An Exact Solution Approach for the Maximum Multicommodity K-splittable Flow Problem

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develop an LP relaxation for UFP on paths that has an integrality gap of $O(\log 2n)$. We also discuss related problems on column-restricted packing integer programs (CPIPs) motivated by the semimonotone property in the Linear Complementarity Problems (LCPs). We introduce and prove some results on a semimonotone type property called $P'_2 \cdot P'$ - property for SDLCP's similar to the already existing results in the LCP theory. Then we prove the equivalence of the $P'_2 \cdot P'$ - property for the Lyapunov and the double sided multiplicative transformations. We also study the implications of $P'_2 \cdot P'$ - properties on the $P$ and $Q$ - properties for the Lyapunov, Stein and double sided multiplicative transformations.

We give a simple $O(\log^2 n)$ approximation for UFP on trees. Using our insights, we develop an LP relaxation for UFP on paths that has an integrality gap of $O(\log^2 n)$. We also discuss related problems on column-restricted packing integer programs (CPIPs).

We consider the unsplittable flow problem (UFP). Most previous work on UFP has focused on the case where the maximum demand of the requests is no larger than the smallest edge capacity - referred to as the “no-bottleneck” assumption. We give a simple $O(\log^2 n)$ approximation for UFP on trees. Using our insights, we develop an LP relaxation for UFP on paths that has an integrality gap of $O(\log^2 n)$. We also discuss related problems on column-restricted packing integer programs (CPIPs).

The stochastic multi-armed bandit (MAB) problem models the exploration exploitation tradeoff. For this problem, traditional index policies become sub-optimal in the presence of side-constraints, such as costs of switching between arms. In this talk, we will present a novel, simple, and general algorithmic technique for handling side-constraints, which yields policies that are not only constant factor approximations, but are also computationally just as efficient as index policies.

For all these problems we give information theoretic lower bounds, and matching or nearly matching upper bounds.

The complexity analysis of some simple principal pivot algorithms for the (generalized) LCP $(G,q)$ with a (vertical block) $P$-matrix $G$ depends on the acyclicity of a certain directed graph associated with $G$ and $q$. This graph is acyclic if the matrix $G$ is a hidden K-matrix. We show that if $G$ has 3 columns, then exists a vector $g$ so that the digraph for LCP $(G,q)$ contains a directed cycle iff $G$ is in the interior of the set of (vertical block) matrices that are not hidden K-matrices.

In this article we study the semimonotone type properties in the Semidefinite Linear Complementarity Problems (SDLCP's) motivated by the semimonotone property in the Linear Complementarity Problems (LCP's). We introduce and prove some results on a semimonotone type property called $P'_2 \cdot P'$ - property for SDLCP's, similar to the already existing results in the LCP theory. Then we prove the equivalence of the $P'_2 \cdot P'$ - property for the Lyapunov and the double sided multiplicative transformations. We also study the implications of $P'_2 \cdot P'$ properties on the $P$ and $Q$ - properties for the Lyapunov, Stein and double sided multiplicative transformations.

We apply the SDDP decomposition to a nonlinear stochastic hydrothermal model where we model nonlinear water head effects and the nonlinear dependence through which other energy products, as bilateral (BC) and physical futures (FC) contracts, are integrated into the Spanish market. In this paper the authors show a practical and efficient UC problem integrating into a mathematical model the technical characteristics of plants, the frequency reserve and the network constraints, with the primary objective of minimizing the operational costs of the system.

This article presents in detail a practical, efficient and novel Mixed Integer Linear Programming approach (MILP) to model a complete Unit Commitment (UC) problem with network linear constraints. In this paper the authors show a practical and efficient UC problem integrating into a mathematical model the technical characteristics of the power plants, the frequency reserve and the network constraints, with the primary objective of minimizing the operational costs of the system.

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1 - Some New Results in Semidefinite Linear Complementarity Problems

A Chandrahekaran, CSIR-SRF, Indian Institute of Technology Madras, Department of Mathematics, IIT Madras, Chennai, TN, 600036, India, cchandru1782@gmail.com, T Parthasarathy, V Vetivel

This article presents in detail a practical, efficient and novel Mixed Integer Linear Programming approach (MILP) to model a complete Unit Commitment (UC) problem with network linear constraints. In this paper the authors show a practical and efficient UC problem integrating into a mathematical model the technical characteristics of the power plants, the frequency reserve and the network constraints, with the primary objective of minimizing the operational costs of the system.

2 - Stochastic Dual Dynamic Programming Applied to Nonlinear Hydrothermal Models

Santiago Cerisola, Researcher, Universitat Politècnica Comillas, Alberto Aguilera 23, Madrid, 28015, Spain, santiago.cerisola@upcomillas.es, Jesus M. Latorre, Andres Ramos

We apply the SDDP decomposition to a nonlinear stochastic hydrothermal model where we model nonlinear water head effects and the nonlinear dependence between the reservoir head and the reservoir volume. We use the McCormick envelopes to approximate the nonlinear constraints that model the efficiency of the plant. We divide these constraints into smaller regions and use the McCormick envelopes for each region. Binary variables are used for this disjunctive programming approach which complicates the application of the decomposition method. We use a variant of the L-shaped method that enables the inclusion of binary variables into the subproblem and perform the stochastic decomposition method. A realistic large-scale case study is presented.

3 - Stochastic Programming Models for Optimal Bid Strategies in the Iberian Electricity Market

Javier Heredia, Professor, Universitat Politècnica de Catalunya, North Campus-C5, Office 206, Jordi Girona, 1-3, Barcelona, 08034, Spain, j.f.javier.heredia@upc.edu, Cristina Corchero

The day-ahead market is not only the main physical energy market of Portugal and Spain in terms of the amount of traded energy, but also the mechanism through which other energy products, as bilateral (BC) and physical futures (FC) contracts, are integrated into the Iberian Electricity Market (MIBEL) energy production system. We propose stochastic programming models that give both the optimal bidding and BC and FC nomination strategy for a price-taker generation company in the MIBEL. Implementation details and some first computational experiences for small real cases are presented.
We first propose a facial reduction algorithm (FRA) for general conic linear programming, and prove some useful properties of the algorithm. Then we establish relationships between FRA and conic expansion algorithm (CEA, a.k.a. the dual regularization approach) by Luo, Sturm, and Zhang. In fact, CEA can be regarded as a dual of special case of FRA. We give some examples that FRA can provide finer sequence of regularizations than CEA.

3 - A Facial Reduction Algorithm for Semidefinite Programming Problems in Polynomial Optimization
Hayato Waki, The University of Electro-Communications, Chofu-gaoka 1-5-1 West Building 4, 311, Chofu-shi, Tokyo, Japan, Tokyo, 182-8585, Japan, hayato.waki@jsb.cs.uwc.ac.jp, Masakazu Muramatsu

Kojima et al. (2005) proposed a method that eliminates redundant monomials for all SOS representations of a given polynomial. In this talk, we reveal a relationship between the elimination method and Facial Reduction Algorithm (FRA) proposed by Bowrein and Wolkowicz (1980), and show that the elimination method not only reduces the size of the SDP problem of finding an SOS representation of the given polynomial but also improves the numerical stability. We also present some examples that the elimination method performs well.

