UNIVERSITY OF WATERLOO, FACULTY OF MATHEMATICS
THE FIELDS INSTITUTE FOR RESEARCH IN MATHEMATICAL SCIENCES

Workshop on:

Novel Approaches to Hard Discrete Optimization

April 26 - 28, 2001

Sponsors:
University of Waterloo, Faculty of Mathematics,
The Fields Institute,
CRM, Centre de Recherches Mathematiques,
PIMS, Pacific Institute for the Mathematical Sciences

Organizing Committee: Kurt Anstreicher
Panos Pardalos
Franz Rendl
Tony Vannelli
Henry Wolkowicz

Staff Coordinator: Frances Hannigan (Waterloo)

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1 Novel Approaches to Hard Discrete Optimization

1.1 Schedule

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WEDNESDAY, April 25, 2001

6:00–10:00 pm	REGISTRATION and RECEPTION at University of Waterloo, Davis Center, Room DC 1301

THURSDAY, April 26, 2001

7:15–8:10 am	Breakfast in DC 1301
8:10–8:20 am	Opening Remarks
8:20–8:30 am	Welcome from Mary Thompson, Dean of Faculty of Mathematics
PLENARY Session R.1	Chairman: William Cunningham Chair of Dept. of Combinatorics & Optimization
8:30–9:20 am	William Cook, *Rice University* *Parallel Search in the Travelling Salesman Problem*
9:30–10:20 am	William Hager *University of Florida* *LP Dual Active Set Algorithm*
10:20–10:45 am	Coffee Break in Room DC 1301
Session R.2	Chairman: Kurt Anstreicher
10:45–11:10 am	Kurt Anstreicher, *University of Iowa* *Solving Quadratic Assignment Problems Using Convex Quadratic Programming Relaxations*
11:15–11:40 am	Jonathan Eckstein, *Rutgers University* *PICO: a massively parallel branch-and-bound toolbox*
11:45–12:10 pm	Catherine Roucairol, *University of Versailles* *Revisiting lower bounds based on linear formulations in the exact solution of the QAP*
12:10–2:00 pm	Lunch in DC 1301

PLENARY Session R.3	Chairman: Panos Pardalos
2:00–2:50 pm	Mauricio Resende, *AT&T Labs Research* *GRASP with path relinking for the three-index assignment problem*
3:00–3:50 pm	Francisco Barahona, *IBM* *Branch and Cut based on the Volume Algorithm*
3:50–4:45 pm	Coffee Break in Room DC 1301
Session R.4	Chairman: Miguel Anjos
4:45–5:10 pm	Miguel F. Anjos, *University of Waterloo* *Properties of a New Semidefinite Relaxation for the Max-Cut Problem*
5:15–5:40 pm	Jean B. Lasserre, *University of Toulouse* *SDP versus linear relaxations for polynomial programming*
FRIDAY, April 27, 2001	
7:30–8:30 am	Breakfast in DC 1301
PLENARY Session F.1	Chairman: Tony Vannelli
8:30–9:20 am	Farid Alizadeh, *Rutgers University* *Symmetric cones, Jordan algebras and polynomial time interior point algorithms*
9:30–10:20 am	Levent Tunçel, *University of Waterloo* *Successive convex relaxation methods for discrete optimization: convergence theory and consequences for approximation*
10:20–10:45 am	Coffee Break in Room DC 1301
Session F.2	Chairman: Yin Zhang
10:45–11:10 am	Sam Burer, *Georgia Tech* *Maximum Stable Set Formulations and Heuristics Based on Continuous Optimization*
11:15–11:40 am	Yin Zhang, *Rice University* *Rank-Two Relaxation Heuristics for Max-Cut and Other Binary Quadratic Programs*

11:45–12:10 pm	Sergiy Butenko, *University of Florida* *Finding Independent Sets in a Graph Using Continuous Multivariable Polynomial Formulations*
12:10–2:00 pm	Lunch in DC 1301
PLENARY Session F.3	Chairman: Henry Wolkowicz
2:00–2:50 pm	C. Johnson, *College of William and Mary* *Physics, Bad Two-Letter Words, Symmetric Word Equations and Funny Completions*
3:00–3:50 pm	Jon Lee, *IBM* *Binary encoding in integer programming*
3:50–4:45 pm	Coffee Break in Room DC 1301
Session F.4	Chairman: Franz Rendl

