2^{nd} Mathematical Programming Society
International Conference on Continuous Optimization

ICCOPT 07 – MOPTA 07

Modelling and Optimization: Theory and Applications 2007

August 13-16, 2007

McMaster University
Hamilton, Ontario, Canada

Sponsors

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Dear Participants,

On behalf of the organizers, it is our pleasure to welcome you to the Second Mathematical Programming Society International Conference on Continuous Optimization, ICCOPT 07, and the Seventh Modelling and Optimization: Theory and Applications Conference, MOPTA 07. The conference is being held August 13-16, 2007, at McMaster University, Hamilton, Ontario. The conference program, with over 350 talks, 14 featured speakers and over 15 posters, offers a great variety of excellent contributions, covering all major areas of continuous optimization, including optimization software and various novel applications. We will also have a session featuring three talented young researchers, the three finalists of the Student Paper Competition.

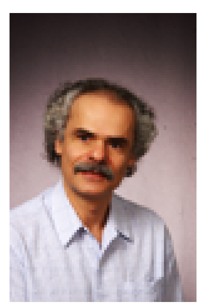
The conference will build on the success of the first ICCOPT conference at the Rensselaer Polytechnic Institute in 2004, and the previous MOPTA conferences held in Hamilton, Waterloo and Windsor. The conference is preceded by a two day Summer School: Saturday, August 11, "Experimental Mathematics with Variational Applications," and Sunday, August 12, "Grid-computing for Optimization: Modelling and Solution."

The conference could not have happened without the dedicated work of the stream and session organizers and their efforts to invite the very best of the field to this conference. Thanks are also due to all the featured speakers, the student volunteers, and Janet Delsey, Oleksandr Romanko and Imre Pólik who ensured seamless organization at various levels.

The social events and the poster session offer ample opportunities to interact with colleagues, meet old friends and make new ones. After the conference, if your time allows, take some moments to visit the beautiful trails and waterfalls of the Niagara Escarpment, explore the trails of Cootes Paradise in the backyard of the McMaster campus or join us for a tour of Niagara Falls. We hope that you enjoy your time at the conference and discover the beauty of the McMaster campus and the Hamilton-Niagara area.

We wish you a pleasant and productive conference.

TAMÁS TERLAKY
McMaster University
Chair of the Organizing Committee



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University of Waterloo
Chair of the Program Committee

McMaster University
Inspiring Innovation and Discovery

Vice-President
(Research & International Affairs)

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On behalf of McMaster, it is my pleasure to welcome you to our University and to the City of Hamilton, for the International Conference on Continuous Optimization.

McMaster is a full-service university with a student population of 23,000 and a faculty complement of 1,150. We have well-established strengths in information technology, materials and manufacturing, integrated health, molecular biology, work & society and globalization. Our pioneering academic programs are problem-based, multi-disciplinary and student-centered, and have been adopted by leading universities around the world.

We've built a modern university on solid traditions as we've grown over our 120 year history. Indeed, our research enterprise has grown with vigor – over the past five years alone, our research income has more than tripled, topping $345 million last year. We're listed among the Top 100 universities of the world and have been named Canada's Research University of the Year. Our 120,000 alumni hail from 128 countries, and when they leave us, they take their McMaster experience with them as they put their knowledge to work and become major contributors to their respective economies.

While there's little doubt your conference program will keep you busy, I encourage you to take some time to see our campus and learn, first-hand, why we've earned the reputation as one of Canada's most innovative universities and one of the country's most attractive campuses. From our state-of-the-art laboratories to our acclaimed McMaster Museum of Art to our brand new $43 million athletics centre to our new McMaster Innovation Park to the beautiful conservation trails that surround our campus – I guarantee, you will more than enjoy the McMaster experience. Best wishes for a great conference and a memorable visit to our campus and our city.

M. A. ElBestawi

Mo Elbestawi
Vice-President, Research and International Affairs

THE CITY OF
HAMILTON
OFFICE OF THE MAYOR

Greetings from the Mayor of Hamilton

On behalf of the City of Hamilton, I am very pleased to welcome you to Hamilton and to the International Conference on Continuous Optimization, taking place at McMaster University from August 13 - 16, 2007.

McMaster University is home to leading edge development and intense research and innovation. It is the ideal forum for researchers interested in all aspects of continuous optimization.

I trust the conference will provide each of you a chance to hear some wonderful keynote speakers, exchange information regarding latest innovations in your fields of expertise and offer a chance to connect with your friends and colleagues from across Canada and the world.

I wish to thank the organizers of this event. It is their hard work and dedication that affords those present, the opportunity to benefit from the conference.

Thank you for coming to Hamilton. I hope that you will have the time to truly experience our city; visit some of our famous attractions and sample some of our many fine restaurants and shopping areas.

We look forward to your next visit.

Sincerely,

Fred Eisenberger
Mayor

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CLOVIS C. GONZAGA (Federal University of Santa Catarina)
RAPHAEL HAUSER (Oxford University)

CONVEX AND NONSMOOTH ANALYSIS
HEINZ BAUSCHKE (UBC Okanagan), SHAWN WANG (UBC Okanagan)

CONVEX OPTMIZATION METHODS
MARC TEBOULLE (Tel-Aviv University)

DATA MINING AND MACHINE LEARNING
W. ART CHAOVALITWONGSE (Rutgers), JIMING PENG (University of Illinois at UC), ROMY SHIODA (University of Waterloo)

DERIVATIVE FREE OPTIMIZATION
VIRGINIA TORCZON (College of William & Mary)
ROBERT MICHAEL LEWIS (College of William & Mary)

ENGINEERING OPTIMIZATION
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GLOBAL OPTIMIZATION
NICK SAHINIDIS (Carnegie Mellon), MOHIT TAWARMALANI (Purdue University)

INTERIOR POINT METHODS AND APPLICATIONS
ERLING ANDERSEN (MOSEK ApS), JACEK GONDZIO (The University of Edinburgh)

LINEAR, SEMIDEFINITE AND CONIC OPTIMIZATION
MASAKAZU KOJIMA (Tokyo Institute of Technology)
KIM-CHUAN TOH (National University of Singapore)

MEDICAL APPLICATIONS IN OPTIMIZATION
MICHAEL FERRIS (University of Wisconsin – Madison)

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ROBERT FOURER (Northwestern University)

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TAMMY KOLDA (Sandia National Laboratories)
HANS MITTELMANN (Arizona State University)

NONSMOOTH OPTIMIZATION
CLAUDE LEMARÉCHAL (INRIA)
KARTIK K. SIVARAMAKRISHNAN (North Carolina State University)

OPTIMIZATION FORMULATIONS AND ALGORITHMS FOR CHEMICAL PROCESSES
LORENTZ T. BEIGLER (Carnegie Mellon), CHRIS SWARTZ (McMaster University)

PDE CONSTRAINED OPTIMIZATION
EKATERINA KOSTINA (University of Heidelberg)

ROBUST OPTIMIZATION
MELVYN SIM (National University of Singapore, Singapore-MIT Alliance)

SIGNAL PROCESSING AND ECE
ZHI-QUAN (TOM) LUO (University of Minnesota)

SPECIAL PURPOSE HEURISTICS AND GENERAL METAHEURISTICS
JOHN CHINNECK (Carleton University)

Summer School

Saturday, August 11

8:00 Registration and breakfast
8:50 Opening Remarks
9:00 Experimental Mathematics: an Introduction
10:15 Break
10:45 Algorithms for Experimental Mathematics
12:00 Lunch
1:30 Inverse Scattering: a Case Study in Experimental Mathematics
2:45 Break
3:15 Further Variational Examples
4:30 Concluding Remarks
6:00 Summer School Banquet (Acclamation Bar&Grill, 191 James Street North)

Sunday, August 12

8:00 Registration and breakfast
9:00 Introduction to Grid Computing
10:00 Decomposition Strategies and Tools
11:00 Coffee break
11:20 Stochastic Programming on a Grid
12:30 Lunch
1:30 The Master-Worker Paradigm
2:30 Integer Programming on a Grid
3:30 Tea Break
4:00 Grid Computing from a Modelling System
5:00 Closing

All events during the Summer School and the Conference are in MDCL unless indicated otherwise.

All the lectures of the Summer School are in MDCL 1309, coffee, lunches and breakfasts are served at the front entrance of MDCL.

Lunch for the Conference is in MUSC in two different rooms, please follow the assignment indicated on your lunch ticket.

The bus for the Summer School Banquet leaves at 5:45 from MDCL. Buses for the Conference Banquet (LIUNA Station) leave at 6:45 from MDCL.

See the maps on the inside back cover for the exact locations of the events.

Conference

Sunday, August 12

4:30 Conference registration starts (MUSC)
6:30 Welcome Reception (MUSC)

Monday, August 13

8:45 Opening
9:00 Plenary Session MA0
10:00 Coffee Break
10:30 Parallel Sessions MB1-9
12:00 Lunch (MUSC)
1:30 Semi-plenary Sessions MS1-3
2:30 Break
2:45 Parallel Sessions MC1-9
4:15 Coffee Break
4:45 Parallel Sessions MD1-9
6:30 Poster Presentations and Reception (MUSC)

Tuesday, August 14

8:30 Parallel Sessions TA1-9
10:00 Coffee Break
10:30 Parallel Sessions TB1-9
12:00 Lunch (MUSC)
1:30 Semi-plenary Sessions TS1-3
2:30 Break
2:45 Parallel Sessions TC1-9
4:15 Coffee Break
4:45 Parallel Sessions TD1-9
7:00 Conference Banquet (LIUNA Station)

Wednesday, August 15

8:30 Parallel Sessions WA1-9
10:00 Coffee Break
10:30 Parallel Sessions WB1-9
12:00 Lunch (MUSC)
1:30 Semi-plenary Sessions WS1-3
2:30 Break
2:45 Parallel Sessions WC1-9
4:15 Coffee Break
4:45 Parallel Sessions WD1-9
7:00 Student Social (MUSC)

Thursday, August 16

8:30 Parallel Sessions RA1-9
10:00 Coffee Break
10:30 Parallel Sessions RB1-9
12:00 Lunch (MUSC)
1:30 Semi-plenary Sessions RS1-3
2:30 Break
2:45 Plenary Session RC0
3:45 Closing

ADRIAN S. LEWIS

Cornell University

NONSMOOTH OPTIMIZATION: FUNDAMENTALS AND APPLICATIONS

Monday, 9:00-10:00, MDCL 1305-1307

Nonsmoothness pervades optimization theory and practice. This talk surveys how current variational-analytic ideas about nonsmooth sets and functions help us understand the structure and conditioning of concrete nonconvex optimization problems, and their numerical solution. I will focus on the basic notion of the normal cone, generalized derivatives, and “regularity”, and on structural tools such as “partial smoothness” and semi-algebraic techniques, sketching how each idea helps in algorithm design and analysis. A variety of examples taken from robust control design illustrate the central themes, including pole placement, distances to instability and uncontrollability, the H-infinity norm, and pseudospectra.

Adrian S. Lewis was born in England in 1962. He is a Professor at Cornell University in the School of Operations Research and Industrial Engineering. Following his B.A., M.A., and Ph.D. degrees from Cambridge, and Research Fellowships at Queens’ College, Cambridge and Dalhousie University, Canada, he worked in Canada at the University of Waterloo (1989-2001) and Simon Fraser University (2001-2004). He is an Associate Editor of the SIAM Journal on Optimization, Mathematics of Operations Research, and the SIAM/MPS Book Series on Optimization, and is a Co-Editor for Mathematical Programming. He received the 1995 Aisenstadt Prize, from the Canadian Centre de Recherches Mathematiques, the 2003 Lagrange Prize for Continuous Optimization from SIAM and the Mathematical Programming Society, and an Outstanding Paper Award from SIAM in 2005. He co-authored the book “Convex Analysis and Nonlinear Optimization” with J.M. Borwein. Lewis’s research concerns variational analysis and nonsmooth optimization, with a particular interest in optimization problems involving eigenvalues.

LORENZ T. (LARRY) BIEGLER

Carnegie Mellon University

OPTIMIZATION METHODS FOR PROCESS DESIGN

Thursday, 2:45-3:45, MDCL 1305-1307

Optimization formulations play a key part in many aspects of chemical process engineering. Moreover, with the application of more accurate and complex process models, a number of important algorithmic challenges must be addressed to deal with these optimization models efficiently. This talk presents an overview of problem classes in chemical process optimization and discusses key characteristics of these problems. In particular, a hierarchy of optimization models is explored, and typical problem formulations and solution strategies are presented at each level of this hierarchy. These are presented in parallel with leading edge research in continuous variable optimization, including complementarity formulations and extensions of large-scale barrier methods.

Larry Biegler has been with Carnegie Mellon University ever since he completed his graduate studies. He is currently a Bayer Professor of Chemical Engineering. After graduating from the Illinois Institute of Technology, Dr. Biegler earned his M.Sc. and Ph.D. degrees from the University of Wisconsin, Madison. Professor Biegler’s research projects are in the areas of design research and systems analysis. His research centers around the development and application of concepts in optimization theory, operations research, and numerical methods for process design, analysis, and control. He has authored or co-authored over 200 archival publications, authored or edited seven books and presented numerous papers at national and international conferences. His accomplishments have been acknowledged by numerous awards, such as the McAfee Award (Pittsburgh Section, 2001) and the Computing in Chemical Engineering Award (CAST Division, 2000) of the American Institute of Chemical Engineers.

The ICCOPT Young Researcher Competition called for submissions of published or nearly published papers from graduate students. The selection committee (Levent Tunçel, Yinyu Ye, Akiko Yoshise) chaired by Kees Roos invited the following contestants to present their work in a dedicated session of the conference.

ALEXANDRE BELLONI
Duke University

NORM-INDUCED DENSITIES AND TESTING THE BOUNDEDNESS OF A CONVEX SET

Alexandre Belloni is an Assistant Professor in The Fuqua School of Business at Duke University. During the year 2006-2007 he was a Herman Goldstine Post-doctoral Fellow at the IBM Watson Research Center in Yorktown. He earned his B.Eng. from the Pontifical Catholic University and his M.Sc. in Mathematical Economics from the Institute for Pure and Applied Mathematics, both in Rio de Janeiro, Brazil. He started his PhD studies at MIT in 2002 under the supervision of Robert Freund. He graduated in 2006. His research interest spans over diverse topics in mathematical programming, statistics/econometrics, probabilistic methods, complexity theory and applications to engineering, management science, marketing and economics. Throughout his studies he received several awards and fellowships from IBM, SIAM and MIT. He received Second Prize at the INFORMS 2006 George Nicholson Student Paper Award competition. In August 2007 he joined The Fuqua School of Business at Duke University as an Assistant Professor of Decision Sciences.
In his spare time he plays field hockey and is a member of the Brazilian national team and also the Boston team.

MUNG CHIANG
Princeton University

GEOMETRIC PROGRAMMING FOR COMMUNICATION SYSTEMS

Mung Chiang is an Assistant Professor of Electrical Engineering and an affiliated faculty of Applied and Computational Mathematics and of Computer Science at Princeton University. He received the B.S. (Honors) in Electrical Engineering and Mathematics, M.S. and Ph.D. degrees in Electrical Engineering from Stanford University. His research areas include nonlinear optimization of communication systems, especially optimization algorithms in broadband access networks, Internet, and wireless networks. Dr. Chiang is the Lead Guest Editor of the Special Issue of IEEE Journal of Selected Areas in Communications on Nonlinear Optimization of Communication Systems and a co-editor of the new Springer book series on Optimization and Control of Communication Systems.
He has received NSF CAREER Award, ONR Young Investigator Award, Princeton University Wentz Junior Faculty Award, Stanford University School of Engineering Terman Award, SBC Communications New Technology Introduction Contribution Award, and Hertz Foundation Fellowship. One of his papers became the Fast Breaking Paper in Computer Science in 2006 according to ISI's citation frequency. He co-authored papers that received best student paper award at IEEE GLOBECOM and best paper award finalists at IEEE VTC and INFOCOM. He is recently selected in TR35 as one of the top 35 young technologists in the world under the age of 35 by Technology Review Magazine.

EISSA NEMATOLLAHI
McMaster University

HOW GOOD ARE INTERIOR POINT METHODS?
KLEE-MINTY CUBES TIGHTEN ITERATION-COMPLEXITY BOUNDS

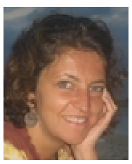
Eissa Nematollahi is a graduating PhD student at the Department of Mathematics and Statistics at McMaster University, supervised by Tamás Terlaky. He is an active member of the Advanced Optimization Laboratory. Before coming to Canada in 2004, he earned his undergraduate degree from Tabriz University and received his M.Sc. degree from Sharif University of Technology in Iran. During his PhD studies he spent three months at the Center for Operations Research and Econometrics (CORE) at the Université catholique de Louvain in Belgium as a Marie Curie Scholarship holder.
His research projects are centred around the properties of the central path of linear optimization problems and in particular, the effect of redundant constraints on the geometry of the central path. He studied both the theory and the algorithms to solve these problems. He was the first to show that the complexity of classical path-following interior point methods cannot be improved further.

Please join us on Tuesday, August 14 in MDCL 1305 (Session TC1) as the finalists present their papers. The abstracts can be found in the conference program. The winner will be announced at the conference banquet.

Monday, 1:30-2:30

Hiroshi Yamashita
Mathematical Systems, Inc., Tokyo
Primal-dual methods for NLP and NLSDP
Session MS1, MDCL 1305

In this talk primal-dual iterative methods for solving nonconvex nonlinear optimization will be described. Main theme is naturally primal-dual interior point methods for usual nonlinear optimization that use line search method and trust region method. Primal-dual exterior point methods that allow the primal variables stay outside feasible region are also described, and are shown to be applicable to parametric optimization problem which is not easy for interior point methods. An interesting possibility of acceleration method for these interior and exterior point methods is described. Primal-dual interior point methods for nonlinear SDP problem and nonlinear SOCP problem will also be described. Numerical results of these methods will be presented.



Katya Scheinberg
IBM, Yorktown
Model Based Derivative Free Optimization
Session MS2, MDCL 1307

Derivative free optimization (DFO) is the field of nonlinear optimization which targets functions whose derivatives exists but are not available and cannot be approximated efficiently. It is often also the case that such functions are expensive to evaluate and/or are noisy. In the past decade there has been a significant increase in research in the area of DFO, much of it in the development of model based methods. There are several practical algorithms that have been proposed, most of them lacking global convergence theory. Those methods that do have convergence theory have to resort to impractical extra steps and conditions. But most of the proposed methods have the "right ingredients" for both convergence theory and practical performance. We will discuss these ingredients and try to fit them in a unifying framework for which we can provide convergence theory.

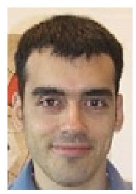
Hubertus Th. Jongen
RWTH Aachen University
Nonlinear Semi-Infinite Programming: Structural Analysis
Session MS3, MDCL 1105

We present a survey on structural results in standard Semi-Infinite Programming (SIP). In particular, we focus on critical points and topological stability. Then, we describe new challenging features appearing in general SIP.

Tuesday, 1:30-2:30

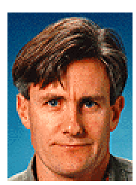
Andy Conn, IBM Watson Research Center
An introduction to an algorithmic framework for mixed integer nonlinear programs
Session TS1, MDCL 1305

Mixed integer nonlinear programming is an area of ever increasing importance and applications that is significantly under researched — no doubt because it presents many difficult challenges. I will present a basic hybrid framework for mixed-integer nonlinear programming. In one extreme case, the method becomes the branch-and-bound approach, where a nonlinear optimization problem is solved in each node of the enumeration tree, and in the other extreme it reduces to the polyhedral outer approximation algorithm, which alternates between the solution of a nonlinear optimization problem and a mixed-integer linear program. Numerical results are presented, using an open source software implementation available on `http://www.coin-or.org`. This work results from an on-going research collaboration between IBM and CMU.



Pablo Parrilo, MIT
Polynomial Optimization
Session TS2, MDCL 1307

Optimization problems involving multivariate polynomials are ubiquitous in many areas of engineering and applied mathematics. Although these problems can sometimes (but not always) be approached using the traditional ideas of nonlinear optimization, in recent years there has been much interest in new techniques, that exploit their intrinsic algebraic features, to provide global solutions or more efficient algorithms. In this talk we survey the basic features of these algebraic approaches, involving sum of squares and semidefinite programming, emphasizing the geometric aspects and a few selected applications in dynamical systems and game theory.



Andrew Philpott, University of Auckland
Stochastic optimization in electricity pool markets
Session TS3, MDCL 1105

Over the past decade, markets for electric power have emerged in many countries. The details of the market mechanisms differ from place to place, but most of them depend on some centralised dispatch pool which sets a price for electricity. Supply and demand decisions are made in advance of this price being set (and affect it) so they are subject to uncertainty. To accommodate this uncertainty, electricity generators offer supply functions rather than fixed generation quantities. Choosing an optimal supply function is then an infinite-dimensional stochastic optimization problem. In my talk I will show how this problem can be attacked using variational techniques that are based on a "market distribution" function. The methodology will be illustrated by showing some examples of optimization models based on these ideas that are being used in the New Zealand electricity market.

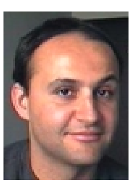
WEDNESDAY, 1:30-2:30

JACEK GONDZIO
The University of Edinburgh
LARGE SCALE (HUGE) PROGRAMMING
Session WS1, MDCL 1305

In this talk we will demonstrate that interior point methods are well-suited to solve very large linear, quadratic and nonlinear programming problems. We will show that the key to solve truly large problems is the ability to understand and exploit their structural properties. Examples of optimization problems arising in different areas of applications will be given. This is joint work with Andreas Grothey.

MELVYN SIM
National University of Singapore
Singapore-MIT Alliance
NEW ROBUST OPTIMIZATION MODELS FOR ADDRESSING STOCHASTIC OPTIMIZATION PROBLEMS
Session WS2, MDCL 1307

A classical robust optimization model assumes that data uncertainty belongs to an uncertainty set and its solution is optimal under the worst-case scenario that might arise within the uncertainty set. Such worst-case solution can be rather conservative in addressing a stochastic programming problem. We show that with additional distributional information, such as independence, known means and bounded supports, standard deviations, bounds on moment generating functions, we can make a robust optimization model less conservative, while keeping it computationally tractable in the form of SOCP. We propose new robust optimization models that approximate hard stochastic programming problems including joint chance constrained problems with recourse and multiperiod dynamic optimization problems. We report computational results comparing solutions obtained from using the robust optimization models with solutions obtained from using sampling approximation of the stochastic programming problems.



MIHAI ANITESCU
Argonne National Laboratory
EMERGING DESIGN CHALLENGES IN THE ADVANCED NUCLEAR FUEL CYCLE
Session WS3, MDCL 1105

Advanced simulation plays a central role in the recently launched global nuclear energy partnership (GNEP). GNEP is an initiative whose purpose is to design a nuclear fuel cycle that enhances energy security, promotes nonproliferation while enabling recycling and consumption of long-lived radioactive waste. We present some of the emerging design challenges of the advanced nuclear fuel cycle, with a particular emphasis on the ones posed by core design and waste reprocessing. Both activities are described by complex multi-physics models with uncertain parameters. In this context, we will discuss some of our initial investigations of using stochastic finite elements for the description of parametric uncertainty.

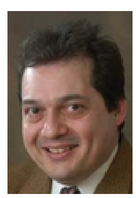
THURSDAY, 1:30-2:30

YINYU YE
Stanford University
FURTHER DEVELOPMENTS OF SDP FOR SENSOR NETWORK LOCALIZATION
Session RS1, MDCL 1305

We present further developments of semidefinite programming (SDP) based approaches for the position estimation problem in Euclidean distance geometry such as graph realization and sensor network localization. We develop new conic relaxation models, weaker than full SDP but stronger than SOCP, for solving large-scale problems with thousands sensors, and demonstrate computational results to show the effectiveness of the new models.

PHILIP E. GILL
University of California, San Diego
NUMERICAL LINEAR ALGEBRA AND OPTIMIZATION
Session RS2, MDCL 1307

In the formulation of practical optimization methods, it is often the case that the choice of numerical linear algebra method used in some inherent calculation can determine the choice of the whole optimization algorithm. The numerical linear algebra is particularly relevant in large-scale optimization, where the linear equation solver has a dramatic effect on both the robustness and the efficiency of the optimization. We review some of the principal linear algebraic issues associated with the design of modern optimization algorithms. Much of the discussion will concern the use of direct and iterative linear solvers for large-scale optimization. Particular emphasis will be given to: (i) the role of convexity in the design of algorithms; and (ii) recent developments in the use of regularization.



NICK SAHINIDIS
Carnegie Mellon University
OPTIMIZATION IN BIOLOGY
Session RS3, MDCL 1105

This talk provides an overview of optimization approaches to modern bioinformatics and systems biology problems. The presentation includes the protein side-chain prediction problem, protein structural alignment, protein and RNA folding prediction, biomolecular structure determination via experimental techniques, and metabolic systems analysis and design. The machinery employed to solve these problems has included algorithms from linear programming, dynamic programming, combinatorial optimization, mixed-integer nonlinear programming, and optimization of differential-algebraic systems. Many of these problems are purely continuous in nature. Yet, they have, to this date, been approached mostly via combinatorial optimization algorithms that are applied to discrete approximations.

The conference is preceded by a two-day summer school. The two days feature two different topics, both of which are motivated by practical applications but rely on theory quite heavily. All the lectures are held in MDCL 1309. Participants are encouraged to bring their laptops for a hands-on experience. Wireless internet access will be available in the building.

Saturday, August 11, 2007	**8:00- 8:50**	Registration and Breakfast
EXPERIMENTAL MATHEMATICS	**8:50- 9:00**	Opening Remarks
WITH VARIATIONAL APPLICATIONS	**9:00-10:15**	Experimental Mathematics: an Introduction (Borwein)
JON BORWEIN	**10:15-10:45**	Break
DAVID BAILEY	**10:45-12:00**	Algorithms for Experimental Mathematics (Bailey)
D. RUSSELL LUKE	**12:00- 1:30**	Lunch
	1:30- 2:45	Inverse Scattering: a Case Study in Experimental Mathematics (Luke)
	2:45- 3:15	Break
	3:15- 4:30	Further Variational Examples (Borwein)
	4:30- 4:40	Concluding Remarks
	6:00- 8:00	Summer School Banquet (Acclamation Bar&Grill, 191 James St N)

This four-lecture Short Course on Experimental Mathematics with applications in areas such as Convex Analysis and Optimization is organized by Jonathan M. Borwein, Dalhousie University. The goal of this course is to present a coherent variety of accessible examples of modern variational mathematics where intelligent computing plays a significant role and in doing so to highlight some of the key algorithms and to teach some of the key experimental approaches. While a working knowledge of some mathematical computing package is an advantage, it is certainly not a prerequisite. The last twenty years have been witness to a fundamental shift in the way mathematics is practiced. With the continued advance of computing power and accessibility, the view that "real mathematicians don't compute" no longer has any traction for a newer generation of mathematicians that can really take advantage of computer aided research, especially given the modern broad-spectrum computational packages such as Maple, Mathematica, and Matlab.
Related text: Jonathan Borwein, David Bailey, Neil Calkin, Roland Girgensohn, D. Russel Luke, Victor Moll, Experimental Mathematics in Action, AK Peters, 2007. `http://www.akpeters.com/product.asp?ProdCode=271X`. There is a discount for attendees.
Related Web sites: `http://www.experimentalmath.info`, `http://users.cs.dal.ca/~jborwein/ema.html` `http://ddrive.cs.dal.ca/~isc/portal`

Sunday, August 12, 2007	**8:00- 9:00**	Registration and Breakfast
GRID-COMPUTING FOR OPTIMIZATION:	**9:00-10:00**	Introduction to Grid Computing (Linderoth)
MODELING AND SOLUTION	**10:00-11:00**	Decomposition Strategies and Tools (Ferris)
MICHAEL FERRIS	**11:00-11:20**	Coffee Break
JEFF LINDEROTH	**11:20-12:30**	Stochastic Programming on a Grid (Wright)
STEPHEN J. WRIGHT	**12:30- 1:30**	Lunch
	1:30- 2:30	The Master-Worker Paradigm (Wright)
	2:30- 3:30	Integer Programming on a Grid (Linderoth)
	3:30- 4:00	Tea break
	4:00- 5:00	Grid Computing from a Modeling System (Ferris)

Computational grids are computing platforms created by harnessing unused CPU cycles from a variety of distributedly-owned workstations and clusters. Condor is a free and popular software tool from which such federated computing platforms can be built. Grids can be very powerful, but they are difficult to use effectively. The short course will give an introduction to several new tools that 1) allow modelers and domain experts to process large collections of optimization problems over a grid and 2) aid an optimizer in developing new algorithms that exploit the CPU power and resources of computational grids. One tool we discuss is GAMS-grid. The GAMS-grid tool allows multiple optimization instances to be generated from a GAMS model, each of these instances being solved concurrently on a Condor-based grid. GAMS-grid automatically recognizes job failures and seamlessly resubmits them to the available grid resources. We describe ongoing development of GAMS-grid, to facilitate inter-processor communication, synchronization, and improved failure recovery. The utility of GAMS-grid will be demonstrated by solving difficult stochastic, equilibrium, and mixed-integer programs.
A simple and powerful paradigm for designing parallel algorithms is the master/worker model in which a master program coordinates the computational effort of a large number of workers, each of which solves a number of subproblems or "tasks." The paradigm is quite flexible - in particular, it allows tasks to be generated dynamically as the computation evolves - and it has been used to implement complex parallel computations such as parallel branch-and-bound efficiently. The second tool we describe in this short course is MW, a programming abstraction that encodes the essential features of the master-worker paradigm, allowing users to program effectively in this paradigm and exploit grid computing without being aware of the details of the grid implementation. We will discuss how MW has been used to solve large-scale combinatorial optimization and stochastic optimization problems. Programs that use these software tools will be demonstrated.

SUMMER SCHOOL BANQUET
SATURDAY, AUGUST 11, 6-8PM
Acclamation Restaurant (191 James Street North)

The bus leaves at 5:45 from MDCL

WELCOME RECEPTION AND REGISTRATION
SUNDAY, AUGUST 12, 6:30-9PM
McMaster University Student Centre, 3rd floor, CIBC Banquet Hall

Registration starts at 4:30pm

POSTER PRESENTATIONS AND RECEPTION
MONDAY, AUGUST 13, 6:30-8:30PM
McMaster University Student Centre, 1st floor, Marketplace

The posters will be on display throughout the conference in MDCL

ICCOPT/MOPTA STUDENT SOCIAL
WEDNESDAY, AUGUST 15, 7-9PM
McMaster University Student Centre, 3rd floor, CIBC Banquet Hall

Organized by the McMaster Graduate Computational Club (MGCC)

CONFERENCE BANQUET (included in registration fee)
TUESDAY, AUGUST 14, 7-10PM
LIUNA Station, (buses leave at 6:30 from MDCL)

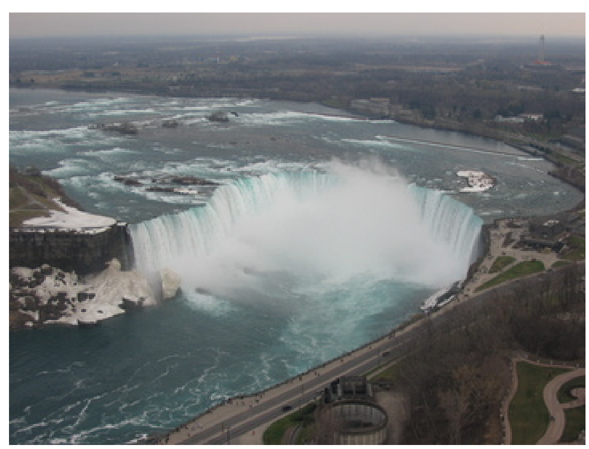
MENU

Assorted Rolls and Butter
Potato and Leek Cream Soup
Liuna Spring Mix with Tomatoes and Cucumbers in a Balsamic Vinaigrette
Your choice of pre-selected Entree
(Chicken DaVinci/Grilled Atlantic Salmon/Roast Prime Rib of Beef/Vegetarian)
Vanilla Crepes with Wild Berries
Coffee and Tea
Niagara VQA wines

Entertainment by First Nations Native Dance Group

PRE- AND POST-CONFERENCE NIAGARA FALLS TOURS $98
SUNDAY, AUGUST 12 AND FRIDAY, AUGUST 17, 9AM-4:30PM
Tour includes (all taxes and gratuities are included):

- Transportation between McMaster University and Niagara Falls by deluxe coaches
- Awe-inspiring “Maid of the Mist” boat ride (souvenir rain coats included)
- Lunch buffet in the Summit Suite of the Skylon Tower with exquisite views of the Falls from 236m (775 feet) above
- Tour of the Sir Adam Beck Generating Station (one of Niagara’s largest hydroelectric facilities)
- Guided tour and wine tasting in the Jackson Triggs winery



STUDENT NIAGARA BUS TRIP $20
FRIDAY, AUGUST 17, 9AM-6PM
A great way to relax after a long conference! Travel by bus to Niagara Falls and enjoy a self-guided tour of the area. You can sign up at the registration desk any time during the conference.

MONDAY

8:45-10:00

MA0 Opening plenary session

10:30-12:00

MB1 Applications of SDP
MB2 Computational Analysis
MB3 Sensitivity Analysis in Convex Programming and Variational Analysis
MB4 Specially Structured Problems
MB5 Financial Optimization
MB6 MPECs
MB7 Optimization in Medicine
MB8 Optimization in a Symbolic/Numeric Environment
MB9 Algorithms for Specially Structured Nonlinear Optimization Problems

1:30-2:30

MS1 Semi-plenary Presentation
MS2 Semi-plenary Presentation
MS3 Semi-plenary Presentation

2:45-4:15

MC1 Applications of SDP
MC2 Nonsmooth Analysis and Applications
MC3 Recent Advances in L^1-minimization Algorithms and Applications
MC4 Convexification and Duality in Global Optimization
MC5 Financial Optimization
MC6 VI/CP (Theory; Algorithms and Their Theory; Applications)
MC7 Robust Optimization in Medical Problems
MC8 Applications of Multidisciplinary Shape Optimization
MC9 PDE Constrained Optimization

4:45-6:15

MD1 Implementations/Interior-Point Methods
MD2 Designing and Testing Algorithmic Improvements for Derivative-free Direct Search Methods
MD3 Practical Performance of IPMs for Conic Programming Problems
MD4 Optimization of Networks
MD5 Financial Optimization
MD6 Topics on MPECs and Applications
MD7 Topics in Nonlinear Semidefinite Programming
MD8 Applications of Multidisciplinary Shape Optimization
MD9 Principles of Convex Optimization

TUESDAY

8:30-10:00

TA1 Nonlinear Programming and IPM
TA2 Convex Vector Optimization
TA3 Medical Problems using Optimization Techniques
TA4 Process Operations
TA5 Recent Theoretical Developments for Derivative-free Direct Search
TA6 Topics in Bilevel Optimization
TA7 Algorithms and Software for Nonlinear Optimization
TA8 PDE Constrained Optimization
TA9 Topics in Robust Optimization

10:30-12:00

TB1 Exploiting Structure in SDP and SOCP
TB2 Projections and Monotone Operators
TB3 Robust Risk Management
TB4 Process Design
TB5 Derivative-free Approaches to Global Optimization
TB6 Optimization in Communications and Signal Processing
TB7 Nonsmooth Optimization Algorithms and Applications
TB8 Pipeline Optimization
TB9 Combinatorial Optimization and Computational Complexity

1:30-2:30

TS1 Semi-plenary Presentation
TS2 Semi-plenary Presentation
TS3 Semi-plenary Presentation

2:45-4:15

TC1 Young Researcher Competition
TC2 Monotone Operators
TC3 Semidefinite Relaxation and Non-Convex Quadratic Optimization
TC4 Advances in Interior Point Methods and Conic Feasibility Problems
TC5 Financial Optimization
TC6 Numerical Methods for Complementarity Problems and MPECs
TC7 Modelling Languages for Conic Optimization
TC8 Optimization in Acoustics
TC9 Nonlinear Programming Software

4:45-6:15

TD1 Interior-point Methods/Implementations
TD2 Nonsmooth Matrix Analysis
TD3 Convex Optmization Methods
TD4 Chemical Processes
TD5 Applications of Robust Optimization
TD6 MPECs: Theory, Algorithms and Applications
TD7 PDE Constrained Optimization
TD8 Industrial Strength Optimization
TD9 Analytic Center and Bundle Methods for Nonsmooth Optimization and Applications

Wednesday

8:30-10:00

WA1 Algorithms and Software for Convex Programming
WA2 Decomposition and Nonsmooth Approaches for Large Scale Conic Optimization
WA3 Convex Vector Optimization
WA4 Robust Network Optimization
WA5 Derivative Free Optimization
WA6 Novel MPEC Applications
WA7 Computational Analysis
WA8 Simulation-Based Optimization
WA9 Process Modelling and Analysis

10:30-12:00

WB1 Convex Approaches for Nonconvex QPs
WB2 Convex Optimization Methods and Beyond
WB3 Polynomial Optimization and SDP
WB4 New Optimization Models and Techniques for Data Clustering
WB5 Derivative-Free Optimization Methods that Model the Objective Function without Taylor Approximations
WB6 Novel MPEC Algorithms
WB7 Derivative-free Nonlinear Programming
WB8 Multilevel and Distributed Optimization
WB9 PDE Constrained Optimization

1:30-2:30

WS1 Semi-plenary Presentation
WS2 Semi-plenary Presentation
WS3 Semi-plenary Presentation

2:45-4:15

WC1 Selected Topics in Conic Programming
WC2 Nonsmooth Analysis and Application
WC3 Continous Approach to Combinatorial Problems
WC4 Optimization and Data Mining
WC5 Heuristics for Global Optimization
WC6 Applications of Global Optimization
WC7 State-of-the-Art in NLP Software
WC8 Multilevel Optimization
WC9 Implementations and Interior-Point Methods

4:45-6:15

WD1 Sensor Networks and Graph Realization
WD2 Duality and Constraint Qualifications
WD3 Applications of Convex Optimization in Statistics and Control
WD4 Convex Optimization Methods
WD5 Robust Risk Management
WD6 Global Optimization
WD7 Advances in Modelling Languages for Continuous Optimization
WD8 PDE Constrained Optimization
WD9 Financial Optimization

Thursday

8:30-10:00

RA1 Algorithms for Structured Conic Convex Optimization
RA2 Algorithms and Applications
RA3 Process Control
RA4 Verification and Computation in Global Optimization
RA5 Applications of Derivative-free Direct Search Methods
RA6 VI/CP (Theory; Algorithms and Their Theory; Applications)
RA7 Distributed Optimization
RA8 Portfolio Optimization
RA9 Linear and Convex Quadratic Programming

10:30-12:00

RB1 Applications of SDP
RB2 Proximal Mappings and Applications
RB3 State-of-the-Art in NLP Software
RB4 Applications of Global Optimization
RB5 Curvature of the Central Path
RB6 Differential Variational Inequalities
RB7 Optimization in Communications and Signal Processing
RB8 Financial Optimization
RB9 Computational Analysis

1:30-2:30

RS1 Semi-plenary Presentation
RS2 Semi-plenary Presentation
RS3 Semi-plenary Presentation

2:45-3:45

RC0 Closing Plenary Presentation

	August 13, Monday	August 14, Tuesday	August 15, Wednesday	August 16, Thursday
8:30–10:00	**MA** Plenary: Adrian Lewis MDCL 1305/1307	**TA**	**WA**	**RA**
10:30–12:00	**MB**	**TB**	**WB**	**RB**
1:30–2:30	**MS** Semi-plenary Yamashita: MDCL 1305 Scheinberg: MDCL 1307 Jongen: MDCL 1105	**TS** Semi-plenary Conn: MDCL 1305 Parrilo: MDCL 1307 Philpott: MDCL 1105	**WS** Semi-plenary Gondzio: MDCL 1305 Sim: MDCL 1307 Anitescu: MDCL 1105	**RS** Semi-plenary Ye: MDCL 1305 Gill: MDCL 1307 Sahinidis: MDCL 1105
2:45–4:15	**MC**	**TC**	**WC**	**RC** Plenary: Larry Biegler MDCL 1305/1307
4:45–6:15	**MD**	**TD**	**WD**	

How to find your session?

You can use the author index and the session chair index at the back of this book to find the code of your session. The session code includes all the information you need to indentify your session (take MC5 as an example):

M **The day of the week:**

- **M** Monday
- **T** Tuesday
- **W** Wednesday
- **R** Thursday

C **The time of the day:**

- **A** 8:30-10:00
- **B** 10:30-12:00
- **S** 1:30-2:30 (Semi-plenary Presentations)
- **C** 2:45-4:15
- **D** 4:45-6:15

5 **The room code:**

- **0** MDCL 1305/1307 (Plenary Presentations)
- **1** MDCL 1305
- **2** MDCL 1307
- **3** MDCL 1105
- **4** MDCL 1110
- **5** MDCL 1016
- **6** MDCL 1309
- **7** MDCL 1009
- **8** MDCL 1010
- **9** MDCL 1008

You can find the floor map of MDCL on the inside back cover.

■ MA0

Monday, 8:30-10:00, MDCL 1305/1307

Opening plenary session

Stream: Nonsmooth Optimization
Chair: *Tamás Terlaky*, McMaster University

1. **Nonsmooth optimization: fundamentals and applications**

   Adrian Lewis, Cornell University

Nonsmoothness pervades optimization theory and practice. This talk surveys how current variational-analytic ideas about nonsmooth sets and functions help us understand the structure and conditioning of concrete nonconvex optimization problems, and their numerical solution. I will focus on the basic notion of the normal cone, generalized derivatives, and "regularity", and on structural tools such as "partial smoothness" and semi-algebraic techniques, sketching how each idea helps in algorithm design and analysis. A variety of examples taken from robust control design illustrate the central themes, including pole placement, distances to instability and uncontrollability, the H-infinity norm, and pseudospectra.