■ FA07
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Integer and Mixed Integer Programming J
Contributed Session
Chair: Illya Hicks, Associate Professor, Rice University, 6100 Main St. - MS 134, Houston, TX, 77005-1892, United States of America, ivhicks@rice.edu

1 - Experiments with Two-row Cuts
Pierre Bonami, CNRS, Aix Marseille Université, 163 Avenue de Luminy, Marseille, France, pierre.bonami@lif.univ-mrs.fr, Gerard Cornuejols, Francois Margot, Amitabh Basu

Most of the cutting plane algorithms implemented in current state of the art solvers rely on cuts that can be derived from a single equation. A natural idea to build more efficient cutting plane algorithms is to use cuts which need more than one equation to be derived. Recently there has been a lot of interest in cutting planes generated from two rows of the optimal simplex tableau. For example, it has been shown that there exist examples of integer programs for which a single cut generated from two rows can dominates the split closure by an arbitrary amount. Motivated by these theoretical results, we study computationally the effect of adding these cutting planes on a set of problems from the MIPLIB library.

2 - Fast Lower Bounds for the Capacitated Arc Routing Problem
Rafael Martinelli, Pontificia Universidad Catolica del Rio de Janeiro, Rua Marques de Sao Vicente, 225 - RDC, Departamento de Informatica, Gavea, Rio de Janeiro, 22453-900, Brazil, rmartinelli@inf.puc-rio.br, Marcus Poggi

We devise a dual ascent algorithm for the Capacitated Arc Routing Problem (CARP) based on the formulation proposed by Belenguer and Benavent. Although this approach may not yield the best possible bounds, it allows a very fast computation. The main difficulty is to select active primal cuts, associated to dual variables, that allow reaching high quality dual bounds. We discuss how to find these cuts and show that the resulting algorithm consistently finds strong lower bounds.

3 - Integer Programming Techniques for General Branchwidth
Illya Hicks, Associate Professor, Rice University, 6100 Main St. - MS 134, Houston, TX, 77005-1892, United States of America, ivhicks@rice.edu

In this talk, we consider the problem of computing the branchwidth and optimal branch decomposition of a symmetric submodular function, the general branchwidth problem. General branchwidth encompasses graphic, hypergraphic, and matroidal branchwidth, as well as carvingwidth and rankwidth. We present the first integer programming model for this general branchwidth problem and offer preliminary computational results for solving our model.
1 - Properties of Integer Feasibility on a Simplex
Karen Aardal, Professor, Delft University of Technology, Mekelweg 4, Delft, 2628 CD, Netherlands, karen.aardal@ewi.nl, Laurence Wolsey

We give a non-trival upper bound on the number of nodes needed to solve the integer feasibility problem on a simplex after it has been reformulated using the Aardal-Hurkens-Lenstra lattice reformulation.

2 - Revival of Vertex Enumeration
Leen Stougie, Professor Doctor, Vrije Universiteit & CWI Amsterdam, De Boelelaan 1105, Amsterdam, 1081HV, Netherlands, lstougie@feweb.vu.nl, Vicente Acuña

The complexity of enumerating vertices of bounded polyhedra is a long standing open problem. Khachiyan et al. (2005) give a negative answer for (unbounded) polyhedra. Research in this field is attracting new attention by the study of metabolic networks. Our new results are a) it is NP-hard to decide if a vertex exists with 2 pre-fixed coordinates in its support, b) enumerating vertices having 1 specific coordinate in their support cannot be done with polynomial delay unless P=NP.

3 - Smallest Compact Formulation for the Permutahedron
Michel Goemans, MIT, Department of Mathematics, Cambridge, MA, 02139, United States of America, goemans@math.mit.edu

We give an extended formulation of the permutahedron (convex hull of all permutations on n elements) with O(n log(n)) variables and O(n log (n)) constraints. We also show that no smaller compact formulation exists (up to constant factors). This answers a question of Alberto Caprara. The results easily generalize to variants of the permutahedron.

4 - Cutting in Branch-and-cut-and-price Algorithms
Simon Spoorendonk, DTU Management Engineering, Produktionstorvet, Building 426, Kgs. Lyngby, 2800, Denmark, spo@man.dtu.dk, Guy Desaulniers, Jacques Desrosiers

Given a Dantzig-Wolfe decomposition of an integer program, this talk presents a general framework for formulating, on the original formulation, valid inequalities derived on an equivalent master problem. It is possible to model these inequalities by adding new variables and constraints to the original formulation. We show how the additional inequalities may give rise to an augmented subproblem. Examples on how to apply this framework are given for the vehicle routing problem with time windows.

5 - The Column Generation Improvement Heuristic (CGI)
Invited Session
Chair: Marco Luebebecke, TU Berlin, Institute of mathematics, Strasse des 17. Juni 136, Berlin, 10623, Germany, m.luebebecke@math.tu-berlin.de

One may propose column generation formulations for combinatorial problems where the pricing subproblem turns out to be another, although identical sometimes, instance of the original problem. When it is not, we point out that finding a profitabile new solution for the subproblem implies an improvement on the current (LP) solution. We discuss this inverse repetition behavior over applications of CGI to routing problems (TSP, TDTP) and nonlinear 0-1 programs (UBQP, MAX-CUT, MAX-CLIQUE). We explore the consequences of this embedded instance transformation in branch-and-price approaches where problem solutions are associated to single columns. Uniting implications on variables coming from different related instances is the current challenge.

6 - An All-integer Column Generation Methodology for Set Partitioning Problems
Elaina Ronnberg, Linkoping University, Department of Mathematics, Division of Optimization, Linkoping, SE-58183, Sweden, elron@mai.liu.se, Torbjorn Larsson

The set partitioning polytope has the quasi-integrality property, that enables the use of simplex pivot based methods for moving between integer solutions associated with linear programming bases. In our methodology each intermediate solution to a restricted master problem is feasible, integer, and associated with simplex multipliers. A subproblem is designed to produce columns that maintain integrality when pivoted into the basis. Criteria for verifying optimality are presented.
We present numerical algorithms to find optimal well rates for a reservoir simulation at various stages of design or for the purposes of tractability. We refer to the use of several layers of models in representing a particular multilevel formulation or a multilevel solution algorithm. The term multi-model refers to the use of several layers of models in representing a particular multilevel formulation or a multilevel solution algorithm. The term multi-model optimization is used to describe the process of optimizing a system that is simulated using two popular time discretization schemes.

First and second order optimality conditions are derived based on the classical approaches in particular for disturbed right-hand side vectors and in case many or all rows are affected by disturbances. In a study on delay resistant train platforming with real-world data this general method has outperformed special purpose methods by 25%.