Special Session on: Bundle Methods & Lagrangian Duality

4:45–5:45 pm	Gerald Gruber, *Universität Klagenfurt*
Title I	*Solving hard optimization problems with linear inequality constraints using bundle methods*
	Ilse Fischer, *Universität Klagenfurt*
Title II	*Solving hard optimization problems with linear inequality constraints using bundle methods*
	Renata Sotirov, *Universität Klagenfurt*
Title III	*Solving QAP using bundle methods*
7:00 pm – on	Banquet at the Laurel Room in South Campus Hall

SATURDAY, April 27, 2001

7:30–8:30 am	Breakfast in DC 1301
PLENARY Session S.1	Chairman: Francisco Barahona
8:30–9:20 am	Ding-Zhu Du, *University of Minnesota* *Approximations for Steiner Trees in Industry*
9:20–10:20 am	Christoph Helmberg, *Konrad-Zuse-Zentrum für Informationstechnik* *Some Applications of Graph Partitioning*
10:20–11:15 am	Coffee Break in Room DC 1301

Session S.2	Chairman: Kees Roos
11:15–11:40 am	Ismael de Farias, Jr., *SUNY at Buffalo* *A Polyhedral Study of the Cardinality Constrained Knapsack Problem*
11:45–12:10 pm	Kees Roos, *TU Delft/University of Leiden* *Maximization of a quadratic form over the intersection of ellipsoids with common center*
12:10–2:00 pm	Lunch in DC 1301
Session S.3	Chairman: Jean-Louis Goffin
2:00–2:25 pm	Ted Ralphs, *Lehigh University* *Implementing Branch, Cut, and Price Algorithms*
2:30–2:55 pm	Faranak Mokhtarian, *Concordia University* *Convex Feasibility Problem with Constraints Given by a Nonlinear Separation Oracle*
3:00–3:25 pm	Arnold Neumaier, *Universität Wien* *Semidefinite constraints related to finite geometry*
3:30–3:55 pm	Jean-Louis Goffin, *McGill University* *Analytic centers methods and mixed integer programming*
4:00–4:25 pm	Coffee Break in DC 1301
Session S.4	Chairman: William Cook
4:25–4:50 pm	Tamon Stephen, *University of Michigan* *On the distribution of values of the QAP*
4:55–5:20 pm	Dorothy Kucar, *University of Waterloo* *A Novel Eigenvector Technique for VLSI Circuit Layout*

Workshop ends

1.2 List of Invited Plenary Speakers

F. Alizadeh	Rutcor Rutgers University, alizadeh@rutcor.rutgers.edu
F. Barahona	IBM fbarahona@watson.ibm.com
W. Cook	Rice University bico@rice.edu
Ding-Zhu Du	University of Minnesota dzd@cs.umn.edu
W. Hager	Florida Gainsville, hager@math.ufl.edu
C. Helmberg	Konrad-Zuse-Zentrum für Informationstechnik helmberg@zib.de
C. Johnson	William and Mary crjohnso@math.wm.edu
J. Lee	IBM Research jonlee@us.ibm.com
M.G.C. Resende	AT&T Bell Labs mgcr@research.att.com
L. Tunçel	University of Waterloo ltuncel@uwaterloo.ca

1.3 List of Sessional Speakers

Miguel F. Anjos	University of Waterloo
Kurt Anstreicher	The University of Iowa
Sam Burer	Georgia Institute of Technology
Sergiy Butenko	University of Florida
Jonathan Eckstein	Rugers University
Ismael de Farias, Jr.	State University of New York at Buffalo
Ilse Fischer	Universität Klagenfurt
Jean-Louis Goffin	McGill University
Gerald Gruber	Universität Klagenfurt
Dorothy Kucar	University of Waterloo
Jean B. Lasserre	University Toulouse
Faranak Mokhtarian	Concordia University
Arnold Neumaier	Universität Wien
Ted Ralphs	Lehigh University
Kees Roos	TU Delft/University of Leiden
Catherine Roucairol	University of Versailles
Renata Sotirov	Universität Klagenfurt
Tamon Stephen	University of Michigan
Yin Zhang	Rice University

1.4 Abstracts

William Cook

Rice University

Parallel Search in the Travelling Salesman Problem

We will present a survey of recent progress in algorithms for large-scale TSP instances, including the solution of a million city instance to within 0.09optimality, the solution of the WhizzKids'96 challenge problem in vehicle routing, and the current status of the unsolved problems in the TSPLIB library of test instances. A common theme of the work is the efficient use of parallel computing environments in discrete optimization.