■ MB1

Monday, 10:30-12:00, MDCL 1305

Applications of SDP

Stream: Conic Programming and Interior Point Methods
Chair: *Brian Borchers*, Department of Mathematics, New Mexico Tech

1. **Approximating the chromatic number via SDP**

   Nebojsa Gvozdenovic, CWI Amsterdam, *Monique Laurent*

We investigate hierarchies of semidefinite approximations for the chromatic number $\chi(G)$ of a graph G. We introduce an operator Ψ mapping any graph parameter $\beta(G)$, nested between the stability number $\alpha(G)$ and $\bar{\chi}(G)$, to a new graph parameter $\Psi_\beta(G)$, nested between $\omega(G)$ and $\chi(G)$; $\Psi_\beta(G)$ is polynomial time computable if $\beta(G)$ is. As an application, there is no polynomial time computable graph parameter nested between the fractional chromatic number $\chi^*(\cdot)$ and $\chi(\cdot)$ unless P=NP. Under some mild assumption, $n/\beta(G) \le \Psi_\beta(G)$ but, while $n/\beta(G)$ remains below $\chi^*(G)$, $\Psi_\beta(G)$ can reach $\chi(G)$. We define new lower bounds for $\chi(G)$ and present some numerical results.

2. **Semidefinite Programming Bounds**

   Frank Vallentin, CWI Amsterdam, *Christine Bachoc*

Many problems in combinatorial optimization and geometry one can formulate as a packing problem in an underlying metric space. Examples include the kissing number problem, error correcting codes, sphere packing. I will explain a general method based on semidefinite programming to find upper bounds for packing problems in metric spaces. This method is a stronger and more flexible extension of the linear programming method which Phillippe Delsarte developed in the seventies. We implemented this approach and we found computationally, but rigorously, new upper bounds for the kissing number problem in several dimensions. In particular we found a unified proof for all cases when the kissing number is known.

3. **A Semidefinite Programming Branch-and-Cut Algorithm for the Minimum k-Partition Problem**

   Bissan Ghaddar, University of Waterloo, *Miguel Anjos*

The minimum k-partition (MkP) problem is a well-known optimization problem encountered in various applications such as telecommunication and physics. In this research, we devise an iterative clustering heuristic (ICH), a novel semidefinite programming (SDP) based heuristic that finds a feasible solution to the MkP problem. We compare ICH to the hyperplane rounding technique of Frieze and Jerrum. Furthermore, the ICH heuristic is used in a SDP-based branch-and-cut algorithm (SBC) to provide feasible solutions at each node of the branch-and-cut tree. We present computational results for the SBC algorithm on several classes of test instances and we show that the SBC algorithm outperforms the LP-based approach using CPLEX.

■ MB2

Monday, 10:30-12:00, MDCL 1307

Computational Analysis

Stream: Convex and Nonsmooth Analysis
Chair: *Warren Hare*, Simon Fraser University

1. **Symbolic Convex Analysis**

   Chris Hamilton, Dalhousie University

Convex optimization is a branch of mathematics dealing with non-linear optimization problems with additional geometric structure. This area has been the focus of considerable recent research due to the fact that convex optimization problems are scalable and can be efficiently solved by interior-point methods. Over the last ten years or so, convex optimization has found new applications in many areas including control theory, signal processing, communications and networks, circuit design, data analysis and finance. Of key importance in convex optimization is the notion of duality, and in particular that of Fenchel duality. This work explores algorithms for calculating symbolic Fenchel conjugates of a class of real-valued functions defined on R^n, extending earlier work to the non-separable multi-dimensional case. It also explores the use of the algorithms in symbolically computing proximal averages and Moreau envelopes.

2. **Proximal Point Stability Theory**

   Warren Hare, IRMACS, Simon Fraser University

Fundamental insights into the properties of a function come from the study of its Moreau envelopes and Proximal point mappings. In this talk we examine the stability of these two objects under several types of perturbations. We work our way from the simple case of tilt-perturbations in the objective function to the complex case of general perturbations in both the objective and proximal parameters.

3. **Using Quadratic Models in Updating Grid Searches**

   Mason Macklem, Faculty of Computing Science, Dalhousie University

Direct search algorithms are designed to solve optimization problems without use of higher-order information, by deterministically sampling the search space and comparing only the values of the objective functions at the selected points. Standard direct search methods have a trade-off between being able to adapt to the local behaviour of the objective function at the expense of potentially converging to non-stationary points, and guaranteeing convergence to stationary points by limiting the flexibility to arbitrarily reshape the search directions used. Recent research has focused on increasing the flexibility in choosing the search directions, either by requiring sufficient descent conditions on each iterate, or by restricting the points in the algorithm at which directions may be updated. We will discuss specific algorithms that use quadratic models of the objective function to update the search directions, and which are designed to fit within these convergent algorithmic frameworks.

■ MB3

Monday, 10:30-12:00, MDCL 1105

Sensitivity Analysis in Convex Programming and Variational Analysis

Stream: Linear, Semidefinite and Conic Optimization
Chair: *Gongyun Zhao*, Dept of Math, National University of Singapore

1. **Identifying the optimal partition in convex quadratic programming**

   Stephen E. Wright, Mathematics and Statistics, Miami University

Given an optimal solution for a convex quadratic programming (QP) problem, it is shown that the optimal partition of the QP can be computed by solving a pair of linear or quadratic programming problems for which nearly optimal solutions are known. A related procedure finds a maximally complementary solution for a monotone linear complementarity problem.

2. **Space of linear programs – Motivations, representations and structures**

   Gongyun Zhao, Dept of Math, National University of Singapore

We consider the space of all linear programs (SLP). The SLP can be partitioned into a finite number of sets $S_1, S_2, \ldots, S_k$, each set containing all LPs which are associated with a common basis. This partition is useful for solving sets of (infinitely many) linear programs, e.g., parametric LPs, in the closed form. A novel tool for characterizing this partition is presented by an ODE $M' = h(M)$ defined on projection matrices M. For any LP, we define a projection matrix, starting from which the solution of $M' = h(M)$ converges to a limit projection matrix which determines the basis of the LP. This establishes a corresponding partition on the space of projection matrices, G. With the help of the vector field $h(M)$ on G, it is promising to discover full characterization of the SLP.

■ MB4

Monday, 10:30-12:00, MDCL 1110

Specially Structured Problems

Stream: Global Optimization
Chair: *Paul Barton*, Department of Chemical Engineering, Massachusetts Institute of Technology

1. **Sequential Search Algorithm for Solving Disjoint Bilinear Programming Problems**

   Churlzu Lim, University of North Carolina at Charlotte

In this talk, we consider a bilinear programming problem constrained by two bounded nonempty polyhedral sets having respective disjoint sets of variables that comprise bilinear terms. Noting that a global minimum can be attained at extreme points of respective polytopes, the problem is viewed as a concave minimization problem having a piecewise linear objective function where each linear function corresponds to an extreme point of a polytope. To find extreme points solution, we propose a sequential search algorithm in which two series of linear programs are alternately solved. One problem yields an unexplored basis of a polytope, while the other provides a stopping condition or a new extreme point that induces a new basis. Disjunctive cuts are added to the latter in order to exclude previously generated extreme points. The algorithm and its motivation is illustrated by numerical examples.

2. **Determination of the optimal ellipsoids for certain slices of an ellipsoid**

   Filiz Gurtuna, UMBC, *Osman Güler*

Optimal ellipsoids for a convex body are the minimum volume ellipsoid covering that body and the maximum volume ellipsoid enclosed by that body. Both problems are important in several fields including nonlinear programming (ellipsoid methods, both circumscribed and inscribed), Banach space geometry, and optimal design. In ellipsoid methods, exact or approximately optimal ellipsoids are needed and it is very difficult to determine these ellipsoids for a general convex body. Our contribution is the determination of exact optimal ellipsoids for a class of convex bodies; slices of ellipsoids. We first prove some general results about the symmetry properties of the optimal ellipsoids, and use this to reduce the dimension. We then attack the optimization problem both by semi-infinite programming techniques and using ideas related to the S-procedure.

3. **Solving Bilevel Programs with a Nonconvex Inner Program**

   Paul Barton, Department of Chemical Engineering, Massachusetts Institute of Technology, *Alexander Mitsos*

A deterministic algorithm for the global solution of nonlinear bilevel programs involving nonconvex functions in both the inner and outer programs is presented. The algorithm is based on a branch-and bound framework and is proved to terminate finitely to a point that satisfies epsilon-optimality in the inner and outer programs. Lower bounds are obtained from the global solution of a relaxed program which in addition to the constraints from the inner and outer programs contains a parametric upper bound to the parametric optimal solution function of the inner program. For the case that the inner program satisfies a constraint qualification tighter lower bounds are obtained based on the KKT necessary conditions of the inner program. Upper bounds are based on probing the solution obtained by the lower bounding procedure. Three branching heuristics are described and analyzed. The algorithm is illustrated with the help of simple examples and numerical results are presented.

■ MB5

Monday, 10:30-12:00, MDCL 1016

Financial Optimization

Stream: Financial Optimization
Chair: *Oleksandr Romanko*, Dept. of Computing and Software, McMaster University
Session organizer: Alexandre d'Aspremont, Princeton University

1. **Large Scale Portfolio Optimization with Piecewise Linear Transaction Costs**

   Marina Potaptchik, CIBC, *Levent Tuncel*, *Henry Wolkowicz*

An optimal portfolio is obtained by minimizing a mean-variance quadratic model, but with the addition of a piecewise linear separable function made up of the transaction costs. Linear equations and inequality constraints are included. We handle the nonsmoothness by using spline approximations. The problem is then solved using a primal-dual interior-point method with a crossover to an active set method. Our numerical tests show that we can solve large scale problems efficiently and accurately.

2. **Adaptive portfolio management**

   Michael Dziecichowicz, Lehigh University, *Aurelie Thiele*

Traditional techniques in portfolio management rely on the precise knowledge of the underlying probability distributions; in practice, however, such accurate information is difficult to obtain because multiple factors affect stock prices on a daily basis. To address this issue, we propose an approach to dynamic portfolio management based on the sequential update of stock price forecasts in a robust optimization setting, where the updating process is driven by the historical observations. Forecasts are updated using only the most recent data when the stock price consistently differs from predictions. In this work, we develop a robust framework to optimal selling time theory. We introduce a wait-to-decide period, and allow actual price movements to drive the best reaction to a bad investment. Numerical results illustrate our strategy, which requires less frequent updating of the problem parameters than in the traditional approach while exhibiting similar performance.

3. **Multi-objective and Parametric Optimization in Financial Modelling**

   Oleksandr Romanko, Department of Computing and Software, McMaster University, *Tamás Terlaky*, *Alireza Ghaffari Hadigheh*

We describe relations between multi-objective optimization, where several conflicting objectives are simultaneously optimized subject to constraints, and parametric analysis that is used to solve such problems. We present our Interior Point Methods based algorithmic and implementation results for solving linear, convex quadratic and second-order cone parametric optimization problems. We illustrate how to model and solve multi-objective problems and outline their applications in finance. A number of examples of financial problems that can be solved using these techniques are presented.

■ MB6

Monday, 10:30-12:00, MDCL 1309

MPECs

Stream: MPECs/Complementarity Problems
Chair: *Sangho Kum*, Department of Mathematics, Chungbuk National University

1. **A New Class of Polynomial Interior-Point Algorithms for $P_*(\kappa)$ Linear Complementarity Problems**

Goran Lesaja, Department of Mathematical Sciences, Georgia Southern University, USA, *Yanqin Bai*, *Kees Roos*

We present short and long step polynomial interior-point algorithms for $P_*(\kappa)$ Linear Complementarity Problems (LCP) based on a new class of parametric kernel functions. The same class of kernel functions was considered earlier for Linear Optimization (LO) by the same authors. This class is fairly general and includes the classical logarithmic function, the prototype self-regular function, and non-self-regular kernel functions as special cases. The iteration bounds obtained in this paper match the best known existing iteration bounds. As far as we know this is the first result on interior-point methods for $P_*(\kappa)$-LCPs based on this class of kernel functions.

2. **An active set method for a new relaxed scheme of MPCCs**

Abdeslam Kadrani, Département d'Informatique, Université de Sherbrooke, *Abdelhamid Benchakroun*, *Jean Pierre Dussault*

We consider a Mathematical program with complementarity constraints (MPCCs). An active set algorithm is proposed, which solves a sequence of relaxed problems derived form MPCCs. Global Convergence results are deduced under weaker assumptions than those used by the smooth regularizations. It is shown that every cluster point of generated sequence is M-stationary under MPCC-Linear Independence Complemenatrity constraints (MPCC-LICQ), and it is B-stationary if the Upper level strict complemenatrity holds.

3. **The penalized Fischer-Burmeister function on symmetric cones**

Sangho Kum, Department of Mathematics, Chungbuk National University, *Yongdo Lim*

The main concern of this paper is so-called symmetric cone complementarity problem (SCCP for short) on Euclidean Jordan algebras. In the case of NCP, Chen et al. proposed the penalized Fischer-Bermeister NCP-function, and investigated its theoretical advantages over other NCP-functions together with robust and promising numerical results. Motivated by their work, in this paper, we show that the main properties of the penalized Fischer-Bermeister NCP-function holds true in a Euclidean Jordan algebra. In fact, under monotonicity and strict feasibility conditions, the boundedness of level sets of the merit function induced by the penalized Fischer-Burmeister function is derived under a general framework of Euclidean Jordan algebras. The proof relies on a new trace inequality on Euclidean Jordan algebras. Moreover, we investigate the strong semismoothness of the penalized Fischer-Burmeister function on Euclidean Jordan algebras.

■ MB7

Monday, 10:30-12:00, MDCL 1009

Optimization in Medicine

Stream: Medical Applications in Optimization
Chair: *Michael Ferris*, University of Wisconsin

1. **Balancing efficiency and equity in designing the liver transplantation system**

Andrew Schaeffer, Industrial Engineering, University of Pittsburgh

Currently in the U.S., OPOs, which are the smallest elements in the allocation process, are grouped into 11 regions. A harvested liver is offered hierarchically to patients, first within the local OPO, then regionally and finally nationwide. We consider the problem of optimizing the design of regions for liver transplantation across the U.S. By using a multi-objective optimization approach, we aim to balance the efficiency of the system and geographical equity throughout the nation. We make use of two parametric integer programming models, one of which aims to maximize the efficiency of the allocation mechanism while considering a minimum equity value, while the other tries to maximize the equity measure across all OPOs subject to a minimum efficiency threshold. We approximate the efficient frontier of this mechanism. Our algorithm follows a path in which the LP frontier is constructed step by step while updating the upper and lower bounds on the the IP efficient frontier.

2. **Treatment Planning for Radiofrequency Ablation for Liver Cancer**

Ariela Sofer, George Mason University

Radiofrequency ablation (RFA) is a minimally invasive technique for killing tumors. A needle diode is placed at the tumor site, and alternating current is applied in the range of radiofrequency. This causes ionic agitation, which in turn creates frictional heat. Temperatures in excess of 55 Celsius kill tissue. The ablation treatment plan is to determine the number of needles and their positions, to guarantee that the entire tumor is killed while damage to vital healthy tissue is minimized. Unlike radiation treatment where a tumor cell is assumed to be killed if the total dose deposited at the cell by all beams exceeds a minimum dose, in RFA a tumor cell will be killed if the temperature generated at the cell by at least one of the needles exceeds the minimum kill temperature. The spread of heat in the tissue is governed by the bioheat equation. We present initial solution approaches that provide approximate solutions of the treatment planning problem in a clinical setting.

3. **Multi-objective Linear Programming for Fluence Map Optimisation**

Matthias Erghott, Engineering Science, University of Auckland, *Lizhen Shao*

The problem of optimising intensities for given beam directions in intensity modulated radiotherapy treatment design can be formulated as a multi-objective linear programme (MOLP). The MOLP has a large number of constraints (defined by voxels or dose points) and variables (defined by bixels or pencil beams), but only three objectives. This motivates solving the problem in objective space. Moreover, due to imprecise dose calculation and other inaccuracies, in practice it is not necessary to solve the problems exactly and a precision of 0.1 or 0.05 Gy often suffices. In this talk we modify Benson's algorithm to solve MOLPs in objectives space so that it computes a set of epsilon-nondominated points. We also formulate a so-called geometric dual of the MOLP and show that solving the dual problem approximately also yields epsilon-nondominated points of the primal. Numerical tests demonstrate that solving the dual can be faster than solving the primal.

■ MB8

Monday, 10:30-12:00, MDCL 1010

Optimization in a Symbolic/Numeric Environment

Stream: Engineering Optimization
Chair: *Paulina Chin*, Maplesoft

1. **Optimization in Maple's Interactive Environment**

Paulina Chin, Maplesoft

Maple's interactive environment allows one to easily set up optimization problems in a natural manner. We show how the use of combined numeric and symbolic tools in such an environment leads to greater ease in modelling and analysis of results. We also discuss the related issues of arbitrary-precision computation and automatic derivative generation, and show several examples from engineering applications.

2. **Using Maple Code Generation and IPOPT to Design Radio Frequency Pulses for use in Spectroscopy (NMR) and Imaging (MRI)**

Andrew Curtis, Department of Medical Biophysics, University of Western Ontario, *Christopher Anand*

We will formulate several related waveform design problems for application to NMR and MRI. Different constrained and unconstrained formulations exist, in which objectives and constraints can be interchanged. We will present one approach motivated by the physics of the problem. This approach results in objectives with dense Hessians, but a smaller number of simpler constraints. At first glance, the Hessians are very expensive to compute, but using symbolic code generation (as implemented in Maple) both first and second derivatives can be computed efficiently by structuring the computation to take advantage of common subexpressions and data locality. Finally, we will discuss preliminary results which indicate an advantage to this approach in terms of computational time and quality of the solution.

3. **Kinematic Modeling, Simulation, and Optimization of a Double-Wishbone Suspension**

Jan Bakus, Maplesoft, *John McPhee*, *Mathieu Leger*

The dynamic stability of a vehicle, as well as fuel efficiency and tire wear, is directly affected by the kinematic behavior of the suspension. As the wheel travels up and down in response to bumps in the road, the camber, caster, and toe-in angles change. This behavior is determined by the location where the suspension connects to the body (hard points). The challenge is to define these hard points in order to achieve best possible camber, caster, and toe-in angles for the vehicle. Using Maple and DynaFlexPro, the topology of the mechanism is described, from which the equations of camber, caster, and toe-in angles are automatically derived and solved by Maple. Using the Global Optimization Toolbox for Maple the optimal suspension behavior can be determined aoutmatically. A mean squared error between a set of standard design curves and calculated curves is used as the objective function. The optimization toolbox then finds the optimal position of all the hard points.

■ MB9

Monday, 10:30-12:00, MDCL 1008

Algorithms for Specially Structured Nonlinear Optimization Problems

Stream: Nonsmooth Optimization

Chair: *Bharath Rangarajan*, Department of Mechanical Engineering, University of Minnesota

1. **A T-algebraic approach to primal-dual interior-point algorithms**

   Chek Beng Chua, Division of Mathematical Sciences, Nanyang Technological University

We present polynomial-time primal-dual interior-point algorithms for homogeneous cone programming. The search directions used in these algorithms are defined via the T-algebraic structure of homogeneous cones. We briefly recall the basics of T-algebras, and define an extension of quadratic maps of Euclidean Jordan algebras. Each primal-dual central path is described with a quadratic map, and the primal-dual search directions are obtained upon linearization.

2. **Subset Selection from Large Datasets for Metamodeling**

   Gijs Rennen, Econometrics and Operations Research, Tilburg University

When building a metamodel of an existing model, we often assume that the data from the original model still has to be generated. However, in several practical applications a large dataset is already available. The general intuition is that using more data from the original model will always result in a better metamodel. Therefore, a large dataset is regarded as a good starting point for building a metamodel. However, we will show that when the dataset is already given, there are situations in which using only a subset has certain advantages. Especially when the large given dataset is nonuniformly distributed, problems can occur. By using a space-filling subset, we can often reduce fitting times, avoid numerical inaccuracies and improve robustness wrt errors in the output data. A number of methods to select a subset will be discussed and compared. Although our focus will be on the effects when fitting metamodels with Kriging, the advantages of using a subset also apply to other methods.

3. **On Solving Specially Structured Large SDPs**

   Bharath Rangarajan, Department of Mechanical Engineering, University of Minnesota

The stability conditions for spatially-distributed control systems give rise to large semidefinite programs with specific structure. The standard gradient techniques are usually employed base on the Dantzig-Wolfe decomposition. We explore related smooth counterparts that can be solved using interior-point techniques which promise a faster asymptotic convergence as well as an improvement in global convergence. However, they lack the ability to be distributed in computation unlike gradient techniques.

■ MS1

Monday, 1:30-2:30, MDCL 1305

Semi-plenary presentation

Stream: Nonlinear Optimization Software

Chair: *Kim Chuan Toh*, National University of Singapore, Singapore-MIT Alliance

1. **Primal-dual methods for NLP and NLSDP**

   Hiroshi Yamashita, Mathematical Systems Inc., Tokyo

In this talk primal-dual iterative methods for solving nonconvex nonlinear optimization will be described. Main theme is naturally primal-dual interior point methods for usual nonlinear optimization that use line search method and trust region method. Primal-dual exterior point methods that allow the primal variables stay outside feasible region are also described, and are shown to be applicable to parametric optimization problem which is not easy for interior point methods. An interesting possibility of acceleration method for these interior and exterior point methods is described. Primal-dual interior point methods for nonlinear SDP problem and nonlinear SOCP problem will also be described. Numerical results of these methods will be presented.

■ MS2

Monday, 1:30-2:30, MDCL 1307

Semi-plenary presentation

Stream: Derivative Free Optimization

Chair: *Sven Leyffer*, Argonne National Laboratory

1. **Model based derivative free optimization**

   Katya Scheinberg, IBM, Yorktown

Derivative free optimization (DFO) is the field of nonlinear optimization which targets functions whose derivatives exists but are not available and cannot be approximated efficiently. It is often also the case that such functions are expensive to evaluate and/or are noisy. In the past decade there has been a significant increase in research in the area of DFO, much of it in the development of model based methods. There are several practical algorithms that have been proposed, most of them lacking global convergence theory. Those methods that do have convergence theory have to resort to impractical extra steps and conditions. But most of the proposed methods have the “right ingredients” for both convergence theory and practical performance. We will discuss these ingredients and try to fit them in a unifying framework for which we can provide convergence theory.

■ MS3

Monday, 1:30-2:30, MDCL 1105

Semi-plenary presentation

Stream: Semi-infinite Optimization

Chair: *Jiming Peng*, University of Illinois at Urbana-Champaign

1. **Nonlinear Semi-Infinite Programming: Structural Analysis**

   Hubertus Th. Jongen, RWTH Aachen University

We present a survey on structural results in standard Semi-Infinite Programming (SIP). In particular, we focus on critical points and topological stability. Then, we decribe new challenging features appearing in general SIP.

■ MC1

Monday, 2:45-4:15, MDCL 1305

Applications of SDP

Stream: Linear, Semidefinite and Conic Optimization

Chair: *Brian Borchers*, Department of Mathematics, New Mexico Tech

1. **Semidefinite Programming and Nuclear Magnetic Resonance**

   Christopher Anand, McMaster University, *Anuroop Sharma*

Nuclear Magnetic Resonance experiments measure the magnetic moments of nuclei. Information about connectivity and morphology of molecules is inferred from the frequency composition of measured signals. The data on which such inferences are made grows with the size and complexity of the molecules. For example, medium sized proteins can require data taking days or even weeks to acquire on expensive spectrometers. This work concerns a novel application of continuous optimization to the design of NMR experiments, optimizing the ratio of information/acquisition time. To set up an optimization problem, we model both the signal generation process, which is highly non-linear, and the quality of the linear reconstruction process, which can be captured using one or more semi-definite constraints. To solve the problem, we linearize the non-linear constraints and solve a linear-semi-definite problem in a (rectangular) trust region. We will discuss variations of the model which could be used to solve problems in other imaging areas, and initial numerical experiments performed using CSDP.

2. **Semidefinite programs with log-barrier terms**

   Mituhiro Fukuda, Global Edge Institute, Tokyo Institute of Technology

The new version of the SDPA permits one to solve semidefinite programs with log-determinant terms with different non-negative weights. Such feature is already included in SDPT3 and partially in MAXDET. Examples of such problems arise in robust optimization, statistics, quantum information theory. Numerical experiments will be given.

3. **An SDP Based Branch and Bound Code For Maximum Independent Set**

   Brian Borchers, Department of Mathematics, New Mexico Tech

We present a branch and bound code for maximum independent set problems that uses semidefinite programming bounds. The SDP bound is known to be much tighter than linear programming bounds. Although the SDP bound requires more computational effort, the greater strength of this bound makes it worthwhile for some large and challenging MIS problems. The code has been used to solve a number of challenging MIS problems arising from coding theory. For these problems further gains in performance are obtained by symmetry breaking strategies. Several challenging problems proposed by Neil Sloane that had not previously been solved have now been solved by this code.

■ MC2

Monday, 2:45-4:15, MDCL 1307

Nonsmooth Analysis and Applications

Stream: Convex and Nonsmooth Analysis

Chair: *Jane Ye*, University of Victoria, Mathematics and Statistics

1. **Variational principles for set-valued mappings with applications to multiobjective optimization**

   Bao Truong, Wayne State University, *Boris Mordukhovich*

This talk primarily concerns the study of general classes of constrained multiobjective optimization problems (including those described via set-valued and vector-valued cost mappings) from the viewpoint of modern variational analysis and generalized differentiation. To proceed, we first establish two variational principles for set-valued mappings, which—being certainly of independent interest—are mainly motivated by applications to multiobjective optimization problems considered in this paper. The first variational principle is a set-valued counterpart of the seminal derivative-free Ekeland variational principle, while the second one is a set-valued extension of the subdifferential principle by Mordukhovich and Wang formulated via an appropriate subdifferential notion for set-valued mappings with values in partially ordered spaces. Based on these variational principles and corresponding tools of generalized differentiation, we derive new conditions of the coercivity and Palais-Smale types ensuring the existence of optimal solutions to set-valued optimization problems with noncompact feasible sets in infinite dimensions and then obtain necessary optimality and suboptimality conditions for nonsmooth multiobjective optimization problems with general constraints, which are new in both finite-dimensional and infinite-dimensional settings.

2. **Partial exact penalty for mathematical programs with equilibrium constraints**

   Jane Ye, University of Victoria, Mathematics and Statistics

For a mathematical programming problem with equality and inequality constraints, it is known that the Mangasarian Fromovitz constraint qualification (MFCQ) leads to an exact penalization. For mathematical programming problem with equality, inequality and abstract constraints, we show that the generalized MFCQ involving the limiting proximal normal cone is a sufficient condition for partial exact penalty. Applying this result to the mathematical programming problem with equalibrium constraints (MPEC), we show that the MPEC GMFCQ, an MPEC variant of MFCQ, leads to a partial exact penalty where all the constraints except a simple linear complementarity constraint are moved to the objective function. The partial exact penalty function, however, is nonsmooth. By smoothing the partial exact penalty function, we design an algorithm which is shown to be globally convergent to an M-stationary point under an extended version of the MPEC GMFCQ.

3. **A Coordinate Gradient Descent Method for Linearly Constrained Nonsmooth Optimization and Support Vector Machines**

   Sangwoon Yun, Mathematics, University of Washington, *Paul Tseng*

Support vector machines (SVMs) training may be posed as a large quadratic program (QP) with bound constraints and a single linear equality constraint. We propose a (block) coordinate gradient descent method for solving this problem and, more generally, linearly constrained nonsmooth optimization, in which the objective function is the sum of a smooth function and a separable convex function. We establish global convergence and, under a local error bound assumption (which is satisfied by the SVM QP), linear rate of convergence for our method when the coordinate block is chosen by a Gauss-Southwell-type rule to ensure sufficient descent. We show that, for SVM QP with n variables, this rule can be implemented in $O(n)$ operations using Rockafellar's notion of conformal realization. Thus, for SVM training, our method requires only $O(n)$ operations per iteration. We report our numerical experience with the method on some large SVM QP arising from two-class data classification.

■ MC3

Monday, 2:45-4:15, MDCL 1105

Recent Advances in L^1-minimization Algorithms and Applications

Stream: Convex Optimization Methods

Chair: *Yin Zhang*, Rice University, CAAM

1. **Nonconvex minimization and compressed sensing**

   Rick Chartrand, Theoretical Division, Los Alamos National Laboratory

Recent work by several authors has shown the surprising ability of l^1 minimization to recover sparse signals and images exactly from very few linear measurements, in the new field known as compressed sensing. In this talk, we consider l^p minimization instead, where $0 < p < 1$. We will see that this allows successful reconstruction with substantially fewer measurements than when $p = 1$. Because this optimization problem is nonconvex, it is very surprising that our numerical results of local l^p minimization match those predicted by the theory of global l^p minimization. We will consider algorithms for (local) l^p minimization with equality constraints (for exact measurements) and with inequality constraints (for noisy measurements). We will examine the state of the underlying theory, and see several numerical examples.

2. **A Numerical Comparison of Compressed Sensing Reconstruction Algorithms**

   Elaine Hale, Rice University, Dept. of Computational and Applied Mathematics

Compressed sensing utilizes the fact that a signal of length n may be reconstructed from $m < n$ linear combinations of its components provided that the measurement matrix is "good" and the signal is sufficiently compressible. In this talk we compare three reconstruction algorithms based on l^1 regularization of the resulting underdetermined least squares problem (Fixed Point Continuation, Gradient Projection for Sparse Reconstruction and an interior point method called l^1_{ls}), and a fourth algorithm designed for strictly sparse signals that claims robustness to measurement noise (Stagewise Orthogonal Matching Pursuit). Solution quality and speed are evaluated for Gaussian and discrete cosine transform (dct) measurement matrices under several noise scenarios; we also investigate the robustness of the l^1 regularization algorithms to the regularization parameter.

3. **A fixed-point continuation algorithm for l_1-regularization**

   Wotao Yin, CAAM, Rice University

We propose a fixed-point continuation algorithm (FPC) based on operator-splitting and continuation to solve the l_1-regularization problem, $\min |x|_1 + f(x)$. The talk will highlight that this algorithm does not require the factorization of f's Hessian, and converges linearly. Thus we argue that FPC may be applied to large-scale problems with dense data, especially when the gradient of f can be computed efficiently and with minimal storage.

4. **Computationally Efficient Solution of a Generalized Total Variation Functional**

   Paul Rodriguez, T7 - Los Alamos National Laboratory

Total Variation (TV) regularization is an established technique for image denoising as well as other restoration problems. A recent development is the replacement of the standard l_2 data fidelity term with an l_1 norm, which, while computationally more challenging, provides a number of advantages. We have developed a new, flexible algorithm capable of minimizing a generalized TV functional with lp data fidelity term. Computationally performance is competitive for the standard l_2-TV case, and significantly faster than most alternatives for l_1-TV. Reasonable choices of algorithm parameters, such as accuracy of the linear solver component, may be made automatically.

■ MC4

Monday, 2:45-4:15, MDCL 1110

Convexification and Duality in Global Optimization

Stream: Global Optimization
Chair: *Mohit Tawarmalani*, Krannert School of Management, Purdue University

1. **Cutting planes for nonlinear and mixed-integer nonlinear programming**

   Ismael de Farias, Dept. of Ind. and Syst. Eng., SUNY Buffalo, *Ming Zhao*

We give new cutting planes for solving nonlinear programming and mixed-integer programming problems through branch-and-cut algorithms. We also give new paradigms such as "simple-set" cutting planes. Finally, we present computational results that demonstrate the efficiency of the cutting planes.

2. **Nonconvex minimization problems with box or integer constraints are not NP-hard unless the canonical dual problems have no global maximizers.**

   David Gao, Department of Mathematics, Virgina Tech

In this talk, the speaker will present a potentially useful canonical duality theory for solving a class of challenging global optimization problems. He will show that the well-known quadratic minimization problems with either convex or nonconvex constraints can be converted into certain dual maximization problems with only convex constraints. N-dimensional conical optimization problems can be transformed into a one-D canonical dual problem. Both global and local optimality conditions can be identified by the triality theory developed by the speaker. Under certain conditions, these canonical dual problems can be solved easily by polynomial algorithms. Therefore, a conjecture on NP-hard problems is proposed which reveals some new insight into global optimization. The title of this talk will be illustrated by challenging applications, including quadratic minimization with multiple nonconvex quadratic constraints, nonconvex conic optimization problems, and integer programming problems.

3. **Extending mixed-integer programming lifting techniques to nonlinear programming**

   Mohit Tawarmalani, Krannert School of Management, Purdue University, *Jean-Philippe Richard*

We propose lifting techniques for generating strong globally-valid cuts for nonlinear programs. As a special case, we find short proofs of recent results in mixed-integer programming. We employ convex extensions to develop sequence independent lifting procedures for nonlinear programs that subsume superadditive lifting theory of integer programs. Finally, we develop specialized our results to mixed-integer bilinear knapsacks and show that similar results are difficult to obtain using traditional integer programming techniques.

■ MC5

Monday, 2:45-4:15, MDCL 1016

Financial Optimization

Stream: Financial Optimization
Chair: *Luis Zuluaga*, Faculty of Business Administration, University of New Brunswick

1. **Robust portfolio optimization using joint uncertainty sets**

   Denis Zuev, University of Oxford

We consider a worst case risk-adjusted return (utility) maximization problem in the light of the optimal asset allocation problem. In our work we assume uncertain nature of expected asset returns only. The risks associated with the investment are modelled as a function of the realised expected returns which are themselves subject to uncertainty. Given the historical data and a realised value of stock returns the portfolio risks are deduced from the maximum likelihood function given the knowledge of the returns. We show that the uncertainty set for both expected returns and risks is much smaller than in some similar works on robust portfolio optimisation. Moreover, the solution to the resulting two level optimisation problem can be obtained by solving a tractable convex problem. At last, we demonstrate computational results of our model in comparison to classical and robust models both on simulated data and on real historical NASDAQ data over 1999-2006 period.

2. **A variational model for dynamical portfolio managing**

   Rene Meziat, Universidad de los Andes, *Nicolás García*

We use calculus of variations tools for modeling the risk and hedging of a capital invested into a changing market whose financial parameters are described by a quadratic function involved in the Lagrangian of a variational principle. To determine such quadratic function, we propose a time-depending efficient frontier estimated dynamically either from judgmental criteria or by short-time measurements of the parameters of classical Markowitz's Portfolio Theory. Thus, we can pose a convex, quadratic variational problem whose solution can be attained by standard numerical procedures on the corresponding Euler-Lagrange equation. This model provides good preliminary results when tested on data from financial crisis where the markets show high volatilities. We comment on several variations of the model including non-risk assets, non convexities and stochastic differential equations constraints. We will present the essential theory and numerical results.

3. **Improving VaR and Skewness of Mean-Variance Portfolios**

   Luis Zuluaga, Faculty of Business Administration, University of New Brunswick

In recent years, there has been a growing interest in developing methodologies to take into account moments of higher order than the variance, in the context of optimal risk-reward portfolio allocation. This is due to the widely accepted belief that asset returns and insurance product line margins are not normally distributed, and their inter-relationships cannot be characterized only by their correlations. Along these lines, we propose an optimization-based model to substantially improve the Value-at-Risk and skewness of portfolios in the mean-variance efficient frontier. Unlike other related methods in the literature, the proposed model is very intuitive, non-iterative, simple to implement, and it can be readily and efficiently solved with state of the art optimization solvers. These characteristics should make our methodology very appealing to both practitioners and researchers in portfolio and risk management.

■ MC6

Monday, 2:45-4:15, MDCL 1309

VI/CP (Theory; Algorithms and Their Theory; Applications)

Stream: MPECs/Complementarity Problems
Chair: *Patrice Marcotte*, University of Montreal

1. **Solution of Structured Complementarity Problems**

   Michael Ferris, University of Wisconsin at Madison, Computer Sciences

We consider extending solution techniques for nonlinear complementarity problems to more general variational problems that arise in specific application areas. Computational efficiencies and specific problem structures will be described along with specific examples to demonstrate the effectiveness of our new approaches. Some modeling tools that aid in defining such problem structure will also be outlined.

2. **Optimal pricing of congested networks**

   Patrice Marcotte, University of Montreal

By imposing suitable tolls on the arcs of a congested transportation network, it is trivially possible to transmute a user-optimal (Wardrop) equilibrium into a system-optimal one. This result can be (less trivially) extended to the case where the valuation of time is not uniform throughout the population. While a simple proof of this result is available when the number of user classes sharing a common valution of time is finite, its adaption to the infinite-dimensional setting where the VOT (value-of-time) parameter is continuously distributed is not straightforward. The aim of this presentation is to discuss the theoretical and computational challenges posed by this problem, and then propose a simple solution based on the implicit treatment of the functional variables.

■ MC7

Monday, 2:45-4:15, MDCL 1009

Robust Optimization in Medical Problems

Stream: Robust Optimization
Chair: *Elodie Adida*, UIC, Department of Mechanical and Industrial Engineering

1. **Efficient Schemes for Robust IMRT Treatment Planning**

   Stephen J. Wright, Computer Sciences Department, University of Wisconsin-Madison, *Arinbjorn Olafsson*

We use robust optimization techniques to formulate an IMRT treatment planning problem in which the dose matrices are uncertain, due to both dose calculation errors and interfraction positional uncertainty of tumor and organs. When the uncertainty is taken into account, the original linear programming formulation becomes a second-order cone program. We describe an efficient approach for solving this problem, and present results to compare the performance of our scheme with more conventional formulations that assume perfect knowledge of the dose matrix.

2. **Robust radiation therapy treatment planning for cancer treatment**

   Yuriy Zinchenko, McMaster University

The recent development of intensity modulated radiation therapy (IMRT) allows radiation dose distribution to be tailored to match the tumor's shape and position avoiding damage to healthy tissue to a greater extent than previously possible. We propose a robust formulation for IMRT treatment planning problem that incorporates intrinsic geometric uncertainties into the model. The approach has the potential to find treatment plans that are more adept at sparing healthy tissue while maintaining the prescribed dose to the target as compared to traditional models. Several strategies to address computational challenges arising in robust IMRT treatment planning will be discussed.

3. **An interlaced beam segment generation and shape modification strategy for radiotherapy optimization**

   Fredrik Carlsson, Mathematics, Royal Institute of Technology, Sweden

Radiation therapy aims to achieve tumor control while sparing healthy tissue. We focus on generating efficient step-and-shoot radiation therapy plans. Such plans are composed of multi-leaf collimator shapes called segments distributed over the beams. We optimize segment shapes and weights simultaneously; a nonconvex optimization with linear and a few nonlinear constraints. We propose a strategy for controlling the number of segments and fine-tuning their shapes. The solution process alternates between two phases. In one phase, weights and shapes of existing segments are optimized. In the other phase, a restricted problem including only the segment weights, is considered. Column generation is applied to this convex problem to create new segments that incorporate physical limitations of the collimator. Results on clinical patient cases indicate that the proposed approach has potential for generating simple high-quality plans while the number of segments can be controlled by the user.

■ MC8

Monday, 2:45-4:15, MDCL 1010

Applications of Multidisciplinary Shape Optimization

Stream: Engineering Optimization
Chair: *Jamshid Samareh*, NASA Langley Research Center

1. **High-Fidelity Multidisciplinary Design Optimization**

   Joaquim Martins, University of Toronto Institute for Aerospace Studies

Multidisciplinary design optimization (MDO) has found many applications to aircraft design. However, due to the complexity of coupling all the disciplines involved, MDO using high-fidelity solvers such as computational fluid dynamics (CFD) and finite-element models (FEM), remains a challenge. A framework for high-fidelity aero-structural optimization will be presented along with the theory developed to address the inherent challenges. The framework combines a three-dimensional CFD solver, a detailed FEM of the wing box, a geometry engine and a gradient-based optimizer to compute the flying shape of the wing and to optimize aircraft configurations with respect to aerodynamic shape and internal structural sizes. The theoretical developments to be presented include coupled sensitivity analysis methods, a subspace optimization method that uses coupled post-optimality sensitivities, adaptive constraint aggregation and the automatic differentiation adjoint (ADjoint) approach.

2. **Scriptable geometry systems for knowledge capture and reuse in MDO**

   Thomas Grandine, Mathematics and Computing Technology, The Boeing Company

The Boeing Company has made considerable beneficial use of scriptable geometry systems in the design and analysis of its products. Such systems have the advantage that design knowledge and rules can be captured in the form of executable scripts which can be transferred between different engineering groups and reused over and over again. The strategy has proven to be a very effective one, and it promises to continue to be useful for a very long time. This talk will explore the attributes of such systems that enable them to be effective in practice and describe some of the lessons that have been learned over the last 30 years in using such systems. The talk will also describe a new effort recently begun intended to provide a fully modern capability by taking advantage of those lessons learned.

3. **Application of Shape optimization for Planetary Entry, Descend, and Landing**

   Jamshid Samareh, NASA Langley Research Center

The first part of this presentation will provide an overview of the current state-of-the-art in multidisciplinary shape optimization. In the second part of the talk, an application on a planetary entry, descend, and landing will be used to identify the requirements for multidisciplinary shape optimization.

■ MC9

Monday, 2:45-4:15, MDCL 1008

PDE Constrained Optimization

Stream: PDE Constrained Optimization
Chair: *Ekaterina Kostina*, University of Marburg

1. **Optimization Algorithms for Inverse Problems in Seismic Wave Propagation**

   Carsten Burstedde, ICES, The University of Texas at Austin

Optimization problems with PDE constraints in form of the seismic wave equation are difficult to solve due to their highly nonlinear nature. Already in the basic setting, that is, unconstrained optimization and standard L_2 or H^1 regularization, a multilevel approach tailored to both the source frequencies and the smoothness of the material is essential to avoid local minima. After introducing a suitable inexact Newton framework, we discuss two extensions of the problem. Firstly, to deal with upper and lower bounds on the material parameters, a primal-dual active set strategy is implemented and examined. Secondly, to resolve discontinuous materials total variation regularization is employed. It is shown that the resulting anisotropy can be dealt with efficiently by a primal-dual reduced space algorithm.

2. **Hamilton-Jacobi Equations in Infinite Dimension for Approximation of Optimal**

   Jesper Carlsson, CSC, KTH, *Anders Szepessy*, *Mattias Sandberg*

Many inverse problems, e.g. in optimal design and reconstruction, can be formulated as optimal control problems. Optimal control problems for low, d, dimensional differential equations, can be solved computationally by their corresponding Hamilton-Jacobi-Bellman partial differential equation in R^{d+1}. I will show how to use Hamilton-Jacobi equations in infinite dimension to regularize and solve optimal design problems for partial differential equations.