We focus on robust linear optimization with uncertainty regions defined by phi-divergence distance measures (e.g. chi-squared, Hellinger). Such uncertainty arise in a natural way if the uncertain parameters depend on an unknown probability distribution and goodness-of-fit tests are used. We show that the robust counterpart of a linear optimization problem with “phi-divergence” uncertainty is tractable. We also apply the theory to expected utility functions; in particular to the newsboy problem.

We present an adaptive multilevel SQP-method for opt. problems governed by nonlinear PDEs with control constraints. Starting with a coarse discretization of the problem we combine a trust-region SQP-method with an implementable adaptive refinement strategy based on error estimators and a criticality measure. In the presence of parabolic PDE constraints the alg. also supports the use of independent discretizations for state and adjoint PDE. We prove global convergence and show numerical results.

We describe a systematic way to generate adjoint code by applying an efficient sparsity exploiting forward mode of AD to the original code. The result is a linear system for the adjoint that can be solved by taking advantage of the original code and the existing structure for multicore and multigrid. We applied this procedure to the parallel, block-structured, multigrid flow solver FASTEST, which uses LES and is written in Fortran. Numerical results of engineering applications will be presented.

We present an adjoint approach for shape optimization in function spaces which is conveniently implementable in that it allows for the use of existing state and adjoint solvers on the current computational domain to obtain exact gradients. This approach is applied to the incompressible instationary Navier-Stokes equations in 2 and 3 space dimensions. Multilevel techniques are realized by using goal-oriented adaptivity w.r.t. to the drag objective functional. Numerical results will be given.

We look upon estimation of the parameters of the single equation multiple linear regression model as an optimization problem and address its solution under the criterion of minimum sum of absolute errors (MSAE). We report a postoptimality analysis that allows evaluation of the sensitivity of the MSAE solution to simultaneous variations in the technical or left-hand side (LHS) coefficients of the linear programming formulation of the MSAE problem.

We examine an approach to the design of complex systems governed by PDEs. Our aim is to compute the warming air temperature as time goes on. The dynamic optimization of a heating and polymerization reaction process for plastic sheet production in a forced-circulated warm air reactor is addressed. The mathematical model is cast as a time dependent Partial Differential Equation system (PDEs). Our aim is to compute the warming air temperature as time function so to drive the plastic sheet temperature to its desired profile as soon as possible while meeting a set of process constraints.
while keeping controlled the accuracy error.

experience, the inexact bundle method allows to skip subproblems solution makes the numerical solution too difficult to deal with. For the particular case of In order to represent accurately uncertainty, many applications of stochastic analysis for this method.

that this method outperforms Monte-Carlo and QMC methods and it remains competitive for two-stage stochastic program. We present a rate of convergence that this method is stochastic when the booking in the primary market is done. There is also an open secondary market for transportation capacity where all players participate including a competitive fringe. This is modelled as a Generalized Nash Equilibrium using a stochastic complementarity problem.

A Benders Decomposition Method for Discretely-Constrained MPEC
Yohsan Shim, University of Maryland, College Park, 1173 Martin Hall, College Park, MD, 20742, United States of America, yshim@umd.edu, Marte Fosdahl, Asger Tomassgard, Steve Gabriel

We present a new variant of Benders method combined with a domain decomposition heuristic to solve discretely-constrained mathematical programs with equilibrium constraints. These bi-level, integer-constrained problems are important for a variety of areas involving infrastructure planning (e.g., energy) although they are computationally challenging. We apply the proposed new method in the natural gas investment decisions under competitive operations and stochastic markets.

Stochastic Optimization G
Contributed Session
Chair: Michael Chen, Post Doctoral Fellow, IBM, TJ Watson Research Center, York Town, NY. vancouver.michael@gmail.com

1 - Monte Carlo Methods for Risk Minimization Problems
Dali Zhang, PhD Student, University of Southampton, School of Mathematics, Southampton, SO17 1BJ, United Kingdom, zhangle@student.soton.ac.uk, Huifu Xu

In the paper we consider a stochastic optimization model where the objective function is the variance of a random function and the constraint function is the expected value. Instead of using popular scenario tree methods, we apply the sample average approximation method to solve it. Under some mild conditions, we show that the statistical estimator of the optimal solution converges at an exponential rate. We apply the proposed model and the method to a portfolio management problem.

2 - Sparse Grid Scenario Generation and its Rate of Convergence
Michael Chen, Post Doctoral Fellow, IBM, TJ Watson Research Center, York Town, NY, United States of America, vancouver.michael@gmail.com, Sanjay Mehrotra

We adapt the sparse grid integration method for scenario generation in stochastic optimization. For problems with sufficient differentiability numerical results show that this method outperforms Monte-Carlo and QMC methods and it remains competitive for two-stage stochastic program. We present a rate of convergence analysis for this method.

3 - An Inexact Bundle Method for Two-stage Stochastic Linear Programming
Welington Oliveira, Federal University of Rio de Janeiro, P.O. Box 68511, Rio de Janeiro, 21941-972, Brazil, wlo@cos.ufrj.br, Claudia Sagastizabal, Susana Scheimberg

In order to represent accurately uncertainty, many applications of stochastic programming consider large scenario trees. However, a large number of scenarios makes the numerical solution too difficult to deal with. For the particular case of two-stage programs, we consider an inexact bundle method applied in a Benders-like decomposition framework. As shown by encouraging numerical experience, the inexact bundle method allows to skip subproblems solution while keeping controlled the accuracy error.

Dike Height Optimization in the Netherlands
Cluster: Nonlinear Mixed Integer Programming
Invited Session
Chair: Kees Roos, Professor, Delft University of Technology. Meckelweg 4, Delft, 2628 CD, Netherlands, c.roos@tudelft.nl

1 - A Numerical Method for the Control of Dike Levels in Continuous Time
Sander van der Pijl, Centrum Wiskunde & Informatica, Science Park 123, Amsterdam, 1098 XG, Netherlands, Sander.van дер.Pijl@cvw.nl

The optimal control of dike heights is a trade-off between the investment costs of dike increases and the expected costs due to flooding. The optimization problem is formulated in continuous time and leads to a so-called Hamilton-Jacobi-Bellman equation. It is a system of second order partial differential equations that need to be solved backward in time. This is achieved by combining a finite-difference ENO spacial discretization with a high-order TVD Runge-Kutta time integration method. As an example, the method is applied to compute the optimum control law for the dike heights of the island of Texel, that will be demonstrated.

