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Contents

Convex relaxation of hybrid discrete-continuous control problems	6
<i>Christian Clason</i>	
On dynamic discrete tomography: Constrained flow and multi assignment problems for plasma particle tracking	7
<i>Peter Gritzmann</i>	
Mathematical Programming and Machine Learning	8
<i>Laura Palagi</i>	
PDE constrained Mixed-Integer Optimal Control	9
<i>Sebastian Sager</i>	
EXPEDIS: Solving Constrained Binary Quadratic Problems via Max-Cut	10
<i>Angelika Wiegele</i>	
Mixed E-duality for E-differentiable vector optimization problems under (generalized) V-E-invexity	11
<i>Najeeb Abdulaleem</i>	
The Flexible Γ-Approach for Robust Nonlinear Discrete and Combinatorial Optimization	12
<i>Dennis Adelhütte</i>	
Efficient and Design-Rule Aware Detailed Routing in VLSI-Design	13
<i>Markus Ahrens</i>	
Using Frank-Wolfe as a Relaxation-Guided Solver for a Class of Robust Combinatorial Problems with an Ellipsoidal Uncertainty Set	14
<i>Chifaa Al Dahik</i>	
On the Circumcentered-Reflection Method for the Convex Feasibility Problem	15
<i>Roger Behling</i>	
Matrix generation algorithms for binary quadratically constrained quadratic problems	16
<i>Enrico Bettiol</i>	
A New Modeling Framework Aligning Different Concepts of Optimization under Uncertainty Applied to Lot Sizing	17
<i>Viktor Bindewald</i>	
Scalable generalized median graph estimation and applications in computational biology	18
<i>David B. Blumenthal</i>	
Optimization over the Efficient Set bi-objective knapsack problem	19
<i>Djamal Chaabane</i>	

Discrete optimization of the sum of ratios	20
<i>Yacine Chaiblaïne</i>	
A Branch-and-Price Algorithm for the Maximum Weight Perfect Matching Problem with Conflict Constraints	21
<i>Alim Buğra Çınar</i>	
Cutting-plane algorithm for robust bi-objective optimization	22
<i>Fabian Chlumsky-Harttmann</i>	
Robust optimization for clustering of big data sets	23
<i>Carina Moreira Costa</i>	
Deep Infeasibility Exploration Method for Vehicle Routing Problems	24
<i>Piotr Cybula</i>	
Global Interconnect Optimization	25
<i>Siad Daboul</i>	
A Mixed-Integer Programming Approach for the T-Row and Multi-Bay Facility Layout Problem with three bays	26
<i>Mirko Dahlbeck</i>	
The Unit Re-balancing Problem	27
<i>Robin Dee</i>	
Improving ADMMs for Solving Doubly Nonnegative Programs through Dual Factorization	28
<i>Marianna De Santis</i>	
Multiobjective Mixed Integer Convex Optimization by a Decision Space Branch-and-Bound	29
<i>Gabriele Eichfelder</i>	
Semidefinite Programming Approach to Optimal Power Flow with FACTS Devices	30
<i>Bartosz Filipecki</i>	
Critical multipliers and how they can be avoided numerically	31
<i>Andreas Fischer</i>	
Mission and Path Planning for Unmanned Aerial Vehicles	32
<i>Armin Fügenschuh</i>	
A continuation method for multiobjective optimization problems with inexact objective gradients	33
<i>Bennet Gebken</i>	
Extending the Robust (Relative) Regret Approach to a Multicriteria Setting	34
<i>Patrick Groetzner</i>	

Computing minimal elements of finite families of sets w. r. t. preorder relations in set optimization	35
<i>Christian Günther</i>	
Optimization over Integer Efficient Set by Decomposition of Criteria Cone	37
<i>Sarah Hamadou</i>	
New neighbourhood generation strategy for BOSCP	39
<i>Imane Hamidi</i>	
Preconditioned Conjugate Gradients in Interior Point Methods for the Bundle Subproblem	40
<i>Christoph Helmberg</i>	
The bilevel continuous knapsack problem with uncertain follower's objective	41
<i>Dorothee Henke</i>	
Faster Linear-Size Adder Circuits	42
<i>Anna Hermann</i>	
ARRIVAL: A Zero-Player Reachability Switching Game	43
<i>Hung Hoang</i>	
Stochastic demands in single allocation hub location	44
<i>Nicolas Kämmerling</i>	
On optimizing a quadratic function over the efficient set	45
<i>Sarah Kentache</i>	
Min-max-min Robust Combinatorial Optimization under Budgeted Uncertainty	46
<i>Jannis Kurtz</i>	
Engineering Fused Lasso Solvers on Trees	47
<i>Elias Kuthe</i>	
On nondegenerate M-stationary points for mathematical programs with sparsity constraint	48
<i>Sebastian Lämmel</i>	
Computing Convex Hulls of Trajectories	49
<i>Andreas Löhne</i>	
Compact Linearization for Binary Quadratic Programs	50
<i>Sven Mallach</i>	
Computing Global Solutions of the Least-Squares Spline Approximation Problem with Free Knots	51
<i>Robert Mohr</i>	
Multiobjective Optimal Control of a Non-Smooth Semi-Linear Elliptic PDE	52
<i>Georg Müller</i>	