3. **Covariance Matrix Computation for Parameter Estimation in Nonlinear Models Solved by Iterative Linear Algebra Methods**

   Ekaterina Kostina, University of Marburg, *Georg Bock*, *Olga Kostyukova*

For solving parameter estimation and optimal design problems, we need the knowledge of covariance matrix of the parameter estimates and its derivatives. So far numerical methods for parameter estimation and optimal design of experiments in dynamic processes have been based on direct linear algebra methods. On the other hand, for very large scale constrained systems with sparse matrices of special structure, e.g. originating from discretization of PDE, direct linear algebra methods are not competitive with iterative linear algebra methods even for forward models. Hence, in case of parameter estimation in PDE models, generalizations of iterative linear algebra methods to the computation of the covariance matrix and its derivatives are crucial for practical applications. One of the intriguing results is that solving nonlinear constrained least squares problems by conjugate gradient methods we get as a by-product the covariance and confidence intervals as well as their derivatives.

■ MD1

Monday, 4:45-6:15, MDCL 1305

Implementations/Interior-Point Methods

Stream: Interior Point Methods and Implementations
Chair: *Jacek Gondzio*, School of Mathematics, Edinburgh University

1. **Primal-dual first-order methods for cone programming**

   Renato Monteiro, School of ISyE, Georgia Tech

We consider the general cone programming problem, and propose primal-dual convex (smooth and/or nonsmooth) minimization reformulations for it. We then discuss first-order methods suitable for solving these reformulations and compare their performance on a set of randomly generated SDPs.

2. **On the implementation of the homogeneous primal-dual algorithm for linear optimization problems.**

   Erling Andersen, MOSEK

The primal-dual interior-point algorithm is one of the most efficient methods for solving large-scale linear optimization problems. However, the primal-dual algorithm has the drawback that it cannot reliable detect a primal and dual infeasible status of the optimization problem. Now if the primal-dual algorithm is applied to the homogenous and self-dual model, then the algorithm also works in the infeasible cases. In this talk we discuss the implementation of the homogeneous primal-dual algorithm. The emphasize is on reliable computation of the search direction and termination of the algorithm.

3. **Iterative solution of augmented systems arising in large-scale interior methods**

   Schenk Olaf, University of Basel

We propose an inertia revealing preconditioning approach for the solution of nonconvex optimization problems. If interior methods with second-derivative information are used for these optimization problems, a linearized KKT system has to be solved. The main issue addressed is how to ensure that the Hessian is positive definite in the null-space of the constraints while neither adversely affecting the convergence of Newton's method or incurring a significant computational overhead. In the nonconvex case, it is of interest to find out the inertia of the current iteration system so that the matrix may be modified a posteriori to obtain convergence to a minimum. In this work, we propose a inertia revealing preconditioned Krylov iteration to solve the linearized Karush-Kuhn-Tucker system of optimality conditions. Our preconditioning approaches are based on maximum weighted matchings and algebraic multi-level incomplete LBL^T factorizations. We test the inertia revealing method within the interior-point solver IPOPT on a large set of nonconvex optimization problems from the CUTE and COPS sets and present numerical results on several large-scale three-dimensional examples from biomedical cancer applications.

■ MD2

Monday, 4:45-6:15, MDCL 1307

Designing and Testing Algorithmic Improvements for Derivative-free Direct Search Methods

Stream: Derivative Free Optimization
Chair: *Virginia Torczon*, Department of Computer Science, College of William & Mary

1. **Non-typical testing of non-derivative methods**

   Margaret Wright, Computer Science Department, Courant Institute of Mathematical Sciences

Despite significant progress during the past 40 years, important issues remain ambiguous and unresolved about the best way to test and compare non-derivative optimization methods. Is the most important thing to obtain an accurate solution? Or, especially for problems with functions that are noisy or based on inaccurate data, should we be measuring the improvements resulting from a relatively small number of function evaluations? Does it make sense to compare model-based methods to geometry-based methods on problems that are known to be smooth? Can we offer confident recommendations about the methods that are likely to be most effective and/or most reliable? The list of such questions is very long, and the speaker will not try to answer them all. Rather, she will discuss strategies that have been helpful in testing several geometry-based methods, both old and new.

2. **Derivative Information in Derivative Free Optimization or Average Curvature Information**

   Trond Steihaug, Department of Informatics, University of Bergen, *Lennart Frimannslund*

The class of Generating Set Search (GSS) Methods is a large class within derivative free optimization methods. We present a GSS method which uses average curvature to generate the search directions. If the function that is minimized is smooth then the average curvature will be a good approximation to the Hessian matrix. Some functions are expensive to evaluate accurately, but cheap to evaluate approximately. The approximated function can be regarded as the original function subject to numerical noise and the function will be non-smooth. We show that partial separability properties can still be exploited in the context of an optimization method although the original function is distorted by noise. We show this by introducing the covariation graph of the variables which may be derived from a data dependency graph. The average curvature can be computed efficiently using information about the covariation graph. In the context of computing the curvature information matrix, we encounter a subproblem of selecting rows from a matrix, where the number of rows is much greater than the number of columns, to obtain a full rank and well-conditioned matrix with minimum effort. Finding the optimal solution to this problem is an open problem. We present an efficient heuristic solution. The theoretical framework we use for computing the curvature information matrix can also be used for approximating Hessians in other derivative free optimization methods.

3. **Applications of simplex gradients in direct search methods**

   Ana Luisa Custodio, New University of Lisbon, *Luís N. Vicente*

We extend the results known about simplex gradients in the continuously differentiable case to nonsmooth functions, in a directional direct search framework. Directional direct search methods are widely used in practice, but, most of the times, they are very slow. Although this efficiency can be improved by applying surrogate-based optimization to the search step of the algorithms, the sampling process inherent to the poll step is partially responsible for the slow performance observed in practice. We introduce a number of ways of making directional direct search methods more efficient by reusing previous evaluations of the objective function. At each iteration, one can attempt to compute an accurate simplex gradient by identifying a sampling set of previous evaluated points with good geometrical properties. This simplex gradient can then be used, for instance, to reorder the evaluations of the objective function in the poll step of the algorithms. Numerical experience will be presented, both concerning real applications and academic problems, which shows that the proposed strategies can enhance significantly the practical performance of directional direct search methods. If time permits, we will outline two new algorithms for derivative free-optimization based on direct search and simplex derivatives.

■ MD3

Monday, 4:45-6:15, MDCL 1105

Practical Performance of IPMs for Conic Programming Problems

Stream: Convex Optimization Methods
Chair: *Fernando Ordonez*, Industrial and Systems Engineering, USC

1. **Generating and Measuring Instances of Hard Semidefinite Programs**

   Henry Wolkowicz, Department of Combinatorics and Optimization, University of Waterloo, *Hua Wei*

Linear Programming, LP, problems with finite optimal value have a zero duality gap and a primal-dual strictly complementary optimal solution pair. On the other hand, there exists Semidefinite Programming, SDP, problems which have a nonzero duality gap. And, there exist SDP problems which have a zero duality gap but no strict complementary primal-dual optimal solution. We refer to these problems as hard instances of SDP. In this presentation, we introduce a procedure for generating hard instances of SDP. We then introduce two measures of hardness and illustrate empirically that these measures correlate well with with the complementarity nullity (the dimension of the common nullspace of primal-dual optimal pairs), as well as with the asymptotic local convergence rate.

2. **Projective Re-Normalization for Improving the Performance of IPMs for Conic Optimization**

   Robert Freund, MIT, *Alexandre Belloni*

We present a methodology based on projective transformation for renormalizing the homogeneous self-dual model for solving conic programs via interior-point methods (IPMs), which aims to improve both the theoretical and practical behavior of a given problem instance. We use random walks to construct the requisite projective transformation, with the goal of achieving a marked decrease in interior-point iterations, particularly for ill-behaved problems. We report our computational results based on this method.

3. **Observed IPM Iterations on Semi-Definite Programming Problems**

   Fernando Ordonez, Industrial and Systems Engineering, USC, *Robert Freund*, *Kim-Chuan Toh*

There is a disconnect between theoretical bounds and the observed number of iterations that an IPM takes to solve a conic problem. In this work we consider different measures of problem instance behavior and empirically test their relation to the observed number of iterations taken by an efficient IPM solver for SDP. We show that for the SDPLIB suite of problems, an agregate geometry measure related to primal and dual feasible regions and Renegar's condition number are well correlated with the number of IPM iterations. In addition we find that a measure of the near-absence of strict complementarity is weakly correlated and a measure of the level of degeneracy of the optimal solution is uncorrelated with IPM iterations on the SDPLIB suite.

■ MD4

Monday, 4:45-6:15, MDCL 1110

Optimization of Networks

Stream: Signal Processing and ECE
Chair: *Mung Chiang*, Electrical Engineering Department, Princeton University

1. **On Characterizing the Throughput Degradation for Network Coding with Two Sessions**

   Chih-Chun Wang, School of Electrical and Computer Engineering, Purdue University, *Ness Shroff*, *Abdallah Khreishah*

For a single multicast session in the network, the throughput of network coding is characterized by the min-cut max-flow theorem. However, when there are multiple sessions in the network, the attainable rate is generally less and one does not know the precise characterization of the overall network throughput. A first step towards solving the aforementioned problem is provided by considering two multicast sessions for general directed acyclic networks. A graph-theoretic characterization is provided for the feasibility of whether two symbols at different sources can be simultaneously multicast to many sinks, while some sinks are interested in only one source symbol. It is proven that the existence of a network coding scheme is equivalent to finding Steiner trees with controlled edge overlaps, and the characterization includes the well-studied butterfly graph as a special case. This characterization further enables new fully distributed, queue-length-based congestion control algorithms.

2. **The Price of Simplicity**

   Srinivas Shakkottai, MS&E, Stanford, *Daron Acemoglu*, *Asuman Ozdaglar*, *Rayadurgam Srikant*

We consider pricing interactions between an ISP and its customers. To maximize its revenue, an ISP should set access charges such that it extracts the full utility from the users of the network. However, such a pricing scheme would have to be based on usage and network conditions. In reality, most networks charge a fixed periodic access price. We will present an algorithm for setting such a price which we call the marginal user principle. We will then characterize the price of simplicity, i.e., the loss in revenue to the ISP due to the use of such a simple fixed-price scheme and discuss strategies for increasing the revenue by using two-tier pricing schemes.

3. **Randomized Algorithms for Full Utilization of Wireless Networks**

   Atilla Eryilmaz, MIT, *Asu Ozdaglar*

The optimal scheduling-routing-rate control problem of wireless networks can be posed as a convex optimization problem, which in turn can be solved using dual and primal-dual algorithms. However, the dynamic nature of such networks along with the desire for practical operation of these algorithms necessitate randomized and low-complexity implementations. In this work, we study the extent to which the sub-optimal nature of these randomized strategies affect the performance of the optimization algorithms.

4. **Tackling Nonconvex Problems in Internet Engineering**

   Mung Chiang, Electrical Engineering Department, Princeton University, *R. Cendrillon*, *J. Huang*, *M. Moonen*, *J. Rexford*, *D. Xu*

This talk surveys some of the recent ideas on open problems in the form of nonconvex optimization in Internet engineering. The first half of the talk examines interference management in DSL, one of the most ubiquitous broadband access networks. We present Autonomous Spectrum Balancing (ASB), a distributed, low-complexity algorithm that solves this nonconvex, coupled problem close to optimality. The second half of the talk turns to routing in the backbone network and the question of whether optimal traffic engineering can be realized using only link state routing and destination based forwarding. We answer this question in the positive by presenting the routing protocol PEFT, path-based exponentially-weighted flow splitting. Unlike today's routing protocol where link weight computation is NP-hard, PEFT link weights can be computed in polynomial time, illustrating the new notion of 'Design for Optimizability'.

■ MD5

Monday, 4:45-6:15, MDCL 1016

Financial Optimization

Stream: Financial Optimization
Chair: *Annamaria Barbagallo*, Department of Mathematics & Statistics, University of Guelph

1. **A New Optimization Approach to Clustering Fuzzy Data for Type-2 Fuzzy System Modeling**

   Mohammad Hossein Fazel Zarandi, Dept. of IE, Amirkabir University of Technology

This paper presents a new optimization method for clustering fuzzy data to generate Type-2 fuzzy system models. For this purpose, first, a new distance measure for calculating the (dis)similarity between fuzzy data is proposed. Then, based on the proposed distance measure, Fuzzy c-Mean (FCM) clustering algorithm is modified. Next, Xie-Beni cluster validity index is modified to be able to valuate Type-2 fuzzy clustering approach. In this index, all operations are fuzzy and the minimization method is fuzzy ranking with Hamming distance. Then, the Type-2 fuzzy system is tuned by an inference algorithm for optimization of the main parameters of Type-2 parametric system. Finally, the proposed Type-2 fuzzy system model is applied in prediction of the steel additives in steelmaking process. It is shown that, the proposed Type-2 fuzzy system is superior in comparison with multiple regressions and Type-1 fuzzy system model, in terms of the minimization the effect of uncertainty in the rule-base fuzzy system models an error reduction.

2. **Dynamic oligopolistic market equilibrium problem: existence and regularity results**

   Annamaria Barbagallo, Department of Mathematics & Statistics, University of Guelph

The aim of the talk is generalized the oligopolistic market equilibrium problem when the data dependent on the time. We study under which assumptions the existence of the dynamic solution is ensured. Moreover, we show that regularity results hold. Then, we apply regularity results to this problem to solve numerically the dynamic equilibrium problem. In particular we introduce a method to compute dynamic equilibria by means of a discretization procedure.

■ MD6

Monday, 4:45-6:15, MDCL 1309

Topics on MPECs and Applications

Stream: MPECs/Complementarity Problems
Chair: *Miguel Anjos*, Management Sciences, University of Waterloo

1. **Using exact penalties to derive a new equation reformulation of KKT systems associated to variational inequalities**

   Paulo J.S. Silva, Department of Computer Science, University of São Paulo

In this talk, we show how to extend the concept of a differentiable exact penalty for Nonlinear Programming to a general KKT system. We arrive on a new reformulation of the system as a semismooth equation. This reformulation is a variation of the classical equation based on the minimum function that incorporates implicitly dual information using multiplier estimates. Even though the gradient of a traditional differentiable exact penalty for optimization usually depends on second order information of the problem data, our reformulation does not use any curvature information and can then be easily implemented. We also specialize our results to solve nonlinear complementarity problems, where we can present simple, verifiable, conditions that ensure that the penalty is exact. Finally, we develop a semismooth Newton method based on the proposed reformulation to solve complementarity problems and show some preliminary computational tests comparing the results to classical reformulations like the ones based on the minimum or on the Fischer-Burmeister functions.

2. **A Global Index Theorem for Degenerate Variational Inequalities**

   Asu Ozdaglar, EECS/MIT, *Alp Simsek*, *Daron Acemoglu*

In this talk, we present an extension of the Poincaré-Hopf Theorem of index theory to generalized critical points of a function on a compact region with nonsmooth boundary, defined by a finite number of smooth inequality constraints. We use the generalized Poincaré-Hopf Theorem to present a global index theorem for variational inequalities. We provide an index formula for the degenerate solutions of variational inequality problems under the injective normal map property, which is a weaker condition than the strong stability used in the study of variational inequalities.

3. **Pricing of Perishable Products under Competition**

   Georgia Perakis, Sloan School, MIT

We present a model for pricing differentiated, substitutable products. Sellers compete through pricing. For various classes of demand functions, we propose a bound on the loss of efficiency in terms of the overall industry profit due to competition. We study the tightness of this bound. Furthermore, we consider a capacitated setting where sellers need to sell a fixed amound of inventory over a finite time horizon. We use ideas from quasi-variational inequalities and robust optimization to study this model. We consider open and closed loop policies. We illustrate how sellers learn these policies as they observe their competitors' prices as time unfolds.

■ MD7

Monday, 4:45-6:15, MDCL 1009

Topics in Nonlinear Semidefinite Programming

Stream: Linear, Semidefinite and Conic Optimization
Chair: *Michal Kocvara*, School of Mathematics, University of Birmingham

1. **Convergence Analysis on Two Algorithms in Nonlinear Semidefinite Optimization**

   Jie Sun, Department of Decision Sciences, National University of Singapore

It appears from recent computational research that the smoothing Newton method and the augmented Lagrangian method are two promising approaches to solving nonlinear semidefinite optimization problems. We present convergence results on the two methods, which include an analysis on the quadratic convergence of a smoothing Newton algorithm and an analysis on the "near superlinear" convergence of the augmented Lagrangian algorithm.

2. **Free Material Optimization for Shells via Semidefinite Programming**

   Stefanie Gaile, Institute for Applied Mathematics II, University Erlangen-Nuremberg, *Guenther Leugering*, *Michael Stingl*

A new method for the optimal design of thin-walled structures like components of cars and airplanes is introduced. Our approach is based on the concepts of Free Material Optimization (FMO). In FMO the full material tensor at each point of the design space is considered as optimization variable. Our particular goal is to find the ultimatively stiffest shell structure for a given set of boundary conditions and load cases. The elastic behaviour of the shell is described by Naghdi's shell model. Lagrange duality theory allows to identify the basic problem as the dual of an infinite-dimensional convex nonlinear semidefinite program. After discretization by the finite element method a finite-dimensional convex semidefinite program is obtained, which can be solved by the nonlinear SDP code PENNON. The presentation is concluded by numerical examples demonstrating the capabilities of our approach.

3. **A Newton-type Augmented Lagrangian Method For Semidefinite Programming**

   Xinyuan Zhao, National University of Singapore, *Defeng Sun*, *Kim-Chuan Toh*

From the perspective of Newton's method, we consider an augmented Lagrangian method using the projection operator over the cone of positive semidefinite matrices, for solving the dual semidefinite programming (SDP) problems. Under the extended strict primal constraint qualification (in particular the primal constraint nondegenracy condition) and the dual constraint nondegeneracy condition, we show that the rate of convergence is at least linear and it is proportional to $1/c$, where c is the penalty parameter that exceeds a certain threshold $\bar{c} > 0$. Numerical experiments on a variety of large linear SDPs are performed and the computational results show that our method are comparable or better than the best results currently available.

■ MD8

Monday, 4:45-6:15, MDCL 1010

Applications of Multidisciplinary Shape Optimization

Stream: Engineering Optimization
Chair: *Jamshid Samareh*, NASA Langley Research Center

1. **Enabling Technology Tools for Multidisciplinary Design Optimization**

   Bharat Soni, Mechanical Engineering, University of Alabama at Birmingham, *Jong-Eun Kim*, *Young Ho Kim*, *Roy P. Koomullil*, *Alan M. Shih*

With the advent and rapid development of high performance computing and communication (HPCC) technology computational fluid dynamics (CFD) and computational structural dynamics (CSD) have emerged as essential tools for engineering analysis and design. Last three decades have seen considerable progress in the development of tools and technologies for addressing CFD and CSD applications. However, accuracy, confidence, thru-put and cost effectiveness in performing CFD and CSD simulations remain the critical barriers associated with complex applications. In response to the perceived need for the development of computational enabling technology tools to address these challenges, a broad-based research and education program utilizing state-of-the-art information technology has been initiated at the High Fidelity Simulations and Enabling Technology Laboratory (HFS&ETL), University of Alabama at Birmingham (UAB). The overview of the HFS & ETL will be presented with emphasis on associated research and development thrusts: (i) Automated and Parametric Geometry-Mesh generation and Adaptation; (ii) Domain specific simulation algorithms and applications; and (iii) Technology tools needed to address multidisciplinary simulations and design optimization. The development of these tools with applications will be presented. Along with CFD and CSD systems, the emphasis will be placed on the enabling technology software libraries: GGTK (Geometry-Grid Tool Kit) and FSITK (Fluid Structure Interaction ToolKit) with their application to engineering design applications. The GGTK with associated MiniCAD system facilitates automatic and parametric generation of geometry and quality meshes timely enough for design study. The FSI toolkit provides a loosely-coupled reusable environment for efficient and accurate load and motion transfer between unmatched meshes utilized in different disciplines. An integrated aerodynamics shape optimization (ASO) framework developed using object-oriented toolkit, DAKOTA as basis will be described with applications. Computational examples will be presented to demonstrate the success of the developed enabling and simulation methodologies. The perspectives, vision, strategic plan, and road map associated with the research in multidisciplinary design optimization will be included.

2. **Using Parametric CAD in Shape Design & Optimization**

   Robert Haimes, MIT Areo/Astro

This talk presents a comprehensive approach for CAD based geometry handling in support of multi-disciplinary analysis and design. By using the Master-Model concepts found in modern CAD systems, the same components can used throughout the design process from conceptual through final design. This approach assumes that the design intent is fully encapsulated within the CAD part and provides associated access throughout. Unlike traditional schemes, the software model presented here allows for "hands-off" automated meshing. In addition, CAD attribution can be used to denote material properties of the part so that specification of boundary conditions can be performed without intervention. Though outside the common view of a Master-Model, shape changes can be applied by adjusting certain curves found within independent sketch CAD features. At part regeneration, the modified curves get extruded, blended, lofted, and/or rotated (based on the parent feature) to produce the new 3D shape.

3. **Shape Optimization via Dynamic Idealization**

   Krishnan Suresh, ME Dept, University of Wisconsin, Madison

The objective of shape optimization is to rapidly generate superior artifacts, through a seamless integration of design and analysis techniques. It is a computationally intensive process, and therefore entails judicious simplification of the underlying CAD model. For simplification to be effective during shape optimization, it must be dynamic, robust and its impact on analysis must be quantifiable. In this talk, I will discuss how these objectives may be achieved through recently proposed concepts such as adjoint correctors and algebraic idealization.

■ MD9

Monday, 4:45-6:15, MDCL 1008

Principles of Convex Optimization

Stream: Convex and Nonsmooth Analysis

Chair: *Juan Peypouquet*, DIM - Universidad de Chile

1. **Modulus of metric regularity of convex mappings**

   Yoshiyuki Sekiguchi, Kwansei Gakuin University

Inverse and implicit function theorems play a crucial role in continuous optimization theory. Metric regularity is one of their mordern form. We investigate fundamental properties of modulus of metric regularity, which expresses a quantitative nature of local behavior of inverse set-valued mappings. In particular, we will present an exact formula for the modulus of regularity of convex set-valued mappings between general Banach spaces. Then the estimate is used to dicuss validity of radius theorem for mappings generated from constraint systems.

2. **A unifying principle for continuous- and discrete-time methods in convex optimization.**

   Juan Peypouquet, DIM – Universidad de Chile

When applied to a convex minimization problem, the proximal point algorithm yields a sequence with the same asymptotic properties as the continuous trajectory given by the steepest descent method; if one converges (weak/strong), so does the other (O. Guler, SICON '91). In this talk we provide a criterion to identify equally-behaved evolution systems which we prove to share certain asymptotic properties in terms of (w/s) ω-limit sets, convergence, almost-convergence, convergence of the averages, etc. This lets us obtain qualitative information about one system by studying the other. Next, we discuss on applications to: Tikhonov regularization and penalization/barrier methods coupled with "diagonal prox" (updating the objective function at each iteration) or the steepest descent method. Finally, we explain how this principle can be used in more general settings including second-order systems, nonconvex problems, and even differential inclusions not having a unique solution.

■ TA1

Tuesday, 8:30-10:00, MDCL 1305

Nonlinear Programming and IPM

Stream: Conic Programming and Interior Point Methods

Chair: *Clovis Gonzaga*, Dept. of Mathematics, Federal University of Santa Catarina, Brazil

1. **A unified conic formulation for convex problems involving powers**

   François Glineur, Université Catholique de Louvain / CORE

This talk introduces a common framework unifying several classes of convex optimization problems including linear programming, second-order cone programming, quadratically constrained convex quadratic programming, l_p programming, minimization of sums of Euclidean or p-norms, geometric programming and entropy programming. Any of these problems can be modelled as a conic optimization problem, where every cone used in the formulation is the conic hull of the epigraph of some convex power function $x \mapsto |x|^p$ for $p \geq 1$. Moreover, every such cone is self-dual, which implies that the dual for every instance belonging to this problem class also belongs to the same class. We will also explain how problems involving exponential and logarithmic functions can actually obtained as limit cases when $p \to \infty$. A solver for this problem class will be described in another talk ("Solving convex problems involving powers with a conic interior-point algorithm", session TC4).

2. **A Recursive Construction of Optimal Self-Concordant Barriers**

   Olena Shevchenko, Department of Mathematics, University of Maryland, Baltimore County

In this talk, we present a recursive formula for optimal dual barrier functions on homogeneous cones. This is done in a way similar to the primal construction of Güler and Tunçel by means of the dual Siegel cone construction of Rothaus. To obtain the formula for the dual barrier, we use invariance of the primal barrier function with respect to a transitive subgroup of automorphisms and the properties of the duality mapping. We will also discuss other relevant issues.

3. **Box trust region methods based on Levenberg-Marquardt and central trajectories**

   Clovis Gonzaga, Dept. of Mathematics, Federal University of Santa Catarina, Brazil

We consider a convex quadratic programming problem for which the analytic center is given as initial point. This is often the case when computing box-constrained trust region steps in nonlinear programming. We study the primal-dual properties of the trajectory described by the Euclidean trust region solutions for increasing radius, and show that they provide a good approximation for the primal-dual central points. This results in a method for solving box constrained trust region problems which starts on the Levenberg-Marquardt trajectory and then switches to the central path. We apply this to the solution of the tangential minimization problem in SQP algorithms.

■ TA2

Tuesday, 8:30-10:00, MDCL 1307

Convex Vector Optimization

Stream: Convex Optmization Methods

Chair: *Xiaoqi Yang*, The Hong Kong Polytechnic University

1. **Optimality conditions for scalar and vector optimization problems with quasiconvex inequality constraints**

   Ivan Ginchev, University of Insubria, Department of Economics, Varese, Italy

We start from a scalar optimization problem with quasiconvex inequality constraints and propose first-order optimality conditions in terms of the Dini-directional derivatives. We show that in the particular case when the objective function and the constraints are pseudoconvex the proposed conditions generalize well-known results of convex programming. The communication will provide a discussion of this result and generalizations (preserving the hypotheses of quasiconvexity of the constraints) both for scalar and vector optimization problems.

2. **On Optimality Conditions for Convex Semi-definite Vector Optimization Problems**

   Gue Myung Lee, Division of Mathematical Sciences, Pukyong National University, *Kwang Baik Lee*

In this talk, we consider a convex semidefinite vector optimization problem (SVOP) involving a convex objective vector function, a matrix linear inequality constraint and a geometric constraint, and define (properly, weakly) efficient solutions for (SVOP) as we do for ordinary vector optimization problems. It is well known that we need constraint qualifications (for example, an interior point condition) for getting optimality conditions for vector optimization problems or convex semidefinite optimization problems. However, in this talk, we present an optimality condition for efficient solutions of (SVOP), which holds without any constraint qualifications. Also, we give optimality conditions for weakly efficient solutions and properly efficient solutions for (SVOP). Furthermore, we give examples for illustrating our optimality conditions.

3. **Vector Optimization Problems and Generalized Proximal Point Algorithms in Banach Spaces**

   Zhe Chen, Department of Applied Mathematics, The Hong Kong Polytechnic University

In this paper, we consider a convex vector optimization problem of finding the set of weakly efficient solutions for an extended valued map from a smooth reflexive Banach space to another smooth reflexive Banach space, with respect to the partial order induced by a closed, convex and pointed cone with a nonempty interior. We introduce a vector-valued generalized proximal point algorithm based on a Bregman function and prove the sequence generated by this algorithm weakly converges to a weakly efficient solution of the vector optimization problem under mild conditions. Our results are some extensions of generalized proximal point algorithms for scalar-valued convex optimization problem.

■ TA3

Tuesday, 8:30-10:00, MDCL 1105

Medical Problems using Optimization Techniques

Stream: Medical Applications in Optimization

Chair: *Michael Ferris*, University of Wisconsin, Computer Sciences

1. **Regularized region-of-interest X-ray tomographic reconstruction by local supersampling**

   Benoit Hamelin, Institut de génie biomédical, École Polytechnique de Montréal, *Yves Goussard*, *Jean-Pierre Dussault*

We present an iterative 2D tomographic reconstruction procedure for a noncentral region of interest (ROI), for which high resolution is required. Confronted with large computation times and dissatisfied with nonlinear multigrid methods, we have devised a "heterogeneous multigrid" procedure based on an irregular sampling of the image. We thereby define the ROI on a fine grid while the rest of the image — the "background" – is sampled on a much coarser grid. The background and the ROI are reconstructed simultaneously from the full set of acquired projections. This approach significantly reduces the computational cost of projection and backprojection operations. We also show that, under conditions, this procedure yields images of quality equivalent to full high-resolution reconstruction within the ROI, with dramatic runtime savings. We discuss these conditions, which involve the respective sampling rates in the background and the ROI, as well as the extent of the ROI.

2. **Tracking of Fiducial Markers for Prostate Cancer Treatment**

   Olesya Peshko, School of Computational Engineering and Science, McMaster University, *Douglas Moseley*, *Tamás Terlaky*, *Cynthia Menard*, *Tim Craig*, *Cathy Rocca*

To design a radiation treatment margin for prostate cancer patients, knowledge of organ motion is important. We design algorithms and software to automatically estimate an extent of motion through a sequence of 2D fluoroscopic images. For this, we detect three fiducial markers inserted in the prostate, and process all the frames to compute markers displacement from their initial positions. The software we develop allows tracking motion changes within one treatment fraction, and between treatments.

3. **Control policies for off-line adaptive radiation therapy**

   Marina Epelman, IOE, University of Michigan

In intensity-modulated radiation therapy for cancer treatments, a treatment is designed to deliver high radiation doses to tumors, while avoiding the healthy tissue. Optimization-based treatment planning often produces sharp dose gradients between tumors and healthy tissue. Due to random shifts during treatment, significant differences between the dose in the 'optimized' plan and the actual dose delivered can occur. Radiation is delivered as a series of small daily fractions, and it has recently become technically possible to measure variations in patient setup and organ shapes and the delivered doses after each fraction. We exploit the dynamic nature of treatment and information gathering by adapting the treatment plan to fraction-to-fraction variations measured during a patient's treatment course within a DP framework. We consider several suboptimal control policies which re-optimize before each fraction and use Bayesian updating of the patient's positional uncertainty distribution.

■ TA4

Tuesday, 8:30-10:00, MDCL 1110

Process Operations

Stream: Optimization Formulations and Algor. for Chemical Processes

Chair: *Chris Swartz*, Chemical Engineering, McMaster University

1. **Coordination of Decentralized Large-Scale Optimal Process Control Problems**

   Anes Dallagi, Chemical and Material Engineering, University of Alberta, *Natalia I. Marcos*, *J. Fraser Forbes*

Manufacturing and processing decision-makers are faced with complex and high-dimensional problems. The problem size, process nonlinearity and uncertainty, and the range of time and process variable scales render centralized decision-making difficult, if not intractable. This situation is most commonly dealt with by decentralizing decision-making. A key issue in decentralized decision-making is ensuring that locally optimal decisions are globally optimal. One approach to ensuring that distributed decision-making produces optimal results is to coordinate the local decision-making processes. In this presentation we are concerned with these issues: how to achieve tractable decomposition schemes for large scale systems and how to efficiently decentralize decision making for complex processes? We begin by presenting, three decomposition-coordination algorithms: price-driven, quantity-driven and prediction-driven. In the second part we provide the decision makers with a coordination tool: an algorithm depending on the input and output of each sub-unit. We also impose to each decentralized unit a new optimal control problem based on its own process but also on the response of the other units including the overall coordinator. The proposed approach is illustrated using an example problem drawn from the chemical engineering literature.

2. **A solution approach for dynamic optimization problems with parametric uncertainty**

   Wolfgang Marquardt, RWTH Aachen University, *Jayashree Kalyanaraman*, *Johannes Gerhard*, *Martin Mönnigmann*

The aim of the presented approach is to find a profile of the control variables that is optimal with respect to the objective function of the dynamic optimization problem and ensures that none of the path and endpoint constraints are violated despite parametric uncertainty. We assume that the uncertainty set is compact and has a smooth boundary. This includes, e.g., a confidence ellipsoid for a Gaussian random variable. Constrained dynamic optimization problems with uncertain parameters can be addressed by a worst-case formulation leading to a bi-level min-max optimization problem. We present an approach to solve the min-max optimization problem in the case that the underlying maximization problem has its solution on the boundary of the uncertainty set. Worst case points are tracked by including first order necessary conditions of optimality (NCO) of the maximization problem as additional equality constraints in the dynamic optimization problem. The NCOs include derivatives of the constraints and require evaluation of the sensitivities of the state variables with respect to the uncertain parameters. As location and number of the worst case points is not known a priori an iterative solution approach is formulated. Case studies from chemical engineering are presented to illustrate the approach.

3. **Comparison of configurations of simulated moving bed processes by multi-objective optimization**

   Yoshiaki Kawajiri, Dept. of Chemical Engineering, Carnegie Mellon University, *Lorenz Biegler*

Configurations of a four-column simulated moving bed chromatographic process are investigated by multi-objective optimization. Various existing column configurations are compared through a multi-objective optimization problem. Furthermore, an approach based on an SMB superstructure is applied to find novel configurations which have been found to outperform the standard SMB configuration. An efficient numerical optimization technique is applied to the mathematical model of the SMB process. It has been confirmed that although the optimal configuration highly depends on the purity requirement, the superstructure approach is able to find the most efficient configuration without exploring various existing configurations.

■ TA5

Tuesday, 8:30-10:00, MDCL 1016

Recent Theoretical Developments for Derivative-free Direct Search

Stream: Derivative Free Optimization

Chair: *Alessandra Papini*, Dipartimento di Energetica "Sergio Stecco", Firenze, Italia

1. **Active Set Identification for a Class of Direct Search Algorithms**

   Virginia Torczon, Department of Computer Science, College of William & Mary, *Robert Michael Lewis*

For generating set search methods for linearly constrained problems, we prove that once the iterates are sufficiently close to a KKT point, there is a clearly identifiable subsequence of iterations for which the working set of constraints equals the set of constraints that make the limit point of the subsequence a KKT point of the problem. Consequently we can reliably estimate the set of active constraints, even in the absence of information about the derivative of the objective. We show how to use this information to accelerate the search.

2. **Piecewise smooth optimization and generating set search methods**

   Claudio Bogani, Dipartimento di Energetica "Sergio Stecco", Universita di Firenze

Generating Set Search methods (GSS) are a class of direct search algorithms for the optimization of a differentiable function f. It is well known that, when GSS are applied to problems where f fails to be everywhere differentiable, convergence to nonstationary points may occur. We propose special GSS methods for problems where the set of nondifferentiability is highly structured: f is smooth on a family of polyhedra and its derivative is discontinuous on the faces of the polyhedra. Two classical instances of such problems are the discrete linear approximation with respect to the 1-norm and the infinity-norm. Convergence is ensured by forcing the set of search directions to reflect the local structure of the nondifferentiability set, near the current iterate. Both theoretical and practical aspects are discussed; some numerical results are reported.

3. **Parallel Variable Distribution for Mesh Adaptive Direct Search**

   Sebastien Le Digabel, École Polytechnique de Montréal

We propose to apply the Parallel Variable Distribution (PVD) technique from Ferris and Magasarian to the Mesh Adaptive Direct Search (MADS) algorithm, which extends the Generalized Pattern Search (GPS) algorithm for nonsmooth optimization. The resulting algorithm intends to solve large problems by using parallel MADS instances optimizing only a portion of the variables. Numerical results illustrate advantages and limitations of this method.

■ TA6

Tuesday, 8:30-10:00, MDCL 1309

Topics in Bilevel Optimization

Stream: MPECs/Complementarity Problems
Chair: *Patrice Marcotte*, University of Montreal
Session organizer: Gilles Savard

1. **Theoretical properties of a network pricing problem**

   Gilles Savard, MAGI, École Polytechnique, *Géraldine Heilporn*, *Martine Labbé*, *Patrice Marcotte*

We consider a bilevel formulation of a network pricing problem, where the arcs that are subject to tolls form a (bi-directional) path, as would be the case for a highway. This presentation is concerned with three issues: (i) the complexity of the problem and some of its variants, (ii) a new class of valid inequalities, together with an efficient separation algorithm, and (iii) the geometrical properties of the valid inequalities, i.e., full dimensionality of the induced polyhedron, and facet properties.

2. **Necessary optimality conditions in optimistic bilevel programming**

   Stephan Dempe, TU Bergakademie Freiberg, *Joydeep Dutta*, *Boris Mordukhovich*

In the talk focus is on necessary optimality conditions for the optimistic version of bilevel programming problems in finite-dimensional spaces. First we discuss different possible approaches. Then the problem is reduced to a nondifferentiable one-level program formulated via (nonsmooth) optimal value function of the parametric lower-level problem in the original model. The optimality conditions of Karush-Kuhn-Tucker type are then obtained by computing basic subgradients of value/marginal functions in variational analysis. We present results obtained for bilevel programs with additional assumptions on the data.

3. **Pareto-Improving Congestion Pricing**

   Siriphong Lawphongpanich, Department of Industrial and Systems Engineering, University of Florida, *Yafeng Yin*

Congestion pricing has been around for over 80 years and many have since recognized it as an efficient method for mitigating congestion. However, getting the public to accept congestion pricing is still an obstacle because users find themselves worse off. To make congestion pricing more appealing, we propose a 'Pareto-improving' tolling scheme to ensure that, when compared to the situation without tolls, some users are better off and no one is worse off in terms of travel costs. Tolls are Pareto-improving when they induce a 'dominating' flow distribution. Under such a flow distribution, some users are better off and no one is worse off when compared to the user equilibrium distribution. We determine the existence of a dominating flow distribution by solving a MPCC.

■ TA7

Tuesday, 8:30-10:00, MDCL 1009

Algorithms and Software for Nonlinear Optimization

Stream: Nonlinear Optimization Software
Chair: *Philip Gill*, Department of Mathematics, University of California, San Diego

1. **Exact Primal-Dual Regularization of Linear Programs**

   Dominique Orban, Math & Indust Eng Dept, Ecole Polytechnique de Montreal, *Michael Friedlander*

We propose a theoretical justification for regularizing the linear systems used to compute search directions in interior-point methods for linear programming when those systems are (nearly) rank deficient. We present a primal-dual infeasible algorithm with explicit primal and dual regularization. The regularization is termed exact to emphasize that, although the linear program is regularized, we are able to recover a solution of the original problem, independently of the values of the regularization parameters. We discuss the implementation of this scheme as part of the open-source GLPK framework.

2. **Inexact Interior-Point Methods for Very Large Nonlinear Programs**

   Frank Curtis, Northwestern University, *Jorge Nocedal*

We discuss the design of optimization algorithms for problems in which it is impractical to factor the linear systems arising in the step computation. When the Hessian is complicated and the constraints are simple, then a projected CG iteration is appropriate. On the other hand, when the constraints are the source of the problem – which is the focus of this talk– it may be best to apply an iterative method to the full KKT system. We discuss some fundamental questions about how such iterative methods should be applied so as to yield both global convergence, a fast asymptotic rate, and scale invariance.

3. **Iterative solution of augmented systems arising in interior methods**

   Anders Forsgren, Department of Mathematics, Royal Institute of Technology (KTH), *Philip E. Gill*, *Joshua D. Griffin*

Iterative methods are proposed for certain augmented systems of linear equations that arise in interior methods for general nonlinear optimization. Interior methods define a sequence of KKT equations that represent the symmetrized (but indefinite) equations associated with Newton's method for a point satisfying the perturbed optimality conditions. These equations involve both the primal and dual variables and become increasingly ill-conditioned as the optimization proceeds. In this context, an iterative linear solver must not only handle the ill-conditioning but also detect the occurrence of KKT matrices with the wrong matrix inertia. A one-parameter family of equivalent linear equations is formulated that includes the KKT system as a special case. The discussion focuses on a particular system from this family, known as the "doubly-augmented system", that is positive definite with respect to both the primal and dual variables. A family of constraint preconditioners is proposed that provably eliminates the inherent ill-conditioning in the augmented system. A considerable benefit of combining constraint preconditioning with the doubly-augmented system is that the preconditioner need not be applied exactly. Finally, two particular "active-set" constraint preconditioners are formulated.

■ TA8

Tuesday, 8:30-10:00, MDCL 1010

PDE Constrained Optimization

Stream: PDE Constrained Optimization
Chair: *Stefan Ulbrich*, Department of Mathematics, TU Darmstadt
Session organizer: Ekaterina Kostina

1. **Fast Algorithms for inverse problems in cardiac electrophysiology**

Santi Swaroop Adavani, University of Pennsylvania, *George Biros*

Inverse problems in electro-cardiography aim at computing the epicardial potential based on the body surface potential measurements. The solution of this problem gives an indirect way of understanding the electrical activity of the heart. This work considers an inverse problem formulated as a PDE-constrained optimization problem which gives a way of estimating electrical activity within the myocardium. This involves recovery of a spatially varying parameter which determines the excitability of each cell, where the forward problem is the Fitz-Hugh Nagumo model for the heart which is a non-linear two species reaction diffusion PDE. A second order operator splitting scheme is used to solve the non-linear forward problem on an adpative mesh using octrees. We use a reduced space approach for the inverse problem where we eliminate the state and adjoint variables and iterate in the inversion parameter space using conjugate-gradients. We precondition the conjugate-gradient with a V-cyle multigrid scheme. The smoother in multigrid is a two-step stationary iterative solver that inexactly inverts an approximate reduced Hessian by exclusively iterating on the high-frequency subspace. We present numerical simulations of the electrical wave propagation in normal and ischaemic hearts. Finally, we present results for the inverse problem and discuss scalabilities of different algorithms used for this problem.