2 - Computing Safe Dike Heights at Minimal Costs
Kees Roos, Professor, Delft University of Technology, Meckelweg 4, Delft, 2628 CD, Netherlands, c.roos@tudelft.nl, Dick den Hertog, Guoyong Gu

Safe dike heights are crucial for protecting life in the Netherlands and many other regions of the world. We discuss issues that arise when modeling the probability of floods, the expected damage and measures to prevent floods. Our aim is to minimize the sum of future investing costs and expected damage over a long period (of about 300 years). We present a mathematical optimization model and a dynamic programming model, as well as some computational results.
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Gleacher Center - 208

Nonlinear Programming A
Contributed Session
Chair: Eiji Mizutani, NTUST, 43 Keelung Road, Section 4, Taipei, Taiwan - ROC, eiji@mail.ntust.edu.tw

1 - A Gauss-Newton Approach for Solving Constrained Optimization via Exact Penalty Functions
Ellen H. Fukuda, IME-USP, Rua Diogo Vaz, 370, apt. 111, Sao Paulo, 01527-020, Brazil, ellen.ime@gmail.com, Paulo J. S. Silva, Roberto Andreani

We propose a Gauss-Newton-type method for solving nonlinear programming problems with general constraints. It uses an extension of a continuous differentiable exact penalty function for variational inequalities, introduced recently by Andre and Silva, and based on the incorporation of a multiplier estimate in the classical augmented Lagrangian. With a less restrictive assumption, we prove exactness and convergence results. Preliminary numerical experiments are also presented.

2 - A Non-monotonic Method for Large-scale Non-negative Least Squares
Dongmin Kim, University of Texas at Austin, 1 University Station, C0500 Taylor Hall 2.124, Austin, TX, 78712, United States of America, dmkim@cs.utexas.edu, Suvrit Sra, Inderjit Dhillon

We present a method for large-scale non-negative least squares (NNLS) problem. In many applications in astronomy, chemometrics, medical sciences, and information retrieval non-negativity arise naturally, whereas the ordinary least-squares must be replaced by NNLS. Our method extends an unconstrained algorithm of Barzilai and Borwein to handle non-negativity constraints. In contrast to other methods based on BB, our algorithm does not curtail the non-monotonicity of the underlying BB method. Without line-search the BB method has been previously shown not to converge. However, by exploiting some properties of the NNLS objective and the simple constraints our algorithm is guaranteed to converge, despite the absence of line-search.

3 - Efficient Hessian Evaluations by Stagewise Backpropagation in Nonlinear Least Squares Problems
Eiji Mizutani, NTUST, 43 Keelung Road, Section 4, Taipei, Taiwan - ROC, eiji@mail.ntust.edu.tw, Stuart Dreyfus

We demonstrate a neural-network (NN) stagewise backpropagation procedure to evaluate the Hessian matrix \( H \) of size \( n \times n \) in explicit nonlinear least squares problems. A conventional wisdom is that the difference between the evaluation cost of \( H \) and that of the so-called Gauss-Newton Hessian is \( O(n^{3}) \). In contrast, our stagewise procedure reduces it down to \( O(n) \) and relatively small values of \( n \), whereas the former decreases linearly with the number of time points. If, however, information is available, for example a bound on one of the nonlinearities, it can be sufficient to only compute the Gauss-Newton Hessian.

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Gleacher Center - 300

Large-Scale Nonlinear Optimization
Cluster: Nonlinear Programming
Invited Session
Chair: Jorge Nocedal, Professor, Northwestern University, EECs Dept, Evanston, IL, 60201, United States of America, nocedal@northwestern.edu

1 - On the Use of Piecewise Linear Models in Nonlinear Programming
Yuchen Wu, PhD Student, Northwestern University, 2145 Sheridan Rd., L375, Evanston, IL, 60208, United States of America, yuchen@northwestern.edu

This paper presents an algorithm for large-scale optimization that attempts to combine the best properties of sequential quadratic programming and sequential linear-quadratic programming methods. It consists of two phases. First, the algorithm constructs a piecewise linear approximation of a quadratic model of the Lagrangian and solves a linear programming problem to determine a working set. The second phase of the algorithm solves an equality constrained subproblem whose goal is to accelerate convergence toward the solution. The paper studies the global and local convergence properties of the new algorithm and presents a set of numerical experiments to illustrate its practical performance.
1 - COIN-OR Triennial Update
Robert Fourer, Professor, Northwestern University, Dept. of Industrial Eng & Mgmt Sciences, 2145 Sheridan Road, Evanston, IL, 60208-3119, United States of America, rfourer@northwestern.edu

The Computational Infrastructure for Operations Research (COIN-OR) initiative was launched 9 years ago at ISMP 2000 to facilitate and encourage development of open software for computational math programming and other OR methods. There has since been considerable growth and development of the initiative, now managed by an independent nonprofit foundation. This update describes opportunities to make use of the initiative's tools and suggests ways to become part of the COIN-OR community.

2 - Bigger, Better, Faster: Update on World’s Fastest Open-source MIP Solver
Laszlo Ladanyi, IBM, 1101 Kitchawan Road, Yorktown Heights, NY, 10598, United States of America, ladanyi@us.ibm.com, Robin Lougee-Heimer, John Forrest

COIN-OR Branch and Cut (CbC) is the world’s fastest open-source mixed-integer program solver. New heuristics, a 2x increase in preprocessing speed, and improved dynamic use of cutting planes have helped realize a significant speedup from version 2.0 (2007) to 2.3 (2008), reducing the geometric mean of time for solved problems by 55% and the problems unsolved within the time limit by 75% on the Mittelmann benchmarks. We survey the recent enhancements and ongoing efforts at further improvement.

3 - New CoinMP Release 1.5: A Simple Free C-API Windows DLL and Unix Solver Library (LP/MIP) based on COIN
Bjarni Kristjansson, President, Maximal Software, 2111 Wilson Boulevard, Suite 700, Arlington, VA, 22201, United States of America, bjarni@maximalsoftware.com

The COIN Open Source Initiative has become very popular in the recent years. To make life easier for users that simply want to solve models and not compile C++ applications, we have developed a standard C-API Windows DLL CoinMP:DLL that implements most of the functionality of CLP, CBC, and CGL. A Linux/Unix version using AutoMake is also available. We will also discuss how CoinMP is currently used with MPL, and how it plays a major role in the Free Development and the Free Academic programs for MPL.

4 - FA22

FA22

COIN-OR Open-source Software for Mathematical Programming
Cluster: Implementations, Software
Invited Session
Chair: Robert Fourer, Professor, Northwestern University, Dept. of Industrial Eng & Mgmt Sciences, 2145 Sheridan Road, Evanston, IL, 60208-3119, United States of America, rfourer@northwestern.edu

20th International Symposium on Mathematical Programming

1 - Dual Averaging Methods for Regularized Stochastic Learning and Online Optimization
Lin Xiao, Researcher, Microsoft Research, 1 Microsoft Way, Redmond, WA, 98052, United States of America, lin.xiao@microsoft.com

We consider regularized stochastic learning and online optimization problems, where the objective function is the sum of two convex terms: one is the loss function of the learning task, and the other is a simple regularization term such as l1-norm for sparsity. We develop extensions of Nesterov's dual averaging method that can explicitly exploit the regularization structure in an online setting. The method achieves the optimal convergence rate O(1/sqrt(t)) for general convex regularization, and a faster rate O(log(t)/t) for strongly convex regularization. Computational experiments confirm the effectiveness of the method for l1-regularized online learning.

