Workshop on

Large Scale Nonlinear and Semidefinite Programming

In memory of Jos F. Sturm (1971–2003)

May 12 – 15, University of Waterloo, Canada

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Contents

1 Welcome **2**
- 1.1 Background . . . 2
- 1.2 Structure of the workshop . . . 2
- 1.3 Sponsors . . . 3

2 In memoriam Jos Sturm (1971 – 2003) **4**
- 2.1 Obituary . . . 4

3 Programme committee **6**

4 General information **7**
- 4.1 Location . . . 7
- 4.2 Poster sessions and prizes . . . 7
- 4.3 Breakfast, coffee, tea, lunches . . . 7
- 4.4 Workshop banquet . . . 7
- 4.5 E-mail . . . 7
- 4.6 Audio visual requirements . . . 8

5 Plenary speakers **9**

6 Programme **11**
- 6.1 Wednesday, May 12th . . . 11
- 6.2 Thursday, May 13th . . . 12
- 6.3 Friday, May 14th . . . 14
- 6.4 Saturday, May 15th . . . 16

7 Abstracts of the talks **18**

8 List of Participants **30**

1 Welcome

Welcome to the Workshop on Large Scale Nonlinear and Semidefinite Programming.

1.1 Background

Interior point methods (IPMs) have changed the landscape for both linear and nonlinear programming in the last fifteen years. In conjunction with breakthroughs in computer hardware, tremendously large problems are being solved. However, the success in linear programming dwarfs that for general Nonlinear Programming and, in particular, for Semidefinite Programming (SDP). The main aim of this workshop is to bring together researchers who work on large scale nonlinear programming, and, in particular, on Cone Programming such as Semidefinite and Second Order Cone Programming. A rich source of large-scale nonlinear problems arises from relaxations of NP-hard combinatorial optimization problems. The success to solve Semidefinite Programs (of moderate size) has resulted in increased interest in higher order relaxations of combinatorial optimization problems, which give tighter relaxations but which are computationally challenging.

Recent progress towards large-scale nonlinear programming is mostly based on algorithmic ideas which avoid using standard interior-point technology. These include first order methods, algorithms which focus on the sparsity structure as well as nonsmooth methods applied to some Lagrangian dual. In addition, several parallel implementations of IPM's as well as column generation-type techniques have been introduced and show promise.

It is the purpose of this workshop to provide a forum to exchange ideas on large sparse programming between researchers in general Nonlinear Programming and those in Cone Programming.

The workshop aims in particular at researchers from the following communities

- algorithmic nonlinear optimization
- combinatorial optimization, dealing with computational methods for NP-hard problems
- computer scientists interested in scientific parallel computing, who share a common interest to do computations on (large-scale) hard combinatorial optimization problems.

1.2 Structure of the workshop

The meeting will consist of a one-day short course followed by contributed presentations spanning three days. In addition to the contributed presentations there are six sessions with plenary lectures, as well as daily poster sessions. Prizes for the best poster will be awarded in different categories.

1.3 Sponsors

The workshop is sponsored by:

- The Fields Institute;
- The Faculty of Mathematics, University of Waterloo;
- MITACS.

2 In memoriam Jos Sturm (1971 – 2003)

This workshop is in memory of our friend and colleague, Jos Sturm, who passed away on December 6, 2003, after an illness of nearly two months. He was only 32 years old.

Our thoughts go to his wife Changquing and daughter Stefanie, and to his family.

Those of us who had the privilege of knowing Jos and working with him will remember him fondly, and will sorely miss his enthusiasm, kindness, and creativity.

A special session of this workshop is devoted to his memory (Friday at 16:45), and to recall the many and varied contributions he made to the field of optimization in his short but illustrious career.

2.1 Obituary

Jos Sturm was born in Rotterdam, The Netherlands, on August 13, 1971. He graduated in August 1993 in operations research from the Department of Econometrics at the University of Groningen, where he had also been a teaching assistant in statistics and a research assistant in econometrics. From Sept 1993 to Sept 1997, he was a PhD student at the Econometric Institute and the Tinbergen Institute of the Erasmus University in Rotterdam, under supervision of Shuzhong Zhang.

Jos spent the academic year 1997/1998 as a post-doctoral fellow at the Communications Research Laboratory (CRL) of McMaster University, Hamilton, Canada, as a TALENT stipend of the Netherlands Organization for Scientific Research (NWO). At McMaster University, he was a member of the ASPC group of Zhi-Quan (Tom) Luo.

After his post-doctoral fellowship at McMaster, he returned to the Netherlands, and from October 1998 to January 2001, he was a lecturer at Maastricht University, at the Department of Quantitative Economics, in the group of Antoon Kolen.

In January 2000, his PhD thesis was awarded the Gijs de Leve prize for the best thesis in operations research in the years 1997-1999 in The Netherlands.

In February 2001, Jos was appointed as an Associate Professor at Tilburg University, and a fellow of CentER (Center for economic research). In July 2001, he was awarded the prestigious Vernieuwingsimpuls (Innovation) grant of the Netherlands Organization for Scientific Research (NWO).