2. **Optimal Control of Flows in Moving Domains**

Bartosz Protas, Department of Mathematics & Statistics, McMaster University, *Wenyuan Liao*, *Donn Glander*

This investigation concerns adjoint-based optimization of viscous incompressible flows (the Navier-Stokes problem) coupled with heat conduction involving change of phase (the Stefan problem) and occurring in domains with moving boundaries. This problem is motivated by optimization of welding techniques used in automotive manufacturing, where the goal is to determine an optimal heat input, so as to obtain a desired shape of the weld pool surface upon solidification. In order to use a gradient based optimization approach, it is necessary to characterize the sensitivity (i.e., the gradient) of the cost functional with respect to the control (the heat input). This can be done conveniently using suitably-defined adjoint equations. A difficulty in the present problem is that the shape of the domain is also a dependent variable, and both the cost functional and the state variables need to be differentiated with respect to evolution of the domain. This is accomplished using methods of "non-cylindrical" calculus which allows us to derive a perturbation system accounting for domain variability. An adjoint system is derived afterwards which, unlike the forward problem, is defined on a domain with a predetermined evolution and also involves ordinary differential equations defined on the domain boundary ("the adjoint transverse system").

3. **Optimizing Control of SMB Processes**

Le Chi Pham, Universität Dortmund, Biochemical and Chemical Engineering, *Achim Kuepper*, *Abdelaziz Toumi*, *Sebastian Engell*

We will present an overview of our work on optimization-based control of various so-called chromatographic SMB processes. These processes consist of a closed circle of columns that are filled with an adsorbent that has different affinities to the substances in the liquid that is pumped through the columns. This leads to different residence times of the substances in the columns and hence to separation. By switching the inlet and outlet ports in the direction of the liquid flow, an effective counter-current operation can be achieved. In our approach, the flows into the columns and the switching times are optimized online with respect to an economic cost function and the specified product purities are included as constraints. The optimization is based on the discretization of a rigorous pde model of the process (the so-called general rate model that consists of two coupled pdes for each substance in each column) with several hundred up to more than 1000 states.

■ TA9

Tuesday, 8:30-10:00, MDCL 1008

Topics in Robust Optimization

Stream: Robust Optimization
Chair: *Elodie Adida*, UIC, Department of Mechanical and Industrial Engineering

1. **Robust Logistic Regression**

Apostolos Fertis, Massachusetts Institute of Technology, *Dimitris Bertsimas*

Data mining has provided a plethora of ways to interpret various sets of data with big cardinality and heterogeneous kinds of information. Logistic regression supposes that the data belong to one of two classes and that each data has a probability of belonging to either class based on its distance from a linear separator. In practice, there might be errors in the independent variables that correspond to the data or even in the class with which the data are associated. In this paper, we propose the Robust Logistic Regression and the Y-Robust Logistic Regression algorithms, which apply the Robust Optimization techniques in finding an estimator for the linear separator. They consider the worst case scenario when calculating the probabilities. The Robust Logistic Regression algorithm deals with uncertainty in the independent variables of the data, whereas the Y-Robust Logistic Regression algorithm deals with uncertainty in the class of the data.

2. **Efficient Algorithm for Deviation Robust MILP Optimization under Interval Data Uncertainty**

Tiravat Assavapokee, University of Houston

This research presents an optimization algorithm for making robust decisions under interval data uncertainty for two-stage mixed integer linear programming problems under deviation robust criterion. The algorithm incorporates iterative Benders' decomposition algorithm, bi-level programming, approximation algorithms, and priority based methods to efficiently solve the overall optimization problem. The algorithm can be effectively applied in solving MILP optimization problem under uncertainty when the joint probability distributions of key parameters are unknown and the only information available to the decision maker is the potential ranges of uncertain parameters. The proposed algorithm has been applied to solve the deviation robust facility location problems under interval data uncertainty. All results illustrate impressive performance in computation time of the proposed algorithm.

3. **Dynamic Pricing and Inventory Control under Uncertainty**

Elodie Adida, UIC, Department of Mechanical and Industrial Engineering, *Georgia Perakis*

We consider a variety of models for dealing with demand uncertainty for a joint dynamic pricing and inventory control problem in a make-to-stock manufacturing system. We introduce a multi-product capacitated, dynamic setting, where demand depends linearly on the price. We address demand uncertainty using various robust and stochastic optimization approaches. We first introduce closed-loop formulations (adjustable robust and dynamic programming), then open-loop models (robust and stochastic approaches). We conclude that the affine adjustable robust approach performs well in terms of realized profits and protection against constraint violation, while being computationally tractable. Furthermore, we compare the complexity of these models and discuss some insights.

■ TB1

Tuesday, 10:30-12:00, MDCL 1305

Exploiting structure in SDP and SOCP

Stream: Conic Programming and Interior Point Methods
Chair: *Mauricio de Oliveira*, Dept of Mechanical and Aerospace Engineering, UCSD
Session organizer: Yuriy Zinchenko

1. **A Homogeneous Algorithm for Monotone Complementarity Problems over Symmetric Cones**

Akiko Yoshise, University of Tsukuba

We consider the monotone complementarity problem over symmetric cones. For solving the problem, a homogeneous model has been proposed and we see that (a) a bounded path having a trivial starting point exists, (b) any accumulation point of the path is a solution of the homogeneous model, (c) if the original problem is solvable then it gives us a finite solution, (d) if the original problem is strongly infeasible, then it gives us a finite certificate proving infeasibility. In this paper, we propose a class of algorithms for numerically tracing the path in (a). Polynomial iteration complexity bounds of the algorithms are derived and the best complexity bounds are achieved for linear or convex quadratic optimization problems over symmetric cones.

2. **Numerical Optimization Assisted by Noncommutative Symbolic Algebra**

Mauricio de Oliveira, Department of Mechanical and Aerospace Engineering, UCSD

This talk describes how a symbolic computer algebra tool (NCAlgebra) that handles matrix (noncommutative) products symbolically can be used to assist the numerical solution of optimization programs where the variables are matrices. Our current focus is on semidefinite programming. The idea is to keep matrix variables aggregated at all steps of a primal-dual interior-point algorithm in which symbolic expressions are automatically generated and used iteratively.

3. **Fully sparse semidefinite programming using automatic differentiation**

   Gun Srijuntongsiri, Computer Science Department, Cornell University, *Stephen Vavasis*

In this paper, we show a way to exploit sparsity in the problem data in a primal-dual interior-point method for solving a class of semidefinite programs. Even when the problem data is sparse, interior-point methods generally still require dense matrices. Our proposed method, on the other hand, does not require any dense matrices. Our method combines Fukuda et al.'s theory of partial matrix completion, conjugate gradient, and a new technique based on automatic differentiation. This technique also avoids the high space complexity normally associated with automatic differentiation in reverse mode. In addition, we propose a preconditioning technique to improve the convergence rate of the conjugate gradient.

■ TB2

Tuesday, 10:30-12:00, MDCL 1307

Projections and Monotone Operators

Stream: Convex and Nonsmooth Analysis
Chair: *D. Russell Luke*, Department of Mathematical Sciences

1. **Some uses of the Fitzpatrick function in the non reflexive case**

   Constantin Zalinescu, Faculty of Mathematics, University Al.I.Cuza Iasi, Romania

The Fitzpatrick function showed already its usefulness in the study of maximal monotone operators in reflexive Banach spaces and it was hoped that it will be also useful in the non reflexive case. In our talk we present some applications of the Fitzpatrick function for obtaining a surjectivity result for operators of type (NI) and some results on the interior of the domain and of the range of a maximal monotone operator.

2. **Convergent Nonconvex Projection Algorithms**

   D. Russell Luke, University of Delaware, Department of Mathematical Sciences

Our goal is two-fold: first to prove the convergence in the convex setting of an algorithm that we have proposed to solve inconsistent feasibility problems, and second to modify the theory to accommodate nonconvexity. Our algorithm is a relaxation of a fixed point operator used by Lions and Mercier to solve differential inclusions. Since our ultimate aim is to prove convergence of projection algorithms for nonconvex phase retrieval problems in crystallography, our focus will be on our particular operator, however it is hoped that the techniques used here are transferable to other cases. Our results complement other recent results on the rate of convergence of alternating projections for consistent nonconvex problems.

■ TB3

Tuesday, 10:30-12:00, MDCL 1105

Robust Risk Management

Stream: Robust Optimization
Chair: *David B. Brown*, Duke University
Session organizer: Akiko Takeda

1. **Worst-Case Violation of Sampled Convex Programs for Optimization with Uncertainty**

   Takafumi Kanamori, Department of Computer Science and Mathematical Informatics, Nagoya University

Sampled convex programs are studied to deal with convex optimization problems including uncertainty. A deterministic approach called robust optimization is commonly applied to solve these problems. On the other hand, sampled convex programs are randomized approach based on constraint sampling. Calafiore and Campi have proposed sufficient number of samples such that only small portion of original constraints are violated at randomized solution. Our main concern is not only the probability of violation, but also the degree of violation, that is, the worst-case violation. We derive an upper bound of the worst-case violation for sampled convex programs under general uncertainty set, and provide the relation between the probability of violation and the worst-case violation. As well as the probability of violation, the degree of violation is also assured to be depressed to small value with sufficiently large number of random samples.

2. **Robust Optimization For Asset Liability and Risk Management Under Uncertainty**

   Oleg Grodzevich, Dept. of Management Sciences, University of Waterloo, *Henry Wolkowicz*, *Samir Elhedhli*

Asset and liability management (ALM) presents a big challenge to financial organizations; a challenge that they have to deal with on a daily basis. Ineffective management decisions not only lead to substantial losses, but can also leave the financial institution open to serious risks. Failure in addressing these risks can have catastrophic consequences. The core challenges for ALM decision-making are: uncertainties in future states of the economy; and consumer behaviour. We propose to use robust optimization methodology to account for these uncertainties, while preserving the computational tractability of the problem. We consider new formulations of ALM within the robust optimization framework. These formulations address some drawbacks of current models in the literature. The models capture the dynamic multi-stage nature of ALM and, therefore, require extensions of the robust optimization methodology to allow for time-dependent multi-period uncertainty modelling and decision-making.

3. **Satisficing measures**

   David Brown, Duke University

In this work we consider a class of measures for evaluating the quality of risky portfolios based on their performance relative to desired targets. We call these measures satisficing measures and show that they are dual to classes of corresponding risk measures. These dual descriptions have significant practical value in that they involve specifications of target or benchmark performance levels. These competing benchmarks or targets are often natural for investors to specify, as opposed to the risk-tolerance type parameters that are necessary for most risk measures and can be difficult to understand intuitively and hard to appropriately specify. Moreover, the satisficing measures we study have quasi-concavity properties which ensure that they appropriately reward for diversification; this in turn implies that we can optimize efficiently over such measures. Finally, we discuss some structural properties of optimal satisficing portfolios and relate them to some standard risk measures.

■ TB4

Tuesday, 10:30-12:00, MDCL 1110

Process Design

Stream: Optimization Formulations and Algorithms for Chemical Processes
Chair: *Larry Biegler*, Carnegie Mellon University

1. **Modeling and Validation of Fuel Cells**

   Arvind Raghunathan, System Dynamics & Optimization, United Technologies Research Center, *Arun Pandy*, *Andrew Haug*

An one dimensional physics based model for a sub-scale Phosphoric Acid Fuel Cell (PAFC) will be presented. The parameters in the model will be estimated based on experimental data. The modeling and parameter estimation approach described is applicable to other fuel cell systems as well. The PAFC model consists of 5 gas micro-porous layers - anode and cathode gas diffusion layers, anode and cathode catalyst layers and the electrolyte matrix. The equations describing the physics in the each layer include the heat, mass and momentum transfer equations for the gas and liquid phases and relevant electrochemical reactions. Catalyst layer models also include effects of carbon monoxide (CO) poisoning and ammonia (NH3) poisoning on the catalyst sites. An approach for estimating the model parameters will be presented. The model parameters to be estimated include ' nominal performance parameters in the absence of CO and NH3, the parameters in the CO and NH3 poisoning equations.

2. **Global Optimization of Reverse Osmosis Networks for Wastewater Treatment and Minimization**

   Yousef Saif, Chemical Engineering Department, University of Waterloo, *A. Elkamel*, *M. Pritzker*

Reverse osmosis has shown itself as a viable technology toward the treatment and minimization of industrial and domestic wastewater streams. The current research presents a deterministic branch and bound global optimization based algorithm for the solution of the reverse osmosis network (RON) synthesis problem. The mathematical programming model describes the RON through nonconvex mixed integer nonlinear programs (MINLP). A piecewise discrete mixed integer linear program (MILP) is derived based on the convex relaxation of the nonconvex terms present in the MINLP formulation to approximate the original nonconvex program and to get a valid lower bound on the global optimum. The MILP model is solved at every node in the branch and bound tree to verify the global optimality of the treatment network within a pre-specified gap tolerance. Several tightening constraints are developed to screen simultaneously the treatment network alternatives during the search, to tighten the variable bounds, and consequently to accelerate the algorithm convergence. Water desalination is considered as a case study to illustrate the global optimization of the RO network.

3. **Unified Architecture for Process Optimization**

Vladimir Mahalec, Department of Chemical Engineering, McMaster University, *Ajay Lakshmanan*, *Granville Paules*

During the last decade there have been several efforts to design and implement generalized architecture for process optimization. At Aspen Technology, since late 1990s there has been a continuing development of an Open Object Model Framework (OOMF) to optimize models used in process design, plant operation and supply chain optimization. OOMF is a core component of design, simulation, and real time optimization solutions for the chemicals, petrochemicals, and refining industries. It serves as a crucial part of production planning, economic optimization and multi-blend optimization solutions for refineries. Furthermore, it facilitates data reconciliation and yield accounting solutions for process plants as well as comprehensive modeling and synthesis solutions. This paper describes the architecture of OOMF and its applications to large scale modeling, process design, production planning, and real-time optimization of plant operation.

■ TB5

Tuesday, 10:30-12:00, MDCL 1016

Derivative-free Approaches to Global Optimization

Stream: Derivative Free Optimization

Chair: *Don Jones*, General Motors

1. **Parallel Global Optimization Using Radial Basis Functions**

Christine Shoemaker, Civil Engr. & Oper. Research, Cornell University, *Rommel Regis*, *Pradeep Mugunthan*

We parallelize a stochastic radial basis function (RBF) method for global optimization building on the serial algorithm by Regis and Shoemaker (INFORMS JOC, 2007). We compare its performance against alternative parallel global optimization methods, including a multistart parallel quasi-Newton method, a multistart implementation of asynchronous parallel pattern search (APPS), a parallel evolutionary algorithm, and another parallel RBF method. We report good results for the parallel stochastic RBF method in comparison with the alternatives on test problems as well as on a computationally expensive parameter estimation problem for a groundwater bioremediation model of chlorinated ethenes.

2. **Techniques for combining global search with generating set search**

Joshua Griffin, Sandia National Laboratories, *Tamara Kolda*

This talk explores combining surrogate-based global optimization with generating set search (GSS) in a distributed computing environment. This permits function evaluations for both the local and global searches to run simultaneously. Our target is optimization problems where function evaluations are based on large-scale, “black box” simulations. A lack of smoothness necessitates the use of derivative-free methods. Because the underlying simulations are computationally expensive, the number of evaluations that can be performed is limited. Consequently, we seek a global optimum (or at least a good estimate) using a small number of evaluations. By combining algorithms, we can effectively share information (i.e., function evaluations) for both building surrogate models and targeting the local search. To increase efficiency we perform function evaluations asynchronously in parallel. To demonstrate effectiveness, we provide numerical results for real world problems.

3. **Adaptive Radial Basis Algorithms (ARBF) for Expensive Black-Box Mixed-Integer Constrained Global Optimization**

Nils-Hassan Quttineh, Department of Mathematics and Physics, Mälardalen University, *Kenneth Holmström*, *Marcus Edvall*

Response surface methods based on kriging and radial basis function (RBF) interpolation have been successfully applied to solve expensive, i.e. computationally costly, global black-box nonconvex optimization problems. We describe extensions of these methods to handle linear, nonlinear and integer constraints. In particular standard RBF and new adaptive RBF (ARBF) algorithms are discussed. Test results are presented on standard test problems, both nonconvex problems with linear and nonlinear constraints, and mixed-integer nonlinear problems. Solvers in the TOMLAB Optimization Environment (http://tomopt.com/tomlab/) are compared; the three deterministic derivative-free solvers rbfSolve, ARBFMIP and EGO with three derivative-based mixed-integer nonlinear solvers, OQNLP, MINLPBB and MISQP as well as GENO implementing a stochastic genetic algorithm. Assuming that the objective function is costly to evaluate the performance of the ARBF algorithm proves to be superior.

■ TB6

Tuesday, 10:30-12:00, MDCL 1309

Optimization in Communications and Signal Processing

Stream: Signal Processing and ECE

Chair: *Wei Yu*, Electrical and Computer Engineering, University of Toronto

1. **Decomposition-based Protocol Design: A Multitude of Possibilities Exposed**

Mikael Johansson, Department of Signals, Systems and Sensors, Royal Institute of Technology (KTH), Stockholm, Sweden, *Björn Johansson*

Recently, there has been a large interest in using mathematical decomposition techniques as a structured means of engineering distributed mechanisms and protocols for solving decision problems in networked systems. In this talk, we will consider a particular class of optimization problems that are useful for estimation applications in sensor networks, and we review how the problem can be solved by various decomposition techniques resulting in different node behavior and requirements on the underlying communication network. Special attention is given to a novel algorithm that extends an existing randomized incremental subgradient method. Using this algorithm, the nodes in the network maintain individual estimates of the optimal point, and they need to exchange information with only their neighbors. We establish convergence properties of the algorithm and illustrate the performance with some examples.

2. **Optimization of Linear Cooperation for Spectrum Sensing in Cognitive Radio Networks**

Shuguang Cui, Texas A&M University

Cognitive radio (CR) technology has been recently proposed to improve spectrum efficiency by having the CRs opportunistically access underutilized frequency bands, where the CRs act as secondary users. Spectrum sensing, as a key enabling functionality in cognitive radio networks, needs to reliably detect signals from licensed Primary Radios (PRs) to prevent interfering transmissions. However, due to the effects of channel fading/shadowing, individual CRs may not be able to reliably detect the existence of a PR. In this work, spectrum sensing is based on the linear combination of local test statistics from multiple individual CRs. Our objective is to maximize the probability of detection satisfying the requirement on the probability of false alarm. We first derive bounds on the probability of detection, and then develop efficient optimization algorithms to find the optimal combining weights, where a non-convex problem is approximately solved by computing a sequence of convex problems.

3. **Complexity-Performance Optimization for Iterative Decoding Systems**

Wei Yu, Electrical and Computer Engineering, University of Toronto, *Ben Smith*, *Masoud Ardakani*, *Frank Kschischang*

The optimal complexity-rate tradeoff for error correcting codes at rates strictly below the Shannon limit is a central question in coding theory. This paper proposes a numerical approach for the joint optimization of rate and decoding complexity for low-density parity-check (LDPC) codes under iterative decoding. A key feature of the proposed optimization method is a new complexity measure that incorporates both the number of operations required to carry out a single decoding iteration and the number of iterations required for convergence. Under certain mild conditions, the complexity measure is shown to be a convex function of the variable edge-degree distribution of the code, allowing an efficient design of complexity-optimized LDPC codes using convex optimization methods. The results presented herein show that when the decoding complexity is constrained, the complexity-optimized codes significantly outperform threshold optimized codes at long block lengths.

■ TB7

Tuesday, 10:30-12:00, MDCL 1009

Nonsmooth Optimization Algorithms and Applications

Stream: Nonsmooth Optimization

Chair: *Robert Mifflin*, Department of Mathematics, Washington State University

1. **Dual convergence of purely primal penalty proximal algorithms for convex programming**

Felipe Alvarez, Mathematical Engineering Department, Universidad de Chile

Consider a generic convex program. Assume neither primal nor dual uniqueness conditions, in particular no strong second order hypothesis. In such a general setting, it is possible to ensure the primal global convergence of several classes of proximal algorithms with hybrid steps (projection, extra-gradient,...) and different error criteria, even when they are combined with one-parameter approximating techniques. These include penalty/barrier methods, for which we identify multiplier sequences depending explicitly on the primal iterates, and we find conditions for their convergence towards a dual optimal solution.

2. **Bridge Regression for Variable Selection**

   James Burke, Math, University of Washington, *Qiuying Lin*

There are a number of linear regression methods where the magnitude of the coefficients is restricted. Ridge regression uses the 2-norm and the lasso uses the 1-norm to restrict the magnitude. An advantage of the lasso is that it reduces the number of nonzero coefficients, and so, subject to suitable data normalization, it can be used as a method for variable selection. If one now considers an l_p "norm" with p between zero and one, then even more coefficients are forced to the value zero enhancing the variable selection properties of the method. This is called bridge regression. Unfortunately, the resulting optimization problem is non-Lipschitzian. In this talk we describe properties of bridge regression as well as methods for solving the underlying optimization problem.

3. **Globalizing a nonsmooth Newton method via path search**

   Stephan Bütikofer, University of Zürich, IOR

We give a framework for the globalization of a nonsmooth Newton method for solving Lipschitz equations introduced by B. Kummer. We start with recalling Kummer's approach to convergence analysis of this method and state his results for local convergence. In a second part we give a globalized version of this method. In our approach we use first a monotone path search idea to control the descent. After elaborating the single steps, we analyze and discuss the proof of global convergence resp. of local superlinear or quadratic convergence of the algorithm. We sketch also a nonmonotone version of the algorithm. In the last part we discuss and illustrate the details of the general algorithm (e.g the computation of a path) for some interesting examples and present results from numerical tests.

■ TB8

Tuesday, 10:30-12:00, MDCL 1010

Pipeline Optimization

Stream: Engineering Optimization

Chair: *Richard Carter*, Advantica Inc.

1. **Mathematical Properties of Compressor Control In Pipeline Networks**

   Michael Herty, TU Kaiserslautern

We are interested in optimization issues arising in the context of gas flow in pipeline networks. We assume the dynamics of the gas is goverened by the isothermal Euler equations being a nonlinear system of hyperbolic partial differential equations. In networks compressor stations are introduced to reduce the pressure loss due to wall friction Mathematically compressor stations are introduced as boundary conditions to these equations. We analyse the well-posedness of the combined model and discuss the optimization of this system. We present analytical as well as numerical results.

2. **Flow models in pipeline transportation networks for natural gas**

   Lennart Frimannslund, Department of Informatics, University of Bergen, *Trond Steihaug*, *Dag Haugland*, *Mohamed El Ghami*

In this talk we will present activities in the project "Regularity and uncertainty Analysis and Management for the NOrwegian gas processing and traNsportAtion system" (RAMONA). Realistic modeling of pipeline gas flow implies extensions of traditional network flow models, and the goal of the project is to develop efficient computational algorithms for such models. The extensions in question include hard side constraints arising from quality requirements at the reception side and mixing of flow streams at junction points. Moreover, the flow capacities in a gas transportation network depend on gas pressures, which in their turn depend on upstream flow. In the talk we will discuss some of the computational challenges introduced by such relations, and outline our current directions of research and preliminary results. This is a joint effort between three universities and two companies.

3. **A Short Term Operational Planning Model for Natural Gas Production Networks**

   Paul Barton, Chemical Engineering, Massachusetts Institute of Technology, *Ajay Selot*

To be useful in practice, short-term operational planning models for natural gas production networks must incorporate nonlinear pressure-flowrate relationships in wells and pipelines, multiple gas qualities, customer requirements and operational constraints. Additional model complexity arises from production sharing contracts that govern product redistribution between different parties having stakes in the system. We present a nonconvex mixed-integer nonlinear modeling framework comprising infrastructure and contractual components to represent such systems realistically and apply it to a real-world scenario from the Sarawak Gas Production System in East Malaysia. Branch-and-bound with customized heuristics that exploit problem structure is applied to solve several model instances to global optimality. Special strategies for efficient solution of large instances of the model with hierarchical multiple objectives are also presented.

■ TB9

Tuesday, 10:30-12:00, MDCL 1008

Combinatorial Optimization and Computational Complexity

Stream: Global Optimization

Chair: *Punita Saxena*, Department of Mathematics, S.R.C.A.S.W (University of Delhi)

1. **Enumeration Technique for Set Covering, Partitioning and Packing Problems with Non-Linear Objective Function: A Combinatorial Approach**

   Ratnesh Rajan Saxena, Department of Mathematics, D.D.U.College (University of Delhi)

Set Covering, Set Partitioning and Set Packing problems belong to the class of 0-1 integer programming problems that are NP-complete. Many applications arise having the packing, partitioning and covering structure. Delivery and routing problems, scheduling problems and location problems, switching theory, testing of VLSI circuits and line balancing often take on a set covering structure. However, if one wishes to satisfy as much demand as possible without creating conflict, it takes on a set packing format. Finally, if every customer must be served by exactly one server, the problem takes on a set partitioning format. In this paper an enumerative technique using Combinatorics is developed to solve these problems with non-linear objective function. Most of the existing procedures such as cutting plane technique or branch and bound technique for solving these problems have their basis in simplex algorithm. The well known Breadth First Search (BFS) and Depth First Search (DFS) techniques of graph theory form the basis of the proposed algorithm. The enumeration procedure developed in the proposed algorithm is a modification of these techniques. The algorithms developed in this paper are supported by numerical examples.

2. **An algorithm to generate graphs with a given Grundy number**

   Tissaoui Anis, Laboratoire PRISMa

A k-colouring of a graph is an assignment of the colours $1,\dots,k$ to the vertices of a graph such that neighbouring vertices have different colour. A Grundy k-colouring is a k-colouring with the following property: every vertex with colour i is adjacent to at least $i-1$ vertices with colour $j \in 1,\dots,i-1$. The Grundy number of a graph is the maximum number of colours such that Grundy colouring exists. We present an algorithm to generate graphs with a given Grundy number having a minimum number of edges.

3. **Efficiency Assessment of Public Transport Undertakings of India using Data Envelopment Analysis**

   Punita Saxena, Department of Mathematics, S.R.C.A.S.W (University of Delhi)

This paper focuses on the performance of Public Transport Undertakings of metropolitan cities of India. The relative performance of these units is measured for three block years using the non-parametric technique of Data Envelopment Analysis. Public Transport is an important part of the overall development of a nation. The State Transport Undertakings constitute a major segment in the public transport system of India wherein, 70% of the intercity bus services are provided by the private operators and the remaining 30% by the State Road Transport Corporations. In the present study, a comparison has been made between the private operators and the government operators from a production efficiency perspective. The paper highlights certain important issues such as efficiency rankings, potential improvements for inefficient units. Although DEA is strong in identifying the inefficient units, it is weak in discriminating among the efficient units. In order to enhance the discriminatory power of DEA, cross efficiencies and modified DEA scores are also used so as to have a ranking amongst the DEA efficient units. Coefficient of concordance has been used to study the independence of the ranking of the units. The implications of DEA results are discussed in the concluding remarks.

■ TS1

Tuesday, 1:30-2:30, MDCL 1305

Semi-plenary presentation

Stream: Nonlinear Optimization Software
Chair: *Tom Marlin*, McMaster University

1. **An introduction to an algorithmic framework for mixed integer nonlinear programs**

   Andy Conn, IBM Watson Research Center, *Pierre Bonami, Lorenz T. Biegler, Andreas Wächter, Gérard Cornuéjols, Ignacio E. Grossmann, Carl D. Laird, Jon Lee, Andrea Lodi, François Margot, Nicolas Sawaya*

Mixed integer nonlinear programming is an area of ever increasing importance and applications that is significantly under researched — no doubt because it presents many difficult challenges. I will present a basic hybrid framework for mixed-integer nonlinear programming. In one extreme case, the method becomes the branch-and-bound approach, where a nonlinear optimization problem is solved in each node of the enumeration tree, and in the other extreme it reduces to the polyhedral outer approximation algorithm, which alternates between the solution of a nonlinear optimization problem and a mixed-integer linear program. Numerical results are presented, using an open source software implementation available on `http://www.coin-or.org`. This work results from an on-going research collaboration between IBM and CMU.

■ TS2

Tuesday, 1:30-2:30, MDCL 1307

Semi-plenary presentation

Stream: Linear, Semidefinite and Conic Optimization
Chair: *Takashi Tsuchiya*, The Institute of Statistical Mathematics

1. **Optimization with polynomials**

   Pablo Parrilo, MIT

Optimization problems involving multivariate polynomials are ubiquitous in many areas of engineering and applied mathematics. Although these problems can sometimes (but not always) be approached using the traditional ideas of nonlinear optimization, in recent years there has been much interest in new techniques, that exploit their intrinsic algebraic features, to provide global solutions and/or more efficient algorithms. In this talk we survey the basic features of these algebraic approaches, involving sum of squares (SOS) and semidefinite programming, emphasizing the geometric aspects and a few selected applications in dynamical systems and game theory.

■ TS3

Tuesday, 1:30-2:30, MDCL 1105

Semi-plenary presentation

Stream: Stochastic Programming
Chair: *Rick Caron*, University of Windsor

1. **Stochastic optimization in electricity pool markets**

   Andrew Philpott, The University of Auckland

Over the past decade, markets for electric power have emerged in many countries. The details of the market mechanisms differ from place to place, but most of them depend on some centralised dispatch pool which sets a price for electricity. Supply and demand decisions are made in advance of this price being set (and affect it) so they are subject to uncertainty (e.g. from fluctuating wind generation or a lack of knowledge about the decisions of other market participants). To accommodate this uncertainty, electricity generators offer supply functions rather than fixed generation quantities. Choosing an optimal supply function is then an infinite-dimensional stochastic optimization problem. In my talk I will show how this problem can be attacked using variational techniques that are based on a "market distribution" function. The methodology will be illustrated by showing some examples of optimization models based on these ideas that are being used in the New Zealand electricity market.

■ TC1

Tuesday, 2:45-4:15, MDCL 1305

Young Researcher Competition

Stream: Convex Optimization Methods
Chair: *Kees Roos*, Delft University of Technology

1. **Norm-induced Densities and Testing the Boundedness of a Convex Set**

   Alexandre Belloni, Duke University

In this paper we explore properties of a family of probability density functions, called norm-induced densities, defined as

$$f_t(x) = \begin{cases} \dfrac{e^{-t\|x\|^p}\,dx}{\int_K e^{-t\|y\|^p}\,dy}, & x \in K \\ 0, & x \notin K, \end{cases}$$

where K is a n-dimensional convex set that contains the origin, parameters $t > 0$ and $p > 0$, and $\|\cdot\|$ is any norm. We also develop connections between these densities and geometric properties of K such as diameter, width of the recession cone, and others. Since f_t is log-concave only if $p \geq 1$, this framework also covers non-logconcave densities. Moreover, we establish a new set inclusion characterization for convex sets. This leads to a new concentration of measure phenomena for unbounded convex sets. Finally, these properties are used to develop an efficient probabilistic algorithm to test whether a convex set, represented only by membership oracles (a membership oracle for K and a membership oracle for its recession cone), is bounded or not, where the algorithm reports an associated certificate of boundedness or unboundedness.

2. **Geometric Programming for Communication Systems**

   Mung Chiang, Princeton University

This paper is a comprehensive treatment on the surprisingly widespread and powerful applications of Geometric Programming (GP) to communication systems. The results include: (1) establishing through GP a sharp characterization of Shannon's duality between information transmission and compression, (2) computing error exponent, the rate according to which decoding errors decay in digital communication systems, by GP, (3) solving a wide range of network resource allocation problems, from power control to buffer allocation, within one unifying framework of GP, (4) showing that achieving proportional fairness in today's network flow control protocol is implicitly solving a GP, (5) developing message-passing algorithms to solve GP in a distributed way in wireless networks. We also discuss "why", in addition to "how", GP can be applied to this wide range of problems in communication systems, through connections such as large deviation theory.

3. **How Good Are Interior Point Methods? Klee-Minty Cubes Tighten Iteration-complexity Bounds**

   Eissa Nematollahi, McMaster University, Department of Mathematics

By refining a variant of the Klee-Minty example that forces the central path to visit all the vertices of the Klee-Minty n-cube, we exhibit a nearly worst-case example for path-following interior point methods. Namely, while the theoretical iteration-complexity upper bound is $O(2^n n^{2.5})$, we prove that solving this n-dimensional linear optimization problem requires at least $2^n - 1$ iterations.

■ TC2

Tuesday, 2:45-4:15, MDCL 1307

Monotone Operators

Stream: Convex and Nonsmooth Analysis
Chair: *Shawn Wang*, Department of Mathematics, UBC Okanagan

1. **Boundary half-strips and the strong CHIP**

   Michel Thera, University of Limoges and XLIM, *E. Ernst*

The talk concerns an application of a geometrical notion called the strong conical hull intersection property - strong CHIP for short - introduced by Deutsch, Li & Swetits. The existence of conditions ensuring that a pair of closed and convex sets has the strong CHIP is based on a classical result by Moreau which states that a pair (C, D) of closed and convex subsets of some locally convex space X has the strong CHIP provided that the inf-convolution of their support functionals is exact. A first partial converse of Moreau's result has recently been proved by Bauschke, Borwein & Li for Hilbert spaces; the result was extended to Banach spaces by Burachik & Jeyakumar. In this presentation we characterize all the closed and convex subsets C of an Euclidean space X s.t., if for some closed and convex set D, the pair (C, D) has the strong CHIP, then the inf-convolution of their support functionals is exact.

2. **A general primal-dual symmetric average**

   Shawn Wang, Department of Mathematics, UBC Okanagan

We provide a general primal-dual symmetric average for two convex functions. It covers many known averages like: arithmetic average, epi-graphical average, and infimal convolution. When applied to the Fitzpatrick function and the conjugate of Fitzpatrick function associated to a monotone operator, our average produces an auto-conjugate (or self-dual Lagrangian) which can be used for explicitly finding the maximal monotone extension of the given monotone operator, which completely solves one of the open questions posed by Fitzpatrick.

■ TC3

Tuesday, 2:45-4:15, MDCL 1105

Semidefinite Relaxation and Non-Convex Quadratic Optimization

Stream: Convex Optimization Methods

Chair: *Amir Beck*, Technion - Israel Institute of Technology

1. **Strong Lagrangian Duality for Nonconvex Quadratic Program: Necessary and Sufficient Condition**

   Shuzhong Zhang, Chinese University of Hong Kong, *Wenbao Ai*

In this talk we present a necessary and sufficient condition for the strong Lagrangian duality relation to hold in nonconvex quadratic programming with two quadratic constraints. Whenever the strong duality holds, the problem can be solved by SDP relaxation followed by a matrix rank-one decomposition scheme. Such nonconvex quadratic programs appear in many applications, including in the solution of the so-called CDT subproblem of the trust-region method for nonlinear optimization.

2. **The relaxed Chebyshev center for bounded error estimation**

   Yonina Eldar, Electrical Engineering, Technion, *Amir Beck*, *Marc Teboulle*

We develop a nonlinear minimax estimator for estimating a vector z in the linear regression model $b = Az + w$ where w is an unknown but bounded noise. We assume that the true vector z lies in an intersection of ellipsoids. To estimate z, we minimize the worst-case estimation error over the given parameter set, which is equivalent to finding the Chebyshev center of the set. Unfortunately, this problem is an intractable non-quadratic optimization problem. Therefore, we approximate it using semidefinite relaxation, and refer to the resulting estimate as the relaxed Chebyshev center (RCC). In the case of two quadratic constraints over the complex domain we show that our relaxation is tight. For an arbitrary number of ellipsoids, we prove that the RCC is unique and feasible. We then show that the constrained least-squares (CLS) estimate for this problem can also be obtained as a relaxation of the Chebyshev center, that is looser than the RCC.

3. **Quadratic Matrix Programming**

   Amir Beck, Technion - Israel Institute of Technology

We introduce and study a special class of nonconvex quadratic problems in which the objective and constraint functions have matrix variables of order $n \times r$. The latter class of problems is termed "quadratic matrix programming" (QMP) of order r. We construct a specially devised semidefinite relaxation (SDR) and dual for the QMP problem and show that under some mild conditions strong duality holds for QMP problems with at most r constraints. Using a result on the equivalence of two characterizations of the nonnegativity property of quadratic functions of the above form, we are able to compare the constructed SDR and dual problems to other known SDR and dual formulations of the problem. We present applications to robust optimization, solution of linear systems immune to implementation errors and to the problem of computing the Chebyshev center of an intersection of balls.

■ TC4

Tuesday, 2:45-4:15, MDCL 1110

Advances in Interior Point Methods and Conic Feasibility Problems

Stream: Conic Programming and Interior Point Methods

Chair: *Luke Winternitz*, University of Maryland / NASA

Session organizer: Coralia Cartis

1. **Solving convex problems involving powers with a conic interior-point algorithm**

   Robert Chares, CORE, Universite catholique de Louvain, Belgium

Numerous convex optimization problems involving powers can be modelled with a unified conic formulation, using only a single family of cones defined as $K_\alpha = \{(x, y, z) \in R_+ \times R_+ \times R \mid x^\alpha y^{1-\alpha} \geq |z|\}$ where $0 \leq \alpha \leq 1$ is a real parameter (see the talk "A unified conic formulation for convex problems involving powers" in session TA1). This talk will discuss interior-point algorithms to solve these problems. These methods rely on a barrier known to be self-concordant for the cones K_α with a low complexity parameter. Both primal-only and primal-dual path-following algorithms will be introduced. In the primal-dual case, although the cones K_α are not symmetric, a method based on explicit primal and dual barrier functions that are conjugate to each other will be presented. These algorithms have been implemented in a MATLAB solver; preliminary computational results on some problem classes will be reported.

2. **Computational Experience with a First-order Algorithm for Computing Nash Equilibria in Sequential Games**

   Samid Hoda, Tepper, CMU, *Javier Pena*, *Andrew Gilpin*, *Tuomas Sandholm*

The Nash equilibrium problem for zero-sum two-player sequential games can be formulated as a linear program. However, even for small sequential games, it is impractical to apply traditional linear programming algorithms. We present a first-order method, based on Nesterov's excessive gap technique, for computing Nash equilibria for this family of games. The algorithm directly solves the saddle-point formulation of the problem and is able to leverage the structure of the game. This approach has proved to be quite successful and we discuss some of our computational experience with the method.

3. **Convergence of a constraint-reduced variant of Mehrotra's Predictor Corrector Algorithm**

   Luke Winternitz, University of Maryland / NASA, *Stacey Nicholls*, *André Tits*, *Dianne O'Leary*

Consider linear programs with many more (dual) inequality constraints than variables (i.e., with $n >> m$, where A is $m \times n$). When interior-point algorithms are used for the solution of such problems, forming the normal matrix may be exceedingly expensive, with CPU time proportional to n, whereas most constraints are inactive at the solution. Constraint reduction approaches for efficiently solving such problems have been considered by Dantzig, Ye et al., Tone, den Hertog et al., and more recently Tits et al. [TAW, SIOPT 2006]. In [TAW], a simple constraint reduction scheme was proposed, and global and local quadratic convergence were proved for an affine-scaling primal-dual method modified according to that scheme. In the present work, similar convergence results are proved for a constraint-reduced variant of Mehrotra's predictor-corrector algorithm. Various heuristics within the [TAW] scheme are considered. Numerical results on a variety of test problems show promise.

■ TC5

Tuesday, 2:45-4:15, MDCL 1016

Financial Optimization

Stream: Financial Optimization

Chair: *Zhaosong Lu*, Department of Mathematics, Simon Fraser University

1. **Pricing A Class of Multiasset Options using Information on Smaller Subsets of Assets**

   Karthik Natarajan, Department of Mathematics, National University of Singapore

We study the pricing problem for the class of multiasset European options with piecewise linear convex payoff in the asset prices. We derive a simple upper bound on the price of this option by constructing a static super-replicating portfolio using cash and options on smaller subsets of assets. The best upper bound is found by determining the optimal set of strike prices that minimizes the cost of this super-replicating portfolio. Under the no-arbitrage assumption, this bound is shown to be tight when the joint risk-neutral distributions for the smaller subsets of assets are known but the complete risk-neutral distribution is unknown. Using a simulation-based optimization approach, we obtain new price bounds for several options.

2. **A New Cone Programming Approach for Robust Portfolio Selection**

   Zhaosong Lu, Department of Mathematics, Simon Fraser University

We consider a factor model for the random asset returns. For this model, we introduce a "joint" ellipsoidal uncertainty set for the model parameters and show that it can be constructed as a confidence region associated with a statistical procedure applied to estimate the model parameters. We further show that the robust maximum risk-adjusted return problem with this uncertainty set can be reformulated and solved as a cone programming problem. Some computational experiments are performed to compare the performances of the robust portfolios corresponding to our uncertainty set and Goldfarb and Iyengar's "separable" uncertainty set. We observe that our robust portfolio has much better performance than Goldfarb and Iyengar's in terms of wealth growth, diversification and transaction costs.

■ TC6

Tuesday, 2:45-4:15, MDCL 1309

Numerical Methods for Complementarity Problems and MPECs

Stream: MPECs/Complementarity Problems

Chair: *Michael Ulbrich*, TU Munich

1. **A new regularization method for MPECs**

Sonja Veelken, TU Muenchen, *Michael Ulbrich*

We present a new regularization method for MPECs, where the complementarity constraints are replaced by a reformulation that is exact for sufficiently non-degenerate compementarity conditions and relaxes only the remaining conditions. A positive parameter determines to what extend the complementarity conditions are relaxed. The regularization is such that a strongly stationary solution of the MPEC is also a solution of the regularized problem if the regularization parameter is chosen sufficiently small. We consider the properties of the resulting parametrized nonlinear programs, compare stationary points and solutions, and present convergence results.

2. **Iterative Methods for Variational Inequalities in Nonsmooth Dynamics**

Mihai Anitescu, Mathematics and Computer Science Division, Argonne National Laboratory, *Alessandro Tassora*

We present a class of iterative methods to solve the sub problems that appear in the simulation of nonsmooth rigid body dynamics with contact and friction. The sub problems are optimization problems that are solved in their dual variational inequality form with a Gauss Seidel like iteration. We prove that the method is globally convergent. Through numerical experiments, we demonstrate that the method scales linearly with with an increasing size of the problem and show that it is very competitive for the simulation of granular flow dynamics.