2 - Rank-Sparsity Incoherence for Matrix Decomposition
Venkata Chandrasekaran, Massachusetts Institute of Technology, 77 Massachusetts Avenue, 32-D570, Cambridge, MA, 02139, United States of America, venkat@mit.edu, Sujay Sanghavi, Pablo A. Parrilo, Alan S. Willsky

Suppose we are given a matrix that is formed by adding an unknown sparse matrix to an unknown low-rank matrix. Our goal is to decompose the given matrix into its sparse and low-rank components. Such a problem arises in a number of applications in model and system identification, but obtaining an exact solution is NP-hard in general. We consider a convex optimization formulation for the decomposition problem. We develop a notion of rank-sparsity incoherence - a condition under which matrices cannot be both sparse and low-rank - to characterize both fundamental identifiability as well as sufficient conditions for exact recovery using our method.

3 - Sparse Linear Combination of Data Classifiers Through Relaxed L0 Regularization
Noam Goldberg, Rutgers University, 640 Bartholomew Rd, Piscataway, United States of America, ngoldberg@rutcor.rutgers.edu, Jonathan Eckstein

We propose a discrete optimization approach to constructing binary classifiers using sparse linear combination of base classifiers. Instead of minimizing the sum of deviations from the margin with respect to a subset of the input data and an l1 penalty, we minimize the number of misclassified points subject to a generalized l0 penalty. We tighten the lP relaxation of the resulting MIP model with novel cutting planes, and approximately solve the model using a column and cut generation algorithm.
three problem both exact and heuristic algorithms will be presented. The number of individuals whose opinion is within a given range is maximized. For model and consider the problem of placing opinions such that after \( r \) turns the extension to obtain efficient algorithms and polynomiality results for some nonlinear problems with simple polyhedral constraints, like nonconvex (standard) OP.

2 - Dual Face Algorithm for Linear Programming

Ping-Qi Pan, Professor, Southeast University, Dept. of Math., Southeast University, Nanjing, 210096, China, panpq@seu.edu.cn

The proposed algorithm proceeds from dual face to dual face, until reaching a dual optimal face along with a pair of dual and primal optimal solutions, compared with the simplex algorithm, which moves from vertex to vertex. In each iteration, it solves a single small triangular system, compared with four triangular systems handled by the simplex algorithm. We report preliminary but favorable computational results with a set of standard Netlib test problems.

3 - The Fundamental Theorem of Linear Programming: Extensions and Applications.

Fabio Tardella, Professor, University of Rome La Sapienza Via del C. Laurenziano, 9, Roma, 00161, Italy, fabio.tardella@uniroma1.it

We describe a common extension of the fundamental theorem of LP and of the Frank-Wolfe theorem for LP problems. We then show that several known and new results providing continuous formulations for discrete optimization problems can be easily derived and generalized with our result. Furthermore, we use our extension to obtain efficient algorithms and polynomiality results for some nonlinear problems with simple polyhedral constraints, like nonconvex (standard) OP.

3 - Fair Assignment of Voting Weights

Nikolas Tautenhahn, Universität Bayreuth, Lehrstuhl für Wirtschaftsmathematik, Bayreuth 93440, Germany, nikolas.tautenhahn@uni-bayreuth.de

Assume we have a board of 50 members who have integral voting weights and a quota \( q_5 \) so that a proposal is accepted if the number of votes in favor of the proposal meets or exceeds \( q_5 \). Finding voting weights which resemble a fair power distribution (e.g., the Shapley-Shubik index) is accomplished by complete enumeration of a superclass of voting games. We characterize these discrete structures and enumerate them.

20th International Symposium on Mathematical Programming

Friday, 2:00pm - 3:30pm

- **FB01**
  Marriott - Chicago A
  **Linear Programming**
  Contributed Session
  Chair: Fabio Tardella, Professor, University of Rome La Sapienza Via del C. Laurenziano, 9, Roma, 00161, Italy, fabio.tardella@uniroma1.it
  
  1 - D-Wolfe Decompositions Putting in the Subproblem the Degenerated Constraints of a Linear Problem
  Francois Soumis, Professor, Polytechnique, 2900 Chemin de la Tour, Montreal, H3C 3A7, Canada, francois.soumis@gerard.ca
  We propose a new Dantzig-Wolfe decomposition based on the improved primal simplex algorithm (IPS). The original problem is partitioned automatically according to its deep algebraic structure rather than by the modeler. Experimental results on some degenerate instances (between 44 and 71\%) show that the proposed algorithms yields computational times that are reduced by an average factor ranging between 3.32 and 13.16 compared to the primal simplex of CPLEX.

  2 - Dual Face Algorithm for Linear Programming
  Ping-Qi Pan, Professor, Southeast University, Dept. of Math., Southeast University, Nanjing, 210096, China, panpq@seu.edu.cn
  The proposed algorithm proceeds from dual face to dual face, until reaching a dual optimal face along with a pair of dual and primal optimal solutions, compared with the simplex algorithm, which moves from vertex to vertex. In each iteration, it solves a single small triangular system, compared with four triangular systems handled by the simplex algorithm. We report preliminary but favorable computational results with a set of standard Netlib test problems.

  3 - The Fundamental Theorem of Linear Programming: Extensions and Applications.
  Fabio Tardella, Professor, University of Rome La Sapienza Via del C. Laurenziano, 9, Roma, 00161, Italy, fabio.tardella@uniroma1.it
  We describe a common extension of the fundamental theorem of LP and of the Frank-Wolfe theorem for LP problems. We then show that several known and new results providing continuous formulations for discrete optimization problems can be easily derived and generalized with our result. Furthermore, we use our extension to obtain efficient algorithms and polynomiality results for some nonlinear problems with simple polyhedral constraints, like nonconvex (standard) OP.

- **FB02**
  Marriott - Chicago B
  **Applications of Discrete Optimization**
  Cluster: Discrete Optimization
  Chair: Nikolas Tautenhahn, Universität Bayreuth, Lehrstuhl für Wirtschaftsmathematik, Bayreuth 93440, Germany, nikolas.tautenhahn@uni-bayreuth.de
  
  1 - Conflict-free University Course Time and Room Scheduling
  Tobias Kreisel, Universität Bayreuth, Lehrstuhl Wirtschaftsmathematik, Universitätstraße 30, 95440 Bayreuth, Bayreuth, Germany, tobias.kreisel@uni-bayreuth.de
  Our goal is a conflict-free schedule with respect to courses of study, i.e. two courses of any course of study must not clash. We approach the problem by means of linear integer programming techniques. To handle the inherently large problem we consider that the level of production of energy is limited by the random level of permitted emission. We describe, under special assumptions, how this problem can be treated computationally. As the first idea, we will study the different convex conservative approximations of the chance constraints defined in second stage of our model, and using Monte Carlo simulation techniques for approximate the expectation function in the first stage by the average.