Jos was the editor of the newsletter SIAG/Optimization Views-and-News of the SIAM Activity Group on Optimization (SIAG/OPT), and a council member-at-large of the Mathematical Programming Society (MPS).

His scholarly works include more than 30 papers, and his PhD thesis was published in edited form in the volume 'High performance optimization', Frenk et al. eds., Kluwer Academic Press, 2000. He was also the author of a widely used optimization software package called SeDuMi.

He is survived by his wife Changqing and daughter Stefanie, and his brother Pim and parents Frans and Els.

3 Programme committee

Organizers:

- Etienne de Klerk, University of Waterloo.
- Franz Rendl, Universitaet Klagenfurt.
- Tamás Terlaky, McMaster University.
- Levent Tunçel, University of Waterloo.
- Tony Vannelli, University of Waterloo.
- Henry Wolkowicz, University of Waterloo.

Address:
Organization Committee Workshop on Large Scale Nonlinear and Semidefinite Programming
p/a Department of Combinatorics and Optimization
Faculty of Mathematics
University of Waterloo
Waterloo, Canada, N2L 3G1

Web-page:
`http://orion.math.uwaterloo.ca/~hwolkowi/w04workshop.d/readme.html`

4 General information

4.1 Location

The workshop will take place in the Arts Lecture Hall on the campus of the *University of Waterloo*:

200 University Ave. W.
Waterloo, Ontario Canada, N2L 3G1
Tel: 519.888.4567

All lectures will be held in **AL 113** of the Arts Lecture Hall building (marked AL on the campus map).

4.2 Poster sessions and prizes

The poster sessions will be in the Arts Lecture Hall building, in rooms **AL 208** and **AL 211**.

Prizes will be awarded for the best posters in the following two categories:

- Best poster by a student;
- Best poster overall.

The participants who will do poster presentations are listed on page 30.

4.3 Breakfast, coffee, tea, lunches

Breakfast, coffee, tea, and lunches are free for registered participants of the workshop and served in the Arts Lecture Hall building, in rooms **AL 208** and **AL 211**. Please wear your workshop badge for identification purposes.

4.4 Workshop banquet

The workshop banquet on Friday evening will be held at the University (Faculty) Club (building UC on the campus map). The banquet is free for registered participants. Your workshop badge will serve as a ticket.

4.5 E-mail

There will be e-mail facilities available in the Mathematics building (MC on the campus map) in the following rooms:

- **MC 3006** available Wednesday through Saturday, except 11:30am–12:30pm on Friday;
- **MC 6080** available Wednesday through Saturday, except 8:00am–12:00 noon on Wednesday and Thursday.

You will receive a guest account name and password in your registration package, which will provide access to a UNIX account.

4.6 Audio visual requirements

There will be an overhead projector available for use with transparencies, as well as an LCD data projector for use with laptops. If you have special additional requirements, please contact one of the organizers on arrival.

5 Plenary speakers

These are the ten plenary speakers at the workshop (in alphabetical order).

- Steven Boyd.
  Department of Electrical Engineering, Stanford University, Packard 264, Stanford, CA 94305, USA.
  boyd@stanford.edu
  `www.stanford.edu/~boyd`

- Nick Gould.
  Computational Science & Engineering CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, UK
  N.I.M.Gould@rl.ac.uk
  `http://www.dci.clrc.ac.uk/Person.asp?N.I.M.Gould`

- Didier Henrion.
  LAAS-CNRS, 7, avenue du Colonel Roche 31 077 Toulouse France
  henrion at laas.fr
  `www.laas.fr/~henrion`

- Michal Kočvara.
  Institute of Applied Mathematics, University of Erlangen-Nuremberg, Martensstr. 3, 91058 Erlangen, Germany
  kocvara@am.uni-erlangen.de
  `www2.am.uni-erlangen.de/~kocvara`

- Jean Lasserre.
  LAAS-CNRS, 7 Avenue du Colonel Roche, 31 077 Toulouse Cedex 4, France
  lasserre@laas.fr
  `http://www.laas.fr/~lasserre/`

- Yurii Nesterov.
  Center for operations research and econometrics (CORE), Voie du Roman Pays, 34, 1348 Louvain-la-Neuve, Belgium
  nesterov@core.ucl.ac.be `http://www.core.ucl.ac.be/staff/nesterov.html`

- Jorge Nocedal.
  Northwestern University, Robert R. McCormick School of Engineering and Applied Science, Electrical & Computer Engineering Department, 2145 Sheridan Road Evanston, Illinois 60208-3118, USA
  nocedal@ece.nwu.edu
  `http://www.ece.northwestern.edu/~nocedal/`

- Pablo Parrilo.
  Automatic Control Laboratory, Swiss Federal Institute of Technology, Physikstrasse 3, ETL I 26, CH-8092 Zürich, Switzerland
  parrilo@control.ee.ethz.ch
  `http://control.ee.ethz.ch/~parrilo/`

- Robert Vanderbei.
  ACE-42 Engineering Quad, Princeton University, Princeton, NJ 08544, USA. rvdb@princeton.edu
  `http://www.princeton.edu/~rvdb/`