William Hager

University of Florida

LP Dual Active Set Algorithm

In this talk, we give an overview of the LP Dual Active Set Algorithm for solving linear programming problems. Our current implementation of this algorithm, involves solving a series of nonsmooth, unconstrained optimization problems. The solution to these subproblems can be obtained using either factorization-based or iterative-based algorithms. With this flexibility, we are able to solve relatively quickly some difficult linear programs associated with the quadratic assignment problem. The numerical results presented in this talk exploit the recent sparse matrix techniques, developed jointly with Timothy Davis, for modifying a sparse Cholesky factorization after a small rank change in the matrix.

Kurt Anstreicher

University of Iowa

Solving Quadratic Assignment Problems Using Convex Quadratic Programming Relaxations

We describe a new approach to the Quadratic Assignment Problem (QAP) based on the use of convex quadratic programming (QP) relaxations. These relaxations are closely related to, but offer a number of advantages over, the well-known projected eigenvalue (PB) bound for QAP. The QP bounds are implemented in a complete branch-and-bound algorithm that solves problem instances to optimality. The branch-and-bound algorithm has been implemented using the Master-Worker (MW) distributed processing system, allowing for the use of a large number of processors over an extended period. The MW implementation has for the first time solved to optimality several large benchmark QAPs, including the nug30 and tho30 problems. The computations associated with these problems are among the largest ever performed in solving discrete optimizations problems to optimality.

Joint work with N.W. Brixius, J.-P. Goux, and J. Linderoth.

Jonathan Eckstein

Rutgers University

PICO: a massively parallel branch-and-bound toolbox

Joint work with Cynthia A. Phillips and William E. Hart, Sandia National Laboratories.

PICO is a general-purpose, object-oriented toolbox for expressing branch-and-bound algorithms and executing them in parallel computing environments. The initial target architecture is the "Janus" supercomputer consisting of 4,536 nodes, each with two Pentium-II processors, although it is designed to be portable and adaptable. PICO is implemented in C++, using the MPI message passing interface, and is intended to be scalable to thousands of processors. Its key innovations include:

1. A novel object-oriented approach to describing branch-and-bound algorithms, permitting many different variants of the method, for numerous applications, to use the same underlying search "engine".
2. An architecture whereby applications can first be developed sequentially using PICO's "serial layer", and then quickly converted to parallel execution.
3. A "stride scheduler" that handles multiple asynchronous parallel on each processing node, and provides a framework for smoothly "blending" branch and bound with other, heuristic search methods in a parallel environment.

We will examine a sample application of PICO to general mixed-integer programming problems, with preliminary computational results on up to 128 processors.

Catherine Roucairol

University of Versailles

Revisiting lower bounds based on linear formulations in the exact solution of the QAP

Joint work with Van-Dat Cung, Thierry Mautor, Catherine Roucairol, Peter Hahn, and Monique Guignard-Spielberg

We revisit a large class of lower bounds for QAP based on a 0-1 linear formulation of the problem. The aim of our work is to better understand and improve, where possible, the dual procedure, a method proposed by Hahn that affords easily calculated and tight lower bounds for the QAP.

First, we recall some results about the 0-1 linearization method proposed by Adams and Sherali in 1986. Their formulation is theoretically superior to alternative published linear formulations of QAP relative to the strength of the continuous relaxation.) Second, we give an alternative presentation of the dual procedure method.

The dual procedure can be viewed as Lagrangean decomposition on the 0-1 linear formulation of QAP. To solve the Lagrangean dual, n-square linear assignment problems of size n-1 plus one of size n are successively solved. The multipliers are obtained not with a subgradient algorithm, but are iteratively adjusted. The method is similar to that of Adams and Sherali, but the adjustment of multipliers is done more effectively.