  2 - Making Wind Power Tradable by Electricity Storage
  Paul Johnson, Research Associate, University of Manchester, Alan Turing Building, Oxford Road, Manchester, M13 9PL, United Kingdom, paul.johnson-2@manchester.ac.uk
  PDEs can model the continuous time dynamics of electricity price, a wind generator’s output and a jointly operated energy store. We derive an optimal rule for the output rate to commit during the next hour, so as to maximize the expected joint NPV of wind power and storage over many operating days. Results can test the viability of storage, and optimise the joint design of the store, the wind generator(s) and their connection to the distribution system.

- **FB03**
  Marriott - Chicago C
  **Models for Electricity Optimization Under Uncertainty**
  Cluster: Optimization in Energy Systems
  Invited Session
  Chair: Nikolas Tautenhahn, Universität Bayreuth, Lehrstuhl für Wirtschaftsmathematik, Bayreuth 93440, Germany, nikolas.tautenhahn@uni-bayreuth.de
  
  1 - Numerical Ideas for Two-stage Stochastic Programs with Chance Constraints
  Paul Bosch, Universidad Diego Portales, Facultad de Ingeniería, Ave. Ejército 441, Santiago, Santiago, Chile, paul.bosch@udp.cl
  Motivated by problems coming from planning and operational management in power generation companies, this work extends the traditional two-stage linear stochastic program by adding probabilistic constraints in the second stage where we consider that the level of production of energy is limited by the random level of permitted emission. We describe, under special assumptions, how this problem can be treated computationally. As the first idea, we will study the different convex conservative approximations of the chance constraints defined in second stage of our model, and using Monte Carlo simulation techniques for approximate the expectation function in the first stage by the average.
2 - Making Wind Power Tradable by Electricity Storage
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FB04
Marriott - Denver
Combinatorial Optimization K
Contributed Session
Chair: Pavlos Eirinakis, PhD Student, Athens University of Economics and Business, Department of Management Science and Technology, 76 Patission Str., Athens, 10434, Greece, peir@aueb.gr
1 - Sequencing and Scheduling in Coil Coating with Shuttlles
Felix Koenig, TU Berlin, Strasse des 17. Juni 136, Berlin, Germany, koenig@math.TU-Berlin.DE, Wiebke Hohn, Marco Luebbecke, Rolf Moehring
Applying combinatorial optimization in real life yields cost savings delighting the industry. Beyond that, at the core of some applications also lies a pretty (sub)problem rejoicing the mathematician. In our application coils of sheet metal are coated with k layers out of hundreds of colors. Coils are stapled together to run through k coaters, and non-productive time occurs e.g. when the color in a coater needs to be changed. Some coaters have two parallel tanks, enabling either parallel colors or cleaning of one tank during production. We present our sequencing and scheduling scheme in use at the plant today, lower bounds proving solution quality, and problems in the edge-wise union of interval graphs as a pretty mathematical subproblem.

2 - On Eulerian Extension Problems and Their Application to Sequencing Problems
Wiebke Hohn, TU Berlin, Strasse des 17. Juni 136, Berlin, 10623, Germany, hoehn@math.TU-Berlin.DE, Tobias Jacobs, Nicole Megow
We introduce a new technique for solving several sequencing problems. We consider the Gilmore-Gomory type Traveling Salesman Problem and two variants of no-wait two-stage flowshop scheduling, the classical makespan minimization problem and a new problem arising in the multistage production process in steel manufacturing. Our technique is based on an intuitive interpretation of sequencing problems as Eulerian Extension Problems. This view reveals new structural insights and leads to elegant and simple algorithms and proofs for this ancient type of problems. As a major effect, we compute not only a single solution; instead, we represent the entire space of optimal solutions.

FB06
Marriott - Kansas City
Conic Programming Approaches to Combinatorial Problems
Cluster: Conic Programming
Invited Session
Chair: Etienne de Klerk, Tilburg University, P.O. Box 90153, Tilburg, 5000 LE, Netherlands, e.deklerk@uvt.nl
1 - Optimizing a Polyhedral-semidefinite Relaxation of Completely Positive Programs
Samuel Burer, University of Iowa, S346 Pappajohn Business Building, Iowa City, IA, 52242-1994, United States of America, Samuel.Burer@uiowa.edu
It has recently been shown that a large class of NP-hard quadratic minimization problems can be modeled as so-called "completely positive programs." A straightforward convex relaxation of this type of program, while theoretically tractable, is still expensive for interior-point methods. In this talk, we propose a decomposition technique to solve the relaxation, which also readily produces lower bounds on the NP-hard objective value. We illustrate effectiveness of the approach for quadratic box-constrained, quadratic assignment, and quadratic multiple knapsack problems. Further, for the box and knapsack cases, we incorporate the lower bounds within an efficient branch-and-bound implementation.

2 - The Difference Between 5 x 5 Doubly Nonnegative and Completely Positive Matrices
Mirjam Dur, University of Groningen, P.O. Box 407, Groningen, 9700 AK, Netherlands, M.E.Dur@rug.nl, Samuel Burer, Kurt Anstreicher
The cone of completely positive (CPP) matrices and its dual cone of copositive matrices arise in several areas of applied mathematics, including optimization. Every CPP matrix is doubly nonnegative (DNN), i.e., positive semidefinite and component-wise nonnegative. Moreover, for n smaller than 5, every DNN matrix is CPP. We investigate the difference between 5 x 5 DNN and CPP matrices. We give a precise characterization of how a 5 x 5 DNN matrix that is not CPP differs from a DNN matrix, and use this characterization to show how to separate an extreme DNN matrix that is not CPP from the cone of CPP matrices.

3 - Conic Programming Formulations of the Traveling Salesman Problem
Etienne de Klerk, Tilburg University, P.O. Box 90153, Tilburg, 5000 LE, Netherlands, e.deklerk@uvt.nl, Dimitri Pasechnik
The traveling salesman problem (TSP) is to find a Hamiltonian cycle of minimum weight in a weighted graph, and is arguably the most famous NP-hard problem in combinatorial optimization. We present a conic programming reformulation of TSP by describing the convex hulls of association schemes, and applying the result to the association scheme of a Hamiltonian cycle (the so-called Lee scheme). The conic programming reformulation of TSP is related to the copositive programming reformulation of the more general quadratic assignment problem from: [Janz Povh, Franz Rendl: Copositive and Semidefinite Relaxations of the Quadratic Assignment Problem, to appear in Discrete Optimization, 2009].
that performs well is introduced. The conventional wisdom about branching up is examined, and a new method is presented.