- Yinyu Ye.
  Terman Engineering Center 316, Department of Management Science and Engineering, School of Engineering, Stanford University, Stanford, CA 94305, USA.
  yinyu-ye@stanford.edu
  `http://www.stanford.edu/~yyye/`

6 Programme

6.1 Wednesday, May 12th

07:30 – 08:45 *Breakfast*

08:45 – 9:00 *Opening Remarks*

Short Course Session W.1. Chairman: Henry Wolkowicz

09:00 – 10:20 Henry Wolkowicz, *Theory of Cone Programming I*

10:20 – 10:40 *Break*

Short Course Session W.2. Chairman: Etienne de Klerk

10:40 – 12:00 Etienne de Klerk, *Theory of Cone Programming II*

12:00 – 14:00 *Lunch*

Short Course Session W.3. Chairman: Levent Tunçel

14:00 – 15:20 Levent Tunçel, *Algorithms for Cone Programming I*

15:20 – 15:40 *Break*

Short Course Session W.4. Chairman: Franz Rendl

15:40 – 17:00 Franz Rendl, *Algorithms for Cone Programming II*

19:00 – 22.00 *Registration and poster session*

6.2 Thursday, May 13th

07:15 – 08:10 *Breakfast*

08:10 – 08:20 *Opening Remarks*

08:20 – 08:30 *Welcome from Alan George, Dean, Faculty of Mathematics*

Plenary session R.1. Chairman: Henry Wolkowicz

08:30 – 09:20 Nick Gould, *An interior-point l_1-penalty method for nonlinear optimization*

09:30 – 10:20 Michal Kocvara, *Towards the solution of large-scale nonlinear SDP problems*

10:20 – 10:45 *Break and poster session*

Session R.2. Chairman: Etienne de Klerk

10:45 – 11:10 Sam Burer, *Local Minima and Convergence in Low-Rank Semidefinite Programming*

11:15 – 11:40 Dimitris Bertsimas, *The Price of Robustness for Conic Optimization*

11:45 – 12:10 Brian Borchers, *How Far Can We Go With Primal-Dual Interior Point Methods For SDP?*

12:10 – 14:00 *Lunch and poster session*

Plenary session R.3. Chairman: Tamás Terlaky

14:00 – 14:50 Yinyu Ye, *Solving very large scale SDPs arisen from ad hoc wireless sensor network localization and other Euclidean geometry problems*

15:00 – 15:50 Jorge Nocedal , *Nonlinear Programming Methods: Iterative solution, Preconditioning and Regularization*

15:50 – 16:45 *Break and poster session*

Session R.4. Chairman: Franz Rendl

16:45 – 17:10 Roland W. Freund, *Passive reduced-order modeling via non-linear semidefinite programming*

17:15 – 17:40 Renato Monteiro, *Convergence Analysis of a Long-Step Primal-Dual Infeasible Interior-Point LP Algorithm Based on Iterative Linear Solvers*

17:45 – 18:10 Robert M. Freund, *Symmetry Functions and Symmetry Points of a Convex Set: Properties, Duality, and Computational Complexity*

6.3 Friday, May 14th

07:30 – 08:10 *Breakfast*

Plenary session F.1. Chairman: Tony Vannelli

08:30 – 09:20 Jean B. Lasserre, *SDP relaxations in robust optimization and mathematical finance*

09:30 – 10:20 Didier Henrion , *GloptiPoly 3 - a Matlab package for globally optimizing polynomial moments*

10:20 – 10:45 *Break and poster session*

Session F.2. Chairman: Kurt Anstreicher

10:45 – 11:10 Charles Johnson, *Solving Symmetric Word Equations for Positive Definite Letters: Theory and Practice*

11:15 – 11:40 Kurt Anstreicher, *Combining RLT and SDP for nonconvex quadratic programming*

11:45 – 12:10 Jonathan Borwein, *A Single Function Variational Principle and Applications*

12:10 – 14:00 *Lunch and poster session*

Plenary session F.3. Chairman: Henry Wolkowicz

14:00 – 14:50 Robert J. Vanderbei, *Designing Fast Distributed Iterations via Semidefinite Programming*

15:00 – 15:50 Stephen Boyd , *Nonlinear Programming Methods: Iterative solution, Preconditioning and Regularization*

Session F.3 (ctd.) Chairman: Henry Wolkowicz

16:00 – 16:25 Mike Todd, *On convergence of IP methods for self-scaled conic programming*

16:25 – 16:45 *Break and poster session*

Special Session in Memory of Jos Sturm. Chairman: Dick den Hertog

16:45 – 17:05 Pim Sturm, *Family Remembrances*

17:05 – 17:20 Dick den Hertog, *In Memoriam*

17:20 – 17:55 Shuzhong Zhang, *Happy years in Groningen and Rotterdam*

18:00 – 18:20 Tom Luo, *Reflections during PostDoc*

18:20 – 18:50 Friends of Jos, *Personal anecdotes/memories*

19:00 *Banquet at the Faculty Club*

6.4 Saturday, May 15th

07:30 – 08:10 *Breakfast*

Plenary session S.1. Chairman: Etienne de Klerk

08:30 – 09:20 Pablo Parrilo, *From coefficients to samples: a new approach to SOS optimization*