3. **A New Filter Method for MPECs**

Sven Leyffer, Argonne National Laboratory, *Todd Munson*

Recently, it has been shown that standard NLP solvers often converge to strongly-stationary solutions of MPECs under certain assumption. However, these solvers still get trapped at spurious stationary points, such as so-called C- or M-stationary points. To date, no method has been shown converge to B-stationary points under reasonable assumptions. This talk presents the first MPEC algorithm that converges globally to B-stationary points. At each iteration, we solve an LPEC to estimate the active set, and then solve an equality constrained QP to accelerate convergence. Global convergence is promoted through the use of a filter and a trust-region. Time permitting, we will present some preliminary numerical results.

■ TC7

Tuesday, 2:45-4:15, MDCL 1009

Modelling Languages for Conic Optimization

Stream: Modelling Languages

Chair: *Imre Pólik*, McMaster University, Department of Mathematics

1. **An overview of conic optimization software**

Imre Pólik, McMaster University, Department of Mathematics

We present the state-of-the-art in conic (semidefinite and second order) optimization. Our main focus is the functionality and usability of the solvers. Algorithmic details will be kept to a minimum. The goal of this talk is to prepare the audience for the following two talks about modelling languages.

2. **CVX: Software for disciplined convex programming**

Michael C. Grant, Stanford University, *Stephen Boyd*

In this talk we present CVX, a software framework in MATLAB for specifying and solving disciplined convex programs. Constraints and objectives are specified in natural MATLAB syntax, and for compliant models the verification of convexity and conversion to solvable form is performed automatically. We will demonstrate the software and discuss its more novel features, such as its conversion of geometric programs to semidefinite programs.

3. **Uncertainty modelling and robust optimization in YALMIP**

Johan Löfberg, Linköping University

Conic optimization has had a tremendous impact on many fields. In many applications in the control and systems theory field, conic programming has been used as a tool to solve robustness problems, i.e. problems where data in the optimization model is uncertain. A typical case is dynamic systems with uncertain parameters. In order to solve the uncertain problem, a reformulation of the uncertain problem to a standard certain problem is typically required. In many cases, this is actually the main portion of the whole work. In this talk, we will present recent features in the MATLAB based modelling language YALMIP that takes care of the whole reformulation step. The user can model uncertainties in an intuitive way and thus concentrate on the actual application. The software tool will automatically select a suitable reformulation procedure, and solve the problem that is derived. Optimal control examples will be used to illustrate the strength and generality of the framework.

■ TC8

Tuesday, 2:45-4:15, MDCL 1010

Optimization in Acoustics

Stream: Engineering Optimization

Chair: *Rick Morgans*, School of Mechanical Engineering

1. **Design of Aircraft Noise Treatment Package Using a Surrogate-Model-Based Optimization Method**

Guillaume Cousineau-Bouffard, Boeing, *Evan B. Davis*, *Evin J. Cramer*, *Martin Meckesheimer*

Design Explorer (D.E.) is a tool developed by the Boeing Math Group to provide surrogate-model-based optimization capabilities for numerical modeling applications. In the example presented, D.E. is linked to VA-One, a commercial Statistical Energy Analysis (SEA) code. The tandem is used to better understand, design and optimize an aircraft's noise control treatment package. The package is defined using a large number of design variables such as noise blanket thicknesses and acoustic material properties. The Design and Analysis of Computer Experiment (DACE) functionalities of D.E. are used to setup an effective Design of Experiments. The analysis illustrates the effectiveness of the surrogate-model-based optimization method at maintaining a balance of effort between global space exploration and local optimization and demonstrating the ability of the overall sequential method at achieving global optimization while minimizing the size of the study.

2. **Case studies in vibroacoustic optimization**

Rick Morgans, School of Mechanical Engineering, The University of Adelaide

This presentation describes recent work in the optimization of very complex or computationally expensive systems such as those found in many engineering acoustics applications. It uses optimization techniques that require no knowledge of the derivative of the objective function, a parallel genetic algorithm and a surrogate optimization technique called Enhanced Global Optimization (EGO). It then describes two example cases, the optimization of the position and design parameters of vibroacoustic absorbers mounted on the interior of a rocket payload bay to reduce the payload pressure fluctuations on launch, and the shape optimization of an audio loudspeaker to improve sound quality.

■ TC9

Tuesday, 2:45-4:15, MDCL 1008

Nonlinear Programming Software

Stream: Nonlinear Optimization Software

Chair: *Pietro Belotti*, Carnegie Mellon University

1. **ASTRAL: An Active-Set Trust-Region Algorithm for Box Constrained Optimization**

Liang Xu, Dept. of Mathematics, University of Washington, *James Burke*

An algorithm for solving large nonlinear optimization problems with simple bounds is described. The algorithm is in the framework of a Quasi-Newton active-set trust-region method. The local active set is identified using projected gradients. Limited memory curvature estimate is used and exploited in solving the trust-region sub-problems. A restart strategy ensures that the algorithm indentifies the optimal constraints in finite number iterations. Local and global convergence properties are established.

2. **Fast NLP Feasibility via Constraint Consensus Methods**

John Chinneck, Systems and Computer Engineering, Carleton University

Constraint Consensus methods are simple and quick heuristics which rapidly achieve near-feasibility for a set of nonlinear constraints given an initial point that may be very far from feasibility. Constraint Consensus heuristics are used as initial point improvement heuristics that greatly increase the ability of a solver to find a feasible solution for a set of nonlinear constraints. They are also used in more advanced multistart heuristics as a way of quickly and cheaply exploring the variable space before launching an expensive full-scale solver. Empirical results are presented.

3. **An Open Source Software for non-convex MINLP**

Pietro Belotti, Carnegie Mellon University, *Francois Margot*, *Ignacio Grossman*, *Larry Biegler*, *Pierre Bonami*, *Jon Lee*, *László Ladányi*, *Andreas Wächter*

We describe a spatial Branch-and-bound algorithm based on a Reformulation-Linearization technique to solve non-convex Mixed-Integer Nonlinear Programming problems. The algorithm has been implemented within the Coin-OR software framework. We discuss the peculiarities of the algorithm: the linearization procedure, a heuristic to find feasible solution, a bound tightening procedure, and branching rules that allow to limit the size of the decision tree. Some experimental results are reported on instances from publicly available MINLP libraries.

■ TD1

Tuesday, 4:45-6:15, MDCL 1305

Interior-point Methods/Implementations

Stream: Interior Point Methods and Implementations

Chair: *Erling Andersen*, MOSEK

1. **On the nested dissection algorithm in interior point methods**

   Csaba Mészáros, MTA SZTAKI

The major computational task of interior point implementation is solving systems of equations with symmetric coefficient matrix by direct factorization methods, therefore, the performance of Cholesky-like factorizations in the implementations is a critical issue. In case of sparse and large problems the efficiency of the factorizations is closely related to the exploitation of the nonzero structure of the problem. A number of techniques were developed for fill-reducing sparse matrix orderings which make Cholesky factorizations more efficient by reducing the necessary floating point computations. We present a variant of the nested dissection algorithm incorporating special techniques that are beneficial for graph partitioning problems arising in the ordering step of interior point implementations. We illustrate the behavior of our algorithm and provide numerical results and comparisons with other graph partitioning packages.

2. **An interior-point approach for convex routing problems in data telecommunication networks**

   Jordi Castro, Statistics and OR Dept., Technical University of Catalonia, Barcelona, *Adam Ouorou*

The routing of data in packet-switched networks plays an important role in the optimization of network performance. This problem is formulated as a (likely very large) convex multicommodity flow problem, each commodity related to the demand from some origin to some destination node. Like most previous approaches, we consider the Kleinrock average delay objective function, augmented with a quadratic reliability term by Stern. This results in a separable nonlinear convex multicommodity problem, which is solved through a specialized interior-point method. This method combines direct and preconditioned iterative solvers for the solution of normal equations. The reliability term is shown to be instrumental for the quality of the preconditioner. If such a term is removed, it is even possible to efficiently solve the resulting problem through a regularized version of the algorithm. The computational results with a set of real and artificial instances show the efficiency of the approach.

3. **Iterative Methods for Large-Scale Unconstrained Optimization**

   Jennifer Erway, Wake Forest University, *Philip Gill*, *Josh Griffin*

Recent advances in large-scale constrained optimization have revived interest in methods based on sequential unconstrained optimization. We consider an interative unconstrained optimization method based on finding an approximate solution of a quadratically constrained trust-region subproblem at each iteration. The trust-region solver is based on the method of sequential subspace minimization, which involves solving the subproblem over a sequence of evolving low dimensional subspaces. Two alternative methods based on the preconditioned conjugate-gradient method are proposed for generating the subspace basis that allow the solution of the subproblem to be found to any prescribed accuracy. Numerical results will be presented.

■ TD2

Tuesday, 4:45-6:15, MDCL 1307

Nonsmooth Matrix Analysis

Stream: Convex and Nonsmooth Analysis

Chair: *Hristo Sendov*, Department of Statistical and Actuarial Sciences, The University of Western Ontario

1. **Mean value inequalities for convex sets**

   Pal Fischer, Math and Stats, U. of Guelph, *Zbigniew Slodkowski*

Let A and B be bounded subsets of R^n of positive Lebesgue measure. We are saying that A is convexly majorized by B if the integral mean of any continuous convex function over B exceeds its mean over A. Several results will be presented about this relation, including the following. Let A and B be symmetric, convex and compact neighbourhoods of 0 in R^n, $n > 1$, and such that A is a subset of B. Then there is a universal positive constant $k(n)$, which depends only on the dimension n, and such that, if A is a subset of $k(n)B$, then A is convexly majorized by B.

2. **Smoothing techniques for Nash equilibria computation of sequential games**

   Javier Pena, Carnegie Mellon University

The Nash equilibrium problem for a two-person, zero-sum sequential game can be formulated as a saddle-point problem over a pair of polytopes that encode the sequential nature of the game. We show that modern smoothing techniques can be successfully applied to this problem. The heart of our approach is a general scheme that constructs prox-functions for the polytopes in the saddle-point formulation.

3. **On the Tuncel conjecture: A new class of self-concordant barriers on sets of symmetric matrices**

   Hristo Sendov, Department of Statistical and Actuarial Sciences, The University of Western Ontario, *Javier Pena*

Given a separable strongly self-concordant function $f : R^n \to R$, we show the associated spectral function $F(X) = (f o L)(X)$ is also strongly self-concordant function, where $L(X)$ is the vector of eigenvalues of the symmetric matrix X. In addition, there is a universal constant O such that, if $f(x)$ is separable self-concordant barrier then $(O^2)F(X)$ is a self-concordant barrier. We estimate that for the universal constant we have $O <= 22$. This generalizes the relationship between the standard logarithmic barriers $-\log(x_1 \ldots x_n)$ and $-\log(\det X)$ and gives a partial solution to a conjecture of L. Tuncel.

■ TD3

Tuesday, 4:45-6:15, MDCL 1105

Convex Optmization Methods

Stream: Convex Optmization Methods

Chair: *Maziar Salahi*, The University of Guilan

1. **Concepts of C(larke) and M(ordukhovich) stationarities in MPECs and EPECs**

   Michal Cervinka, Charles University, Faculty of Mathematics and Physics and Academy of Sciences of the Czech Republic, Institute of Information Theory and Automation

For certain subclasses of mathematical programs with equilibrium constraints (MPECs) we can introduce different notions of stationarity. Namely, for MPECs with equilibrium constraints governed by single-valued and locally Lipschitz solution map, we define Mordukhovich or Clarke stationary points applying the respective calculus rules. Also, for MPECs with generalized complementarity constrains, possibly with nonunique solution to complementarity problem, based on the geometry of multipliers in the biactive case, we define M- and C-stationary points. We show the relations between above mentioned stationarities for MPECs for which both methods could be applied. We also focus on subclasses of so-called equilibrium problems with equilibrium constraints (EPECs) for which, e.g., for development of a homotopy method for computation of C-stationary points, these relations form a crucial link between theoretical existence results and numerically tractable geometric structure of such points.

2. **On Boundedness Of (Quasi-) Convex Integer Optimization Problems**

   Wieslawa Obuchowska, Department of Mathematics, East Carolina University

In this paper we are concerned with problem of boundedness and the existence of optimal solutions to the constrained integer (quasi-)convex programming problem. We present necessary and sufficient conditions for boundedness of either a faithfully convex or quasi-convex polynomial function over the feasible set contained in Z^n, and defined by a system of faithfully convex inequality constraints (satisfying some mild assumption) and/or quasi-convex polynomial inequalities, where all coefficients are rational. The conditions for boundedness are provided in the form of an implementable algorithm, terminating after finite number of iterations. We also prove that for the considered class of problems the optimal solution set is nonempty.

3. **Correcting an inconsistent set of linear inequalities by generalized Newton Method**

   Maziar Salahi, The University of Guilan, *Saeed Ketabchi*

Inconsistency in linear inequalities of a model is often occurs in practice due to various reasons. Correcting this sort of problem have been studied before. We consider it for further investigation. At the first step we aim to correct the inconsistent system by minimal changes in the right hand side or resources vector. This leads to a convex quadratic optimization problem, but the objective function is differentiable just once. Definitely it can be solved by gradient based algorithms, however due to their slow convergence, here we aim to apply second order algorithms. To do so, we employ the generalized Newton method and our computational results on various randomly generated problems show the superior performance to the gradient based algorithms. Then we consider changes in both the right hand side and coefficient matrix. Doing the correction by minimal changes in the data here leads to fractional quadratic problem which is efficiently handled by the generalized Newton Method.

■ TD4

Tuesday, 4:45-6:15, MDCL 1110

Chemical Processes

Stream: Optimizatino Formulations and Algorithms for Chemical Processes
Chair: *Feliksas Ivanauskas*, Vilnius University

1. **Optimal control of Constrained Time-lag Systems - Necessary Conditions, Numerical Treatment and Applications for Chemical Engineering**

   Laurenz Goellmann, Dept. of Mech. Engineering, Muenster - University of Applied Sciences at Steinfurt, Germany, *Daniela Kern*, *Helmut Maurer*

In this talk we consider retarded optimal control problems with constant delays in state and control variables under mixed control-state inequality constraints. First order necessary optimality conditions in the form of Pontryagin's minimum principle are presented and discussed as well as numerical methods based upon discretization techniques and nonlinear programming. It is shown that the Lagrange multipliers associated with the programming problem provide a consistent discretization of the advanced adjoint equation for the delayed control problem. Finally, the theory and the proposed numerical method are illustrated by examples from chemical engineering. We discuss the optimal control of a continuous stirred chemical tank reactor system (CSTR) in order to apply the proposed algorithm and to compare the computed results with the theory.

2. **Regret and Revise: Managing the Uncertain LP**

   Danielle Zyngier, Honeywell Process Solutions, *Thomas Marlin*

Linear Programming problems have a wide range of industrial applications, such as closed-loop real-time optimizers and open-loop production planning models. We present a new profit-based metric for monitoring the performance of uncertain LPs. In addition, this technique automatically determines best- and worst-case parameter realizations in a single optimization problem. Many standard methods are available for estimating the effects of parameter uncertainty on the objective function without a basis change such as traditional sensitivity analysis. Our work introduces a new diagnostic method for uncertain LP problems that detects the most significant sources of uncertainty from a profit perspective and that allows for uncertainty levels that span multiple optimal bases. The monitoring and diagnosing techniques are applied to both open-loop and closed-loop optimization problems. Different examples are shown that demonstrate the power of the proposed methods.

3. **An application of numerical simulation to the optimum design of highly sensitive and stable biosensors**

   Feliksas Ivanauskas, Vilnius University, *Romas Baronas*

Biosensors are sensing devices made up of a combination of a specific biological element, usually the enzyme, that recognizes a specific analyte and the transducer that translates the biorecognition event into an electrical signal. The signal is proportional to the concentration of the target analyte-substrate. The electrode geometry and parameters significantly influence the biosensor sensitivity and stability, so how to optimize the electrode geometry and parameters is one of the key problems in research today. This paper presents an approach to optimize the biosensor characteristics based on numerical simulation of the biosensor response. Two-dimensional-in-space mathematical models for the following biosensors have been developed: a plate-gap biosensor, a multi-layer biosensor, an array of enzyme micro-electrodes and some others. The models are based on the reaction-diffusion equations containing a nonlinear term related to the enzymatic reaction.

■ TD5

Tuesday, 4:45-6:15, MDCL 1016

Applications of Robust Optimization

Stream: Robust Optimization
Chair: *Dessislava Pachamanova*, Babson College

1. **Robust optimization and risk preferences in stochastic programming**

   John Birge, The University of Chicago, Graduate School of Business

The representation of risk preferences has been a discussion topic in stochastic programming since the first models with probabilistic constraints and recourse. This talk will consider these models and robust optimization formulations in a comprehensive framework based on utility theory. The focus will be on building models that are consistent with risk preferences and information states. Examples will be given illustrating the motivation for various formulations including robust characterizations of value-at-risk constraints.

2. **Robust Inventory Control using Tractable Replenishment Policies**

   Chuen-Teck See, NUS, *Melvyn Sim*

We propose tractable replenishment policies for a multiple period, single product inventory control problem under ambiguous demands, that is, only limited information of the demand distributions such as known mean, support and deviation measures are available. We obtain the parameters of the tractable replenishment policies by solving a deterministic optimization problem in the form of tractable second order cone optimization problem (SOCP). Our framework extends to correlated demands and is developed around a factor based model, which has the ability to incorporate business factors as well time series forecast effects of trend, seasonality and cyclic variations. Computational results show that with correlated demands, our model outperforms state independent basestock policies derived from dynamic programming and an adaptive myopic policies.

3. **Constructing Risk Measures from Uncertainty Sets**

   Dessislava Pachamanova, Babson College, *Melvyn Sim*, *Karthik Natarajan*

We illustrate the correspondence between uncertainty sets in robust optimization and some popular risk measures in finance, and show how robust optimization can be used to generalize the concepts of these risk measures.

■ TD6

Tuesday, 4:45-6:15, MDCL 1309

MPECs: Theory, Algorithms and Applications

Stream: MPECs/Complementarity Problems
Chair: *Uday Shanbhag*, Industrial and Enterprise Systems Engineering

1. **Long-Run Equilibrium Modeling of Alternative Emissions Allowance Allocation Systems in Electricity Power Markets**

   Jinye Zhao, Department of Mathematical Sciences, RPI, *Jong-Shi Pang*, *Benjamin Hobbs*

Carbon dioxide allowance trading systems for electricity generators are in place in the European Union and in several U.S. states. An important question in the design of such systems is how allowances are to be initially allocated: by auction, by grandfathering, or by allocating based on recent output, fuel, or other decisions. The latter system can bias investment, operations, and product pricing decisions, resulting in increased costs relative to the other systems. A nonlinear complementarity model is proposed for investigating the long-run equilibria that would result under alternative systems for power markets characterized by time varying demand and multiple technology types. Existence of equilibria is shown under mild conditions, and application to a simple system is discussed.

2. **Generalized Nash equilibrium problems under uncertainty: An application to electricity markets**

   Ankur Kulkarni, University of Illinois at Urbana-Champaign, *Uday Shanbhag*

Competition in electricity markets coupled with uncertainties in demand and fuel prices have significant consequences on the types of problems faced by market participants. Agents are faced by stochastic optimization problems parametrized by the decisions of their competitors. The object of interest is then the solution to an equilibrium program under uncertainty, specifically a stochastic Nash equilibrium problem. By allowing agents to bid in the capacity market and real-time markets in successive periods, our dynamic model leads to a class of stochastic complementarity problems. By proving the properies of the resulting matrices, we are able to ensure existence of a solution. The second part of the paper presents a scalable convergent algorithm for solving such a problem that relies on matrix-splitting methods. Finally, we provide some numerical results to show utililty of such an approach.

3. **A Second-Order Method for Mathematical Programs with Complementarity Constraints**

   Uday Shanbhag, Industrial and Enterprise Systems Engineering, *Angelia Nedich*

We consider the solution of mathematical programs with complementarity constraints, when first and second derivatives are available. We present a primal-dual method reliant on both negative curvature and Newton directions. A curvilinear search over a combination of these directions is employed for purposes of globalization. We prove that the iterates satisfy a global convergence result under somewhat weaker assumptions. We conclude by discussing the performance of the algorithm on a test problem set of quadratic programs with equilibrium constraints.

■ TD7

Tuesday, 4:45-6:15, MDCL 1009

PDE Constrained Optimization

Stream: PDE Constrained Optimization
Chair: *Georg Bock*, University of Heidelberg
Session organizer: Ekaterina Kostina

1. **Adaptive Multilevel Methods for PDE-Constrained Optimization**

   Ulbrich Stefan, Department of Mathematics, TU Darmstadt, *Ziems Jan Carsten*

We present a class of inexact adaptive multilevel SQP-methods for the efficient solution of PDE-constrained optimization problems. The algorithm starts with a coarse discretization of the underlying optimization problem and provides 1) implementable criteria for an adaptive refinement strategy of the current discretization based on local error estimators and 2) implementable accuracy requirements for iterative solvers of the PDE and adjoint PDE on the current grid such that global convergence to the solution of the infinite-dimensional problem is ensured. Numerical results are presented.

2. **Adaptive finite element discretizations for PDE constrained optimization**

   Wolfgang Bangerth, Department of Mathematics, Texas A&M University

Partial differential equations are typically solved on computational meshes (for example for the finite element method) that one attempts to choose such that the numerical approximation is accurate enough for a given purpose. Due to the extremely high cost of solving many PDEs accurately, PDE constraint optimization often has to deal with the fact that the constraint can only be solved rather crudely, in contrast to the situation in ODE constrained optimization. Newer approaches use coarse computational meshes in the initial optimization iterations where high accuracy is not required, and adapt meshes for higher accuracy in later optimization steps. While this can reduce computational cost, the fact that state and possibly parameter spaces change their dimension and meaning between iterations presents unique challenges when attempting to measure progress of iterations. In this talk, we will discuss how to derive algorithms for the situation of changing discretizations and show numerical experiments.

3. **Adaptive finite volume method for distributed non-smooth parameter identification**

   Eldad Haber, Emory University

In this talk we develop a finite volume adaptive grid refinement method for the solution of distributed parameter estimation problems with almost discontinuous coefficients. We discuss discretization on locally refined grids, as well as optimization and refinement criteria. An OcTree data structure is utilized. We show that local refinement can significantly reduce the computational effort of solving the problem, and that the resulting reconstructions can significantly improve resolution, even for noisy data and diffusive forward problems.

■ TD8

Tuesday, 4:45-6:15, MDCL 1010

Industrial Strength Optimization

Stream: Engineering Optimization
Chair: *Paul Frank*, Mathematics and Computing, The Boeing Company

1. **A Fully General, Exact Algorithm for Nesting Irregular Shapes**

   Don Jones, General Motors

This paper introduces a fully general, exact algorithm for nesting irregular shapes on a material resource. The shapes and material can be arbitrarily shaped polygons, and the shapes can be arranged using both translations and rotations. The key idea is to inscribe a few circles inside each irregular shape and then replace the non-overlap constraints for the shapes with non-overlap constraints for the inscribed circles. This results in a close approximation to the original nesting problem that has the form of quadratic programming problem (QP). For sufficiently small problems, the QP approximation can be solved to optimality. The approximation via inscribed circles can then be refined, and the QP resolved, until an acceptable solution to the original problem is found.

2. **Optimization Models in Drilling Design and Reservoir Simulation**

   Amr El-Bakry, ExxonMobil Upstream Research, *Matthias Heinkenschloss*, *Klaus Wiegand*

In this presentation we will cover two Upstream optimization models that arise in two areas in the development of hydrocarbon assets. In drilling wells, the goal is to minimize cost while maintaining the integrity of the well. To this end, a physics-base model is integrated with a technique to quantify uncertainty in the drilling design process. The over all model is optimized using a combination of derivative-free and derivative-based methods. Selected recent examples of the use of this technology will be demonstrated. The second optimization model arises in reservoir management. We will present simplified-physics models and outline their deficiencies. Then we will present the use of a PDE-based reservoir simulation for reservoir management optimization. Finally we will discuss preliminary analysis of the sensitivities of a user-defined objective function with respect to controllable parameters.

3. **Extending the Reach of Response Model Optimization**

   Paul Frank, Mathematics and Computing, The Boeing Company, *Donald Jones*, *Amr El-Bakry*

This talk describes methods for extending response-model-based optimization to problems having 'large' numbers of variables. Response-model-based optimization has proven effective for many important Boeing applications. Typically, application of these methods has been limited to problems having on the order of 50 variables. This dimensional limit is due to several factors. These include the large number of simulation code runs required as data for the initial response models, and the computational cost and numerical computation challenges for computing response models in high dimensions. To overcome these difficulties, a solution method will be described that combines partitioning of the variables with a successful response-model-based method for constrained problems in lower dimensions.

■ TD9

Tuesday, 4:45-6:15, MDCL 1008

Analytic Center and Bundle Methods for Nonsmooth Optimization and Applications

Stream: Nonsmooth Optimization
Chair: *Samir Elhedhli*, University of Waterloo
Session organizer: Joe Naoum-Sawaya

1. **A Two-Phase ACCPM based Benders decomposition for integer programming**

   Joe Naoum-Sawaya, Department of Management Sciences, University of Waterloo, *Samir Elhedhli*

The Analytic Centre Cutting Plane Method (ACCPM) has proven successful when applied to linear programming master problems within decomposition approaches. This talk explores the use of ACCPM in a Benders decomposition framework where the master problems are mixed integer programs. A Two-phase algorithm is developed, where in the first phase, ACCPM is applied to the LP version of the master problem. An approximate integer analytic centre is then constructed to generate Benders cuts that are used to initialize the Benders algorithm in the second phase. Approximate central analytic centres are heuristically constructed. A number of heuristics are discussed and compared, one of which uses the properties of analytic centres and could be applied to general integer problems. We numerically evaluate the quality of the cuts proposed by ACCPM and the effect of the heuristics in speeding the convergence of Benders decomposition.

2. **A VU-algorithm for partly smooth convex minimization**

   Robert Mifflin, Department of Mathematics, Washington State University, *Claudia Sagastizabal*

Partly smooth functions have nonsmoothness that can be well-behaved enough to be exploited by optimization algorithms for rapid convergence. This is the case for functions with primal-dual gradient structure. Along a smooth manifold, such a function is smooth, while on the subspace orthogonal to the manifolds's tangent space the function's graph is V-shaped. A VU-type algorithm for minimizing a maximum-eigenvalue function was introduced a few years ago. This algorithm needed full knowledge of the function's eigen-structure. A recently published proximal bundle VU-algorithm implements natural VU-decomposition ideas for general convex functions. In contrast to the maximum-eigenvalue algorithm, this VU-algorithm exploits function structure without having to know it explicitly. To follow a "primal-dual track" superlinearly, U-Newton predictor-steps alternate with V-corrector-steps. V-space approximation comes from a prox-parameter-dependent bundle subroutine that constructs a V(cutting-plane)-model of the function using past subgradients. As a by-product, a U-gradient (approximating a Riemannian gradient relative to the smooth manifold) is available for the U-Newton step. This talk describes an improved proximal bundle VU-algorithm that preserves global convergence while incorporating a new strategy for the prox-parameter variation. Results of numerical experiments are presented to validate the new approach.

3. **Solving Block-Angular Linear Programs by Using a Hybrid Method Combining ACCPM and DW**

   Jiarui Dang, University of Waterloo

The analytical center cutting plane method (ACCPM), which can be viewed as an interior-point-based decomposition approach, has superior global convergence properties, but its main feature, staying away from the boundary, prevents it from producing an exact optimal solution. Conversely, the simplex-based Dantzig-Wolfe decomposition method (DW) achieves greater accuracy because it can reach the vertices of the feasible region. In this paper, we propose a hybrid solution approach that seeks to combine the advantages of both. We start with ACCPM, and then switch to DW after a few iterations (usually when the current point is sufficiently close to the optimal solution). There is little computational effort required for the switch. Experiments indicate that for large problems, the hybrid approach appears to have both accuracy and a fast convergence rate.

■ WA1

Wednesday, 8:30-10:00, MDCL 1305

Algorithms and Software Packages for Convex Programming

Stream: Linear, Semidefinite and Conic Optimization

Chair: *Katsuki Fujisawa*, National Institute of Advanced Industrial Science and Technology

1. **Correlative sparsity in primal-dual interior-point methods and efficient SOCP formulations**

   Kazuhiro Kobayashi, National Maritime Research Institute

Exploiting sparsity is a key issue in solving large-scale optimization problems. The most time-consuming part of primal-dual interior-point methods for linear optimization problem is solving the Schur complement equation at each iteration, usually by the Cholesky factorization. The computational efficiency is affected by the sparsity of the coefficient matrix of the equation which is determined by the sparsity of an problem. We show if an problem is correlatively sparse, then the coefficient matrix of the Schur complement equation inherits the sparsity, and a sparse Cholesky factorization applied to the matrix results in no fill-in.We also show how an efficient SOCP formulation that increases the computational efficiency can be obtained by investigating the relationship between the sparsity of an SOCP formulation and the sparsity of the Schur complement matrix. Numerical results are included to demonstrate the performance of the SOCP formulation.

2. **The present and future of SeDumi**

   Tamás Terlaky, McMaster University, Department of Computing and Software, *Imre Pólik*, *Yuriy Zinchenko*

It has been three years now that our research group took over the development of SeDuMi. In this talk we review our efforts so far to maintain and develop this worthy package and we present how we seem to have reached a point where a major rewrite of the package is necessary. There are certain factors that hold SeDuMi back. We discuss our plans to rewrite the software with new features and extensions in mind.

3. **On the implementation and usage of SDPT3, version 4.0**

   Kim-Chuan Toh, Mathematics, National University of Singapore, and Singapore-MIT Alliance, *Michael J. Todd*, *R. H. Tütüncü*

We describe some recent developments in the Matlab software SDPT3. The current version is designed to solve conic programming problems whose constraint cone is a product of semidefinite cones, second-order cones, nonnegative orthants and Euclidean spaces; and whose objective function is the sum of linear functions and log-barrier terms associated with the constraint cones. The latter includes determinant maximization problems with linear matrix inequalities. Sparsity and block diagonal structure are exploited in the computations. We also exploit low-rank structures in the constraint matrices associated the semidefinite blocks if such structures are explicitly given. Various techniques to improve the efficiency and stability of the algorithm are incorporated. Numerical experiments show that this general purpose code can solve more than 80% of a total of about 300 test problems to an accuracy of at least 10^{-6} in relative duality gap and infeasibilities.

■ WA2

Wednesday, 8:30-10:00, MDCL 1307

Decomposition and Nonsmooth Approaches for Large Scale Conic Optimization

Stream: Nonsmooth Optimization

Chair: *Kartik K. Sivaramakrishnan*, Department of Mathematics, North Carolina State University

1. **Selective Gram-Schmidt orthonormalization for conic cutting surface algorithms**

   John E. Mitchell, RPI, Math Sciences, *Vasile L. Basescu*

It is not straightforward to find a new feasible solution when several conic constraints are added to a conic optimization problem. Examples of conic constraints include semidefinite constraints and second order cone constraints. In this paper, a method to slightly modify the constraints is proposed. Because of this modification, a simple procedure to generate strictly feasible points in both the primal and dual spaces can be defined. A second benefit of the modification is an improvement in the complexity analysis of conic cutting surface algorithms. Complexity results for conic cutting surface algorithms proved to date have depended on a condition number of the added constraints. The proposed modification of the constraints leads to a stronger result, with the convergence of the resulting algorithm not dependent on the condition number.

2. **Decomposition Based Interior Point Methods for Two and Multistage Stochastic**

   Sanjay Mehrotra, IEMS, Northwestern University, *Shengyuan Chen*

We study the two-stage and multi-stage stochastic convex problems whose feasible set admits non-degenerate self-concordant barrier functions. We show that the barrier recourse function for these problems constitute a self-concordant family. This allows us to propose an interior point decomposition algorithm similar to the one proposed by Zhao for this more general setting. The self-concordance property of the two-stage and multi-stage convex problem also allows us to develop a decomposition approach for the multi-stage case.

3. **A PARALLEL conic interior point decomposition approach for BLOCK-ANGULAR semidefinite programs**

   Kartik K. Sivaramakrishnan, Department of Mathematics, North Carolina State University

Semidefinite programs (SDPs) with a BLOCK-ANGULAR structure occur routinely in practice. In some cases, it is also possible to exploit the SPARSITY and SYMMETRY in an unstructured SDP, and preprocess it into an equivalent SDP with a block-angular structure. We present a PARALLEL CONIC INTERIOR POINT DECOMPOSITION approach to solve block-angular SDPs. Our aim is to solve such a SDP in an iterative fashion between a master problem (a quadratic conic program); and decomposed and distributed subproblems (smaller SDPs) in a parallel computing environment. We present our computational results with the algorithm on several test instances; our computations were performed on the distributed HENRY2 cluster at North Carolina State University.

■ WA3

Wednesday, 8:30-10:00, MDCL 1105

Convex Vector Optimization

Stream: Convex Optmization Methods

Chair: *Xiaoqi Yang*, The Hong Kong Polytechnic University

1. **Characterizing the Nonemptiness and Compactness of the Solution Set of a Vector Variational Inequality by Scalarization and Applications**

   Xiaoqi Yang, The Hong Kong Polytechnic University

In this paper, the nonemptiness and compactness of the solution set of a pseudomonotone vector variational inequality (resp. a system of pseudomonotone vector variational inequalities) defined in a finite dimensional space are characterized in terms of that of the solution sets of a family of linearly scalarized variational inequality problems. The obtained results are then applied to characterize the nonemptiness and compactness of the weak Pareto solution set of a pseudoconvex vector optimization problem, and that of the solution set of a pseudoconvex vector Nash equilibrium problem and to derive necessary and sufficient conditions for two types of Levitin-Polyak well-posednesses of a cone-constrained monotone vector variational inequality.

2. **Characterizations of the Nonemptiness and Boundedness of Weakly Efficient Solution Sets of Convex Vector Optimization Problems in Real Reflexive Banach Spaces**

   Sien Deng, Department of Math Sciences, Northern Illinois University

Under a weak compactness assumption on functions involved, which always holds in finite-dimensional normed linear spaces, this work extends various characterizations of the nonemptiness and boundedness of weakly efficient solution sets of convex vector optimization problems, obtained previously by the author in the real finite-dimensional normed linear space setting, to those in the real reflexive Banach space setting. If time permits, applications of the results will be discussed.

3. **Characterizing General Pareto Optima**

   Mark Rentmeesters, Department of Mathematics, East Carolina University

For convex objective functions, all Pareto optima, whether proper or improper, can be characterized as a lexicographic optimum of some ordered sequence of weighted sums of these objectives. Moreover, although lexicographic optima by their nature are improper Pareto optima, it is nevertheless possible to state both necessary and sufficient Kuhn-Tucker conditions for these optima by considering each lexicographic level of such conditions to hold as constraining conditions on optimality at each successively lower priority level. The result is a sequence of second-order conditions that can then be used to characterize Pareto optima in general, whether proper or improper.

■ WA4

Wednesday, 8:30-10:00, MDCL 1110

Robust Network Optimization

Stream: Robust Optimization

Chair: *Nicolas Stier-Moses*, Columbia University

1. **Robust optimization: A case in forest operations planning**

   Jorge Vera, Dept. Industrial Engineering, Universidad Catolica de Chile

Decision Support Systems based on optimization models have long been used to support decision making in the forest industry. One specific application is the planning of harvesting operations, in which decisions have to be made regarding harvesting, machinery use and transportation to pulp plants and saw mills. Yield coefficients used in these models are only an approximation given the natural variabilities, as well as process irregularities. To cope with this problems, we develop in this paper a robust optimization model which generates solutions which satisfies demand constraints for a given variability in the yield coefficient. Different solution and modeling methodologies are presented, including an adversarial approach. We show results that illustrates the trade-off between the robustness requirement and the deterioration in the objective function. We also show evaluations of the robustness of the solutions using Monte Carlo simulation.

2. **Expected Shortfall Constraints via Robust Optimization**

   Anuj Manuja, IEOR Department, Columbia University, *Garud Iyengar*

This paper is concerned with providing solution methods for linear optimization problems with uncertain parameters. It is well-known that the robust optimization methodology can be used to construct tractable approximations for such uncertain problems. The robust optimization based approximations available in the literature only control the probability of constraint violation, they do not control the degree of constraint violation. In this paper, we propose a new formulation that allows the decision-maker to control both the probability and expected value of constraint violation. We show how to construct tractable approximations for this new formulation. We also discuss the application of the formulation to staffing/routing problem in call centers and inventory control problems.

3. **Robust Wardrop Equilibrium**

   Nicolas Stier-Moses, Columbia University, *Fernando Ordonez*

Network games can be used to model competitive situations where players select routes to minimize cost. Common applications include traffic, telecommunication and logistic networks. Although traditional models have assumed that cost only depends on congestion, normally there is also an uncertain component. Hence, in our model players are aware of the uncertainty and select routes by solving a robust optimization problem. Indeed, a robust Wardrop equilibrium (RWE) as a flow in which all players select a robust shortest path. Such a solution always exists and can be computed through efficient column generation methods. We show through a computational study that a RWE tends to be more fair than a Wardrop equilibrium (which ignores the uncertainty). Hence, this solution reduces the regret that players experience after the uncertainty is revealed. In addition, we show there is a pricing mechanism with which one can coordinate players into a socially optimal solution.

■ WA5

Wednesday, 8:30-10:00, MDCL 1016

Derivative Free Optimization

Stream: Derivative Free Optimization

Chair: *Jose Luis Morales*, Northwestern University

1. **Multiobjective optimization through a series of single-objective formulations**

   Walid Zghal, Polytechnique MontrÃľal/GERAD, *Charles Audet*, *Gilles Savard*

This work deals with bound constrained multiobjective optimization (MOP) of nonsmooth functions for problems in which the structure of the objective functions either cannot be exploited, or is absent. Typical situations arise when the functions are computed as the result of a computer simulation. We first present definitions and optimality conditions as well as a two families of single-objective formulations of MOP. Next, we propose a new algorithm called BIMADS for the biobjective (BOP) problem (i.e., MOP with two objective functions). The property that Pareto points may be ordered in BOP and not in MOP is exploited by our algorithm. BIMADS generates an approximation of the Pareto front by solving a series of single-objective formulations of BOP. These single-objective problems are solved using the recent MADS(mesh adaptive direct search) algorithm for nonsmooth optimization. The Pareto front approximation is shown to satisfy some first order necessary optimality conditions based on the Clarke calculus. Finally, BIMADS is tested on problems from the literature designed to illustrate specific difficulties encountered in biobjective optimization, such as a nonconvex or disjoint Pareto front, local Pareto fronts or a non-uniform Pareto front.

2. **Derivative-free Optimization in Revenue Management**

   Mikhail Nediak, Queen's School of Business, *Tatsiana Levina*, *Yuri Levin*, *Jeff McGill*

We present two applications of derivative-free optimization in revenue management. The first one is the problem of dynamic pricing of a stock of perishable items to maximize the expected revenues. A consumer demand model is unknown, the company learns it through successive observations (online) and incorporates it in pricing decisions. Learning is accomplished by updates of a finite-sample approximation to the posterior distribution of model parameters. Thus, expected revenues can only be evaluated by Monte-Carlo methods suggesting a derivative-free optimization approach. The second application is a cargo shipping problem on a network of flights operated on a fixed periodic schedule. The problem is to maximize the expected present value of profit by controlling accept/reject decisions for booking requests and dispatching accepted packages through the network. We discuss the structural properties of the acceptance policy and numerical approximation schemes.

3. **The role of geometry in practical DFO algorithms**

   Jose Luis Morales, Northwestern University, *Jorge Nocedal*, *Giovanni Fasano*

Our main goal in this research is to understand the role of geometry in the practical performance of algorithms that make use of quadratic polynomial models. In the first part of the talk we present a numerical study on a set of CUTE problems. In the second part we attempt to use existing theory to explain the numerical results.

■ WA6

Wednesday, 8:30-10:00, MDCL 1309

Novel MPEC Applications

Stream: MPECs/Complementarity Problems

Chair: *Todd Munson*, MCS Divsion, Argonne National Laboratory

1. **MPEC Approaches to Estimation of Structural Models**

   Che-Lin Su, Kellogg School of Management, Northwestern University, *Ken Judd*

Maximum likelihood estimation of structural models is regarded as computationally difficult. This impression is due to a focus on the Nested Fixed-Point (NFXP) approach [Rust, Econometrica (1987)]. We present a direct optimization approach to the problem and show that it is significantly faster than the NFXP approach when applied to the canonical Zurcher bus repair model. The NFXP approach is inappropriate for estimating games since it requires finding all Nash equilibria of a game for each parameter vector considered, a generally intractable computational problem. We reformulate the problem of maximum likelihood estimation of games so into an optimization problem that is qualitatively no more difficult to solve than standard problems.

2. **Comparative study of methods for modeling contact and friction in physical simulation**

   Binh Nguyen, CS Department, RPI, *Jeff Trinkle*

Contact and friction modeling is one of the biggest challenges in physical simulation. In this talk, I will compare set of popular methods used in applications from computer games to engineering analysis. They range from penalty methods to complementarity-based methods. I will show how they are derived from a common instantaneous-time model including a physical assumptions made to speed solution times. I also will compare results using a range of time-stepping methods applied to several examples. This study suggests several open mathematical problems.

3. **A Geometrically Implicit Time-Stepping Method for Multibody Systems with Intermittent Contact**

   Steve Berard, CS Department, RPI, *Jeff Trinkle*, *Srinivas Akella*, *Nilanjan Chakraborty*

We present a fully implicit time-stepping scheme for multibody systems with intermittent contact by incorporating the contact constraints as a set of complementarity and algebraic equations within the dynamics model. Two primary sources of stability and accuracy problems in time stepping schemes for differential complementarity models of multibody systems are the use of polyhedral representations of smooth bodies and the approximation of the distance function (arising from the decoupling of collision detection from the solution of the dynamic time-stepping subproblem). Even the simple example of a disc rolling on a table without slip encounters these problems. We model each object as an intersection of convex inequalities and write the contact constraints as a complementarity constraint.

