity analysis plays an important role in optimization. For semidefinite programming, much research on sensitivity analysis still needs to be done. A seemingly unrelated question for SDP is the analytical properties of the central path. In this paper we study some properties of the central path for SDP with application to sensitivity analysis for SDP.

FR1-D-CO123

Analysis for a Class of Long-step Primal-Dual Interior-Point Algorithms for SDP

Zhang Yin

Rice University

Monteiro Renato D. C.

Keywords: long-step algorithms

We present a unified analysis for a class of long-step primal-dual path-following algorithms for semidefinite programming whose search directions are a subclass of the Monteiro-Zhang class of directions. We show that in this subclass the Nestrov-Todd direction possesses the best iteration-complexity provable by our analysis.

TU1-G-IN11

Capital Growth with Security

Ziemba William T.

Faculty of Commerce, University of British Columbia

MacLean Leonard C.

This paper considers the multiperiod allocation of capital with several risky assets. With the objective of maximizing the growth of capital and conditions requiring that specific financial milestones are achieved with high probability, the problem is formulated as a stochastic optimization model. Our approach uses a disjunctive form for the probabilistic constraints, which identifies an outer problem of choosing our optimal set of scenarios, and an inner (conditional) problem of finding the optimal investment decisions for a given scenario set. We show that the multiperiod inner problem is composed of a sequence of conditional one period problems. An example is provided for the allocation of wealth in tocks, bonds and cash across international markets.

MO-pm-CO2

Discrete Optimization in Public Rail Transport

Zimmermann Uwe T.

Technische Universität Braunschweig

Bussieck Michael R. - Winter Thomas

Keywords: discrete optimization - public transport

Many problems arising in traffic planning can be modelled and solved using discrete optimization. We will focus on recent developments which were applied to large scale real world instances.

Most railroad companies apply a hierarchically structured planning process. Starting with the definition of the underlying network used for transport one has to decide which infrastructural improvements are necessary. Usually, the rail system is periodically scheduled. A fundamental base of the schedule are the lines connecting several stations with a fixed frequency. Possible objectives for the construction of the line plan may be the minimization of the total cost or the maximization of the passengers's comfort satisfying certain regulations. After the lines of the system are fixed, the train schedule can be determined. A criterion for the quality of a schedule is the total transit time of the passengers including the waiting time which should be minimized satisfying some operational constraints. For each trip of the schedule a train consisting of a locomotive and some carriages is needed for service. The assignment of rolling stock to schedule trips has to satisfy operational requirements. A comprehensible objective is to minimize the total cost. After all strategic and tactical planning the schedule has to be realized. Several external influences, for example delayed trains, force the dispatcher to recompute parts of the schedule on-line.

TH4-C-CO122

Optimality and Duality in Parametric

Convex Lexicographic ∅Programming

Zlobec S.

Department of Mathematics and Statistics, McGill University

Floudas Christodoulos A.

We study parametric convex lexicographic optimization problems with two objectives. Using basic tools of convex analysis and point-to-set topology, we find conditions for continuity of the optimal value function, give characterizations of global and local optima, and formulate a Lagrangian duality theory. These results are readily applicable to bilevel convex programs.

TU-pm-SPO

Free Material Optimization via Mathematical Programming

Zowe Jochem

Inst. of Applied Mathematics, University of Erlangen-Nürnberg

Kocvara Michal - Bendse Martin P.

This paper deals with a central question of structural optimization which is formulated as the problem of finding the stiffest structure which can be made when both the distribution of material as well as the material itself can be freely varied. We consider a general multi-load formulation and include the possibility of unilateral contact. The emphasis of the presentation is on numerical procedures for this type of problem, and we show that the problems after discretization can be rewritten as mathematical programming problems of special form. We propose iterative optimization algorithms based on penalty-barrier methods and interior-point methods and show a broad range of numerical examples that demonstrates the efficiency of our approach.

TH2-E-CO21

Trust Region Methods for Solving Nonlinear Complementarity Problems

Zupke Martin

Institute of Applied Mathematics, University of Hamburg

Kanzow Christian

Keywords: global and superlinear convergence - merit function - nonlinear complementarity problems - semismooth equation - trust region method

In this talk a trust region method is proposed for solving the nonlinear complementarity problem. The trust region method is based on a semismooth equation reformulation using a recently introduced one-parametric class of NCP-functions. We will make use of the fact that the natural merit function associated to the equation reformulation is continuously differentiable. Instead of solving the full-dimensional trust region subproblem, we consider the intersection of this subproblem with a low-dimensional subspace containing at least the direction of steepest descent and a generalized Newton direction. As a consequence, the subproblem can be solved with a low computational burden, and the overall algorithm can still be shown to be globally and locally superlinearly/quadratically convergent.

FR1-I-CM121

Order Relations on Sets of Boolean Variables

Zwicker William S.