Inner Parallel Cuts for Mixed-Integer Convex Optimization	53
<i>Christoph Neumann</i>	
Optimizing operational kitting efforts by a scheduling MILP	54
<i>Frederik Ostermeier</i>	
Homotopy continuation for piecewise linear systems	55
<i>Manuel Radons</i>	
Solving set optimization problems using multiobjective subproblems	56
<i>Stefan Rocktäschel</i>	
Temperature-Based Trajectory Optimization for Wire-Arc Additive Manufacturing	57
<i>Johannes Schmidt</i>	
Haplotype Threading: Accurate Polyploid Phasing from Long Reads	58
<i>Sven Schrinner</i>	
A general branch-and-bound framework for global multiobjective optimization	59
<i>Oliver Stein</i>	
Non-Smooth Optimization: Abs-Normal NLPs versus MPECs	60
<i>Marc C. Steinbach</i>	
A Meet and Regret heuristic for the dynamic vehicle synchronization problem with soft time windows	61
<i>Belma Turan</i>	
A New Proximity Measure Based on KKT Conditions for Multiobjective Optimization Problems	62
<i>Leo Warnow</i>	
Efficient computation of the Wasserstein-∞ metric for distributions with finite support	63
<i>Ralf Werner</i>	
On an assignment problem for multi-way bucketed Cuckoo hash tables on genome-scale data	64
<i>Jens Zentgraf</i>	

EXPEDIS: Solving Constrained Binary Quadratic Problems via Max-Cut

Angelika Wiegele

Alpen-Adria-Universität Klagenfurt, Universitätsstraße 65–67, 9020 Klagenfurt, Austria.

Email: angelika.wiegele@aau.at

We address the problem of minimizing a quadratic function subject to linear constraints over binary variables. We introduce the exact solution method called **EXPEDIS** where the constrained problem is transformed into a max-cut instance, and then the whole machinery available for max-cut can be used to solve the transformed problem. We derive the theory in order to find a transformation in the spirit of an exact penalty method; however, we are only interested in exactness over the set of binary variables. In order to compute the maximum cut we use the solver BiqMac. Numerical results show that this algorithm can be successfully applied on various classes of problems.

Joint work with: Nicolò Gusmeroli

Optimization Areas:

- Conic Optimization
- Convex Optimization
- Discrete and Combinatorial Optimization

Mixed E -duality for E -differentiable vector optimization problems under (generalized) V - E -invexity

Najeeb Abdulaleem

Department of Mathematics, Hadhramout University
P.O. BOX : (50511-50512), Al-Mahrah, Yemen.
Faculty of Mathematics and Computer Science, University of Łódź
Banacha 22, 90-238 Łódź, Poland.
Email: nabbas985@gmail.com

In this paper, a class of E -differentiable vector optimization problems with both inequality and equality constraints is considered. The so-called vector mixed E -dual problem is defined for the considered E -differentiable vector optimization problem with both inequality and equality constraints. Then, several mixed E -duality theorems are established under (generalized) V - E -invexity hypotheses.

KEY WORDS: E -differentiable function; V - E -invex function; Generalized convexity; Mixed E -duality.

AMS Classification: 90C26, 90C30, 90C46.

Optimization Areas:

- Multiobjective Programming
- Nonlinear Programming

The Flexible Γ -Approach for Robust Nonlinear Discrete and Combinatorial Optimization

Dennis Adelhütte

Friedrich-Alexander-Universität Erlangen-Nuremberg, Department Mathematik
Cauerstraße 11
91058 Erlangen.