The branching direction heuristic used in a MIP solver has a significant impact on the quality of the solution. Discrimination is very important in the science. It is approached from the statistics and mathematical programming such as SVM. Several discriminant models are developed by IP and LP. Especially, IP-OLDF based on minimum classification number criterion reveals new surprised facts about discrimination. It is evaluated by training data (four kinds of data sets) and evaluation data (100 sets of re-sampling data). LINGO models prove its robustness (generalization ability).

2 - On the Polyhedral Properties of a Discrete-time MIP Formulation for Production Planning

Konstantinos Papalamprou, PhD Student, London School of Economics and Political Science, Operational Research Group, London School of Economics, Houghton Str., London, WC2A 2AE, United Kingdom, k.papalamprou@lse.ac.uk, Christos Maravelias

We study the properties of the polyhedron defined by the constraints of a discrete-time mixed integer programming formulation for the production planning of chemical processes. This formulation is decomposed into two subproblems and polyhedral results regarding their linear programming relaxations are provided. Furthermore, we show how extensions of total unimodularity can be used. We are mainly concerned with k-regularity and we show how this property can be used in order to address large scale production planning problems. We are also focused on presenting special cases of this problem for which combinatorial algorithms can be applied.

3 - Single-machine Scheduling over Long Time Horizons by Logic-based Benders Decomposition

Elvin Coban, Carnegie Mellon University, 5000 Forbes Avenue, Tepper School of Business, Pittsburgh, PA, 15213, United States of America, ecoban@andrew.cmu.edu, John Hooker

We use logic-based Benders decomposition to minimize tardiness in single-facility scheduling problems with many jobs and long time horizons. Release dates and due dates are given. An MILP-based master problem allocates jobs to segments of the time horizon, and a constraint programming-based subproblem schedules the jobs in each segment. Computational results are reported on the success of decomposition for scaling up exact solution methods for problems of this kind.

2 - An Extended Formulation for the Traveling Salesman Problem with Time Windows

Andrea Tramontani, DEIS, University of Bologna, Viale Risorgimento, 2, Bologna, 40136, Italy, andrea.tramontani@unibo.it, Sanjeeb Dash, Oktay Gunluk, Andrea Lodi

The Traveling Salesman Problem with Time Windows (TSPTW) is a well known generalization of the classical TSP where each node must be visited within a given time window. We present an extended integer linear programming formulation for TSPTW, based on a relaxed discretization of time windows. The proposed formulation yields strong lower bounds and leads to strong valid inequalities that can be efficiently separated within a classical branch-and-cut framework. The resulting branch-and-cut algorithm is tested on hard benchmark instances from the literature. The results show that the proposed formulation is effective in practice for tackling TSPTW. Interestingly, several unsolved benchmark instances are here solved for the first time.

3 - Computational Results on the Cunningham-Geelen Algorithm for Solving Integer Programs

Susan Margulies, Pfeiffer-VIGRE Post-doctoral Instructor, Rice University, Dept. of Computational and Applied Math, 6100 Main P.O. Box 1892, Houston, TX, 77251, United States of America, susan.margulies@rice.edu, Illya Hicks, Jing Ma

Consider the integer program max(∑Tx: Ax = b, x ≥ 0,) where A is non-negative and the column-matroid of A (denoted by M(A)) has constant branch width. Cunningham and Geelen introduce a pseudo-polynomial time algorithm for solving this integer program that takes a branch decomposition T of M(A) as input. We describe a heuristic for finding T and report on computational results of a C++ implementation of this algorithm, where the input branch decomposition T is produced by this heuristic.

3 - Trends in Mixed Integer Programming IX

Cluster: Integer and Mixed Integer Programming Invited Session

Chair: Andrea Lodi, DEIS, University of Bologna, Viale Risorgimento, 2, Bologna, 40136, Italy, andrea.lodi@unibo.it

Co-Chair: Robert Weismantel, Professor, Otto-von-Guericke University Magdeburg, Institute for Mathematical Optimization, Universitatsplatz 2, Magdeburg, 39106, Germany, weismant@math.uni-magdeburg.de

1 - A Study of MIP Branching Direction Heuristics

John Chinneck, Professor, Carleton University, Systems and Computer Engineering, 1125 Colonel By Drive, Ottawa, ON, K1S 5B6, Canada, chinneck@se.can.carleton.ca, Jennifer Pryor

The branching direction heuristic used in a MIP solver has a significant impact on the solution speed. We report on an extensive empirical study of branching direction selection heuristics used in reaching the first integer-feasible solution. The conventional wisdom about branching up is examined, and a new method that performs well is introduced.
FB10
Marriott - Chicago G
Black-box Optimization of Expensive Functions with Many Variables and Many Nonlinear Constraints
Cluster: Global Optimization
Invited Session
Chair: Don Jones, General Motors, 3023 Sylvan Drive, Royal Oak, MI, 48073, don.jones@gm.com
1 - Radial Basis Function Algorithms for Large-scale Nonlinearly Constrained Black-box Optimization
Rommel Regis, Assistant Professor, Saint Joseph’s University, Mathematics Department, 5600 City Avenue, Philadelphia, PA, 19131, United States of America, rregis@sju.edu
We develop derivative-free optimization algorithms that are suited for expensive black-box objective functions with many variables and many nonlinear black-box constraints. Our algorithms utilize radial basis function models to approximate the objective function and the black-box constraints and to identify promising function evaluation points for subsequent iterations. We present some numerical results on a black-box optimization problem in the automotive industry.

2 - Implementation of a One-stage EGO Algorithm
Nils-Hassan Quittineh, PhD Student, Mälardalen University, U3-269, Högskoleplan 1, Rosenhill, Västerås, 721 23, Sweden, nisse.quittineh@mdh.se, Kenneth Holmström
The original EGO algorithm finds a new point to sample in a two-stage process. First, the interpolation parameters are optimized with respect to already sampled points, then in a second step these estimated values are considered true in order to optimize the location of the new point. The use of estimated values introduces a source of error. Instead, in the One-Stage EGO algorithm, both parameter values and the location of a new point are optimized at once, removing the source of error. The new subproblem becomes more difficult, but eliminates the need of solving two subproblems. Difficulties in implementing a fast and robust One-Stage EGO algorithm in TOMLAB are discussed, especially the solution of the new subproblem.

3 - Enhancements to the Expected Improvement Criterion
Alexander Forrester, Lecturer, University of Southampton, School of Engineering Sciences, University Road, Southampton, SO17 1BJ, United Kingdom, Alexander.Forrester@soton.ac.uk, Don Jones
Optimization methods relying on kriging surrogate models often use the “expected improvement” criterion. Unfortunately, with sparse sampling (few points in many dimensions), the prediction error in the kriging models may be severely underestimated, resulting in an excessively local search. A modification of the standard method is presented which avoids the underestimation of error and thereby ensures bias towards global search.