Department of Mathematics, Union College

Taylor Alan D.

There seems to be only one reasonable way to strictly order the individual variables of a Boolean function (equivalently, the players of a simple game) so as to realize the idea of dominant influence. The resulting transitive relation <-sub-I has been rediscovered several times. Those Boolean functions for which <-sub-I is total form a natural class properly extending the threshold functions. Less well known is that there are several reasonable extensions of <-sub-I to a relation on sets of variables. Two of these are known (apparently to disjoint groups of researchers) and are intransitive. Two others are new, and have transitive strict forms but intransitive weak forms <-or-=. We show that the latter feature is unavoidable, and discuss the natural classes of functions associated with each relation.

Chairpersons

Speakers and Authors

Speakers, authors and coauthors with the page number of the abstracts where they appear as speaker (**bold**), author (normal) or coauthor (*itallics*).

Index of Keywords

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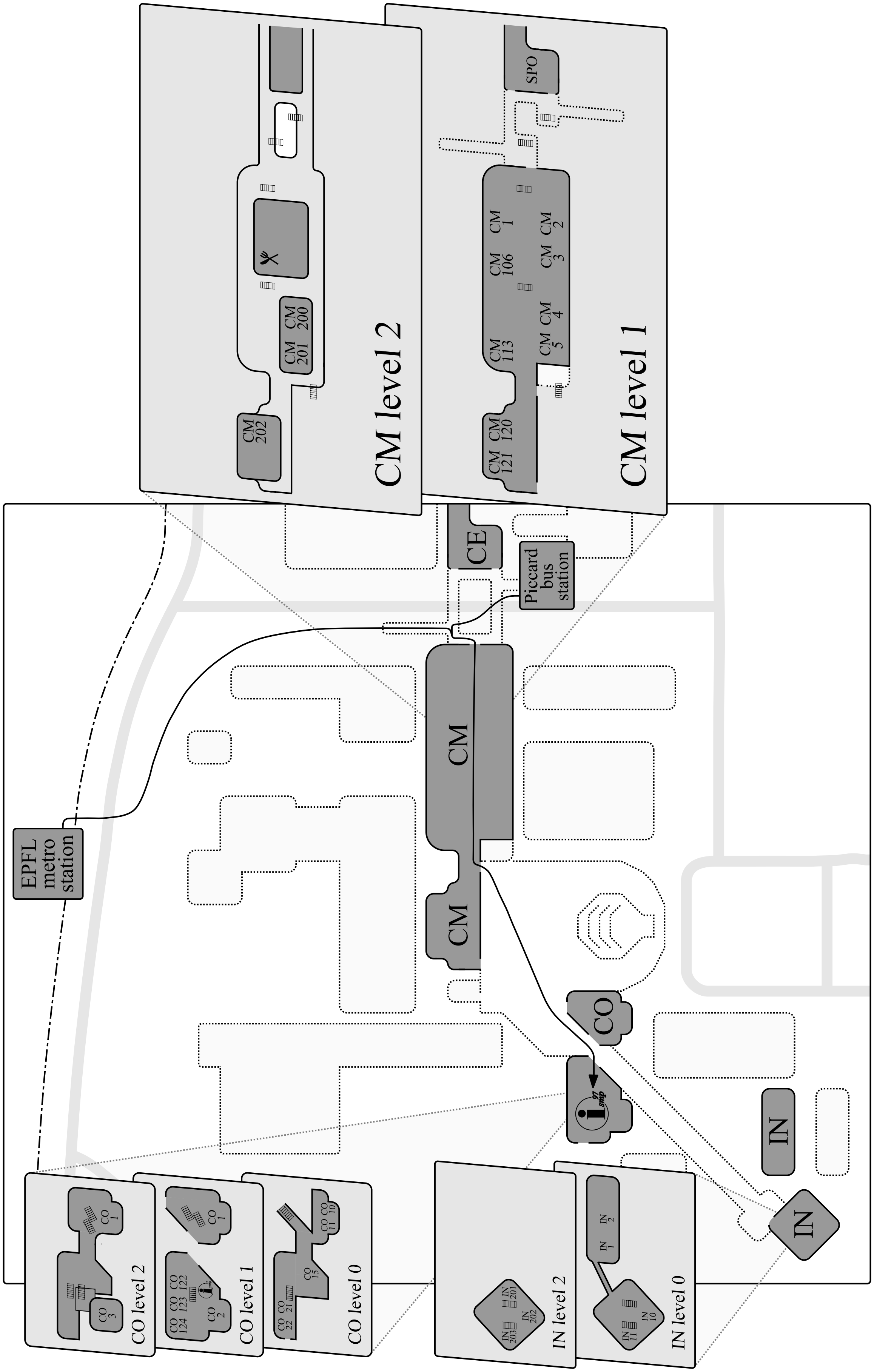

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