09:30 – 10:20 Yurii Nesterov, *Recent progress in efficient approximation of joint spectral radius*

10:20 – 11:05 *Break and poster session*

Session S.2 (ctd.). Chairman: Kartik Krishnan

11:05 – 11:30 Gabor Pataki, *Bad semidefinite programs: they all look the same*

11:35 – 12:00 Florian Jarre, *Sensitivity Result and Convergence Analysis for a Sequential Semidefinite Programming Method*

12:10 – 13:00 *Lunch and poster session*

Session S.3. Chairman: Jean-Louis Goffin

13:00 – 13:25 Philip E. Gill, *Trust-Search Methods for Large-Scale Optimization*

13:30 – 14:55 John Lee, *A masked spectral bound for maximum-entropy sampling*

14:00 – 14:25 James Renegar, *Hyperbolic programming algorithms relying on derivative cones*

14:30 – 15:00 *Break and poster session*

Session S.3. Chairman: Henry Wolkowicz

15:00 – 15:25 Paul Tseng, *On conic programming relaxation and SDP relaxation of 2-ball trust region problem*

15:30 – 15:55 Kim-Chuan Toh, *Computational experiences in solving large scale SDPs by Krylov subspace methods*

15:55 – 16:30 *Break and final poster session*

16:30 – 17:00 *Poster prize session*

17:00 *Closing*

7 Abstracts of the talks

The abstracts of all talks are given below. The ordering is alphabetic with respect to the name of the *speaker*.

Combining RLT and SDP for nonconvex quadratic programming.

Kurt Anstreicher
University of Iowa, US

Abstract

We consider relaxations for nonconvex quadratic programming based on combinations of the Reformulation-Linearization Technique (RLT) and Semidefinite Programming (SDP). For pairs of variables that are not near their upper or lower bounds, adding the semidefinite constraint provides a large reduction in the feasible region for the corresponding product variables in the RLT relaxation. We give computational results on nonconvex box-constrained and quadratically constrained problems. We also illustrate the effect of adding order constraints to RLT and SDP relaxations to improve bounds on highly symmetric problems.

The Price of Robustness for Conic Optimization.

Dimitris Bertsimas
Sloan School of Management, Massachussetts Institute of Technology, US

Abstract

In earlier proposals, the robust counterpart of conic optimization problems exhibits a lateral increase in complexity, i.e., robust LPs become SCOPs, robust SCOPs become SDPs, and robust SDPs become NP-hard. We propose an approach that under which (a) robust conic optimization problems retain their original structure, i.e., robust SCOPs remain SCOPs and robust SDPs remain SDPs, (b) we establish probabilistic guarantees for robustness that lead to explicit ways for selecting parameters that control robustness.

(Joint work with Melvyn Sim.)

How Far Can We Go With Primal–Dual Interior Point Methods For SDP?

Brian Borchers
New Mexico Tech, Socorro, US

Abstract

Primal-Dual interior point methods, and in particular the HKM method, are used in several of the available codes for semidefinite programming, including CSDP, SeDuMi, SDPA, SDPT3. These methods have proven to be quite satisfactory for a variety of small and medium sized problems. However, larger problems have not been solvable by primal-dual methods. This presenter will review the computational difficulties associated with solving larger problems by primal-dual methods, look at the characteristics of some medium to large scale SDP problems, and report on progress in solving larger problems with CSDP.

(Joint work with Joseph Young.)

A One Perturbation Variational Principle and Applications.

Jonathan Borwein
Dalhousie University, Canada

Abstract

We study a variational principle with a common perturbation function ϕ for all proper lower semicontinuous extended real-valued functions f on a metric space X.

- Necessary and sufficient conditions are given for the perturbed $f + \phi$ to attain its minimum.
- For separable Banach space we may use a perturbation function that is also convex and Hadamard-like differentiable.
- We give three applications to differentiability of convex functions on separable and more general Banach spaces.
- We pose various open questions.

Designing Fast Distributed Iterations via Semidefinite Programming.

Stephen Boyd
Stanford University, US

Abstract

The general setting we consider involves a process, iteration, or method in which the computation or communication at each step is local, determined by a given graph, and involves some parameters or coefficients that affect its convergence speed. Examples include a Markov chain on a graph, where the transition probabilities affect the mixing rate of the chain; distributed averaging, where the local weights affect the global speed of convergence to the average; and distributed weighted gradient methods for resource allocation, where the weights affect the speed of convergence to the optimal allocation.

We show how semidefinite programming can be used to choose the coefficients or parameters in these methods to yield fastest (or in some cases, just fast) convergence. We also show how weights suggested by the celebrated Metropolis-Hastings algorithm (for fast convergence in Monte Carlo Markov Chain simulation) transcribe well to other applications, such as distributed averaging.

(Joint work with Lin Xiao.)

Local Minima and Convergence in Low-Rank Semidefinite Programming.