Finally, we propose some improvements to the dual procedure. We will show that, even if the recently proposed quadratic bound of Anstreicher is theoretically tighter, the dual procedure branch-and-bound requires far fewer node evaluations. As parallelization and massive computing power seem to be the only way to go for solving larger problems (n¿30), we will discuss this point.

Mauricio Resende

AT&T Labs Research

GRASP with path relinking for the three-index assignment problem

This talk describes variants of GRASP (greedy randomized adaptive search procedure) with path relinking for the three index assignment problem (AP3). GRASP is a multi-start metaheuristic for combinatorial optimization. It usually consists of a construction procedure based on a greedy randomized algorithm and local search. Path relinking is an intensification strategy that explores trajectories that connect high quality solutions. Several variants of the heuristic are proposed and tested. Computational results show clearly that this GRASP for AP3 benefits from path relinking and that the variants considered in this paper compare well with previously proposed heuristics for this problem. GRASP with path relinking was able to improve the solution quality of heuristics proposed by Balas and Saltzman (1991), Burkard, Rudolf, and Woeginger (1996), and Crama and Spieksma (1992) on all instances proposed in those papers. We show that the random variable "time to target solution," for all proposed GRASP with path relinking variants, fits a two-parameter exponential distribution. To illustrate the consequence of this, one of the variants of GRASP with path relinking is shown to benefit from parallelization.

This is joint work with R.M. Aiex, P.M. Pardalos, and G. Toraldo.

Francisco Barahona

IBM

Branch and Cut based on the Volume Algorithm

We present a Branch-and-Cut algorithm where the Volume Algorithm is applied to the linear programming relaxations arising at each node of the search tree. This means we use fast approximate solutions to these linear programs instead of exact but slower solutions given by the traditionally used simplex method. We present computational results with the Max-Cut and Steiner Tree problems. We show evidence that one can solve these problems much faster with the Volume Algorithm based Branch and Cut code than with a dual simplex based one. This is joint work with Laszlo Ladanyi.

Miguel F. Anjos

University of Waterloo

Properties of a New Semidefinite Relaxation for the Max-Cut Problem

Semidefinite programming (SDP) has become an area of intense research in recent years. One reason for this is its application to obtain tight convex relaxations for quadratic boolean optimization. We consider the Max-Cut problem for a complete graph with arbitrary edge weights.

Anjos and Wolkowicz recently introduced two new SDP relaxations for the Max-Cut problem that are obtained using a "second lifting". We focus on the tighter of these relaxations. After briefly sketching the process that yields the SDP relaxations, we will describe some connections between the rank of the matrix variable of the relaxation and the rank of the matrix obtained by projecting it back to the lower dimensional space. We will also present numerical evidence for the strength of this relaxation for several types of graphs and edge weights.

Jean B. Lasserre

University of Toulouse

SDP versus linear relaxations for polynomial programming

We consider the generic global minimization of a multivariate polynomial on $[0,1]^n \cap \Omega$ where the set Ω is defined with polynomial inequalities. We then compare two hierarchies of relaxations, namely, the LP-based relaxations in the spirit of the RLT procedure of Sherali and Adams and recent SDP (semi definite programming) relaxations. The comparison is analyzed via different representations of polynomials, positive on a compact semi algebraic set.

Farid Alizadeh

Rutgers University

Symmetric cones, Jordan algebras and polynomial time interior point algorithms

We present an overview of algebraic techniques used to design polynomial time primal-dual interior point algorithms for optimization over symmetric cones. As a result we show that most algorithms originally designed for semidefinite programming extend to all symmetric cone optimization problems with appropriate use of Jordan algebraic techniques.

Joint work with Stefan Schmieta

Levent Tunçel

University of Waterloo

Successive convex relaxation methods for discrete optimization: convergence theory and consequences for approximation

I will first present iteration-complexity analyses of discretized Successive Convex Relaxation Methods (SCRMs) for computing the convex hulls of solutions of systems of quadratic inequalities. These methods generate finite (but very fast growing) dimensional linear programming or semidefinite programming problems in each iteration. Then, I will specialize the results to computing the convex hulls of solutions of finite systems of polynomial inequalities with bounded degree. Finally, I will further specialize the iteration bounds to computing approximations to the convex hulls of solutions of combinatorial optimization problems.

Most of this talk is based on joint work with S. Xu.