Email: dennis.adelhueette@fau.de

In this talk, we study the flexible Γ -approach that was first introduced by Bertsimas and Sim in [1] for robust mixed-integer linear optimization problems under uncertainty. This approach is flexible with respect to the level of conservatism. It is often used for combinatorial optimization problems with uncorrelated interval uncertainty. Let an objective function $c^T x$ with $c = (c_i)_{i=1,\dots,m}$ and uncertain coefficients residing in intervals be given. One chooses an integral parameter $\Gamma \in \{0, 1, \dots, m\}$ that regulates the level of conservatism. Algorithmically tractable equivalent reformulations are derived that determine optimum solutions which are robust against at most Γ many coefficients that attain their worst-case uncertainty realization. We generalize this approach to non-linear (discrete and combinatorial) optimization problems under uncorrelated uncertainty and derive algorithmically tractable reformulations. If the objective function is a sum of m functions under uncorrelated uncertainty, one aims to find solutions which are robust against $\Gamma \in \{0, 1, \dots, m\}$ functions deviating from their nominal value. Thereby, we consider two cases, namely concavity (and especially linearity) and non-concavity of the functions in the uncertainty. In order to derive equivalent optimization problems with a finite number of constraints, we apply re-formulation techniques that were introduced in [2] and explicitly formulate robust counterparts for some nonlinear combinatorial problems.

As an example, we derive an algorithmically tractable counterpart for simple piecewise linear functions which are convex (but not concave) in the uncertainty. Finally, we demonstrate that the computational complexity of the given robust counterparts depends on the geometry of the uncertainty, the structure of the feasible set and that of the nominal objective function.

Joint work with: Jana Dienstbier, Frauke Liers

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Optimization Areas:

- Application of Optimization in Real-World Problems
- Discrete and Combinatorial Optimization
- Mixed-Integer Non-Linear Optimization
- Robust Optimization

Efficient and Design-Rule Aware Detailed Routing in VLSI-Design

Markus Ahrens

Research Institute for Discrete Mathematics, University of Bonn

Lennéstr. 2

53113 Bonn

Germany.

Email: ahrens@dm.uni-bonn.de

In VLSI-routing, we need to pack millions of vertex-disjoint Steiner trees into a graph with billions of vertices, while respecting a set of complicated design rules. Routing is solved in two or more stages: Global routing computes an approximate layout for each Steiner tree, solving the global packing problem while ignoring local constraints. We consider detailed routing which computes the actual layout based on the global routing solution. Since detailed routing requires very fast algorithms, the Steiner trees are usually built out of paths.

We present our design-rule aware path search framework that is based on an efficient implementation of Dijkstra's algorithm and demonstrate its effectiveness on real-world instances. Our implementation of this algorithm is part of BonnRoute, a routing solution developed at the University of Bonn in joint work with IBM that was used for the design of hundreds of chips, e.g. the CPU in Summit, the currently fastest supercomputer. An earlier version of the path search is described in [1].

Moreover, we propose to compute each Steiner tree with a single call of a modified version of the Dijkstra-Steiner algorithm [2] (a goal-oriented version of the Dreyfus-Wagner algorithm [3]). We modify the algorithm to find Steiner trees that are similar to the global routing solution in terms of topology and approximate location of Steiner points, thereby recovering electrical and packing properties optimized in global routing. Moreover, the restrictions speed up the algorithm in theory and in practice.

Joint work with: Stefan Rabenstein

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Optimization Areas:

- Application of Optimization in Real-World Problems
- Discrete and Combinatorial Optimization

Using Frank-Wolfe as a Relaxation-Guided Solver for a Class of Robust Combinatorial Problems with an Ellipsoidal Uncertainty Set

Chifaa Al Dahik

FEMTO-ST institute, Univ. Bourgogne Franche-Comté, CNRS, ENSMM, Besançon, France.

Email: chifaa.dahik@femto-st.fr

This work addresses a specific class of combinatorial problems with correlated cost coefficients belonging to an ellipsoidal uncertainty set. An absolute robust problem in these settings is a well-known NP-Hard problem [1]. To tackle this problem, we propose a heuristic approach based on the Frank-Wolfe (FW) algorithm [2]. In our approach, we take a radically different perspective on FW by looking at the exploration power of the integer inner iterates of the method. Experimental tests have been realized for the robust shortest path problem as a first test case to discover the behavior of our approach. Comparisons with the optimal solution given by the mixed integer second order cone programming [3] solver of CPLEX have also been provided. Our main discovery is that, for small dimensional instances, our algorithm is able to provide the same optimal integer solution as CPLEX, after no more than a few hundred iterations. Moreover, as opposed to CPLEX, our FW-guided integer exploration approach applies to large scale problems as well, such as graphs with thousands of edges (i.e. big grid graphs, Barcelona graph and Berlin-Mitte-Center graph). Our findings are illustrated by comprehensive numerical experiments.

Joint work with: Zeina Al Masry, Stéphane Chrétien, Jean-Marc Nicod, and Landy Rabehasaina

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Optimization Areas:

- Application of Optimization in Real-World Problems
- Mixed-Integer Non-Linear Optimization
- Robust Optimization