Sam Burer
University of Iowa, US

Abstract

The low-rank semidefinite programming problem ($LRSDP_r$) is a restriction of the semidefinite programming problem (SDP) in which a bound r is imposed on the rank of X, and it is well known that $LRSDP_r$ is equivalent to SDP if r is not too small. In this paper, we classify the local minima of $LRSDP_r$ and prove the optimal convergence of a slight variant of the successful, yet experimental, algorithm of Burer and Monteiro, which handles $LRSDP_r$ via the nonconvex change of variables $X = RR^T$. In addition, for particular problem classes, we describe a practical technique for obtaining lower bounds on the optimal solution value during the execution of the algorithm. Computational results are presented on a set of combinatorial optimization relaxations, including some of the largest quadratic assignment SDPs solved to date.

Trust-Search Methods for Large-Scale Optimization.

Philip E. Gill
University of California, San Diego, US

Abstract

Recent research on interior methods has re-emphasized the role of sequential unconstrained optimization for the solution of very large nonconvex problems. However, existing line-search and trust-region methods for unconstrained optimization may get into difficulty near points at which the Hessian is singular. In such cases, line-search methods may require many iterations to converge, and trust-region methods may require many iterations to solve the constrained subproblem. A new class of methods is proposed that combines the best features of trust-region and line-search methods. These "trust-search" methods maintain the rapid convergence associated with trust-region methods while solving the subproblem at a cost comparable to that of a line-search method.

(This work is joint with Julia Kroyan.)

An interior-point l_1-penalty method for nonlinear optimization .

Nick Gould
CCLRC Rutherford Appleton Laboratory, Oxfordshire, UK

Abstract

We discuss the merits of a mixed interior/exterior-point method for nonlinear programming in which all nonlinear constraints are treated by an ℓ_1 penalty function. Building on a proposal by Mayne and Polak (1976), a suitable decomposition of the constraints allows us to derive an exact differentiable penalty function involving only inequality constraints, which may then be treated using a logarithmic barrier. Exactness of the exterior penalty function eliminates the need to drive the corresponding penalty parameter to infinity. Global and fast local convergence of the proposed scheme are exposed. A special purpose trust-rgeion method for the underlying penalty-barrier subproblem will be outlined. The algorithm is implemented as part of the GALAHAD library under the same SUPERB. Numerical results comparing the present method to state-of-the-art nonlinear programming codes will be reported.

(Joint work with Dominique Orban (Montréal) and Philippe Toint (Namur))

GloptiPoly 3 - a Matlab package for globally optimizing polynomial moments.

Didier Henrion
LAAS-CNRS, Toulouse, France

Abstract

GloptiPoly is a Matlab package to build and solve convex linear matrix inequality (LMI) relaxations of optimization problems over polynomial moments. The first version of GloptiPoly, released in February 2002, allows to solve (generally non-convex) optimization problems with polynomial objective function and constraints, with detection of global optimality and automatic extraction of global optimizers, see http://www.laas.fr/ henrion/software/gloptipoly

In this talk, we present the main features of GloptiPoly version 3, a major new release of this package: symbolic manipulation of multivariate polynomials, additional linear constraints on moments, reductions in the number of variables and size of the LMI relaxations. Various applications are described: robust and non-linear systems control, robust optimization, optimization of rational functions, performance analysis for stochastic systems in mathematical finance.

(Joint work with Jean-Bernard Lasserre, LAAS-CNRS Toulouse, France.)

Sensitivity Result and Convergence Analysis for a Sequential Semidefinite Programming Method.

Florian Jarre
Universitaet Duesseldorf, Germany

Abstract

We present a simple sensitivity result for solutions of linear semidefinite programs under small arbitrary perturbations of the data. The result is generalized to nonlinear programs with nonlinear semidefiniteness constraints. This generalization is used to derive an elementary and self-contained proof of local quadratic convergence of a sequential semidefinite programming (SSP) method.

A key advantage of the SSP method lies in the fact that the choice of the symmetrization procedure can be shifted in a very natural way to the linear semidefinite subproblems, and thus being separated from the process of linearizing and convexifying the data of the nonlinear SDP. Globalization techniques and small scale numerical results will be discussed.

(Joint work with Roland W. Freund (Bell Laboratories, Murray Hill, NJ, USA))

Solving Symmetric Word Equations for Positive Definite Letters: Theory and Practice.

Charles R. Johnson
College of William and Mary, Williamsburg, Va., US

Abstract

By a symmetric word in two letters A and B we mean the juxtaposition of a finite sequence of A's and B's that reads the same right-to-left as left-to-right. We interpret A and B as independent positive definite (PD) matrices and juxtaposition as matrix multiplication. If S(A,B) is a symmetric word in two PD letters A and B, it is easily seen that P = S(A,B) is also PD. By a symmetric word equation, we mean one of the form

$$P = S(A, B)$$

in which P and B are given PD matrices. We discuss the solvability of symmetric word equations for a PD matrix A and describe an algorithm for solving for A. Such word equations arise in the study of a long standing problem from quantum physics, and the current work is joint with Chris Hillar (UC, Berkeley).

Towards the solution of large-scale nonlinear SDP problems.