Sam Burer

Georgia Institute of Technology

Maximum Stable Set Formulations and Heuristics Based on Continuous Optimization

The stability number for a given graph G is the size of a maximum stable set in G. The Lovasz theta number provides an upper bound on the stability number and can be computed as the optimal value of the Lovasz semidefinite program. In this paper, we show that restricting the matrix variable in the Lovasz semidefinite program to be rank-one or rank-two yields a pair of continuous, nonlinear optimization problems each having the global optimal value equal to the stability number. We propose heuristics for obtaining large stable sets in G based on these new formulations and present computational results indicating the effectiveness of the heuristics.

Yin Zhang

Rice University

Rank-Two Relaxation Heuristics for Max-Cut and Other Binary Quadratic Programs

Semidefinite relaxation for certain discrete optimization problems involves replacing a vector-valued variable by a matrix-valued one, producing a convex program while increasing the number of variables by an order of magnitude. As useful as it is in theory, this approach encounters difficulty in practice as problem size increases. In this paper, we propose a rank-two relaxation approach and construct continuous optimization heuristics applicable to some binary quadratic programs, including primarily the Max-Cut problem but also others such as the Max-Bisection problem. A computer code based on our rank-two relaxation heuristics is compared with two state-of-the-art semidefinite programming codes. We will report some rather intriguing computational results on a large set of test problems and discuss their ramifications.

Sergiy Butenko

University of Florida

Finding Independent Sets in a Graph Using Continuous Multivariable Polynomial Formulations

Two continuous formulations of the maximum independent set problem on a graph $G = (V, E)$ are considered. Both cases involve the maximization of an N-variable polynomial over the N-dimensional unit hypercube, where N is the number of nodes in G. Two (polynomial) objective functions $F(X)$ and $H(X)$ are considered. Given any solution X in the hypercube, we propose polynomial-time algorithms, based on these formulations, for finding maximal independent sets with cardinality greater than or equal to $F(X)$ and $H(X)$, respectively. A relation between two approaches is studied. Results of computational experiments for some of the DIMACS clique benchmark graphs are presented. Finally, a more general statement for dominating sets is proved.

This is joint work with J. Abello, P.M. Pardalos, and M.G.C. Resende.

C. Johnson

College of William and Mary

Physics, Bad Two-Letter Words, Symmetric Word Equations and Funny Completions

A long-standing problem from physics suggests several questions about 2-letter words in positive definite matrices. One is "which guarantee positive eigenvalues?" In the analysis of this question, certain equations involving symmetric words arise, and these have become quite interesting. After some motivation, we discuss symmetric word equations, a matrix completion analog, and raise the question of whether symmetric word equations might be solved with semidefinite programming.

Jon Lee

IBM

Binary encoding in integer programming

In the context of integer programming, it is an old and simple trick to encode general integer variables in binary. I will describe polyhedral methods for some situations of "integer convexity", where use of the trick makes sense.

Gerald Gruber

Universität Klagenfurt

Solving hard optimization problems with linear inequality constraints using bundle methods

Ilse Fischer

Universität Klagenfurt

Solving hard optimization problems with linear inequality constraints using bundle methods

Renata Sotirov

Universität Klagenfurt

Solving QAP using bundle methods

We consider the problem of maximizing a concave function $c : \mathbb{R}^n \to \mathbb{R}$ subject to finitely many constraints. In particular, given $c : \mathbb{R}^n \to \mathbb{R}$, $A \in \mathbb{R}^{m \times n}$, $b \in \mathbb{R}^m$ and a convex set X we deal with

$$(\mathbf{P}) \qquad \max c(x) \quad \text{s.t. } x \in X, \quad Ax \leq b.$$

The number of constraints m could be very large, hence solving $(\mathbf{P})$ directly is too difficult. The goal is selecting important inequalities of $Ax \leq b$ to get a good approximation of the original problem. We present a method which leads to such an approximation in reasonable time.

We use this method to solve combinatorial optimization problems which fit into this framework such as Max-Cut and QAP. For these two problems numerical results will be presented.