■ WA7

Wednesday, 8:30-10:00, MDCL 1009

Computational Analysis

Stream: Convex and Nonsmooth Analysis

Chair: *Yves Lucet*, Computer Science, Arts & Sciences, UBC Okanagan

1. **The Colourful Feasibility Problem**

   Tamon Stephen, Department of Mathematics, Simon Fraser University, *Antoine Deza*, *Sui Huang*, *Tamás Terlaky*

A colourful version of the linear programming feasibility problem is to find a feasible basis that respects a given colouring (partition) of the vertices. This problem was presented by Barany and Onn in 1997, it is still not known if a polynomial time algorithm exists. We compare the methods introduced by Barany and Onn with new methods. We perform benchmarking on generic and ill-conditioned problems, as well as recently introduced highly structured problems. We show that some algorithms can lead to cycling or slow convergence, but we provide extensive numerical experiments which show that others perform much better than predicted by complexity arguments. We conclude that an effective method in practice is a proposed multi-update algorithm.

2. **Projected Kalman Filtering with Application to Dynamic Emission Tomography**

   Joe Qranfal, Mathematics, Simon Fraser University, *Germain Tanoh*

Classical SPECT reconstruction algorithms assume that the activity does not vary in time. This is not always the case in practice. For instance, when we study Teboroxime cardiac images, the activity varies in time. Thus arises the need of exploring dynamic SPECT. We formulate a state-space model of this ill-posed inverse problem which we solve using the optimal Kalman filter and smoother. While other methods assume a priori knowledge about the activity behavior, Kalman assumes little. However, standard Kalman filter does not guarantee the nonnegativity of the estimated activity; which does not have any physical meaning. In this talk we explore a new Kalman reconstruction approach with projection to ensure the image feasibility. Numerical results are provided.

3. **Proximal regularization of dynamic inverse problems**

   Germain Tanoh, IRMACS, Simon Fraser University

The properties of an object under study in standard inverse problems are assumed static; while in dynamic inverse settings we are interested in its changes over time. We describe a new regularization method for computing a spatio-temporal smooth solution. We analyze a splitting algorithm using Bregman proximity operators to solve the problem in two steps. First we perform a spatial regularization step; then we follow it by a temporal regularization one. Application to dynamic SPECT imaging shows that our approach is able to reconstruct the dynamics of a tracer distribution in an organ.

■ WA8

Wednesday, 8:30-10:00, MDCL 1010

Simulation-Based Optimization

Stream: Engineering Optimization

Chair: *Genetha Gray*, Sandia National Labs

1. **Selection of Parameters for Maximizing the Lifetime of a Polymer Extrusion Filter**

   Kathleen Fowler, Department of Mathematics Clarkson University, *Lea Jenkins*, *Brian McClune*, *Chris Cox*

We consider an extrusion filter used to remove debris from a polymer melt before the liquid is spun into a fiber. We seek the optimal parameters to maximize the lifetime of the filter using a simulator developed at the Center for Advanced Engineering Fibers and Films (CAEFF). The simulator must work as a 'black-box' in conjunction with a derivative-free optimization algorithm. We present preliminary numerical results obtained with a variety of sampling methods for optimization.

2. **Kriging models that are robust with respect to simulation errors**

   Dick den Hertog, CentER, Tilburg University, Tilburg, The Netherlands

In the field of the Design and Analysis of Computer Experiments (DACE) meta-models are used to approximate time-consuming simulations. These simulations often contain small simulation-model errors in the output variables. In the construction of meta-models, these errors are often ignored. Therefore, in this paper, we study the construction of Kriging models that are robust with respect to simulation-model errors. We introduce a robustness criterion, to quantify the robustness of a Kriging model. Based on this robustness criterion, two new robust Kriging methods are introduced. We illustrate these methods with the approximation of the Six-hump camel back function and a real life example. Furthermore, we validate the two methods by simulating artificial perturbations. Finally, we consider the influence of the Design of Computer Experiments (DoCE) on the robustness of Kriging models.

3. **Modeling Heart Rate Regulation During Sit-to-Stand and Head-Up Tilt**

   April Alston, NC State

Orthostatic stress tests such as postural change from sit-to-stand and head-up tilt are common procedures used to study short-term regulation of the cardio-respiratory system. During orthostatic stress, arterial and cardiopulmonary baroreflexes aid in maintaining blood pressure by regulation of heart rate. We present a model with 17 parameters that can predict the underlying dynamics of heart rate regulation and its relationship to blood pressure in response to orthostatic stress. To estimate the parameters, an inverse least squares problem is formulated and solved using the Nelder-Mead nonlinear optimization technique. Finally, an analysis comparing the differences between postural change from sit-to-stand and head-up tilt is done based on data sets obtained from healthy elderly subjects.

■ WA9

Wednesday, 8:30-10:00, MDCL 1008

Process Modelling and Analysis

Stream: Optimization Formulations and Algorithms for Chemical Processes

Chair: *Angelo Lucia*, University of Rhode Island

Session organizer: Andy Hrymak

1. **Parameter Estimation in Continuous-Time Dynamic Models with Uncertainty**

   Kim McAuley, Chemical Engineering, Queen's University, *M. Saeed Varziri*, *P. James McLellan*

Chemical engineers who develop fundamental dynamic models estimate model parameters using noisy data. Often, modelers believe that their models are imperfect due to simplifying assumptions. We have developed a new parameter-estimation technique that explicitly considers model imperfections and measurement errors. Our proposed method is based on Maximum-Likelihood (ML) estimation. The likelihood criterion is approximated by means of spline-smoothing and collocation techniques, which are used to discretize the differential equations. The resulting objective function contains three parts that account for measurement errors, model uncertainty and unknown initial conditions. The method extends benefits of collocation techniques to stochastic dynamic models with uncertain inputs and nonstationary disturbances. The ML formulation ensures unbiased and consistent parameter estimates. Theoretical confidence intervals agree with empirical confidence intervals from Monte Carlo simulations.

2. **Optimal evaluation of free energies by molecular simulation**

   David Kofke, University of Buffalo

Efforts in recent years to improve molecular simulation algorithms have been very successful, and perhaps have improved the utility of molecular simulation even more than advances in raw computing power occurring over the same period. An important application is the calculation of free-energy differences, required for analyses of equilibria, solvation, binding, stability, kinetics, etc. Some popular approaches to calculating the free energy are highly prone to systematic errors, and simple countermeasures often do not improve the outcome. We show that the key consideration influencing the accuracy is the overlap of the important regions of phase space for the systems of interest. We are developing measures to quantify this overlap and we examine the connection between them and the performance of the calculations. We use these ideas to formulate simple variants of the basic technique that can be applied to increase the likelihood of obtaining a good result.

3. **A New Approach to the Synthesis & Optimization of Energy Efficient Chemical Processes**

   Angelo Lucia, University of Rhode Island, *Amit Amale*

The focus of this talk will be on the optimization aspects of energy efficient aspect of chemical process design based on the novel concept of shortest stripping lines. The importance of the interplay between optimization and process engineering as it applies to two important and open issues in process synthesis and design 1) The sensitivity of design methodologies to trace component compositions in product streams. 2) The synthesis and design of non-pinched energy efficient multi-unit processes. will also be described. General optimization formulations are given and numerical results are presented that show that each of these issues can be resolved using the shortest stripping line methodology. Geometric illustrations are used to elucidate key points and show that the concept of shortest stripping lines represents a true unification of all existing methods for finding minimum energy requirements for a variety of chemical processes. It also can find solutions other methods cannot and thus, in our opinion, lays the foundation for the next generation of energy efficient process synthesis and design tools.

■ WB1

Wednesday, 10:30-12:00, MDCL 1305

Convex Approaches for Nonconvex Quadratic Programs

Stream: Conic Programming and Interior Point Methods
Chair: *Samuel Burer*, Department of Management Sciences, University of Iowa

1. **Properties of the Optimal Solutions to Shor Relaxation of Box QP**

   Jieqiu Chen, The University of Iowa, *Samuel Burer*

We study non-convex box-constrained quadratic programming and compare three SDP relaxations of increasing complexity. The simplest is Shor's relaxation (with an additional constraint to bound the feasible region), while the second and third relaxations are gotten by incorporating relaxations of the QP's first- and second-order KKT conditions into Shor's relaxation. By analyzing certain properties of the QP at optimality, we show (surprisingly) that all three relaxations are equivalent. Extensions of this result and their relevance to solving NP-hard quadratic programs are discussed.

2. **A Unified Theorem on SDP Rank Reduction**

   Anthony Man-Cho So, Stanford University

We consider the problem of finding a low-rank approximate solution to a system of linear equations in symmetric, positive semidefinite matrices, where the approximation quality of a solution is measured by its maximum relative deviation, both above and below, from the prescribed quantities. We show that a simple randomized polynomial-time procedure produces a low-rank solution that has provably good approximation qualities. Our result provides a unified treatment of and generalizes several well-known results in the literature. In particular, it contains as special cases the Johnson-Lindenstrauss lemma on dimensionality reduction, results on low-distortion embeddings into low-dimensional Euclidean space, and approximation results on certain quadratic optimization problems.

3. **On the Copositive Representation of Binary and Continuous Nonconvex Quadratic Programs**

   Samuel Burer, Department of Management Sciences, University of Iowa

We show that any nonconvex quadratic program having a mix of binary and continuous variables over a bounded feasible set can be represented as a linear program over the dual of the cone of copositive matrices. This result can be viewed as an extension of earlier separate results, which have established the copositive representation of a small collection of NP-hard problems.

■ WB2

Wednesday, 10:30-12:00, MDCL 1307

Convex Optimization Methods and Beyond

Stream: Convex Optmization Methods
Chair: *Paul Tseng*,

Session organizer: Michael Friedlander

1. **A root-finding algorithm for large-scale basis pursuit denoising**

   Michael Friedlander, UBC Computer Science

The basis pursuit (BP) problem seeks a minimum one-norm solution of an underdetermined least-squares problem. The related BP denoise (BPDN) problem fits the least-squares problem only approximately, and a single parameter determines an "L-curve" that traces the trade-off between the least-squares fit and the one-norm of the solution. We describe a root-finding algorithm, suitable for large-scale problems, for finding arbitrary points on this curve. At each iteration, a gradient-projection method approximately minimizes a least-squares problem with an explicit one-norm constraint. Only matrix-vector operations are required. The primal-dual solution of this problem gives function and derivative information needed for the root-finding method.

2. **General Projective Splitting Methods for Sums of Monotone Operators**

   Jonathan Eckstein, MSIS Department and RUTCOR, Rutgers University, *Benar Svaiter*

Consider finding a zero of the sum of a finite number of arbitrary maximal monotone operators on a Hilbert space, a problem that generalizes convex optimization and monotone variational inequalities. A splitting method is an iterative solution procedure that acheives decomposition by using only the resolvents or inverses of the individual operators. Prior splitting schemes for more than two operators use a product space reformulation to reduce the problem to the two-operator case. We present a new class of projective splitting methods that does not depend on this reformulation, and has numerous novel features. The proximal parameters in the operator resolvents may vary between iterations and between operators, and the order of operator evaluation may change from iteration to iteration. We prove convergence of this scheme under minimal assumptions and using a relative error criterion for approximately evaluating resolvents. The analysis is based on decomposably constructing separators for a certain extended solution set, and generalizes our prior work for the two-operator case.

3. **On extremal ellipsoids associated to a convex body**

   Osman Güler, Department of Mathematics and Statistics, University of Maryland (UMBC), *Filiz Gurtuna*

Every convex body K has associated with it many natural ellipsoids. Many of these have variational characterization such as the well known (unique) minimum volume ellipsoid circumscribing K and the maximum volume ellipsoid inscribed in K. These and other ellipsoids have applications in many diverse areas, both pure and applied, from Banach space theory to optimal design. Over the last hundred years, many methods have been advanced to study these ellipsoids. In this talk, we first give a modern synthesis of the powerful semi-infinite programming approach to extremal ellipsoids. We then investigate the invariance properties of these ellipsoids using group theory. This allows, among other, the explicit determination of the extremal volume ellipsoids for some classes of convex bodies from the optimality conditions. In the companion talk of F. Gurtuna in Session MB4, this is done for some classes of convex bodies.

■ WB3

Wednesday, 10:30-12:00, MDCL 1105

Polynomial Optimization and Semidefinite Programming

Stream: Linear, Semidefinite and Conic Optimization

Chair: *Takashi Tsuchiya*, The Institute of Statistical Mathematics

1. **Variational characterizations of eigenvalues in Euclidean Jordan algebras**

   Michel Baes, ESAT/Katholieke Universiteit van Leuven

Euclidean Jordan algebras constitute the most natural algebraic framework for self-scaled programming. They can be seen as an extension of real symmetric matrices, and the standard concept of eigenvalues, defined as the roots of a characterisic polynomial, also exists in this framework. These eigenvalues happen to be real. Variational characterizations of eigenvalues are included among the most important technical tools to understand how these eigenvalues vary under perturbations of their argument. These characterizations are of primal importance to investigate differentiability properties of functions of eigenvalues. They also lead to many useful inequalities. In this talk, we extend Wielandt's variational characterization of partial sums of eigenvalues to the framework of Euclidean Jordan algebras. Particular cases of this result include Fan's Theorem and Fischer's Theorem. As byproducts of our result, we derive Weyl's, Liidskii's, Mirski's inequalities for Jordan algebras.

2. **Hyperbolic polynomials and SOS matrices**

   Pablo Parrilo, Massachusetts Institute of Technology

In this talk we describe some remarkable connections between hyperbolic polynomials and sum of squares (SOS) polynomial matrices. In particular, we show that the problem of recognizing and certifying whether a given homogeneous trivariate polynomial is hyperbolic or not is exactly equivalent to a semidefinite programming problem. Furthermore, we also discuss our recent efficient algorithm for explicitly finding an SOS decomposition of univariate polynomial matrices (in joint work with E. Aylward and S. Itani). This method is inspired by the Hamiltonian-type methods used for the solution of Riccati equations. In combination with the earlier described results, this algorithm can be used to efficiently produce certificates of polynomial hyperbolicity.

3. **A Matrix-Dilation Approach to Robust Semidefinite Programming**

   Yasuaki Oishi, Department of Information Systems and Mathematical Sciences, Nanzan University

An approach to robust semidefinite programming is discussed with its advantages over the sum-of-squares approach. The idea is to solve an approximate problem constructed from the given robust semidefinite programming problem based on the division of the region of the uncertain parameters. The approximation error converges to zero as the resolution of the division becomes higher. Although a related approach is possible with sum-of-squares polynomials, a major difference is that an upper bound on the approximation error is obtained in the present approach as a function of the resolution. Techniques for the reduction of the computational time are also discussed.

■ WB4

Wednesday, 10:30-12:00, MDCL 1110

New Optimization Models and Techniques for Data Clustering

Stream: Data Mining and Machine Learning

Chair: *Jiming Peng*, Department of IESE, UIUC

A session to honour the memory of Peter L. Hammer.

1. **Recent Advances in Logical Analysis of Data**

   Tiberius Bonates, Rutgers Center for Operations Research (RUTCOR)

Logical Analysis of Data (LAD) is a classification method based on Boolean optimization, combinatorics and logic. LAD was first proposed in Hammer (1986) and Crama and Hammer (1988), and further developed in a series of papers (Boros et al. (1997, 2000), Alexe et al. (2001,2002,2003,2006), Bonates and Hammer (2006)). In this talk we present some of the latest developments in LAD, with an emphasis on the application of column generation for constructing large margin classifiers and for extending the LAD methodology to deal with regression problems. We report on computational experience with the application of the proposed algorithms to commonly used benchmark problems from the machine learning literature. Finally, we comment on some of the current research on LAD.

2. **Exploiting separability for large-scale Support Vector Machine training**

   Kristian Woodsend, School of Mathematics, Edinburgh University

We present a formulation for Support Vector Machine training problems, suitable for both linear and non-linear kernels, that exploits separability of the Hessian while keeping a small number of constraints. For large dense data sets of l samples and k attributes, where $l >> k$, a single iteration of the algorithm has an overall complexity of $O(lk^2)$. Our approach can be applied to 1-norm classification, 2-norm classification and epsilon-insensitive regression, and it can be adapted for parallel processing to handle massive datasets. Numerical experiments using real-world and artificial datasets confirm performance, and show that, unlike state-of-the-art SVM software based on active set methods which are greatly affected by the level of noise in the data, our formulation completes in a predictable amount of time; for example, training time of the SensIT dataset was reduced by a factor of 50.

3. **Refining Spherical K-Means for Clustering Documents**

   Jiaping Zhu, Computational Engineering and Science, McMaster University, *Jiming Peng*

Spherical k-means is a popular algorithm for document clustering. However, it may still yield poor performance in some circumstances. In this paper, we consider a discrete optimization model for spkmeans. By using the convexity of objective function and specific structure of constraint set, we first reformulate the discrete problem as an equivalent convex maximization problem with linear constraints. Then we characterize the local optimality of relaxed problem. Based on the characteristics, we refine the spherical k-means algorithm by alternatively performing spherical k-means and switching data points between clusters. This strategy guarantees that the refined algorithm can always attain a local optimal solution.

4. **Optimization models and techniques for clustering**

   Jiming Peng, Department of IESE, UIUC

In this talk, we will briefly review some emerging optimization models and challenges in cluster analysis, and discuss the solving techniques for these problems.

■ WB5

Wednesday, 10:30-12:00, MDCL 1016

Derivative-Free Optimization Methods that Model the Objective Function without Taylor Approximations

Stream: Derivative Free Optimization

Chair: *Dick den Hertog*, Department of Econometrics & Operations Research, Tilburg University

1. **On the number of interpolation points when constructing quadratic models for minimization without derivatives**

   Michael Powell, DAMTP, University of Cambridge

The author has developed the NEWUOA software for minimization without derivatives. Most changes to the variables are derived by trust region methods that use quadratic models of the objective function. When a model is updated, the new model has to satisfy m interpolation conditions, and any freedom is taken up by minimizing the Frobenius norm of the change to the second derivative matrix of the model. Usually the author picks $m = 2n + 1$, where n is the number of variables. The work per iteration is only of magnitude $(m+n)^2$, which has allowed several test problems with over 100 variables to be solved successfully. At the time of writing this abstract, the author has begun to investigate the merits and disadvantages of other choices of m. A report on the progress of this research will be presented.

2. **Recent results on trust region methods for deriviative free optimization**

   Andrew R. Conn, Watson Research Center, *Katya Scheinberg*, *Luís Vicente*

I will present some recent results on derivative free optimization that have broader implications than the title might suggest and that do in fact relate to Taylor series approximations.

3. **Optimization by Radial Basis Function Interpolation in Trust Regions**

   Stefan Wild, Cornell University, School of ORIE, *Christine Shoemaker*, *Rommel Regis*

We present a new derivative-free algorithm, ORBIT, for unconstrained local optimization of computationally expensive functions. A trust region framework using interpolating Radial Basis Function (RBF) models is employed similar to that proposed by Oeuvray and Bierlaire. Such RBF models often allow the algorithm to approximate nonlinear functions using fewer function evaluations than the polynomial models considered by present techniques. The recent work of Conn, Scheinberg, and Vicente can be used to prove global convergence to a first-order stationary point. While this result is encouraging, in practice the computational expense of the objective function will prevent convergence. We present numerical results on test problems and an Environmental Engineering application to motivate the use of ORBIT when only a relatively small number of expensive function evaluations are available.

■ WB6

Wednesday, 10:30-12:00, MDCL 1309

Novel MPEC Algorithms

Stream: MPECs/Complementarity Problems

Chair: *Todd Munson*, MCS Divsion, Argonne National Laboratory

1. **On the global solution of linear programs with linear complementarity constraints**

   Jing Hu, Department of Mathematical Sciences, RPI, *Jong-Shi Pang*

We present a parameter-free integer-programming based algorithm for the global solution of a linear program with linear complementarity constraints. The cornerstone of the algorithm is a minimax integer program formulation that characterizes and provides certificates for the three outcomes-infeasibility, unboundedness, or solvability. An extreme point/ray generation scheme in the spirit of Benders decomposition is developed, from which valid inequalities in the form of satisfiability constraints are obtained. We establish the finite termination of the algorithm and report computational results using the algorithm for solving randomly generated problems of reasonable sizes. The results establish that the algorithm can handle infeasibility, unbounded, and solvable models effectively.

2. **An active set method for mathematical programs with linear complementarity constraints**

   Lifeng Chen, Industrial Engineering and Operations Research, Columbia University, *Donald Goldfarb*

We study mathematical programs with linear complementarity constraints (MPLCC) for which the objective function is smooth. Here we propose a primal-dual active set projected Newton method for MPLCCs, which maintains the feasibility of all iterates. At every iteration the method generates a working set for predicting the active set. The projected step direction on the subspace associated with this working set is determined by the current dual iterate; while other elements in the step direction are computed by a Newton system. Our method has strong convergence properties. In particular, under the MPLCC-linear independence constraint qualification (LICQ), any accumulation point of the generated iterates is a B-stationary solution (i.e., a first-order solution) to the MPLCC.

3. **Soving Multi-Leader-Common-Follower Games**

   Todd Munson, MCS Divsion, Argonne National Laboratory, *Sven Leyffer*

Multi-leader-common-follower games arise when modeling two or more competitive firms, the leaders, that commit to their decisions prior to another group of competitive firms, the followers, that react to the decisions made by the leaders. These problems lead in a natural way to equilibrium problems with equilibrium constraints (EPECs). We develop a characterization of the solution sets for these problems and examine a variety of nonlinear optimization and nonlinear complementarity formulations of EPECs. We distinguish two broad cases: problems where the leaders can cost-differentiate and problems with price-consistent followers. We demonstrate the practical viability of our approach by solving a range of medium-sized test problems.

■ WB7

Wednesday, 10:30-12:00, MDCL 1009

Derivative-free Nonlinear Programming

Stream: Nonlinear Optimization Software

Chair: *Joshua Griffin*, Sandia National Laboratories

1. **A derivative-free approach for solving system of nonlinear equations**

   Hongchao Zhang, Institute for Mathematics and Its applications, USA, *Andrew R. Conn*, *Katya Scheinberg*

In this talk, we discuss an approach to solve the following system of nonlinear equations: $f_i(x) = 0, i = 1, \ldots, m$, where $x \in R^n$ and $f_i : R^n \to R$, $i = 1, \ldots, m$, are nonlinear functions, but their derivatives are not available. This problem arises frequently and becomes more important in computational science and engineering. We apply Powell' s least Frobenius norm updating strategy to asymptotically build at least fully-linear models for each f_i. With the help of these approximation models, a generalized Levenberg-Marquardt approach is applied for minimizing the least squares residue of the problem. Numerical results indicating this approach is very promising compared with using NEWUOA (Powell, 2004) for the least squares minimization directly and performs more efficient and stable than LMDIF (Moré etc., 1980). Performances of the algorithm for system of nonlinear equations with noise will also be discussed.

2. **Statistical guidance for robust pattern search**

   Matt Taddy, UCSC

We have augmented pattern search optimization with the statistical guidance of a Treed Gaussian Process (TGP) emulator to create a new hybrid algorithm for more robust local optimization. I will describe the TGP model and the resulting hybrid method, and we will present some results. The TGP emulator will also be used to provide sensitivity analysis and a probabilistic analysis of convergence.

3. **Derivative-free Optimization Methods in DAKOTA with Applications**

   Brian Adams, Sandia National Laboratories

DAKOTA is a Sandia National Laboratories toolkit for optimization, uncertainty quantification, and sensitivity analysis with large-scale computational models. It includes algorithms for optimization, uncertainty quantification, parameter estimation with nonlinear least squares, and sensitivity/variance analysis with DOE and parameter study capabilities. Through strategies, these algorithms may be combined with each other and/or with surrogate models. I will survey the DAKOTA framework and methods available through it, focusing on global and derivative-free optimization methods, and in particular, new capabilities enabled by integration of the templated metaheuristics framework (J. Watson). I will demonstrate combination of derivative-free methods with surrogates, use in efficient global reliability assessment (B.J. Bichon), and application to reliability-based design optimization of micro-electro-mechanical systems. DAKOTA is freely available from `http://www.cs.sandia.gov/DAKOTA`.

■ WB8

Wednesday, 10:30-12:00, MDCL 1010

Multilevel and Distributed Optimization

Stream: Engineering Optimization

Chair: *Philippe Toint*, FUNDP University of Namur, Belgium

1. **Solving the Trust-Region Subproblem Using Multilevel Techniques**

   Dimitri Tomanos, FUNDP - University of Namur

We propose a new technique to be used along with multilevel methods that solves the trust-region subproblem by applying a multilevel version of the MorÃl'-Sorensen method. The main advantage of this approach is to have more insight on the elimination of the error. We present here the new method, some numerical results and possible future discussions.

2. **Using aggregate gradients in Hessian updates for partially separable unconstrained optimization**

   Vincent Malmedy, FUNDP - University of Namur, Belgium

In quasi-Newton methods, dense Hessian updates represent a main obstacle to solve large-scale unconstrained optimization problems because of the limited memory capacities. Fortunately, these problems often have a partially separable structure. We present an Hessian update that takes advantage of this property without requiring the knowledge of the corresponding gradient decomposition. Convergence properties are shown as well as some numerical experiences inside a recursive multilevel trust-region algorithm. A better integration in this framework is currently under investigation by conceiving a positive-definite update and by trying to use information from several levels.

3. **Low-Complexity Distributed Power Optimization for DSL Networks**

   Paschalis Tsiaflakis, ESAT-SCD, K.U.Leuven

Modern DSL networks suffer from significant crosstalk between different lines in the same cable bundle. This crosstalk can lead to a major performance degradation. By optimizing the transmit powers, the impact of crosstalk can be minimized leading to spectacular performance gains. In this work, a Karush-Kuhn-Tucker (KKT) perspective is presented on state-of-the-art distributed power optimization algorithms. Furthermore a novel low-complexity distributed algorithm is proposed based on the KKT conditions of the nonconvex transmit power optimization problem. The algorithm is compatible with current state-of-the-art DSL hardware and outperforms existing distributed algorithms.

■ WB9

Wednesday, 10:30-12:00, MDCL 1008

PDE Constrained Optimization

Stream: PDE Constrained Optimization
Chair: *Michael Ulbrich*, TU Muenchen
Session organizer: Ekaterina Kostina

1. **PDE Constrained Optimization Using Efficient High Level Abstraction-Based Simulation tools**

   Bart van Bloemen Waanders, Sandia National Laboratories, *Kevin Long*, *Judith Hill*

Large scale PDE constrained optimization provides for an efficient way to solve large optimization problems constrained by complex physics. Unfortunately, significant implementation costs are associated with enabling the necessary linear objects within simulation codes. This is especially daunting when dealing with large monolithic production codes. In this talk, we present a symbolic approach to PDE constrained optimization that makes use of high level abstraction syntax to specify the finite element weak form of PDE based equations. The 'Nihilo/Sundance' toolkit is able to parse simple notation for PDE operators and generate three dimensional, parallel simulation codes. Central to Nihilo is a capability to efficiently perform large scale PDE constrained optimization by deriving the optimality conditions and specifying the resulting equations in the finite element weak form. We demonstrate Nihilo on an interface tracking problem, using level set and optimization algorithms.

2. **Length-scale and spatial locality effects in the optimization of systems**

   Robert Lewis, Department of Mathematics, College of William and Mary

We discuss locality in length-scale and space in the optimization of systems governed by differential equations. These analytical features have consequences for the development of multi-scale/multigrid optimization schemes. We present analytical and numerical results that suggest why, in some cases, multi-scale methods will be effective for such optimization problems, and discuss why, in other situations, an element of domain decomposition may be more appropriate.

3. **Optimal control problems with L^1 control cost and applications for the placement of control devices**

   Georg Stadler, ICES, UT Austin

We analyze optimal control problems with L^1-control cost. Due to the nonsmooth objective functional, the optimal controls are identically zero on large parts of the control domain. For applications, in which one cannot spread control devices (or actuators) all over the domain, this provides information about where it is most efficient to put them. Structural properties of L^1 control cost solutions are discussed. Model problems are solved solved using a semismooth Newton method. By means of numerical tests we show the usefulness of the approach for the location of control devices and discuss the efficiency of the algorithm.

■ WS1

Wednesday, 1:30-2:30, MDCL 1305

Semi-plenary presentation

Stream: Conic Programming and Interior Point Methods
Chair: *Mike Powell*, DAMTP, University of Cambridge

1. **Large Scale Optimization with Interior Point Methods**

   Jacek Gondzio, School of Mathematics, University of Edinburgh, *Andreas Grothey*

In this talk we will demonstrate that interior point methods are well-suited to solve very large linear, quadratic and nonlinear programming problems. We will show that the key to solve truly large problems is the ability to understand and exploit their structural properties. Examples of optimization problems arising in different areas of applications will be given.

■ WS2

Wednesday, 1:30-2:30, MDCL 1307

Semi-plenary presentation

Stream: Robust Optimization
Chair: *Stephen J. Wright*, Computer Sciences Department, University of Wisconsin

1. **New robust optimization models for addressing stochastic optimization problems**

   Melvyn Sim, National University of Singapore, Singapore-MIT Alliance

A classical robust optimization model assumes that data uncertainty belongs to an uncertainty set and its solution is optimal under the worst-case scenario that might arise within the uncertainty set. Such worst-case solution can be rather conservative in addressing a stochastic programming problem. We show that with additional distributional information, such as independence, known means and bounded supports, standard deviations, bounds on moment generating functions, we can make a robust optimization model less conservative, while keeping it computationally tractable in the form of SOCP. We propose new robust optimization models that approximate hard stochastic programming problems including joint chance constrained problems with recourse and multiperiod dynamic optimization problems. We report computational results comparing solutions obtained from using the robust optimization models with solutions obtained from using sampling approximation of the stochastic programming problems.

■ WS3

Wednesday, 1:30-2:30, MDCL 1105

Semi-plenary presentation

Stream: Stochastic Programming
Chair: *Bartosz Protas*, McMaster University

1. **Emerging design challenges in the advanced nuclear fuel cycle**

   Mihai Anitescu, Argonne National Laboratory

Advanced simulation plays a central role in the recently launched global nuclear energy partnership (GNEP). GNEP is an initiative whose purpose is to design a nuclear fuel cycle that enhances energy security, promotes nonproliferation while enabling recycling and consumption of long-lived radioactive waste. We present some of the emerging design challenges of the advanced nuclear fuel cycle, with a particular emphasis on the ones posed by core design and waste reprocessing. Both activities are described by complex multi-physics models with uncertain parameters. In this context, we will discuss some of our initial investigations of using stochastic finite elements for the description of parametric uncertainty.

■ WC1

Wednesday, 2:45-4:15, MDCL 1305

Selected Topics in Conic Programming

Stream: Conic Programming and Interior Point Methods
Chair: *Simon Schurr*, Department of Combinatorics and Optimization, University of Waterloo

1. **An Efficient Re-scaled Perceptron Algorithm for Conic Systems**

   Alexandre Belloni, Duke University, *Robert M. Freund*, *Santosh Vempala*

The classical perceptron algorithm is an elementary algorithm for solving a homogeneous linear inequality system $Ax > 0$. A natural condition measure associated with this algorithm is the Euclidean width t of the cone of feasible solutions, and the iteration complexity of the perceptron algorithm is bounded by $1/t^2$. Dunagan and Vempala have developed a re-scaled version of the perceptron algorithm with an improved complexity of $O(n\ln(1/t))$ iterations (with high probability). We explore extensions of the concepts of these perceptron methods to the general homogeneous conic system $Ax \in K$ where K is a regular convex cone. We provide a conic extension of the re-scaled perceptron algorithm based on the notion of a deep-separation oracle of a cone. We give a general condition under which the re-scaled perceptron algorithm is theoretically efficient, i.e., polynomial-time; this includes the cases when K is the cross-product of second-order cones, and the positive semi-definite cone.

2. **Strong Duality and Embedding Methods for Semidefinite Programming**

   Qinghong Zhang, Northern Michigan University

In this talk, duals for standard semidefinite programming problems from both the primal and dual sides are formulated. Explicit expressions of the minimal cones and their dual cones are obtained. Under some assumptions imposed on certain sets, duality formulations resulting from regularizations for both primal and dual problems can be expressed explicitly in terms of equality and inequality constraints involving three vector and matrix variables. Like the Extended Lagrange-Slate Dual, the newly developed duals guarantee strong duality. These new duals can be used in the analysis of embedding strategies for solving a semidefinite programming problem (in either primal or dual form).

3. **Strong Duality and Stability in Conic Convex Optimization**

   Simon Schurr, Department of Combinatorics and Optimization, University of Waterloo, *Levent Tunçel*, *Henry Wolkowicz*

For nonlinear convex optimization problems, in the absence of a constraint qualification strong duality need not hold. Moreover, constraint qualifications are closely tied to numerical stability and well posedness. The Extended Lagrange Slater dual of Ramana is an SDP dual for which strong duality holds without a constraint qualification. We explain when an extension of Ramana's algorithm to general conic convex problems efficiently computes a strong dual. We also give other strong duals that do not require a constraint qualification, and that are defined solely in terms of the data of the given problem. We then present an algorithm that solves in an efficient and stable way feasible conic convex optimization problems, including those for which the Slater constraint qualification fails. Necessary and sufficient conditions for a finite nonzero duality gap are given, and it is shown how these can be used to generate instances satisfying this property. Numerical tests are included.

■ WC2

Wednesday, 2:45-4:15, MDCL 1307

Nonsmooth Analysis and Application

Stream: Convex and Nonsmooth Analysis
Chair: *Shawn Wang*, Mathematics, UBC Okanagan

1. **New calculus results for Clarke subgradient and convexified coderivatives in reflexive spaces**

   Hoang Nguyen, Wayne State University, *Boris Mordukhovich*, *Nam Nguyen*

Using recent developments and techniques in variational analysis, we establish new results on generalized differential calculus for convex-valued normal/coderivative/subgradient constructions for sets, set-valued mappings, and nonsmooth functions in reflexive Banach spaces. The results obtained particularly extend known calculus rules for Clarke generalized gradients in both finite-dimensional and infinite-dimensional settings.

2. **Extended coderivative and subdifferential calculus in smooth Banach spaces**

   Hung Phan, Wayne State Univeristy, *Boris Mordukhovich*, *Mau Nam Nguyen*

In this talk, we study generalized differential properties of set-valued mappings and extended real-valued functions. First, we introduce the intersection rule for viscosity normal cones in smooth Banach spaces. The results obtained allow us to develop new calculus rules for viscosity coderivatives of set-valued mappings and subdiferentials of extended real-valued functions in a convenient way.

3. **Variational Analysis of Pseudospectra**

   Chin How Jeffrey Pang, Center for Applied Mathematics, Cornell University

An important tool for analyzing and designing robust properties of non-normal matrices, the pseudospectrum of a square matrix A is the set of eigenvalues attainable when A is perturbed within some fixed spectral distance. We characterize Lipschitz continuity of the pseudospectrum, as a set-valued function of A. With this technique, we deduce Lipschitz properties of the pseudospectral abscissa - the largest real part of elements in the pseudospectrum, and, analogously, the pseudospectral radius. Our approach nicely illustrates diverse techniques of modern variational analysis. Pseudospectral Lipschitz behavior fails exactly at critical points of the resolvent norm, which in turn are related to coalescence points of pseudospectral components.

■ WC3

Wednesday, 2:45-4:15, MDCL 1105

Continous Approach to Combinatorial Problems

Stream: Linear, Semidefinite and Conic Optimization
Chair: *Antoine Deza*, McMaster University

1. **Exploiting algebraic symmetry in semidefinite programming relaxations of the quadratic assignment problem**

   Etienne de Klerk, Dept. Econometrics and OR, Tilburg University, *Renata Sotirov*

The quadratic assignment problem (QAP) contains the travelling salesman problem as a special case and even small instances are notoriously difficult to solve in practice. Semidefinite programming provides some of the strongest convex relaxations of QAP, but the SDP instances are in turn difficult to solve due to their large sizes. In this talk we show how to exploit algebraic symmetry of the cost matrices when present, in order to greatly reduce the size of the SDP relaxations. This approach has allowed us to compute the best known bounds for a number of instances from QAPLIB, a library of QAP instances.

2. **Approach to the realizability problem of oriented matroids by seminidefinite programming**

   Sonoko Moriyama, Graduate School of Information Science and Technology, University of Tokyo, *Hiroshi Imai*, *Hiroyuki Miyata*

Oriented matroids (OMs) are combinatorial abstraction of geometric configurations. One of the important problems in OMs is to decide whether a given OM has a geometric configuration. This realizability problem is known to be NP-hard. Even though it is generally hard to prove the realizability of OMs, there are cases where the relizability and non-realizability is efficiently proven with simple certificates. In this talk, we focus attention on one of such certificates, biquadratic final polynomials (BFP). BFP is a method to determine non-realizability of OMs by relaxing Grassmann-Plücker relations by linear programs in a special manner, and seems to be especially powerful method for determining non-realizabity of OMs. On the other hand, there exists a non-realizable OM which is not decided by BFP. Then, in order to find non-realizable OMs not determined by BFP, we propose a new certificate to decide non-realizabilty of OMs by relaxing the G.P. relations by semidefinite programming.

3. **Polytopes and Arrangements: Diameter and Curvature**

   Antoine Deza, McMaster University, *Tamás Terlaky*, *Yuriy Zinchenko*

By analogy with the conjecture of Hirsch, we conjecture that the order of the largest total curvature of the central path associated to a polytope is the number of inequalities defining the polytope. By analogy with a result of Dedieu, Malajovich and Shub, we conjecture that the average diameter of a bounded cell of an arrangement is less than the dimension. We prove continuous analogues of two results of Holt-Klee and Klee-Walkup: we construct a family of polytopes which attain the conjectured order of the largest total curvature, and we prove that the special case where the number of inequalities is twice the dimension is equivalent to the general case. We substantiate these conjectures in low dimensions and highlight additional links.

■ WC4

Wednesday, 2:45-4:15, MDCL 1110

Optimization and Data Mining

Stream: Data Mining and Machine Learning
Chair: *Tiberius Bonates*, Rutgers Center for Operations Research (RUTCOR)

A session to honour the memory of Peter L. Hammer.

1. **A Branch-and-Prune Algorithm for the Discretizable Molecular Distance Geometry Problem**

   Carlile Lavor, Department of Applied Mathematics - State University of Campinas, *Leo Liberti*, *Nelson Maculan*

The molecular distance geometry problem (MDGP) can be defined as finding the Cartesian coordinates of the atoms of a molecule given some atom pairs whose distances are known. Usually, the MDGP is formulated as a continuous global minimization problem, where the number of local minimizers increases exponentially in terms of the size of the molecule. The MDGP arises in NMR analysis which provides a set of inter-atomic distances for a protein. The backbone chain of a protein is a linear atom ordering such that the distances related to the atom pairs $(i,i+1)$ and $(i,i+2)$ are known. Under the additional (realistic) assumption that NMR analysis can provide at least all distances between atom pairs $(i,i+3)$, we can show that the MDGP can be discretized yielding a fast branch-and-prune algorithm.

2. **Extensions of Logical Analysis of Data for Medical Applications**

   Pierre Lemaire, IRCCyN / Ecole des Mines de Nantes

Logical Analysis of Data (LAD) has already been applied on several biomedical applications [Bonates and Hammer, 2006]. In this talk we shall present two developments designed to cope with new requirements. For a problem of height-loss due to irradiation during childhood, we shall show how Combinatorial regression - an extension of LAD to numerical outputs (instead of the classical binary ones) - allowed to precisely characterize the influences of several variables for a problem of height-loss due to irradiation during childhood. For the diagnosis of growth hormone deficiency, there is a need for very simple (e.g., straightforwardly usable by a GP) and accurate classifiers. We shall show an the concept of Functional patterns allowed to meet this requirement by aggregating many Boolean patterns into one single (non-binary) condition.

3. **An Empirical Study of Bagging LAD for Medical Datasets**

   Anupama Reddy, Rutgers Center for Operations Research (RUTCOR), *Gabriela Alexe*

Logical Analysis of Data (LAD) is a combinatorics and optimization based data mining methodology. LAD has been very successfully applied to a wide array of classification problems. In this study, we focus on applying LAD to medical and biological datasets. In most cases, such datasets are very noisy. Thus, classifiers built on these datasets tend to be unreliable and have low accuracies. In order to overcome these problems, we apply the concepts of Bagging to LAD, i.e. we build LAD classifiers on random samples taken from the training dataset and then integrate these classifiers by computing the weighted mean values of the discriminant scores, where the weights are the out-of-bag accuracies of the corresponding models. To validate this methodology we perform a large empirical study on several different categories of medical datasets: clinical, image, genetic, and SNP array data.

■ WC5

Wednesday, 2:45-4:15, MDCL 1016

Heuristics for Global Optimization

Stream: Special Purpose Heuristics and General Metaheuristics
Chair: *John Chinneck*, Systems and Computer Engineering, Carleton University

1. **GRASP for continuous global optimization**

   Michael Hirsch, Raytheon, Inc., Net-Centric Systems, *Panos Pardalos*, *Mauricio Resende*

We describe a method adapted from Feo and Resende's GRASP metaheuristic, first proposed for solving combinatorial optimization problems, to solve global optimization problems with continuous objective functions and box constraints. In computational experiments, the algorithm is shown to avoid the trappings of local minima, always converging to a global minimum. This method is very easy to implement, is applicable to any global optimization problem, and does not make use of derivative information, thus making it a well-suited general approach for solving global optimization problems. We compare our approach with several other heuristics on a set of benchmark test functions. In addition, we also discuss the application of our approach to some real-world challenging problems.

2. **Developments in the AMIGO Solver for General Mixed Integer Optimization**

   Zsolt Ugray, Utah State University, Logan, UT, USA, *János D. Pintér*

We introduce AMIGO, an Advanced Mixed Integer Global Optimizer. AMIGO incorporates the LGO (Lipschitz Global Optimizer) solver suite for continuous global/local optimization, enhanced by strategies for handling integer variables. We discuss the algorithmic framework and show illustrative numerical examples.

3. **A steering heuristic towards the optimization of a function subject to convex constraints**

   Ran Davidi, Computer Science, Graduate Center, CUNY, *Gabor Herman*

We recently proposed a class of iterative methods that in each iteration apply a combination of projections towards a feasible region determined by given convex sets. In each iterative step, the algorithms are allowed to perturb the existing point before applying the next combination of projections. We proved that each of the algorithms in the proposed class is guaranteed to converge to a point of the feasible region, provided only that the perturbations that are applied satisfy some mild restrictions. The freedom in the choice of the perturbations opens up a plethora of heuristics for optimizing a given function subject to the convex constraints, by selecting the perturbations so that they steer the iterative process towards the optimizer of the given function. We illustrate the approach by applying it to an image processing problem of tomographic reconstruction from projections in which the minimization of total variation (or another similar function) is required.