Michal Kočvara
University of Erlangen-Nuremberg, Germany

Abstract

Memory requirements and complexity of Hessian assembling are limiting factors when solving large-scale linear SDPs by second-order methods. The situation becomes dramatic when trying to solve nonlinear SDPs. We propose a first order method that is based on the Augmented Lagrangian algorithm whereas the linear systems are solved by the preconditioned conjugate gradient method. The new algorithm is implemented in the code PENNON. We will refer on computational experience for linear and nonlinear SDPs.

(Joint work with Michael Stingl, University of Erlangen)

SDP relaxations in robust optimization and mathematical finance.

Jean B. Lasserre
LAAS-CNRS, Toulouse, France

Abstract

We first consider a robust optimization problem of the form $\max_{z\in\Omega}\min_{x\in K} p(x,z)$ where K is a semi-algebraic set, Ω is a convex set defined by LMIs, and p is a polynomial, linear in z for fixed x. We show that the optimal value can be approximated as closely as desired by a sequence of SDP relaxations. The latter relaxations are also interpreted in terms of a global optimization problem (with a single "max"). We also investigate the same problem but interchanging the $\max_z$ and $\min_x$ operators, and compare with the former problem.

In mathematical finance we propose a numerical procedure for pricing a class of exotic options of european type, via moments and SDP relaxations. In this approach we provide two monotone sequences of upper and lower bounds on the price to evaluate, and convergence to the exact price is guaranteed in a number of cases. Finally, our numerical experiments on a sample of problems show that very good results are obtained in all cases.

A masked spectral bound for maximum-entropy sampling.

John Lee
IBM T.J. Watson Research Center, Yorktown Heights, NY, US

Abstract

We introduce a new "masked spectral bound" for the maximum-entropy sampling problem.This bound is a continuous generalization of the very effective "spectral partition bound." Optimization of the masked spectral bound requires the minimization of a nonconvex, nondifferentiable objective over a semidefiniteness constraint. We describe a nonlinear affine scaling algorithm to approximately minimize the bound. Implementation of the procedure obtains excellent bounds at modest computational expense.

(Joint work with Kurt Anstreicher.)

Recent progress in efficient approximation of joint spectral radius.

Yurii Nesterov
Université catholique de Louvain, Belgium

Abstract

The joint spectral radius of a set of matrices is a measure of the maximal asymptotic growth rate that can be obtained by forming long products of matrices taken from the set. This quantity appears in a number of application contexts but is notoriously difficult to compute and to approximate. We introduce in this paper a procedure for approximating the joint spectral radius of a finite set of matrices with arbitrary high relative accuracy. Our approximation procedure is polynomial in the size of the matrices once the number of matrices and the desired accuracy are fixed. An essential element of our technique is a semidefinite lifting of linear operators.

Nonlinear Programming Methods: Iterative solution, Preconditioning and Regularization.

Jorge Nocedal
Northwestern University , US

Abstract

We first discuss the relative strengths of interior and active set methods for three classes of problems: (i) problems in which the Hessian is not sparse or is not available; (ii) very large problems; (iii) problems that do not satisfy constraint qualifications. Some attention will be given to a new active set approach that uses linear programming techniques to identify the active set. The second part of the talk focuses on the use of iterative linear algebra techniques in interior and active-set methods. Preconditioning and regularization are essential to achieve robustness over a wide range of applications.

From coefficients to samples: a new approach to SOS optimization.

Pablo A. Parrilo
ETH Zurich, Switzerland

Abstract

We introduce a new methodology for the numerical solution of semidefinite relaxations arising from the sum of squares (SOS) decomposition of multivariate polynomials. The method is based on a novel SOS representation, where polynomials are represented by a finite set of values at discrete sampling points, complemented by an orthogonalization technique. The methods have very appealing theoretical and numerical properties; the associated semidefinite programs are better conditioned, and have a rank one property that enables a fast computation of search directions in interior point methods. The results are illustrated with examples, and numerical results for a preliminary implementation.

(Joint work with Johan Löfberg (ETH Zurich).)

Bad semidefinite programs: they all look the same.

Gabor Pataki
University of North Carolina, Chapel Hill, US

Abstract

SDP's duality theory has been somewhat less well studied than its algorithmic aspects. Strong duality, – expected in linear programming fails in many cases, and the variety of how things can go wrong is bewildering: one can have non-attainment in either one of the primal and the dual problems, attainment on both sides, but a finite duality gap, etc.

The main result we present in this talk is a surprisingly simple, exact, "excluded minor" type characterization of all semidefinite systems that have a badly behaved dual for some objective function.

The characterization is based on some new, fundamental results in convex analysis on the closedness of the linear image of a closed convex cone. In particular, our result is a *necessary* condition for the closedness of the linear image – as opposed to the usual *sufficient* conditions, such as the existence of a Slater-point, or polyhedrality. Our conditions are necessary *and* sufficient, when the cone belongs to a large class, called *nice* cones.

Our closedness criteria lead to exact characterizations for other badly behaved convex programs as well, such as second order cone programs, quadratically constrained convex quadratic programs, and geometric programs - essentially all efficiently solvable, convex optimization problems.

Hyperbolic programming algorithms relying on derivative cones.

James Renegar
Cornell University, Ithaca, NY, US

Abstract

A hyperbolic program is a conic optimization problem in which the cone is the domain for a hyperbolic polynomial. Linear programming and semi-definite programming are the prominent examples.