Ding-Zhu Du

University of Minnesota

Approximations for Steiner Trees in Industry

After Euclidean and rectilinear Steiner minimum trees were found to have polynomial-time approximation schemes in 1996, many researchers have moved their interests to Steiner trees in industries, including bottleneck Steiner trees, directed Steiner trees, on-line Steiner trees, dynamic Steiner trees, multiweight Steiner trees, Steiner trees with minimum number of Steiner points, class Steiner trees, etc. In this talk, we would like to give an overview on approximations for those variations of Steiner trees.

Christoph Helmberg

Konrad-Zuse-Zentrum für Inforationstechnik

Some Applications of Graph Partitioning

We report on our experience with semidefinite relaxations applied to spin-glasses, bisection problems, clustering of statistical data and frequency assignment for GSM networks.

Ismael de Farias, Jr.

State University of New York at Buffalo

A Polyhedral Study of the Cardinality Constrained Knapsack Problem

A cardinality constrained knapsack problem is a continuous knapsack problem in which no more than a specified number of variables are allowed to be nonzero. Cardinality constraints abound in areas such as finance, scheduling, manufacturing, etc. Following the approach of Beale and Tomlin, we do not introduce binary variables to enforce the cardinality constraint, but rather we enforce it directly in the branch-and-cut algorithm through a specialized branching scheme, and the use of strong inequalities valid in the space of continuous variables. We extend the concept of cover inequalities, commonly used in 0-1 programming, to this class of problems, and we show how they can be lifted to generate facets of the convex hull of the feasible set. We implement our cuts and we report computational results that demonstrate their effectiveness. We also show how our branch-and-cut algorithm can benefit from techniques used in constraint programming.

Kees Roos

TU Delft/University of Leiden

Maximization of a quadratic form over the intersection of ellipsoids with common center

We demonstrate that if $A_1, \ldots, A_m$ are symmetric positive semidefinite $n \times n$ matrices with positive definite sum and A is an arbitrary symmetric $n \times n$ matrix, then the relative accuracy, in terms of the optimal value, of the semidefinite relaxation

$$\max_X \{\mathrm{trace}(AX) \mid \mathrm{trace}(A_i X) \leq 1, i = 1, \ldots, m; X \succeq 0\}$$

of the optimization program

$$x^T A x \to \max \mid x^T A_i x \leq 1, i = 1, \ldots, m$$

is not worse than $1 - \frac{1}{2\ln(2m^2)}$. It is shown that this bound is sharp in order, as far as the dependence on m is concerned.

Ted Ralphs

Lehigh University

Implementing Branch, Cut, and Price Algorithms

Branch, cut, and price is an LP-based branch and bound technique in which both cuts and variables are generated dynamically throughout the search tree. This leads to interesting challenges when implementing such algorithms. In this talk, we discuss a variety of issues involved in implementing branch, cut, and price in both sequential and parallel computing environments. We will draw on our experience implementing two different generic frameworks for BCP—SYMPHONY, written in C, and COIN/BCP, written in C++. Both are open-source and available on the Web.

Faranak Mokhtarian

Concordia University

Convex Feasibility Problem with Constraints Given by a Nonlinear Separation Oracle

A case of the convex feasibility problem where the set is defined by a "separation oracle" is considered. Complexity of an Analytic Center based algorithm used to solve the problem is studied. At each iteration of the algorithm, the oracle checks for feasibility. If a feasible point is not found it returns either a strongly convex quadratic or a linear cut through an approximate analytic center of the current outer approximation of the feasible set; otherwise, the algorithm stops.

Arnold Neumaier

Universität Wein

Semidefinite constraints related to finite geometry

In my talk, I'll discuss how certain problems from finite geometry, coding theory and the theory of distance regular graphs lead to sets of inequalities with linear and semidefinite constraints. Their infeasibility leads to nonexistence results, and a knowledge of the affine subspace containing the feasible set leads to geometric conditions for the configurations that define the set of inequalities.

Jean-Louis Goffin

McGill University

Analytic centers methods and mixed integer programming

The most effective way to solve realistic MIPs (mixed integer programs) is branch and price, which is based on Lagrangean relaxation, with the possible use of combinatorial cuts. Lagrangean relaxation provides better bounds than the traditional branch and bound method, which relax the integer requirement, while combinatorial cuts tighten the LP or the Lagrangean relaxations.