FB11
Marriott - Chicago H
Robust Optimization B
Contributed Session
Chair: Jeff Linderoth, Associate Professor, University of Wisconsin-Madison, 1513 University Avenue, Madison, WI, 53706, United States of America, linderoth@cae.wisc.edu
1 - Design Optimization Under Uncertainty Using Clouds
Martin Fuchs, CERFACS, 42 avenue Gaspard Coriolis, Toulouse, F-31057, France, martin.fuchs81@gmail.com
Bilevel design optimization problems with nonlinear black box objective functions constrained by mixed integer design choices arise naturally in uncertain real-world models. We represent uncertainties by a polyhedral cloud in many dimensions), the prediction error in the kriging models may be severely underestimated, resulting in an excessively local search. A modification of the standard method is presented which avoids the underestimation of error and thereby ensures bias towards global search.

2 - Robustness in Multi-objective Optimization Based on a User Perspective
Peter Lindroth, Chalmers University of Technology / Volvo 3P, Chalmers Tvargata 3, Gothenburg, SE-41296, Sweden, peter.lindroth@chalmers.se, Christoffer Cronvik
The question of robustness is essential for practical problems that are sensitive to small perturbations in the variables or the model parameters. We present a new definition of robustness of solutions to multi-objective optimization problems. The definition is based on an approximation of the underlying utility function for each decision maker. We show an efficient computational procedure to evaluate robustness, and we present numerical results for real-world problems.
1 - On Techniques to Solve Perfect Information Stochastic Games

G Ravindran, Head, SQC and OR Unit, Indian Statistical Institute Chennai Centre, Old No.110, New No.37, I Floor, Nelson Manickam Road, Aminjikarai, Chennai, TN, 600029, India, gravi@hotmail.com

We discuss techniques to solve 2-player, Perfect Information Stochastic Games and some subclasses. We look at solving these games through Linear Complementarity Problem (LCP) formulations and Vertical LCP formulations. We also discuss feasibility of solving different Linear Programs (LP) simultaneously.

2 - On the Structure of Simple Stochastic Games and Algorithms to Solve Them

Nagarajan Krishnamurthy, PhD Student, Chennai Mathematical Institute, Plot H1, SIPCOT IT Park., Padur PO, Siruseri, Kancheepuram District, TN, 603103, India, naga.research@gmail.com, T Parthasarathy, G Ravindran

We study the structure of Simple Stochastic Games (SSG) and propose new Linear Complementarity Problem (LCP) formulations. We analyze the structure of the underlying matrices in these formulations and discuss feasibility of solving them. We also discuss polynomial time algorithms to solve some subclasses of SSGs.

Stochastic Optimization H

2 - Stochastic Semidefinite Programming under Uncertainty

Yuntao Zhu, Assistant Professor, Arizona State University, P.O. Box 37100, Phoenix, AZ, 85069-7100, United States of America, yuntao.zhu@asu.edu

In this talk we introduce a new stochastic optimization paradigm termed Stochastic Semidefinite Programming (SSDP). The formulation of SSDP is stressed as well as applications and solving algorithms.

1 - Colorful Carathéodory Selections from Convex Hulls of Unions & Sumsets, for Variational Analysis

James E. Blevins, Uppsala University, Statistics Department (Ekonomikum), Box 513, Uppsala, 751 20, Sweden, James.Blevins@statistik.uu.se

Carathéodory's lemma was generalized for unions and sum sets/subdifferentials, epigraphs and levelsets/concern variational analysis, nonsmooth optimization & stochastic programming.

Models for Designing Trees with Node Dependent Costs

Pedro Moura, DEIO - CIO, Faculdade de Ciencias da Universidade de Lisboa, Campo Grande, Bloco C6 - Piso 4, Lisbon, 1749-016, Portugal, pmoura@fc.ul.pt, Luis Gouveia

We discuss models for a variant of the classical Minimum Spanning Tree Problem and the Prize-Collecting Steiner Tree Problem where, besides the traditional costs/prizes in the objective function we include a concave modular cost function which depends on the degree value of each node in the solution. Computational results taken from instances with up to 100 nodes will be presented.

An Exact Solution Approach for the Maximum Multicommodity K-splittable Flow Problem

Mette Gamst, PhD Student, Technical University of Denmark, Productionstovret, Building 426, Room 58, Kgs. Lyngby, 2800, Denmark, gamst@man.dtu.dk

This talk concerns the NP-hard Maximum Multicommodity k-splittable Flow Problem (MMkFP) in which each commodity may use at most k paths between its origin and its destination. A new branch-and-cut-and-price algorithm is presented. The master problem is a two-index formulation of the MMkFP and the pricing problem is the shortest path problem with forbidden paths. A new branching strategy forcing and forbidding the use of certain paths is developed. The new branch-and-cut-and-price algorithm is computationally evaluated and compared to results from the literature. The new algorithm shows very promising performance by outperforming existing algorithms for several instances.
1 - Hybrid Algorithms for Unconstrained Optimization Problems
Darin Mohr, University of Iowa, 15 MacLean Hall, Iowa City, IA, 52242-1419, United States of America, dgmohr@math.uiowa.edu

Quasi-Newton algorithms are widely used in unconstrained optimization while Runge-Kutta methods are widely used for the numerical integration of ODEs. In this work we consider hybrid algorithms combining low order implicit Runge-Kutta methods for gradient systems and quasi-Newton type updates of the Jacobian matrix such as the BFGS update.

20th International Symposium on Mathematical Programming
1 - Exact Finite Approximations of Average-cost Countable Markov Decision Processes
Arie Leizarowitz, Professor, Technion-Israel Institute of Technology, Department of Mathematics, Israel, la@techunix.technion.ac.il, Adam Shwartz
We introduce an embedding of a countable Markov decision process which produces a finite Markov decision process. The embedded process has the same optimal cost, and shares dynamics of the original process within the approximating set. The embedded process can be used as an approximation which, being finite, is more convenient for computation and implementation.

2 - A Proximal Point Method in Nonreflexive Banach Spaces
Elena Resmerita, Johannes Kepler University, Institute of Industrial Mathematics, Linz, 4040, Austria, elena.resmerita@jku.at, Alfredo Iusem
We propose an inexact version of the proximal point method and study its properties in nonreflexive Banach spaces, both for the problem of minimizing convex functions and of finding zeroes of maximal monotone operators. Using surjectivity results for enlargements of maximal monotone operators, we prove existence of the iterates in both cases. Then we recover most of the convergence properties known to hold in reflexive and smooth Banach spaces for the convex optimization problem.

3 - Version of the Second Welfare Theorem for Welfare Economies with Public Goods
Aychiluhim Habte, Benedict College, 1600 Harden Street, Columbia, United States of America, habtea@benedict.edu, Boris Mordukhovich
In this paper we have considered nonconvex infinite dimensional welfare economic model with public goods and obtained necessary optimality conditions, a version of the second welfare theorem, in both approximate and exact forms. The approximate forms are expressed in terms of FaàsCEOeget normal cone and the exact forms are expressed in terms of the basic normal cones. Our main tool from variational analysis is the so called extremalprinciple.