Directional derivatives of hyperbolic polynomials yield new hyperbolic polynomials, and with them, new cones, what we call the "derivative cones." In previous talks, we have presented algorithms built using the derivative cones, in which the original cone is first approximated by a much simpler cone, and in which, over time, the simple cone is deformed to become the original cone, all the while the resulting path of optimal solutions being traced.

Although the approach possessed elegance and novelty, in certain regards the deformation cones seemed computationally sub par, especially in that the derivative directions did not evolve over time in a way that incorporated new information generated by the algorithms as the paths of optimal solutions were traced. When six months ago we turned attention to this shortcoming, we found an unexpected wealth of topics waiting to be explored. The talk will begin by carefully setting the stage, and the go on to discuss the key ideas and taunting puzzles as they stand at the time of the conference.

Convergence of infeasible-interior-point methods for self-scaled conic programming.

Michael J. Todd
Cornell University, US

Abstract

We present results on global and polynomial-time convergence of infeasible-interior-point methods for self-scaled conic programming, which includes linear and semidefinite programming. First, we establish global convergence for an algorithm using a wide neighborhood. Next, we prove polynomial complexity for the algorithm with a slightly narrower neighborhood. Both neighborhoods are related to the wide (minus infinity) neighborhood and are much larger than the 2-norm neighborhood. We also provide stopping rules giving an indication of infeasibility.

(Joint work with B.K. Rangarajan.)

On conic programming relaxation and SDP relaxation of 2-ball trust region problem.

Paul Tseng
University of Washington, Seattle, USA

Abstract

We consider conic programs with low rank constraints and their approximation by dropping the low rank constraints. In particular, we consider an SDP-based approximation algorithm for solving the 2-'ball' trust region problem. We present performance bounds and numerical experience in the context of 2-ellipsoid trust region algorithms for equality constrained nonlinear programming.

Computational experiences in solving large scale SDPs by Krylov subspace methods.

Kim-Chuan Toh
National University of Singapore

Abstract

We report our computational experiences on solving large scale SDPs via a primal-dual interior-point method (IPM) for which the linear system in each iteration is solved by a preconditioned Krylov subspace method such as the PCG method. Large scale SDPs often arise from the SDP relaxation of hard combinatorial problems, and even larger ones arise if the semidefinite matrix variable is also constrained to have non-negative elements. In the second half of the talk, we discuss the construction of preconditioners and related computational issues for the linear systems arising from an SDP where its matrix elements are also constrained by a large number of linear inequalities.

Using optimization to solve some problems in astrophysics.

Robert J. Vanderbei
Princeton University, US

Abstract

I will discuss two applications of nonlinear optimization. The first involves finding new surprising orbits for the n-body problem by minimizing the action functional. The second is the design of a telescope aperture that provides the extreme high-contrast one needs in order to image Earth-like planets orbiting nearby stars. The problem here is to maximize light throughput subject to certain constraints on the Fourier transform of the light transmission function.

Solving very large scale SDPs that arise from ad hoc wireless sensor network localization and other Euclidean geometry problems.

Yinyu Ye
Stanford University, US

Abstract

We describe an iterative distributed and decomposed semidefinite programming (SDP) method for solving localization problems that arise from ad hoc wireless sensor network and other Euclidean distance geometry. Using the method, we can solve very large scale semidefinite programs which are intractable for the centralized methods. Our decomposition scheme seems applicable to solving other semidefinite programs, and, like linear programming, is a most effective way to solve very large-scale problems in general.

8 List of Participants

This is the list of registered workshop participants as of April 14th, 2004, in alphabetical order. Participants who are doing a a poster presentation have a $*$ next to their names.

1. Alfakih, Abdo. University of Windsor.
2. Al-Homidan, Suliman. King Fahd University of Petroleum & Minerals.
3. Amini, Keyvan. McMaster University.
4. Anjos*, Miguel. University of Southhampton.
5. Anstreicher, Kurt. University of Iowa.
6. Bai, Yanqin. Delft University of Technology.
7. Barnes*, Earl. Georgia Tech.
8. Bauschke, Heinz. University of Guelph.
9. Bertsimas, Dimitris. Massachussetts Institute of Technology.
10. Borchers, Brian. New Mexico Tech.
11. Borwein, Jonathan. Simon Fraser University.
12. Boyd, Stephen. Stanford University.
13. Braams, Bastiaan, J. Emory University.
14. Burer*, Sam. University of Iowa.
15. Cabrera, Hector Ramirez. University of Chile.
16. Cho*, Gyeong-Mi. McMaster University.
17. Chua*, Chek Beng. University of Waterloo.
18. Deza, Antoine. McMaster University.
19. Edwards, Mclean. University of Guelph.
20. Elabwabi, Gamal. Delft University of Technology.
21. Elhedhli, Samir. University of Waterloo.
22. Fortin*, Charles. McGill University.
23. Freund, Robert M. Massachussetts Institute of Technology.
24. Freund, Roland W. Bell Labs.