■ WC6

Wednesday, 2:45-4:15, MDCL 1309

Applications of Global Optimization

Stream: Global Optimization
Chair: *Miguel Anjos*, Department of Management Sciences, University of Waterloo

1. **Complexity issues for Nonnegative Matrix Factorization**

   Stephen Vavasis, Combinatorics & Optimization, U. Waterloo, *Ali Ghodsi*, *Michael Biggs*

Nonnegative matrix factorization (NMF) is emerging as an important tool for data analysis and classification, particularly for image and text datasets. The problem is often posed as an optimization problem, namely, minimize the norm distance of the product of two low-rank nonnegative matrices to a given nonnegative matrix A that encodes the data. We consider the NMF problem from a slightly different "greedy" point of view and establish positive and negative results on the complexity of solving the problem.

2. **Solution of the Kissing Number problem by Quasi Monte Carlo variant of the Multi Level Single Linkage method**

   Sergei Kucherenko, Centre for Process Systems Engineering, Imperial College London. UK

Two different mathematical programming formulations to the kissing number problem (KNP) are presented. The Kissing Number is defined as the maximum number of D-dimensional spheres of radius r that can be placed adjacent to a central sphere of the same radius. A novel global optimization method for solving large-scale nonlinear and continuous mixed-integer problems is developed and applied to KNP. This method combines some of the advantages of deterministic and stochastic methods. It is based on the application of Sobol' sequences to multi-level single linkage methods (MLSL). It is shown that the application of Sobol' sequences can significantly increase the efficiency of MLSL. A C++ solver called SobolOpt employing the developed technique is applied to a number of test and practical problems of various complexities. Numerical results for the KNP for dimensions up to 4 and new solutions to the coordination number problem for dimensions up to 8 are presented.

3. **Globally optimal and near-optimal solutions for large single-row facility layout problems**

   Miguel Anjos, Department of Management Sciences, University of Waterloo, *Anthony Vannelli*

We are concerned with the single-row facility layout problem (SRFLP), which asks for a linear placement of rectangular facilities with varying lengths on a straight line so as to minimize the total cost associated with the (known or projected) interactions between facilities. We construct a suitable semidefinite programming relaxation, prove some of its theoretical properties, and use it to obtain the first globally optimal layouts for large SRFLPs with up to 30 departments, some of which have been studied in the literature since 1988. This approach is now being extended to provide nearly-optimal solutions to SRFLPs with up to 100 departments. Our latest results will be reported.

■ WC7

Wednesday, 2:45-4:15, MDCL 1009

State-of-the-Art in NLP Software

Stream: Nonlinear Optimization Software
Chair: *Hans Mittelmann*, Dept. Math Stats, Arizona State University

1. **Current progress in the code PENNLP**

   Michal Kočvara, School of Mathematics, University of Birmingham, *Jan Fiala*, *Michael Stingl*

Recent development in the nonlinear programming code PENNLP will be presented. The code is based on a generalized augmented Lagrangian algorithm and is intended to solve large scale nonconvex problems. The current development includes mainly the use of iterative solvers for the solution of the Newton system, direct treatment of equality constraints and the implementation of the filter method. Results of extensive numerical studies will be presented.

2. **TOMLAB - Large-Scale Optimization in MATLAB, LABVIEW and .NET**

   Kenneth Holmström, Mathematics and Physics, Mälardalen University, *Marcus Edvall*

The optimization environment TOMLAB, `http://tomopt.com`, has seen a tremendous growth during the last years. Most state-of-the-art optimization software has been hooked up, e.g. KNITRO, SNOPT and CONOPT for large-scale nonlinear programming, and CPLEX and Xpress-MP for large-scale mixed-integer programming. Unique tools for global black-box mixed-integer nonconvex problems have been developed. Originally developed for MATLAB, now TOMLAB is available for LabView as TOMVIEW and .NET as TOMNET. TOMLAB is interfaced with the modelling language AMPL and the DIFFPACK package for advanced PDE solutions. This talks gives an overview over the latest developments.

3. **FilMINT: A linearizations-based MINLP solver**

   Kumar Abhishek, Industrial Engg., Lehigh University

We describe a new solver for mixed integer nonlinear programs that implements a linearizations-based algorithm in a branch-and-cut framework. The new solver, FilMINT, uses the MINTO branch-and-cut framework for solving the MILP, and filterSQP, an active set solver, for solving the nonlinear programs that arise as subproblems in the algorithm. We use the advanced features of the MILP framework and present detailed computational experiments that show the benefit of these techniques. We offer new suggestions for generating and managing linearizations that are shown to be efficient on a wide range of MINLPs. Detailed computational experiments and comparisons to existing MINLP solvers are presented, highlighting the framework's effectiveness.

■ WC8

Wednesday, 2:45-4:15, MDCL 1010

Multilevel Optimization

Stream: Engineering Optimization
Chair: *Philippe Toint*, FUNDP University of Namur, Belgium

1. **Multilevel infinite-norm trust-region method for bound-constrained optimization**

   Melodie Mouffe, CERFACS, Toulouse, France, *S. Gratton*, *Ph. L. Toint*, *M. Weber Mendonca*

This talk will consider multilevel infinite-norm trust-region for both unconstrained and bound-constrained optimization. We will develop the reasons why the use of infinite norm trust-region improves the multilevel Euclidian-norm trust-region algorithm designed by S. Gratton, A. Sartenaer and Ph. L. Toint. We will also detail the design of the coarse problem, especially the management of bound constraints. Convergence is proved to first-order critical points from arbitrary starting points. Preliminary numerical results are very encouraging on both unconstrained problems and bound-constrained problems.

2. **A Line search Multigrid Method for Large-Scale Convex Optimization**

   Zaiwen Wen, Department of Industrial Engineering and Operations Research at Columbia University, *Donald Goldfarb*

We present a multigrid line search method based on Nash's MG/OPT multilevel optimization approach for solving discretized versions of convex infinite dimensional optimization problems. Global convergence is proved under fairly minimal requirements on the minimization method used at all grid levels. In particular, our convergence proof does not require that these minimization, or so-called "smoothing" steps, which we interpret in the context of optimization, be taken at each grid level in contrast with multigrid algorithms for PDEs which fail to converge without such steps. Preliminary numerical experiments show that our method is promising.

3. **A multilevel limited-memory method**

   Philippe Toint, FUNDP University of Namur, Belgium

We present a technique that allows the exploitation of the multilevel structure of certain unconstrained optimization problems that arise in connexion with the solution of PDEs. The method is an extension of the limited-memory quasi-Newton method. It uses the propagation of approximate secant equations to and from the lower levels, thereby potentially adding more than one new secant information for a single difference in gradients at the fine level. Some numerical results are presented that suggest a substantial gain in efficiency for problems of suitable eigenstructure.

■ WC9

Wednesday, 2:45-4:15, MDCL 1008

Implementations and Interior-Point Methods

Stream: Interior Point Methods and Implementations
Chair: *Jean-Pierre Dussault*, Département d'informatique

1. **Convergence of truncated half-quadratic and Newton algorithms**

   Christian Labat, Johns Hopkins, *Jerome Idier*

We address the minimization of penalized least squares (PLS) criteria customarily used for edge-preserving restoration and reconstruction of signals and images. This framework embodies medical applications such as X-ray tomography, ultrasound deconvolution and MRI denoising. The minimization of PLS criteria can be addressed using a half-quadratic (HQ) scheme. In the case of large-scale problems, the cost of the HQ approach is usually too high. In practice, it is rather proposed to implement an inexact HQ algorithm using a truncated conjugate gradient (TCG) method. This principle echoes that of truncated-Newton algorithms. Our contribution is to establish the convergence of the resulting truncated algorithms (HQ or Newton), under the same conditions required for the exact HQ scheme. Indeed, convergence is granted whatever the number of performed iterations of TCG. According to our experimental study on a deconvolution problem, the fastest versions correspond to severe truncation.

2. **Interior-Point Methods for Dynamic Optimization**

   Alexandre Caboussat, Department of Mathematics, University of Houston

Dynamic optimization problems arise when coupling an optimization problem with ordinary differential equations. We present a numerical method for the resolution of a dynamic optimization problem arising in the modeling of the dynamics of an atmospheric aerosol particle. The optimization problem for the determination of the global minimum of energy of the particle is treated with a primal-dual interior-point method. The ordinary differential equations are discretized in time with an implicit scheme and coupled with the KKT system of nonlinear equations that consists of the first order optimality conditions. An extended primal-dual interior-point method is used at each time step. Sequential quadratic programming techniques are used to decouple and solve the KKT Newton system. Tracking techniques of the time of activation/deactivation of inequality constraints are proposed. Numerical results are presented for one organic aerosol particle and warm-starting techniques are discussed.

3. **First, second and higher order methods for nonlinear optimization**

   Jean-Pierre Dussault, Département d'informatique

We survey variants of first, second and higher order methods that were proposed to solve optimization problems. We will focus on unconstrained problems in this talk. Taking advantage of results from automatic differentiation to estimate the computing costs for obtaining function values, gradients, and higher order derivative of the relevant functions, we discuss the expected strengths and weaknesses of the algorithms. In particular, a common folklore recommendation, namely "if second derivative are available, use a modified Newton's method" appears questionable, even for small-scale problems. Our presentation proposes some explanations for this phenomenon, sometimes previously observed, but to our knowledge, not yet fully understood.

■ WD1

Wednesday, 4:45-6:15, MDCL 1305

Sensor Networks and Graph Realization

Stream: Conic Programming and Interior Point Methods
Chair: *Abdo Y. Alfakih*, Univ. of Windsor

1. **Sensor Network Localization, Euclidean Distance Matrix Completions, and Graph Realization**

   Nathan Krislock, Combinatorics and Optimization, University of Waterloo, *Yichuan Ding*, *Jiawei Qian*, *Henry Wolkowicz*

We study Semidefinite Programming, SDP, relaxations for Sensor Network Localization, SNL, with anchors and with noisy distance information. The main point of the paper is to view SNL as a (nearest) Euclidean Distance Matrix, EDM , completion problem and to show the advantages for using this latter, well studied model. We first show that the current popular SDP relaxation is equivalent to known relaxations in the literature for EDM completions. The existence of anchors in the problem is not special. The set of anchors simply corresponds to a given fixed clique for the graph of the EDM problem. We next propose a method of projection when a large clique or a dense subgraph is identified in the underlying graph. This projection reduces the size, and improves the stability, of the relaxation.

2. **A Semidefinite Programming Approach to Graph Realization**

   Yinyu Ye, Stanford University, *Anthony So*

It is a trivial matter to see that given the coordinates of n points in R^k, the distance between any two points can be computed efficiently. However, the inverse problem — given a subset of interpoint distances, find the coordinates of points (called a realization) in R^k (where $k \geq 1$ is fixed) that fit those distances — turns out to be anything but trivial. This problem arises from many applications, such as sensor network localization and molecular conformation. Recently, Biswas and Ye (2004) have proposed a semidefinite programming (SDP) based model for the problem, and So and Ye (2005,2006) have analyzed its theoretical properties. In this talk, we will first review some of those properties. In particular, we will discuss the notion of unique k-realizability, as well as a connection between the SDP model and the theory of tensegrities in discrete geometry. Then, we will present two recent results. First, we demonstrate the existence of uniquely k-realizable instances with the property that the graphs are sparse. This refutes a common belief in the sensor network literature, namely that the graph of a uniquely k-realizable instance must be dense. Second, we show that the Maximum Variance Unfolding (MVU) method introduced in the machine learning literature is in fact a special case of our SDP model. This observation leads to some interesting open questions, which we shall also discuss.

3. **Global rigidity and uniqueness of graph realizations in Euclidean space**

   Abdo Y. Alfakih, Univ. of Windsor

Let $G = (V, E, w)$be an edge-weighted graph. A realization of G in R^k is a mapping of the vertices of G into points in R^k such that every two adjacent vertices v_i and v_j of G are mapped into points p^i and p^j whose Euclidean distance is equal to the weight $w_i j$. Graph realizations have important applications in molecular conformations, wireless sensor networks, multidimensional scaling (statistics), satellite ranging etc. In this talk we present some recent results concerning the problem of determining whether or not a given realization of G in R^k is unique in space of dimension k (globally rigid), and whether or not it is unique in all dimensions. These results are presented from an SDP methodology point of view.

■ WD2

Wednesday, 4:45-6:15, MDCL 1307

Duality and Constraint Qualifications

Stream: Convex and Nonsmooth Analysis

Chair: *Bot Radu Ioan*, Faculty of Mathematics, Chemnitz University of Technology

1. **Regularity conditions for Fenchel-Lagrange duality in infinite dimensional spaces**

   Gert Wanka, Chemnitz University of Technology, Faculty of Mathematics, *Radu Ioan Bot*, *Sorin-Mihai Grad*

We consider different so-called Fenchel-Lagrange dual problems to linearly perturbed convex optimization problems in separated locally convex spaces with geometric and inequality constraints defined by closed convex ordering cones. Strong, stable strong and total duality are characterized by means of the weakest regularity conditions known so far. In particular, we consider different regularity conditions of closedness type using the epigraphs of the conjugate functions to the functions involved in the primal problem. Further, we offer some new subdifferential-type regularity conditions ensuring total Fenchel-Lagrange duality. In particular instances our regularity conditions turn into some constraint qualifications recently published by other authors.

2. **The Hahn-Banach-Lagrange theorem**

   Stephen Simons, UC Santa Barbara

We discuss the Hahn-Banach-Lagrange theorem, a generalized form of the Hahn-Banach theorem. As applications, we derive various results on the existence of linear functionals in functional analysis, on the existence of Lagrange multipliers for convex optimization problems, with an explicit sharp lower bound on the norm of the solutions (multipliers), on finite families of convex functions (leading rapidly to a minimax theorem), on the existence of subgradients of convex functions, and on the Fenchel conjugate of a convex function. We give a complete proof of Rockafellar's version of the Fenchel duality theorem, and an explicit sharp lower bound for the norm of the solutions of the Fenchel duality theorem in terms of elementary geometric concepts.

3. **A new condition for maximal monotonicity via representative functions**

   Radu Ioan Bot, Faculty of Mathematics, Chemnitz University of Technology, *Ernő Róbert Csetnek*, *Wanka Gert*

We give a weak sufficient condition for the maximal monotonicity of the operator $S + A * TA$, where $S : X \mapsto X^*$, $T : Y \mapsto Y^*$ are two maximal monotone operators, $A : X \to Y$ is a linear continuous mapping and X, Y are reflexive Banach spaces. The condition is formulated using the representative functions of the operators involved. The proof of the main result uses an idea due to Borwein and shows once more the usefulness of convex analysis in treating the problem of maximality of monotone operators. We prove that our condition is weaker than the generalized interior-point conditions given so far in the literature. In particular, we rediscover some sufficient conditions given in the past by using the so-called Fitzpatrick function for the maximal monotonicity of the sum of two maximal monotone operators.

■ WD3

Wednesday, 4:45-6:15, MDCL 1105

Applications of Convex Optimization in Statistics and Control

Stream: Linear, Semidefinite and Conic Optimization

Chair: *Lieven Vandenberghe*, UCLA Electrical Engineering Department

1. **On Large-Margin Training of Gaussian Models**

   Lin Xiao, Microsoft Research

We consider supervised training of multiple Gaussian models. The problem is to estimate parameters of multiple Gaussian distributions based on a set of labeled data. If the data set is noisy or inadequate, large-margin discriminative training can be a good alternative for the classical maximum-likelihood estimation. We consider a large-margin training method that separates each class from others using two concentric ellipsoids with maximum separation ratio. Soft margins are used to handle nonseparable data. For each class, we compute the separating ellipsoids using semidefinite programming, and rescale them to fit a Gaussian model.

2. **Full Regularization Path for Sparse Principal Component Analysis**

   Alexandre d'Aspremont, Princeton University

Given a sample covariance matrix, we examine the problem of maximizing the variance explained by a particular linear combination of the input variables while constraining the number of nonzero coefficients in this combination. This is known as sparse principal component analysis and has a wide array of applications in machine learning and engineering. We formulate a new semidefinite relaxation to this problem and derive a greedy algorithm that computes a full set of good solutions for all numbers of non zero coefficients, with complexity $O(n^3)$, where n is the number of variables. We then use the same relaxation to derive sufficient conditions for global optimality of a solution, which can be tested in $O(n^3)$. We show on toy examples and biological data that our algorithm does provide globally optimal solutions in many cases.

3. **Polynomial Lyapunov Functions for Control Systems**

   Sanjay Lall, Stanford University

We consider the problem of stability analysis for linear control systems. We show how to construct Lyapunov certificates of stability for some commonly occuring situtations including robust stability analysis and systems with delays, and give bounds on the degree of the polynomials required.

■ WD4

Wednesday, 4:45-6:15, MDCL 1110

Convex Optimization Methods

Stream: Convex Optmization Methods

Chair: *Catherine Mancel*, LARA/ ENAC (French School of Civil Aviation)

1. **Sensitivity Analysis of the Maximum Entropy Problem**

   Qing Luo, Computer Science Department,University of Southern California, *Ming-Deh Huang*

We consider the maximum entropy problem with linear equality constraints. This problem arises in various applications, including the multidimensional contingency table computation, self assembly and natural language processing. The classical method of Iterative Proportional Scaling solves the problem when the variables involved represent probability functions. This method was extended by the authors to solve the problem in the general case where all restrictions are removed. In this talk we will present the sensitivity analysis on this method. From the perspective of application, the sensitivity analysis when applied self assembly provides information on how the equilibrium concentrations of species change as a result of small perturbation to the initial concentrations. The sensitivity analysis also arises in natural language processing. Moreover, it is helpful for backward error estimation in real computation.

2. **A Convex Optimization Framework for the Unequal-Areas Facility Layout Problem**

Ibolya Jankovits, Department of Management Sciences, University of Waterloo, *Chaomin Luo*, *Miguel F. Anjos*, *Anthony Vannelli*

The unequal-areas facility layout problem (FLP) is concerned with finding the optimal arrangement of a given number of non-overlapping indivisible departments with unequal area requirements within a facility. We present a convex-optimization-based framework for efficiently finding competitive solutions for this problem. The framework is based on the combination of two mathematical programming models. The first model is a convex relaxation of the layout problem that establishes the relative position of the departments within the facility, and the second model uses semidefinite optimization to determine the final layout. Aspect ratio constraints that restrict the occurrence of overly long and narrow departments in the computed layouts are taken into account by both models. We present computational results showing that the proposed framework consistently produces competitive, and often improved, layouts for well-known large instances when compared with other approaches in the literature.

3. **An extension of Furness Algorithm to Elastic Trip Distribution Forecast**

Catherine Mancel, LARA/ ENAC (French School of Civil Aviation), *Daniel Carretero Herrera*, *Felix Mora-Camino*

The optimization problem considered in this communication is related with the long term forecasting of the traffic growth in a large air transportation network. This problem is crucial when planning the necessary investments in airports, fleets and air traffic control equipments. The proposed approach makes use of two different optimization models : One model is devoted to demand forecasting, the other is devoted to the definition of air transport supply according with a profit maximization behavior. To take into account the effect of travel costs in the distribution of demand over a network, an extension of the maximization entropy approach is considered, leading to a non classical trip distribution problem. In this communication, once the optimality conditions for the resulting optimization problem are established, an extension of the Furness algorithm is proposed to solve it numerically. Convergence issues and numerical results in the case of medium size problems are discussed.

■ WD5

Wednesday, 4:45-6:15, MDCL 1016

Robust Risk Management

Stream: Robust Optimization

Chair: *Akiko Takeda*, Mathematical and Computing Sciences, Tokyo Institute of Technology

Session organizer: David Brown

1. **Robust Portfolio Selection under Downside Risk Measures**

Shu-Shang Zhu, Department of Management Science, Fudan University, *Duan Li*, *Shou-Yang Wang*

We investigate a robust version of the portfolio selection problem under a risk measure based on the lower-partial moment (LPM), where uncertainty exists in the underlying distribution. We demonstrate that the problem formulations for robust portfolio selection based on the worst-case LPMs of degree 0, 1 and 2 under various structures of uncertainty can be cast as mathematically tractable optimization problems, such as linear programs, second-order cone programs or semidefinite programs. We perform extensive numerical studies using real market data to reveal important properties of several aspects of robust portfolio selection. We can conclude from our results that robustness does not necessarily imply a conservative policy and is indeed indispensable and valuable in portfolio selection.

2. **A Conservative Approximation Approach to a Chance-Constrained Convex Program with Application to the Value-at-Risk Minimization**

Jun-ya Gotoh, Department of Industrial and Systems Engineering, Chuo University, *Yuichi Takano*

In this research, we consider a conservative approximation approach to a convex program with a chance (probabilistic) constraint. By introducing a parameter which indicates the approximation accuracy, the resulting optimization problem has a nonconvex feasible region represented by a D.C. inequality or a difference of two convex sets. We develop two global optimization algorithms and apply them to the value-at-risk (VaR) minimization, which is a special case of the problem and is often formulated as a 0-1 mixed integer program (MIP). A nice point of the proposed D.C. formulation is that the degree of its nonconvexity is almost independent of the number of scenarios, which contrasts with the fact that the MIP formulation requires 0-1 variables with the number of scenarios. Some comparative computational results will be given, presenting characteristics of the algorithms.

3. **Application of Conditional Value-at-Risk to Statistical Learning Problems**

Akiko Takeda, Mathematical and Computing Sciences, Tokyo Institute of Technology

The observed data in statistical learning problems are sometimes affected by outliers or measurement errors. Statistical learning methods such as support vector machines (SVMs) aim to identify the underlining structure behind the observed data. The objective of this work is to describe several SVMs from the viewpoints of robust optimization and conditional value-at-risk (CVaR) minimization: a well-known hard margin SVM for a classification problem is regarded as a robust optimization approach, and also, extended nu-SVM of Perez-Cruz et al. is as CVaR minimization approach. Moreover, in place of each data sample, an ellipsoidal uncertainty set can be considered in order to take into account the measurement errors, as introduced in the total least squares context. We apply the CVaR criterion for statistical learning problems under measurement errors, and compare the learning results of CVaR minimization approach to those of total support vector classification approach.

■ WD6

Wednesday, 4:45-6:15, MDCL 1309

Global Optimization

Stream: Global Optimization

Chair: *Alexander Engau*, Department of Mathematical Sciences, Clemson University

1. **A heuristic method for nonlinear unconstrained global optimization: Electromagnetism meta-heuristic**

Seyyed Hassan Taheri, Department of Mathematics, Ferdowsi University of Mashhad, *Jafar Saberi Nadjafi*

In this paper, we give a modified Electromagnetic Meta-Heuristic search method (MEM) for finding a global minimum of a nonlinear function with continuous variables. The proposed scheme can be used either as a stand-alone approach or as an accompanying procedure for other methods. The performance of MEM is reported through extensive numerical experiments on some well known functions. Comparing their performance with that of other meta-heuristics shows that MEM is promising in practice. Especially, MEM is shown to be very efficient and robust for large scale problems.

2. **A New Search Direction for Self-dual Conic Optimization**

Kees Roos, TU Delft, *Guoyong Gu*

Finding a search a direction for solving a Conic Optimization optimization problem by an interior-point method becomes more complicated if the problem contains semidefinite constraints. Several researchers have proposed "symmetrizing schemes" to overcome this difficulty. As a result many different search directions nowadays. In 1997 Zhang proposed a generic symmetrization strategy depending on a scaling matrix P. Other directions, proposed around the same time, turned out to arise by different choices of the matrix P. It is well known that every conic optimization problem and its dual can be embedded in a self-dual conic optimization problem. Existing software (as SeDuMi, MOSEK,...) uses this embedding technique, and is known for its stability and its ability to decide reliably whether a given primal-dual pair is solvable with vanishing duality gap or not. We propose a natural way to symmetrize in case the given conic optimization problem is self-dual.

3. **Using Domination and Approximation Concepts in Multi-objective Programming**

Alexander Engau, Department of Mathematical Sciences, Clemson University

In this talk, we first review the notion of nondominated solutions for multiobjective programs and highlight the difference between dominance in multicriteria optimization and preferences in decision making. Thus motivated, we propose two approaches to facilitate the selection of preferred solutions using the concept of general domination structures and approximation. The first approach introduces a new preference model and is based on a variable domination structure that can be described by a collection of Bishop-Phelps cones. The second approach decomposes the original objective function and uses the concept of epsilon-efficiency to coordinate tradeoffs between the individual solution sets which we illustrate on a truss design problem from engineering optimization. Supporting theoretical results are given, and as time permits we conclude with several implications of our results on multiobjective programming and scalarization techniques for other domination and approximation concepts.

■ WD7

Wednesday, 4:45-6:15, MDCL 1009

Advances in Modeling Languages for Continuous Optimization

Stream: Modelling Languages
Chair: *Robert Fourer*, Dept of Industrial Engineering & Management Sciences, Northwestern Univ

1. **ZIMPL: A Solver Independent Open Source Modelling Language**

   Thorsten Koch, Zuse Institute Berlin

ZIMPL is a freely available open source algebraic modelling language. Originally intended for linear mixed integer programming, it has recently been extended to support also certain non-linear models. ZIMPL is very portable and can be used either standalone, embedded into an application, or linked to a solver. We will give an overview of the language itself and its interfaces, mention unique features, discuss recent and planned enhancements, and report experiences made when using ZIMPL in courses and industry projects.

2. **A Domain Specific Language for Numerical Optimization**

   Joseph Young, Rice University-CAAM, *Walid Taha*

The classes of reliably solvable optimization problems has increased dramatically during the last ten years or so. These optimization problems include convex cone programs such as semidefinite programs and second-order cone programs. Although many of these problems have promising applications, tools that model these problems remain primitive. One difficulty in modeling these problems occurs during the formulation. Frequently, two or more equivalent formulations exist for a given model such that one formulation arises naturally, but the other one is more conducive to efficiently solving the problem. Since the process of transforming one formulation into the other can be difficult to an average practitioner, tools that automate this process are essential in making our problem-solving capability accessible. We present some preliminary results of a new domain specific language design for numerical optimization. The goal of this language is to represent difficult optimization problems succinctly while automating transformations of the formulation. Our technical contribution to this area is the formal semantics of such a language, a static type system that gives information about the structure of the problem, and the properties of these transformations.

3. **New Directions in Applying AMPL for Continuous Optimization**

   Robert Fourer, Dept of Industrial Engineering & Management Sciences, Northwestern Univ

For most of their existence, optimization modeling languages have worked with the same kinds of algebraic expressions and the same kinds of solvers. Lately the pace of change has accelerated, however, as languages have been extended to keep up with solvers for global optimization, conic programming, optimization under uncertainty, and various hybrids with discrete optimization problems. This presentation will reviews language extensions for such purposes, using mainly the AMPL language for illustrations.

■ WD8

Wednesday, 4:45-6:15, MDCL 1010

PDE Constrained Optimization

Stream: PDE Constrained Optimization
Chair: *Bart van Bloemen Waanders*, Sandia National Laboratories
Session organizer: Ekaterina Kostina

1. **Mesh-independence of semismooth Newton methods revisited**

   Michael Ulbrich, TU Muenchen

Mesh independence is a very desirable property for numerical methods that involve the discretization of an infinite dimensional problem. Important applications are, e.g., optimal control problems with PDEs. Roughly, mesh independence ensures that for sufficiently fine discretizations the numerical algorithm behaves very much like its abstract counterpart for the infinite dimensional problem. The derivation of such results for semismooth Newton methods, which are very well suited for constrained optimal control problems, turns out to be quite involved. The aim of this talk is to point out the intrinsic difficulties, to discuss possibilities for establishing mesh independence results, and to present new results.

2. **Recent Progress in Real-Time Optimal Control of Dynamic Processes**

   Georg Bock, IWR, University of Heidelberg

The paper reports on recent progress in the real-time computation of constrained closed-loop optimal control, and the special case of nonlinear model predictive control, of large DAE systems. Through a combination of, among others, the direct multiple shooting approach, inexact SQP or Gauss-Newton methods and a perturbation embedding, the "real-time iteration" approach has been developed in the last few years. One basic feature is that in each iteration of the optimization process the latest process data are used. Through precomputation of Hessians, gradients and QP factorizations the response time to perturbations of states and systems parameters is minimized. The new approach was shown to be orders of magnitude faster than previous approaches based on application of off-line optimization methods. It is shown how it is further drastically accelerated by special algorithmic schemes for on-line feasibility and optimality improvement, and a primal-dual on-line active set strategy (OASeS), so that it is capable of solving optimal control problems even of very fast processes on-line.
(based on joint work of the Heidelberg optimization group (M. Diehl, J. Ferreau, E. Kostina, J. P. Schloeder) and the Stuttgart process control group (F. Allgoewer, R. Findeisen).

3. **Regularization and Discretization of State Constrained Optimal Control Problems**

   Svetlana Cherednichenko, Johann Radon Institute for Computational and Applied Mathematics, *Arnd Roesch*

A family of elliptic optimal control problems with pointwise state and mixed constraints is considered. We analyse an approximation to the optimal solution for the finite element discretization of the involved partial differential equations. In particular, the main difficulties occur for cases with pure state constraints. To overcome these difficulties we use here a Lavrentiev type of regularization. We are interested in the convergence rate with respect to the regularization parameter and in the error estimate with respect to the grid size for the finite element discretization of the partial differential equations. Choosing certain relation between the regularization parameter and the mesh size, we have obtained a convergence near to an order of 1. Therefore, we benefit from tuning parameters.

■ WD9

Wednesday, 4:45-6:15, MDCL 1008

Financial Optimization

Stream: Financial Optimization
Chair: *Michael Best*, Dept of Combinatorics and Optimization, University of Waterloo

1. **Are European puts overpriced while European calls are not?**

   Thamayanthi Chellathurai, Canadian Imperial Bank of Commerce, *Michael Best*

The seminal Black-Scholes equation, that governs the dynamics of the price of any derivative security, is derived under many assumptions. One of them is that there are no short-sale restrictions on the risky asset based on which the derivative security is written. To be able to sell a stock short, one must borrow it. It may be expensive and difficult to borrow stocks that are in high demand for borrowing. The objective of this paper is to analyse the effects of srort-sale restrictions on the prices of European put options using stochastic optimal control theory. Numerical solutions are obtained by solving the resultant Hamilton-Jacobi-Bellman equation.

2. **A Fuzzy Data envelopment Analysis model to evaluate the banks performance**

   Tlig Houssine, GIAD-Sfax-Tunisia, *Rebai Abdelwaheb*

The analysis of bank performance requires a model that enables us to analyze various factors, which are qualitative and quantitative by nature, with a system approach. The objective of this study is to establish a fuzzy data envelopment analysis model (FDEA) in which financial and no financial criteria are used together. To solve this model, we propose an approach based on the comparison of fuzzy numbers. We adopt 24 Tunisian banks as an empirical example to demonstrate the feasibility and the effectiveness in our proposed fuzzy DEA model.

3. **An Algorithm for Portfolio Optimization with Transaction Costs**

   Michael Best, Dept of Combinatorics and Optimization, University of Waterloo

We consider the problem of maximizing an expected utility function of n assets, such as the mean-variance or power utility function. Associated with a change in an asset's holdings from its current or target value is a transaction cost. These must be accounted for in practical problems. A straightforward way of doing so results in a $3n$ dimensional optimization problem with $3n$ additional constraints. This higher dimensional problem is computationally expensive to solve. We present a method for solving the $3n$ dimensional problem by solving a sequence of n dimensional optimization problems, which account for the transaction costs implicitly rather than explicitly. The method is based on deriving the optimality conditions for the higher dimensional problem solely in terms of lower dimensional quantities. The new method is compared to Cplex in a series of numerical experiments.

■ RA1

Thursday, 8:30-10:00, MDCL 1305

Algorithms for Structured Conic Convex Optimization

Stream: Conic Programming and Interior Point Methods

Chair: *E. Alper Yildirim*, Department of Industrial Engineering, Bilkent University

Session organizer: Robert Freund

1. **On Khachiyan's Algorithm for the Computation of Minimum-Volume Enclosing Ellipsoids**

   E. Alper Yildirim, Department of Industrial Engineering, Bilkent University, *Michael J. Todd*

Given a finite set A of vectors, we study the problems of computing an approximate rounding of the convex hull of A and an approximation to the minimum-volume enclosing ellipsoid of A. For centrally symmetric sets, we establish that Khachiyan's barycentric coordinate descent (BCD) method is closely related to the ellipsoid method. For these two problems, we propose an algorithm, which draws upon the algorithms of Khachiyan and Kumar-Yildirim(KY), that computes an approximate solution to the dual optimization formulation of the minimum-volume enclosing ellipsoid problem that satisfies a more complete set of approximate optimality conditions than either of the two previous algorithms. Our algorithm retains the improved complexity estimate and the core set result of the KY algorithm.

2. **Linear Convergence of a Modified Frank-Wolfe Algorithm for Computing Minimum Volume Enclosing Ellipsoids**

   S. Damla Ahipasaoglu, ORIE, Cornell University, *Peng Sun*, *Michael J. Todd*

We show linear convergence of a simple first-order algorithm for the minimum volume enclosing ellipsoid problem and its dual, the D-optimal design problem of statistics. We also generalize the results for the Frank-Wolfe algorithm on the unit simplex. We will present a comparative computational study which confirms the attractive features of the algorithm.

3. **Inner and outer approximations of copositive programs**

   Franz Rendl, Institute of Mathematics, Univ. Klagenfurt, *Florian Jarre*, *Manuel Bomze*

We will look at some copositive formulations of NP-hard combinatorial optimization problems and consider approximating these models from outside (to get relaxations) and from inside (to get feasible solutions).

■ RA2

Thursday, 8:30-10:00, MDCL 1307

Algorithms and Applications

Stream: Convex and Nonsmooth Analysis

Chair: *Isao Yamada*, Tokyo Institute of Technology

1. **The CQ Algorithm, with Extensions and Applications**

   Charles Byrne, Dept. of Mathematical Sciences, Univ. of Massachusetts Lowell

The CQ algorithm is an iterative method for finding x in the convex set C with Ax in the convex set Q. The algorithm requires no nested inversions. It has, as particular cases, the Landweber and projected Landweber methods and the simultaneous ART. It has been extended recently by other researchers and applied to intensity-modulated radiation therapy by Censor et al. Recent work by Combettes et al. has shown the CQ algorithm to be a particular case of forward-backward splitting.

2. **Iterated maps that solve hard problems**

   Veit Elser, Department of Physics, Cornell University

A large variety of problems, including some well known NP-complete problems, can be formulated as constraint satisfaction instances of the following type: find a point in a Euclidean space that lies in the intersection of two sets A and B. This characterization would be uninteresting without the additional observation that sets A and B can usually be found for which the problem of finding a nearest point in A or B, individually, is easy. We describe an iterated map built from the projections to the sets A and B that generalizes a highly successful iterative method for phase retrieval. When applied to hard combinatorial search problems, this iterated map finds solutions at a rate that is competitive with linear programming based methods.

3. **Optimization over possibly nonconvex fixed point set of certain mappings and its signal processing applications**

   Isao Yamada, Tokyo Institute of Technology

The goal of this talk is to demonstrate that a variety of signal processing problems can naturally be formulated as an optimization problem: minimize a convex function over the fixed point set of certain nonlinear mappings in real Hilbert space. Typical examples will be introduced with their algorithmic solutions including an extremly simple yet powerful algorithm: hybrid steepest descent method. This algorithm can be applied flexibly to many cases where the fixed point set is given as a closed convex set. We also present a novel idea to approximate soundly the ideal solution of the ill-conditioned linear inverse problems. The idea leads unfortunately to an optimization problem over a nonconvex fixed point set, but fortunately its complete solution is achieved.

■ RA3

Thursday, 8:30-10:00, MDCL 1105

Process Control

Stream: Optimization Formulations and Algorithms for Chemical Processes

Chair: *Tom Marlin*, Chemical Engineering, McMaster University

1. **Simultaneous Design and Control of Chemical Processes under Uncertainty and External Perturbations: A Robust Modeling Approach**

   Hector Budman, Chemical Engineering University of Waterloo, *Luis Ricardez*, *Peter Douglas*

This paper presents a new approach to integrate process design and control. The key idea in this method is to represent the systemâĂŹs closed-loop nonlinear behavior as linear models complemented with uncertain model parameters. Then, robust control tools are applied to calculate infinite time-horizon bounds on the process stability, the process feasibility and the worst-case scenario. Bounds on the standard deviations of the controlled variables are found by a Linear Matrix Inequality formulation whereas bounds on the maximal deviations are found with a Structured Singular Value analysis. The new methodology was applied to the simultaneous design and control of the Tennessee Eastman Process which is a challenging open loop unstable process. Although several researchers have studied the controllability of this process, the integration of design and control has not been previously addressed for this system. The resulting design avoids the solution of computationally intensive dynamic optimizations since the integration of design and control problem is reduced to a nonlinear constrained optimization problem.

2. **Model discontinuities as complementarity constraints: Applications in process control**

   Rhoda Baker, McMaster University, Department of Chemical Engineering, *Chris Swartz*

Discontinuities arise in engineering optimization when the dynamic models describing a system change depending on the value of the current states. In this presentation we demonstrate how certain discontinuities that arise within process control can be formulated as complementarity constraints and inserted into a simultaneous dynamic optimization framework. In particular, we focus on proportional-integral controllers with actuator saturation and systems with constrained model predictive control (MPC). In the former, a bilinear formulation is used, while in the latter case the multilevel problem is transformed into a single level problem by replacing the inner MPC quadratic programs by their first order optimality conditions. Various solution approaches for the resulting mathematical program with complementarity constraints (MPCC) are explored, including interior point based strategies and penalty approaches. We demonstrate the approach through application to case studies involving process design with rigorous actuator saturation handling, comparison of different anti-reset windup approaches, back-off from constraints with constrained MPC, integrated process and control design with MPC, and optimal reference trajectory management for systems with setpoint transitions. Where possible, the solution performance is compared to an equivalent problem formulation that uses binary variables to represent the discontinuities.

3. **Network Based Analysis of Decision Making in Complex Organizations: The Adaptive Enterprise**

   B. Erik Ydstie, Carnegie Mellon University, *Michael Wartman*

We give an overview of how decision making processes in complex business organizations can be understood from a process systems point of view. A modeling framework to capture the dynamics of business systems is introduced based on network theory. Financial processes in a business organization is modeled using conservation laws for assets and liabilities. By defining a value function that consists of the sum of all individual values of assets and liabilities, we can demonstrate how a business systemâĂŹs objective of maximizing its total value is connected to maximizing its profit over time. An enterprise consisting of independently managed business units is modeled as a network where units are uniquely connected through flows for transformation and transfer elements. We derive a general way of describing interconnections in business networks through representations that capture the topology of interconnection. We show that distributed and decentralized optimization lead to optimality.

■ RA4

Thursday, 8:30-10:00, MDCL 1110

Verification and Computation in Global Optimization

Stream: Global Optimization

Chair: *Baker Kearfott*, Department of Mathematics, University of Louisiana at Lafaye

1. **SparsePOP: A sparse semidefinite programming relaxation of polynomial optimization problems**

   Hayato Waki, Department of Mathematical and Computing Sciences, Tokyo Institute of Technology, *Masakazu Kojima*, *Kim Sunyoung*, *Masakazu Muramatsu*

SparsePOP is a MATLAB implementation of a sparse semidefinite programming (SDP) relaxation method proposed for polynomial optimization problems (POPs). The sparse SDP relaxation is based on a method proposed by Lasserre. Lasserre's method constructs a hierarchy of SDP problems whose optimal values are lower bounds for the global optimal value of a given POP. However, a good lower bound for global optimal values of medium- or large-scale POPs can not be achieved since SDP problems generated by Lasserre's method are untractable by current SDP implementations, such as SDPA, SeDuMi and SDPT3. By exploiting sparsity, we reduce the size of resulting SDP problems. As a result, SparsePOP can solve sparse POP instances up to 1000 variables and often outperforms Lasserre's method. In this talk, we present the spase SDP relaxation, the usage of SparsePOP and some numerical results.

2. **Automatic convexity detection for global optimization**

   Xiaowei Bao, Chemical and Biomolecular Engineering, University of Illinois at Urbana-Champaign, *Nick Sahinidis*

An automatic convexity detection algorithm is developed and implemented. The convexity detection scheme has three main parts: a decomposition of the function to facilitate convexity detection, a bounding process to provide useful bounds as an aid for accurate convexity detection, and a convexity detection process that relies on existing tools from convexity analysis. We use this procedure to preprocess problems before they are turned for solution to the branch-and-reduce global optimization algorithm. Computational results with 32 problems from the globallib collection demonstrate that the proposed convexity identification scheme improves the performance of the BARON global optimization solver significantly by allowing the solver to strengthen its lower bounds and reduce the relaxation gap once convexity has been automatically identified and this information has been provided to the solver through its CONVEX_EQUATIONS construct.

3. **Handling Singularities in Deterministic Global Optimization**

   Baker Kearfott, Department of Mathematics, University of Louisiana at Lafaye

Ill-posedness and singularity occur more frequently in practical optimization problems than some mathematical theory would lead us to believe. Furthermore, existence of such higher-dimensional sets of global optimizers or approximate global optimizers can be useful to the consumer of the output of global optimization software. However, such software, as a rule, presently often gives a single optimizing point, with no indication that a manifold of solutions exists. In this work, we propose algorithms to identify and efficiently characterize such manifolds of optimizers, within the context of deterministic branch and bound algorithms.

■ RA5

Thursday, 8:30-10:00, MDCL 1016

Applications of Derivative-free Direct Search Methods

Stream: Derivative Free Optimization

Chair: *Robert Michael Lewis*, Department of Mathematics, College of William & Mary

1. **Optimization as a Tool for the Calibration of an Electrical Circuit Simulator**

   Genetha Gray, Sandia National Labs

In this talk, we will focus on the problem of simulator calibration where calibration refers to the process of determining the values for some relevant simulator parameters. Here, we are interested in some electrical device models of Xyce, an electrical circuit simulator. Calibration involves minimizing the differences between the simulated data and some experimental data. We will describe the process of experimental data collection, the relevant metrics, the selection of the simulator parameters being calibrated, and the objective function. We will focus on the applicability of an optimization method which hybridizes direct search and stochastic process for the solution of this problem.