At every node of the B&B tree, a nondifferentiable convex function (NDO) needs to be optimized. The classical NDO techniques, such as the Dantzig-Wolfe decomposition algorithm or subgradient optimization, have weaknesses, such as unreliable convergence or the lack of a rigorous termination criterion. The analytic center cutting plane method (ACCPM), as well as bundle methods, have attempted to improve on this, and have done rather well.

We will present a full branch and price method that uses extensions of ACCPM, including hot starts at the child nodes, using a dual Newton method. Computational results will be reported on.

Extensions of ACCPM to the case of quadratic or SDP cuts will also be reported. Theoretical results show that a central SDP cut can be added in $p \log p$ Newton steps, where p is the dimension of the added SDP cut. This leads to an alternative to the spectral bundle method.

This talk reports on work by my doctoral students Samir Elhedhli and Mohammas Oskoorouchi.

Tamon Stephen

University of Michigan

On the distribution of values of the QAP

We examine the distribution of values of a quadratic objective function on permutations. We describe both a “bullseye” distribution, where large values are concentrated near the optimum, and a ”flat” distribution, where the maximum is isolated.

We then examine when each distribution arises, and get guaranteed complexity bounds from some simple algorithms based on random or partial enumeration. This also offers some insight into the performance of local search heuristics.

Our techniques touch on representation theory.

This is joint work with Alexander Barvinok.

Dorothy Kucar
University of Waterloo

A Novel Eigenvector Technique for VLSI Circuit Layout

Modern integrated circuit design involves laying out circuits which consist of millions of circuit elements. Due to the sheer complexity, determining optimal circuit connectivity is a very difficult problem. How a circuit is interconnected is the single most important factor in performance criteria such as signal delay, power dissipation, circuit size and cost. These factors dictate that interconnections-wires be made as short as possible. The wire-minization problem is formulated as a sequence of discrete optimization sub-problems. These problems are known to be NP-hard which can only be solved approximately using simulated annealing, tabu search or linear programming techniques. Nevertheless, these methods are computationally expensive and the quailty of solution depends to a great extent on an appropriate choice of starting configuration. An eigenvector model for solving very hard discrete optimization problems in Very Large Scale Integrated (VLSI) design which overcomes some of these shortcomings is proposed. In particular, the computational cost is reasonable-of the order of n-squared running time.

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2 Local Waterloo Information

2.1 Building Hours

The doors to the Math and Computer Building (MC) and the Davis Center (DC) at The University of Waterloo are open 24 hours a day, 7 days a week. However, the seminar room DC 1302 will only be opened from 8:30 am to 5:00 pm and DC 1301 will only be available during break times.

2.2 Telephone Instructions

The main phone number for The Department of Combinatorics and Optimization is (519) 888-4567 ext. 3482. For the on-campus Switchboard dial 0. Dialing 9 connects you with an outside line.

2.3 Photocopying and Faxing

Facilities for local faxing and photocopying are available in the Copy Center next to the main entrance of the Davis Center Library. You will be charged for their use.

2.4 Computing Facilities

If you wish to check your e-mail, please see Frances Hannigan in MC 5027 for a password, user-id, and terminal room number. This account will allow you to "telnet" only to your home servers. Otherwise, there are computers available in the Davis Center Library that are web-capable if you wish to "surf the web."

2.5 University of Waterloo Libraries

The main research library for the University of Waterloo is the Dana Porter Library, located on-campus. The library is open Monday to Friday 8:00 am to 11:00 pm and Saturday and Sunday 11:00 am to 11:00 pm.

The main Mathematics Research Library is located on the ground floor of the Davis Center – check your hand-outs in your conference folders for its location and times of operation.

2.6 Campus Map

Campus Map located elsewhere on the web-page.

REV = Ron Eidt Village

MC = Mathematics & Computer

DC = Davis Center

Follow the signs posted by the walking paths towards Ring Road and the PAC (Physical Activities Complex). Once on Ring Road and facing the PAC, walk south just past the SLC (Student Life Centre) and the MC building will appear immediately to your left. Again, follow the paths to MC, walking past it and onto the service road. Follow the service road to the other side of Ring Road. Just before the stop sign at the intersection of the service road and Ring Road, there will be a door into the Davis Centre on your right. Enter here and walk towards the main foyer - DC 1301 will appear on your right.