25. Fukuda*, Mituhiro. New York University.
26. Gill, Philip E. San Diego Supercomputer Center (SDSC).
27. Glineur*, François. UCL/CORE.
28. Goffin, Jean-Louis. McGill University.
29. Greenberg, Harvey. University of Colorado.
30. Gould, Nick. CCLRC Rutherford Appleton Laboratory.
31. Hanafizadeh, Payam. University of Waterloo.
32. Helmberg, Christoph. Chemnitz University.
33. Henrion, Didier. LAAS-CNRS.
34. Den Hertog, Dick. Tilburg University.
35. Ho, Jackie C.K., York University.
36. Illes, Tibor. Eotvos Lorand University.
37. Jarre, Florian. University of Dusseldorf.
38. Johnson, Charles. College of William and Mary.
39. Kamali, Mahtab. University of Waterloo.
40. De Klerk, Etienne. University of Waterloo.
41. Kočvara, Michal. University of Erlangen-Nuremberg.
42. Krishnan*, Kartik. McMaster University.
43. Kruk, Serge. Oakland University.
44. Lasserre, Jean. LAAS-CNRS.
45. Lee, Jon. IBM T.J. Watson Research Center.
46. Lewis, Adrian. .Simon Fraser University.
47. Li, Chi-Kwong. College of William and Mary.
48. Lu, Zhaosong. Georgia Institute of Technology.
49. Luo, Tom. McMaster University.
50. Ma, Guoxuan. McMaster University.
51. Mahootchi, Masoud. University of Waterloo.
52. Mittelmann, Hans. Arizona State University.

53. Monteiro, Renato. Georgia Institute of Technology.
54. Nakata, Maho. Tokyo University.
55. Nayakkankuppam, Madhu. University of Maryland.
56. Nematollahi, Eissa. McMaster University.
57. Nesterov, Yurii. Université catholique de Louvain.
58. Nocedal, Jorge. Northwestern University.
59. O'Neal, Jerome. Georgia Institute of Technology.
60. Ordóñez, Fernando. University of Southern California.
61. Parrilo, Pablo. Swiss Federal Institute of Technology.
62. Pasechnik*, Dmitrii V. (Dima). J.W. Goethe-University.
63. Pataki, Gabor. University of North Carolina.
64. Pena, Javier. Carnegie Mellon University.
65. Peng, Jiming. McMaster University; Hamilton.
66. Peyghami, Mohammad Reza. McMaster University.
67. Pinar, Mustafa. Bilkent University.
68. Pinter, Janos D. Dalhousie University.
69. Pólik*, Imre. McMaster University.
70. Ponnambalam (Ponnu), Kumaraswamy. University of Waterloo.
71. Pothen, Alex. Old Dominion University.
72. Potra, Florian. University of Maryland.
73. Povh*, Janez. Universitaet Klagenfurt.
74. Rangarajan*, Bharath. Cornell University.
75. Rendl, Franz. Universitaet Klagenfurt.
76. Renegar, James. Cornell University.
77. Roos, Kees. Delft University of Technology.
78. Romanko*, Oleksandr. McMaster University.
79. Salahi*, Mazier. McMaster University.
80. Saunders, Michael. Stanford University.

81. Schurr, Simon. University of Maryland.
82. Sendov, Hristo. University of Guelph.
83. Shioda*, Romy. University of Waterloo.
84. Sim, Chee-Khian. National University of Singapore.
85. Sim, Melvyn. Massachusetts Institute of Technology.
86. Sotirov*, Renata. McMaster University.
87. Stoyan, Stephen. McMaster University.
88. Terlaky*, Tamás. McMaster University.
89. Todd, Mike. Cornell University.
90. Tongryeol, Seol. McMaster University.
91. Toh, Kim-Chuan. National University of Singapore.
92. Toint, Philippe. The University of Namur.
93. Tseng, Paul. University of Washington.
94. Tunçel, Levent. University of Waterloo.
95. Tutuncu, Reha. Carnegie Mellon University.
96. Vanderbei*, Robert. Princeton University.
97. Vannelli, Tony. University of Waterloo.
98. Vaz, Anthony Faria. Risk Analytics.
99. Wang, Mingyan. Chinese Academy of Sciences.
100. Wiegele*, Angelika. University of Klagenfurt.
101. Wolkowicz*, Henry. University of Waterloo.
102. Xia, Yu. McMaster University.
103. Yildirim, Alper, E. SUNY at Stony Brook.
104. Ye, Yinyu. Stanford University.
105. Zhang, Guoqing. University of Windsor.
106. Zhang, Shuzhong. The Chinese University of Hong Kong.
107. Zhu*, Xiaohang. McMaster University.

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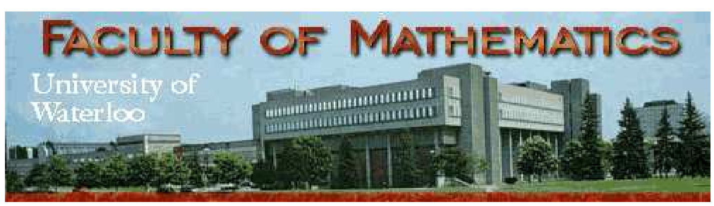

University of Waterloo, Faculty of Mathematics