2. **Quantitative Object Reconstruction via X-Ray Tomography, Abel Transforms, and Mixed Variable Optimization**

   Mark Abramson, Department of Mathematics and Statistics, Air Force Institute of Technology, *Thomas Asaki*, *J. E. Dennis*, *Kevin O'Reilly*, *Rachael Pingel*

We consider the problem of quantitatively reconstructing a cylindrically symmetric object using Abel transform-based x-ray tomography. Specifically, we obtain radiograph data by x-raying an object and attempt to quantitatively determine the number and types of materials and the thicknesses of each concentric material layer. Current methodologies either fail to provide a quantitative description of the object or are generally too slow to be useful in practice. As an alternative, we model the problem as a mixed variable program, in which some variables are nonnumeric and for which no derivative information is available. The Audet-Dennis mixed variable pattern search (MVPS) algorithm is applied to the x-ray tomography problem, by means of the NOMADm MATLAB software package. Numerical results are provided for several test objects and show that, while there are difficulties to be overcome, our approach is very promising for solving this class of problems in practice.

3. **Real time drag minimization using a generating set search method**

   Marianne Jacobsen, Aeronautical and Vehicle Engineering, KTH

Minimizing drag of aircraft is of great importance to make flying more efficient. Here, the focus is to use control surfaces, such as ailerons and flaps, to continuously make small changes to the shape of the wing to reduce drag. The optimization problem to be solved is to minimize drag while keeping lift constant, and also keeping the control surfaces within some given bounds. The objective function in the optimization problem is the measured drag. No numerical model is used, and difficulties mainly involve noise in the measured signals and problems with repeatability. Due to these difficulties, derivatives are assumed not to give reliable information about the problem, and instead a generating set search method is used. The talk will include experimental results from a wind tunnel test in which a wing with 20 independent control surfaces has been used to validate the use of the generating set search method for drag minimization.

■ RA6

Thursday, 8:30-10:00, MDCL 1309

VI/CP II (Theory; Algorithms and Their Theory; Applications)

Stream: MPECs/Complementarity Problems

Chair: *Xiaoming Yuan*, Department of Management Science, Shanghai Jiao Tong University

1. **Smoothing Mathematical Programs with Equilibrium Constraints via Neural Network Function**

   Mohamed Tawhid, Thompson Rivers Univ

We propose a smoothing approach based on neural network function to solve a mathematical program with equilibrium constrains (MPEC) in which the constraints are defined by a parametric variational inequality. We reformulate MPEC as an equivalent one level nonsmooth optimization problem. Then, this nonsmooth optimization problem will transfer to a sequence of smooth optimization problems that can be solved by standard available software for constrained optimization. Our results obtained in this paper continue to hold for any mathematical program with parametric nonlinear complementarity/mixed complementarity constraints. Also, we test the performance of the proposed smoothing approach on as set of well-known problems and give some comparisons between our approach and other smoothing approaches.

2. **Newton Methods for Equations with Semismooth Jacobians and NCPs**

   Christina Oberlin, University of Wisconsin, *Stephen J. Wright*

The local convergence of Newton's method to solutions of nonlinear equations that are singular yet satisfy a certain regularity condition is discussed. A result of Griewank, concerning the convergence of Newton's method from a starlike domain of such a solution, is extended to equations whose Jacobian is only strongly semismooth at the solution. A simple acceleration technique for Newton's method yields fast linear convergence to these solutions. These results are applied to a nonlinear-equations reformulation of the nonlinear complementarity problem (NCP) whose derivative is strongly semismooth. Conditions on the solution of the NCP are derived to ensure that our regularity condition is satisfied.

3. **An approach of system of nonlinear equations to structured variational inequalities**

   Xiaoming Yuan, Department of Management Science, Shanghai Jiao Tong University

To solve variational inequalities with separate structures, we present a new approach of systems of nonlinear equations. Inheriting the well-known alternating directions method (ADM) and the Logarithmic-Quadratic Proximal (LQP) method, the original problem is solved via solving systems of nonlinear equations. Consequently, some attractive numerical algorithms are presented, whose global convergence are proved under mild assumptions. Preliminary numerical results for traffic equilibrium problems verify the computational preferences of the new algorithms.

■ RA7

Thursday, 8:30-10:00, MDCL 1009

Distributed Optimization

Stream: Convex Optmization Methods

Chair: *Asu Ozdaglar*, EECS/MIT

1. **Distributed Subgradient Methods for Multiagent Optimization**

   Angelia Nedich, IESE, University of Illinois at Urbana Champaign, *Asuman Ozdaglar*

We present a distributed computational model for optimizing a sum of convex objective functions corresponding to multiple agents. For solving this (not necessarily smooth) minimization problem, we consider a subgradient method that is distributed among the agents. In this model, each agent minimizes his/her own objective while exchanging the estimate information with the neighbors according to some rules. We study such a distributed computation model with and without the presence of delays in the agent system. We provide convergence results and convergence rate estimates for the subgradient method. Our convergence rate results explicitly characterize the tradeoff between a desired accuracy of the generated approximate optimal solutions and the number of iterations needed to achieve the accuracy.

2. **Energy Efficient Distributed Optimization**

   Zhi-Quan Luo, Electrical and Computer Engineering, University of Minnesota

We consider a distributed optimization problem whereby two nodes S_1, S_2 wish to jointly minimize a common convex quadratic cost function $f(x_1;x_2)$, subject to separate local constraints on x_1 and x_2, respectively. Suppose that node S_1 has control of variable x_1 only and node S_2 has control of variable x_2 only. The two nodes locally update their respective variables and periodically exchange their values over a noisy channel. We analyze the communication energy required to compute an epsilon approximate solution. Our analysis shows that the communication energy must grow at least like $O(1/\varepsilon)$. Extensions to multiple node case will be described.

3. **Coordinatewise distributed methods for large scale convex optimization**

   Paul Tseng, University of Washington

We present methods that distribute computation coordinatewise and are suited for solving large scale convex optimization problems such as those that arise in sensor network localization and total-variation based image restoration.

■ RA8

Thursday, 8:30-10:00, MDCL 1010

Portfolio Optimization

Stream: Financial Optimization

Chair: *Victor DeMiguel*, London Business School

1. **Optimizating taxable portfolios with many assets**

   Song Yang, University of South Australia, *John Birge*

Capital gains taxes present complications for portfolio optimization with even a small number of assets. Many assets, however, provide a distinct advantage over few assets for tax purposes because of the ability to use capital losses to offset other income and due to the re-setting of the tax basis at death. In previous work, we used a continuum approximation of a homogeneous equity portfolio to model an extreme case of multiple assets and to capture the potential value in holding multiple assets. In this talk, we will review that model for both an all-equity and single-bond plus equity portfolio. We will then present extensions that includes labor income (taxed at a higher rate than capital gains) and an additional asset class (e.g., house) that allows for tax-free borrowing.

2. **Solution Techniques for Large-Scale Financial Planning Problems**

   Marco Colombo, School of Mathematics, University of Edinburgh, *Jacek Gondzio*, *Andreas Grothey*

We present computational techniques tailored to solving large-scale structured problems with an interior point solver for convex quadratic programming problems. We are particularly interested on a wide range of financial planning problems, resulting in linear, quadratic or non-linear formulations. The deterministic equivalent formulations of stochastic programming problems have huge dimensions even for moderate numbers of assets, time stages and scenarios per time stage. However stochastic programming problems are highly structured. The key to the efficient solution of such problems is therefore the ability to exploit their structure. In the solution approaches presented, we exploit the inherent structure of the problems at the linear algebra level as well as at the moment of generating warm-start points. This allows to solve (very) large-scale instances.

3. **Improving Performance By Constraining Portfolio Norms: A Generalized Approach to Portfolio Optimization**

   Victor DeMiguel, London Business School

In this paper, we provide a general framework for identifying portfolios that have superior out-of-sample performance even in the presence of estimation error. This general framework relies on solving the traditional minimum-variance problem (based on the sample covariance matrix) but subject to the additional constraint that the norm of the portfolio weight vector be smaller than a given threshold. Moreover, we show how the conjugate gradient method can be used to provide a first-order approximation to the proposed norm-constrained portfolios. We provide numerical results that show that the proposed methodologies perform well out of sample.

■ RA9

Thursday, 8:30-10:00, MDCL 1008

Linear and Convex Quadratic Programming

Stream: Linear, Semidefinite and Conic Optimization

Chair: *Shahadat Hossain*, Department of Mathematics and Computer Science, University of Lethbridge

1. **Matrix perturbation and support set invariancy in linear optimization**

   Alireza Ghaffari Hadigheh, Math, Azarbaijan Tarbiat Moallem University, *Tamás Terlaky*

Support set invariancy sensitivity analysis for linear optimization has been studied first by Hadigheh and Terlaky when perturbation happens in the right hand side and/or objective function data. In this point of view to sensitivity analysis, one wants to find the range of variation for parameter value where there is an optimal solution for each parameter value in this interval with its support set as the support set of the given optimal solution for unperturbed problem. The obtained interval is referred to as support set invariancy interval. Here, we consider the variation in the left hand side of constraints, so-called technological data, when linear optimization problem is in canonical form and find the related support set invariancy interval. We also consider the case, when the right hand side of constraints and objective function data varies in addition to technological data but with identical parameters. Simple examples depict the obtained results.

2. **An open source solution approach to configure a supply network with uncertain demand**

   Guoqing Zhang, Industrial & Manufacturing System Engineering, University of Windsor, *Sicheng Chen*

In this paper, we consider a manufacturerâĂŹs supply network design problem by combining strategic acquisition decisions with inventory management. The manufacturer produces multiple products but faces uncertain demand for each product. A mixed integer nonlinear model is presented to formulate the problem, with the objective of minimizing the manufacturerâĂŹs expected profit. We use BONMIN with AMPL to illustrate the advantage of using open-source software to solve the stochastic supply chain design problem. The user defined external function of AMPL is used to calculate the integration function of the distribution. The preliminary result for a real case is also provided.

3. **On the Complexity of a Timetabling Problem**

   Shahadat Hossain, Department of Mathematics and Computer Science, University of Lethbridge

We investigate the computational complexity of the sub-problems in a multi-phase heuristic of an educational timetabling problem that has been proposed recently. We show that the sub-problems arising in each of the phases are, in general, NP-hard. Employing appropriate heuristics that exploit "local information" for solving the individual sub problems is expected to produce "qualitatively" and "quantitatively" superior solution compared with solving the problem as a whole.Preliminary computational test results using constraint programming technology for the sub-problems are presented.

■ RB1

Thursday, 10:30-12:00, MDCL 1305

Applications of SDP

Stream: Conic Programming and Interior Point Methods
Chair: *Renata Sotirov*, Tilburg University, The Netherlands

1. **New worst cases for polynomial optimization via group-invariant SDPs**

   Hartwig Bosse, CWI

This talk presents the first unrestricted family of polynomials which are non-negative but not sums-of squares. The presented construction demonstrates the use of group-representation theory in semi-definite programs (SDP) resulting from polynomial optimization problems. Surprising at first sight only, not every non-negative (PSD) polynomial is a sum of squares (SOS) of other polynomials. The relation between PSD and SOS polynomials is far from being only a historically challenging topic; the hardness of polynomial optimization actually comes in via the difference between the two. But although there are (provably) many polynomials which are PSD but not SOS, few are currently known. The talk presents a family of PSD polynomials which are not SOS, encompassing all previously known examples. Moreover, the construction presented in the talk may serve as an explicit example of the use of group-representation theory in order to reduce the size of SDPs.

2. **New Korkin-Zolotarev Inequalities**

   Stefan van Zwam, Department of Mathematics and Computer Science, Technische Universiteit Eindhoven

We show how to reformulate a classical problem from the geometry of numbers, that of finding the maximum density of a lattice sphere packing, as an optimization problem with linear, positive semidefinite, and rank-1 constraints, and a linear objective function. This is possible because we can restrict the set of positive definite quadratic forms (i. e. the structures that describe, up to an equivalence, all lattices) to the set of Korkin-Zolotarev (KZ-)reduced forms. We propose a branch-and-bound process on the relaxation of this problem (where we have dropped the rank-1 constraints) to approximate the optimal rank-1 solutions. We have successfully used this method to prove new inequalities valid for all KZ-reduced forms. These inequalities give information on the structure of lattices. Interestingly, very few inequalities of this type suffice to prove all known exact bounds on the maximum density of a lattice sphere packing.

3. **Exploiting group symmetry in truss topology optimization**

   Renata Sotirov, Tilburg University, The Netherlands

We consider semidefinite programming (SDP) formulations of certain truss topology optimization problems, where a lower bound is imposed on the fundamental frequency of vibration of the truss structure. We show how one may automatically obtain symmetric designs, by eliminating the 'redundant' symmetry in the SDP problem formulation. This has the advantage that the original SDP problem is substantially reduced in size for trusses with large symmetry groups. Thus, we are able to solve truss topology optimization problem of a size that is very challenging for the present state-of-the-art interior point method softwares for semidefinite programming.

■ RB2

Thursday, 10:30-12:00, MDCL 1307

Proximal Mappings and Applications

Stream: Convex and Nonsmooth Analysis
Chair: *Heinz Bauschke*, Mathematics, UBC Okanagan

1. **A proximal-projection method for finding zeros of set-valued operators: Part I**

   Dan Butnariu, Department of Mathematics, University of Haifa, Haifa, Israel, *Gábor Kassay*

In a reflexive Banach space X we consider the following problem: Given a multivalued operator from X to its dual, a nonempty closed (not necessarily convex) subset C of X and a proper Legendre lower semicontinuous convex function f on X with the property that the intersection C' of C with $domA$ is nonempty and contained in $int(domf)$, find x in C' such that 0 belongs to Ax, provided that such a point exists. Our purpose is to present a framework for convergence analysis of an iterative procedure we call the proximal-projection method and meant to approximate solutions of this problem. This method determines sequences in which the next iterate x' is the proximal projection with respect to f of a vector in $f(x) - Ax$, with x the current iterate, onto a closed convex approximation of C'.

2. **A proximal-projection method for finding zeros of set-valued operators: Part II**

   Gábor Kassay, Faculty of Mathematics, Babes-Bolyai University Cluj, Romania, *Dan Butnariu*

We show that under suitable and general conditions the proximal-projection method described in Part 1 produces weak (and in some situations strong) approximations of solutions for the problem of finding zeros of a set-valued operator given on a reflexive Banach space X. The approximation procedure in certain circumstances is no more and no less than the proximal point method with Bregman distances. This leads us to show that the proximal point algorithm converges for a large class of monotone operators, without requiring maximality. The proximal-projection method is also a tool for solving monotone variational inequalities via their Tikhonov-Browder regularization, and implicitly for solving optimization problems which can be represented as variational inequalities. These facts are shown within two corollaries of our main convergence theorem. We also pay attention to the special case when the space X is finite dimensional and show that in this case some of the requirements made on the problem data can be dropped. Accordingly, in finite dimensional spaces the conclusions of the above mentioned corollaries can be reacher at lesser cost for the operators involved.

3. **The proximal average**

   Heinz Bauschke, Mathematics, UBC Okanagan, *Rafal Goebel*, *Yves Lucet*, *Shawn Wang*

The recently introduced proximal average of two convex functions is a convex function with many useful properties. In this talk, I will introduce the proximal average for finitely many convex functions. The basic properties of the proximal average with respect to the standard convex-analytical notions (domain, Fenchel conjugate, subdifferential, proximal mapping, and others) are provided.

■ RB3

Thursday, 10:30-12:00, MDCL 1105

State-of-the-Art in NLP Software

Stream: Nonlinear Optimization Software
Chair: *Hans Mittelmann*, Dept. Math Stats, Arizona State University

1. **Solution of Large-Scale Nonlinear Programming Problems with IPOPT**

   Carl Laird, Texas A&M University, *Andreas Wächter*

We present recent developments to IPOPT, an interior-point NLP solver. The IPOPT algorithm has been recently implemented in an object-oriented framework. This framework allows develoment of advanced decomposition techniques, and straightforward use of alternate linear solvers. We will present scaleup results of a parallel decomposition implementation for problems with an almost block diagonal structure and pass-on variables. We will also discuss recent improvements to the IPOPT algorithm.

2. **LOQO, an Interior-Point Code for Nonconvex Nonlinear Programming**

   Hande Benson, Department of Decision Sciences, Drexel University, *David Shanno*, *Robert Vanderbei*

We will present the latest advances in LOQO, a general-purpose code that implements an interior-point method for solving nonconvex nonlinear programming problems. Of particular note will be the primal-dual penalty approach for solving and warmstarting nonlinear programming problems, including its application to mixed-integer nonlinear programming.

3. **Benchmarks of NLP Software**

   Hans Mittelmann, Dept. Math Stats, Arizona State University

As an excerpt from our benchmarking effort we will present performance results of selected continuous and discrete NLP software

■ RB4

Thursday, 10:30-12:00, MDCL 1110

Applications of Global Optimization

Stream: Global Optimization

Chair: *János Pintér*, Pintér Consulting Services

1. **A modified algorithm for sequence alignment using Ant Colony System**

   Yang Dai, Department of Bioengineering, University of Illinois at Chicago

In this study, we used the Ant Colony System (ACS) to develop a heuristic algorithm for sequence alignment. This algorithm is an improvement on ACS-MultiAlignment, which was proposed in 2005 for predicting major histocompatibility complex (MHC) class II binders, which is a critical step in vaccine development. The numerical experiments indicate that this algorithm is 1450 times faster than ACS-MultiAlignment and is much faster than the Gibbs sampling algorithm.

2. **Optimization techniques for phase retrieval based on single-crystal X-ray diffraction data**

   Alexander Smith, Chemical and Biomolecular Engineering, University of Illinois at Urbana-Champaign, *Nick Sahinidis*

A vast majority of structural solutions are derived from X-ray diffraction, especially in the case of important biological macromolecules. The computation of a structure from X-ray diffraction data, however, is a very challenging problem. A major obstacle, “the phase problem”, represents a dilemma in which phase information, critical to computation of the 3D structure of a crystal, is not directly measurable in a traditional X-ray diffraction experiment. This paper provides a review and critical analysis of the major techniques currently used in phase determination from single crystal X-ray diffraction data. An overview of each approach is given, and attention focuses on optimization models at the crux of each method, with a critical assessment of each problemâĂŹs contemporary standing and suggestions for future work in improving on published techniques.

3. **LGO Solver Suite for Global/Local Optimization: New Features**

   János Pintér, Pintér Consulting Services

The Lipschitz Global Optimizer (LGO) software serves for constrained global and local optimization under very general assumptions. In this talk, we review several recently added features that serve practical user demands. New features include the customized handling of computationally expensive models, and a presolver/scaling option.

■ RB5

Thursday, 10:30-12:00, MDCL 1016

Curvature of the Central Path

Stream: Linear, Semidefinite and Conic Optimization

Chair: *Takashi Tsuchiya*, The Institute of Statistical Mathematics

1. **Bilinear complementary conditions for positive polynomials**

   Farid Alizadeh, School of Business and RUTCOR, Rutgers University, *Nilay Noyan*, *Gábor Rudolf*

For a proper cone $K \subset \mathbb{R}^n$ and its dual cone K^* the complementary slackness condition $x^T s = 0$ defines an n-dimensional manifold $C(K)$ in the space $\{ (x,s) \mid x \in K,\ s \in K^* \}$. When K is a symmetric cone, this manifold can be described by a set of n bilinear equalities. This fact proves to be very useful when optimizing over such cones, therefore it is natural to look for similar optimality constraints for non-symmetric cones. In this paper we examine the cone of positive polynomials P_{2n+1} and its dual, the closure of the moment cone M_{2n+1}. We show that there are exactly 4 linearly independent bilinear identities which hold for all $(x,s) \in C(K)$, regardless of the dimension of the cones. Since these are not sufficient to describe $C(P_{2n+1})$ we then look for more complicated constraints and present a set of $2n+3$ valid cubic conditions. We then establish similar results for the cone of positive polynomials. In an Appendix we give some examples of cones where our approach can be used to show that no non-trivial bilinear optimality constraints exist.

2. **Volumetric Path and Klee-Minty Constructions**

   Eissa Nematollahi, McMaster University, *Tamás Terlaky*

By introducing redundant Klee-Minty examples, we have previously shown that the central path can be bent along the simplex path. In this paper, we seek for an analogous result for the volumetric path defined by the volumetric barrier function. Although we only have a complete proof in 2D, the evidence provided by some illustrations anticipates that a Klee-Minty construction exists for the volumetric path in general dimensions too.

3. **Geometrical analysis of central trajectories and interior-point algorithms**

   Takashi Tsuchiya, The Institute of Statistical Mathematics

In a recent paper by Monteiro and Tsuchiya, we analyzed a curvature integral on the central trajectory for linear programs introduced by Sonnevend, Stoer and Zhao. The integral provides an asymptotic rigorous estimate on the number of iterations of the Mizuno-Todd-Ye predictor-corrector algorithms in the sense that it predicts precisely the number of iterations when the opening of the neighborhoood approaches zero. Furthermore, it was also shown that the total curvature, i.e., the improper integral of the curvature from zero to infinity, exists and is bounded as $O(n^{3.5} L_A)$, where n is the number of variables and L_A is the input bit size of the problem. In this talk, we reflect the concept of the curvature of central trajectories in interior-point algorithms and discuss several possible extensions of these results.

■ RB6

Thursday, 10:30-12:00, MDCL 1309

Differential Variational Inequalities

Stream: MPECs/Complementarity Problems

Chair: *Mihai Anitescu*, Argonne National Laboratory

1. **Uniqueness for differential complementarity problems**

   David Stewart, Department of Mathematics, University of Iowa

Differential complementarity problems consist of a differential equation with an additional input, together with a complementarity problem involving this input. Provided that the problem has the right form, and has index one in the sense that differentiating the data of the complementarity problem once in time gives an invertible expression for the input, then the question of uniqueness comes down to the nature of a single matrix. If this matrix is symmetric and positive definite then uniqueness can be shown, but if the matrix is positive definite but not symmetric, the question is much more complex. Connections with related problems (projected dynamical systems, linear complementarity systems, convolution complementarity problems) and issues (Zeno solutions) are outlined.

2. **Time-dependent games and migration problems with applications.**

   Monica-Gabriela Cojocaru, Mathematics & Statistics, University of Guelph, *Annamaria Barbagallo*

We present a general model of equilibrium problems involving time-dependent Nash games and time-dependent migration problems. The model uses the concepts of evolutionary variational inequalities and double-layer dynamics to deal with the built-in dynamics. We first discuss the theoretical model from the perspective of existence, uniqueness and regularity of solutions, as well as answer questions about their stability. We then present an application to vaccination games.

3. **Non-Zenoness of a Class of Differential Variational**

   Lanshan Han, Rensselaer Polytechnic Institute

The Zeno phenomenon of a switched dynamical system refers to the infinite number of mode switches in finite time. The absence of this phenomenon is crucial to the numerical simulation of such a system by time-stepping methods and to the understanding of the behavior of the system trajectory. Extending a previous result for a strongly regular differential variational inequality, this paper establishes that a certain class of non-strongly regular differential variational inequalities is void of the Zeno phenomenon. The proof involves many supplemental results that are of independent interest. Specialized to a frictional contact problem with local compliance and polygonal friction laws, this non-Zenoness result is of fundamental significance and the first of its kind.

■ RB7

Thursday, 10:30-12:00, MDCL 1009

Optimization in Communications and Signal Processing

Stream: Signal Processing and ECE

Chair: *Tim Davidson*, Electrical and Computer Engineering, McMaster University

1. **On the quality of semidefinite relaxation for detection**

   Joakim Jalden, School of Electrical Engineering, Royal Institute of Technology, Stockholm, Sweden

Maximum likelihood (ML) detection of binary (antipodal) signals transmitted over a multiple antenna wireless channel requires the solution of a binary constrained quadratic program. As this problem is known to be NP-hard in general the use of semidefinite relaxation (SDR) has been suggested as a computationally attractive near optimal alternative to the ML detector. Additionally, the probability of detection error for the resulting SDR detector has through simulations been shown to be extremely close to that of the optimal ML detector. However, existing performance guarantees for the relaxation (which are based on a worst case type of analysis) fail to explain these observations. In this work we analytically quantify the error probability performance of the SDR detector by taking the random nature of the detection problem into account. Specifically, we study the performance in the high signal to noise (SNR) regime.

2. **Approximation Bound for the SDP Relaxation of Multicast Transmit Beamforming Problem**

   Tsung-hui Chang, National Tsinghua University, *Zhi-Quan Luo*

We consider the max-min-fair transmit beamforming problem for a multi-group broadcasting application. Since this nonconvex quadratic optimization problem is NP-hard, we consider an approximation approach based on semidefinite relaxation. We show that the worst case approximation ratio for this problem is linear in the number of receivers.

3. **Quality Constrained Broadcasting with Channel Uncertainty: Semidefinite and Quasi-convex Formulations**

   Michael Botros Shenouda, McMaster University - Electrical and Computer Eng., *Tim Davidson*

We consider the design of linear precoders for broadcast channels with Quality of Service (QoS) constraints for each user, with uncertain channel state information at the transmitter. We consider a deterministically-bounded model for the channel uncertainty of each user, and our goal is to design a robust precoder that minimizes the total transmitted power required to satisfy the users' QoS constraints for all channels within a specified uncertainty regions of users' channels. Since this problem is not known to be computationally tractable, we derive three conservative design approaches that yield convex and computationally-efficient restrictions of the original design problem. The three approaches yield semidefinite program (SDP) formulations that offer different trade-offs between the degree of conservatism and the size of the SDP. We also show how these approaches can be used to derive efficiently-solvable quasi-convex restrictions of other related design problems, including the determination of the size of the largest tolerable uncertainty set, and the robust counterpart to the problem of maximizing the minimum signal-to-interference-plus-noise-ratio (SINR) subject to a given power constraint.

■ RB8

Thursday, 10:30-12:00, MDCL 1010

Financial Optimization

Stream: Financial Optimization

Chair: *Hongxia Yin*, School of Mathematical Sciences, Graduate University of Chinese Academy of Sciences

1. **Optimization techniques for estimating non-parametric econometric models**

   Fabian Bastin, University of Montreal, *Cinzia Cirillo*, *Philippe L. Toint*

We consider estimation techniques involving random parameters. The estimation is achieved by optimizing sample average approximations of non-linear nonconvex stochastic programs. We assume here that contrary to the parametric case, random distributions are unknown, but independent, and we examine how to fit their corresponding inverse cumulating distributions during the optimization process. Using B-cubic splines, we show how to adapt the original estimation problem to a constrained program that can be efficiently solved by means of an adapted trust-region approach. The technique is applied to mixed logit model estimation. We first examine the problem of value of time distribution across a heterogeneous population in travel demand analysis. We next consider central bank interventions in the foreign exchange market. In particular, data from the Japanese Central Bank are used to analyze the factors determining the choice between various possible policies in daily interventions.

2. **Smooth and Semismooth Newton Methods for Constrained Approximation and Estimation**

   Hongxia Yin, School of Mathematical Sciences, Graduate University of Chinese Academy of Sciences, *Liqun Qi*, *Chen Ling*

It is observed that the constrained L_2 approximation problem, the convex best interpolation problem and the density estimation problems can all be reformulated as a system of smooth or semismooth equations by using the Lagrange (or Fenchel) duality theory. Moreover, the obtained equations contain integral functions in the same form. In the paper, we investigate the differentiability, (strong) semismoothness of the integral functions and the H"older continuity of their Jacobians. Then we introduce a globalized Newton method for solving these problems. Convergence analysis and numerical tests for option price approximation and density estimation with wavelet basis are also given.

3. **Modified Matched Field Processing Method Based on Wavelet Basis Functions**

   Mostafa Bakhoday Paskyabi, Control Research Institute, Guilan University, Iran, *Azizollah Valinejad*

Matched field processing (MFP) is a signal-processing technique based on comparison of measured data with predicted data by using numerical solvers of underwater wave equation. In the MFP, the received signals by spatial antenna of sensors must apply for determining source localization and estimation of environmental parameters. In order to derive the parameters of interest from received signals, the array must operate as spatial filtering that this lead to an optimization problem. In this paper, objective function is minimum variance that is based on minimizing the variance between the received signal and implemented result of wave propagation simulator by using wavelet transformation. The main idea of method follows the same idea as that of in match mode processor. In this approach, the data are projected in the space of orthogonal basis function known as modal space prior to processing into objective function. In our proposed method, we employ Daubechies wavelet basis functions into two reasons: 1- It is applied as numerical solver of underwater wave equation (wavelet Galerkin method), 2- The decay property of wavelet coefficients is employed for eliminating the modes that consist of high ratio of signal to noise. The method is applied for a standard benchmark.

■ RB9

Thursday, 10:30-12:00, MDCL 1008

Computational Analysis

Stream: Convex and Nonsmooth Analysis

Chair: *Yves Lucet*, Computer Science, Arts & Sciences, UBC Okanagan

1. **The piecewise linear quadratic (PLQ) model**

   Mike Trienis, UBCO - computer science

We recall current fast algorithms for computer-aided convex analysis and point out convergence limitations when applied to compute advanced transforms such as the proximal average. As a solution, we examine the class of Piecewise Linear-Quadratic (PLQ) functions. As standard convex operations are closed within this class of functions it offers a natural framework to work in. Additionally, it allows efficient (linear-time) algorithms for all such operations. Finally, we extend the model to the nonconvex case.

2. **Decomposition of monotone operators with linear graphs**

   Liangjin Yao, UBC Okanagan

We consider the decomposition of a maximal monotone operator the graph of which is a linear subspace into the sum of an antisymmetric operator and the subdifferential of a function that is convex, lower semicontinuous, and proper. In addition, we discuss the representation of continuous linear maximal monotone operators by autoconjugate functions.

3. **Hybrid Symbolic-Numeric Algorithms for Computational Convex Analysis**

   Yves Lucet, Computer Science, Arts & Sciences, UBC Okanagan

Computational convex analysis focuses on developing efficient tools to compute fundamental transforms arising in convex analysis. Symbolic computation tools have been developed, and have allowed more insight into the calculation of the Fenchel conjugate and related transforms. When such tools are not applicable one turns to numerical computation. Starting from the drawbacks of current numerical algorithms we consider the class of piecewise linear-quadratic functions which, allows the robust numerical computation of compositions of transforms such as the recently investigated proximal average. The algorithms presented are hybrid symbolic-numeric and provide a robust practical convex calculus.

■ RS1

Thursday, 1:30-2:30, MDCL 1305

Semi-plenary Presentation

Stream: Conic Programming and Interior Point Methods
Chair: *Michael J. Todd*, Cornell University

1. **Further Developments of SDP for Sensor Network Localization**

   Yinyu Ye, Stanford University

We present further developments of semidefinite programming (SDP) based approaches for the position estimation problem in Euclidean distance geometry such as graph realization and sensor network localization. We develop new conic relaxation models, weaker than full SDP but stronger than SOCP, for solving large-scale problems with thousands sensors, and demonstrate computational results to show the effectiveness of the new models.

■ RS2

Thursday, 1:30-2:30, MDCL 1307

Semi-plenary Presentation

Stream: Interior Point Methods and Implementations
Chair: *Clovis Gonzaga*, Federal University of Santa Catarina

1. **Numerical Linear Algebra and Optimization**

   Philip E. Gill, University of California, San Diego

In the formulation of practical optimization methods, it is often the case that the choice of numerical linear algebra method used in some inherent calculation can determine the choice of the whole optimization algorithm. The numerical linear algebra is particularly relevant in large-scale optimization, where the linear equation solver has a dramatic effect on both the robustness and the efficiency of the optimization. We review some of the principal linear algebraic issues associated with the design of modern optimization algorithms. Much of the discussion will concern the use of direct and iterative linear solvers for large-scale optimization. Particular emphasis will be given to: (i) the role of convexity in the design of algorithms; and (ii) recent developments in the use of regularization.

■ RS3

Thursday, 1:30-2:30, MDCL 1105

Semi-plenary Presentation

Stream: Global Optimization
Chair: *Michael Ferris*, University of Wisconsin

1. **Optimization in Biology**

   Nick Sahinidis, Carnegie Mellon University

This talk provides an overview of optimization approaches to modern bioinformatics and systems biology problems. The presentation includes the protein side-chain prediction problem, protein structural alignment, protein and RNA folding prediction, biomolecular structure determination via experimental techniques, and metabolic systems analysis and design. The machinery employed to solve these problems has included algorithms from linear programming, dynamic programming, combinatorial optimization, mixed-integer nonlinear programming, and optimization of differential-algebraic systems. Many of these problems are purely continuous in nature. Yet, they have, to this date, been approached mostly via combinatorial optimization algorithms that are applied to discrete approximations.

■ RC0

Thursday, 2:45-4:15, MDCL 1305/1307

Closing Plenary Presentation

Stream: Engineering Optimization
Chair: *Henry Wolkowicz*, University of Waterloo

1. **Optimization Methods for Chemical Process Engineering**

   Larry Biegler, Carnegie Mellon University

Optimization formulations play a key part in many aspects of chemical process engineering. Moreover, with the application of more accurate and complex process models, a number of important algorithmic challenges must be addressed to deal with these optimization models efficiently. This talk presents an overview of problem classes in chemical process optimization and discusses key characteristics of these problems. In particular, a hierarchy of optimization models is explored, and typical problem formulations and solution strategies are presented at each level of this hierarchy. These are presented in parallel with leading edge research in continuous variable optimization, including complementarity formulations and extensions of large-scale barrier methods.

Posters will have to be set up on the first floor of the McMaster University Student Centre for the reception on Monday evening. After the reception the posters will be transferred to MDCL and will be on display throughout the conference (for the exact location see the floor map of MDCL on the inside back cover).

P1. Real Roots of Quadratic Interval Polynomials

Ibraheem Alolyan, King Saud University, Department of Mathematics

The aim of this presentation is to study the roots of interval polynomials. The characterization of such roots is given and an algorithm is developed for computing the interval roots of quadratic polynomials with interval coefficients.

P2. A fast parametric maximum flow algorithm for total variation minimizations

Wotao Yin, CAAM, Rice University, *Donald Goldfarb*

We present a recent approach for decomposing functions that arise in total variation based models for image processing into gray-scale levels and for solving these models for each level using parametric max flow algorithms. This approach is compared to existing approaches based on PDEs and SOCPs. In addition, we demonstrate that a full 3D brain MRI image in a high resolution can be processed by the proposed algorithm within one minute on a standard PC.

P3. On some LP duality results

Constantin Zalinescu, Faculty of Mathematics, University Al.I.Cuza Iasi, Romania

Recently Clark published an interesting linear programming duality result in which the usual (algebraic) dual problem is replaced by a topological dual with the aim to have not duality gap under certain usual hypotheses met in mathematical finance. We present some examples to show that an extra condition is needed for having the conclusion.

P4. Large Scale Network Utility Maximization

Argyrios Zymnis, Stanford University EE Department

In this paper we present a primal-dual algorithm for solving network utility maximization problems. At each iteration we compute an approximate Newton step by using preconditioned conjugate gradients and for this reason our algorithm can scale to very large networks. We compare this algorithm to dual decomposition for cases where the utility functions are logarithmic. We show through numerical examples that the primal dual algorithm clearly outperforms dual decomposition in cases were the network is congested. Our algorithm can also handle utility functions which are not strictly concave and this constitutes an additional advantage compared to dual decomposition.

P5. Characterizing General Pareto Optima

Mark Rentmeesters, Department of Mathematics, East Carolina University

For convex objective functions, all Pareto optima, whether proper or improper, can be characterized as a lexicographic optimum of some ordered sequence of weighted sums of these objectives. Moreover, although lexicographic optima by their nature are improper Pareto optima, it is nevertheless possible to state both necessary and sufficient Kuhn-Tucker conditions for these optima by considering each lexicographic level of such conditions to hold as constraining conditions on optimality at each successively lower priority level. The result is a sequence of second-order conditions that can then be used to characterize Pareto optima in general, whether proper or improper.

P6. Protein-Protein Docking using Normal Modes

Vanitha Suresh, Computer Sciences, University of Wisconsin. Madison, *Stephen J. Wright*, *Julie Mitchell*, *Roummel Marcia*, *Peter Koenig*

Protein-protein docking is an important problem in Computational Biology. Several methods have been proposed to predict the final structure of docked complexes with reasonable accuracy. However, most of these methods assume that the two proteins are rigid. Our approach to protein-protein docking incorporates flexibility via low-frequency normal modes i.e. large-scale domain movements. In addition to the standard rigid-body degrees of freedom, we use degrees of freedom representing displacements along the low-frequency normal modes. The docking problem is hence formulated as the unconstrained minimization of the potential energy (AMBER) of the protein-protein complex with respect to these degrees of freedom. A prototype has been implemented in C/C++ with the BFGS algorithm for local optimization of the starting points (from ZDOCK) and GAUSSTER (Gaussian Cluster) for the global optimization. Preliminary results are discussed in this poster.

P7. CANCELLED

P8. Meta-heuristics for MRI sampling trajectory design

Andrew Curtis, McMaster Computing and Software

Data acquisition strategies for magnetic resonance imaging appear as sampling trajectories through the Fourier transformed density of the subject, or k-space. Significant gains in scan speed result from acquiring partial k-space, at the expense of reduced image quality and aliasing. Traditional methods of designing such (under)sampling patterns fall into three categories: methods that are easy to implement (i.e. Cartesian), methods that aim to satisfy the Nyquist criteria (Spiral, Teardrop), and heuristic methods. In Durga, a large set of 3d k-space trajectories are designed to pass through pseudo-random goal points, and their shapes are constrained by machine and other scan sequence specific parameters (moment nulling, etc) via optimization of many individual SOCP problems. These trajectories are then combined into subsets corresponding to a desired acquisition time and under sampling ratio. Exhaustive search of subsets is infeasible and as such a genetic algorithm is employed to sample the parameter space, finding solutions more than 7 standard-deviations better than random assignment of subsets. Numerical simulations show excellent performance, and confirm that the lack of symmetry in the trajectory set serves to eliminate structured aliasing in the final image.

P9. Class of Fractional Optimization Problems

Hamid R. Ghaffari, School of Computational Engineering and Science, McMaster University

In this project we introduce and study a new class of optimization problems called Fractional Optimization Problems. This problem can be considered as an optimization problem with objective, constraints, or both as a fraction (ratio) of two affine functions. This can also be considered as a subclass of quadratic optimization with two rank Hessian objective or constrain function. This kind of problem can be widely found in reconstruction in image process in Magnetic Resonance Imaging. We use this class and proposed methods in this project, based on Interior Point Methods, to find a clear MRI picture.

P10. An Ellipsoid Based Method for Solving Quasi-convex Vector Optimization Problems

Augusto Moura, Electrical Engineering - Federal University of Minas Gerais, *Ricardo Takahashi*

This paper introduces an Ellipsoid Based Method for solving quasi-convex vector optimization problems. The HiSPE (Historical Search Polyhedron Ellipsoid) Method uses in each iteration an intersection of semi-spaces defined by multiple hyper-planes obtained from current or already calculated values of active constraints and cost functions. During the convergence path, the sequence of semi-spaces' intersections is generated in a way that at least one non-dominated point is preserved after the intersection of all past semi-space intersections. This yielded intersection region, named the historical search polyhedron, is used in the current iteration to shrink the ellipsoid that embeds the search region until the ellipsoid's volume becomes small enough. The HiSPE's global convergence is assured by the same conditions in which Shor's Ellipsoid algorithm converges. Finally, the preliminary test results indicate that HiSPE algorithm produces effective gains in different sized problems.

P11. Comparison of derivative-free optimization implementations of deterministic computer experiments

Luis Rios, University of Illinois at Urbana-Champaign

A group of software implementations of derivative-free optimization algorithms are described and tested on a collection of publicly available problems.

P12. Variational Analysis of Pseudospectra

Chin How Jeffrey Pang, Center for Applied Mathematics, Cornell University

An important tool for analyzing and designing robust properties of non-normal matrices, the pseudospectrum of a square matrix A is the set of eigenvalues attainable when A is perturbed within some fixed spectral distance. We characterize Lipschitz continuity of the pseudospectrum, as a set-valued function of A. With this technique, we deduce Lipschitz properties of the pseudospectral abscissa - the largest real part of elements in the pseudospectrum, and, analogously, the pseudospectral radius. Our approach nicely illustrates diverse techniques of modern variational analysis. Pseudospectral Lipschitz behavior fails exactly at critical points of the resolvent norm, which in turn are related to coalescence points of pseudospectral components.

P13. Optimization of Heat Problem

Kimia Ghobadi, School of Computaional Engineering and Science, McMaster University, *Ned Nedialkov*, *Tamás Terlaky*

We consider a heat-transfer problem, where a one-dimensional bar is heated at its ends. The temperature at each point is bounded below by a given function. The initial conditions are fixed, while the boundary conditions control the temperature, such that it is above its lower-bound. Our goal is to minimize the energy needed to satisfy it. If we derive the optimality conditions and then optimize the system of equations, then this optimization problem is not solvable with traditional optimal control methods. However, by discretizing it in time and space, we translate this problem into a convex-quadratic problem. The related coefficient matrices are large and very sparse. A good optimization solver, for example Mosek, can solve this problem efficiently, even for very fine discretizations. In this presentation, we explore the properties of the convex-quadaratic problem, and in particular, its duality properties and the sparsity structure of the matrices that arise.

P14. Multi-Objective and Parametric Optimization: Models, Algorithms and Applications in Finance

Oleksandr Romanko, Department of Computing and Software, McMaster University, *Tamás Terlaky*, *Alireza Ghaffari Hadigheh*

We describe relation between multi-objective optimization, where several conflicting objectives are simultaneously optimized subject to constraints, and parametric analysis that is used to solve such problems. We present our Interior Point Methods based algorithmic and implementation results for solving linear, convex quadratic and second-order cone parametric optimization problems. We illustrate how to model and solve multi-objective problems and outline their applications in finance.

P15. Sensor Network Localization, Euclidean Distance Matrix Completions, and Graph Realization

Nathan Krislock, Combinatorics and Optimization, University of Waterloo, *Yichuan Ding*, *Jiawei Qian*, *Henry Wolkowicz*

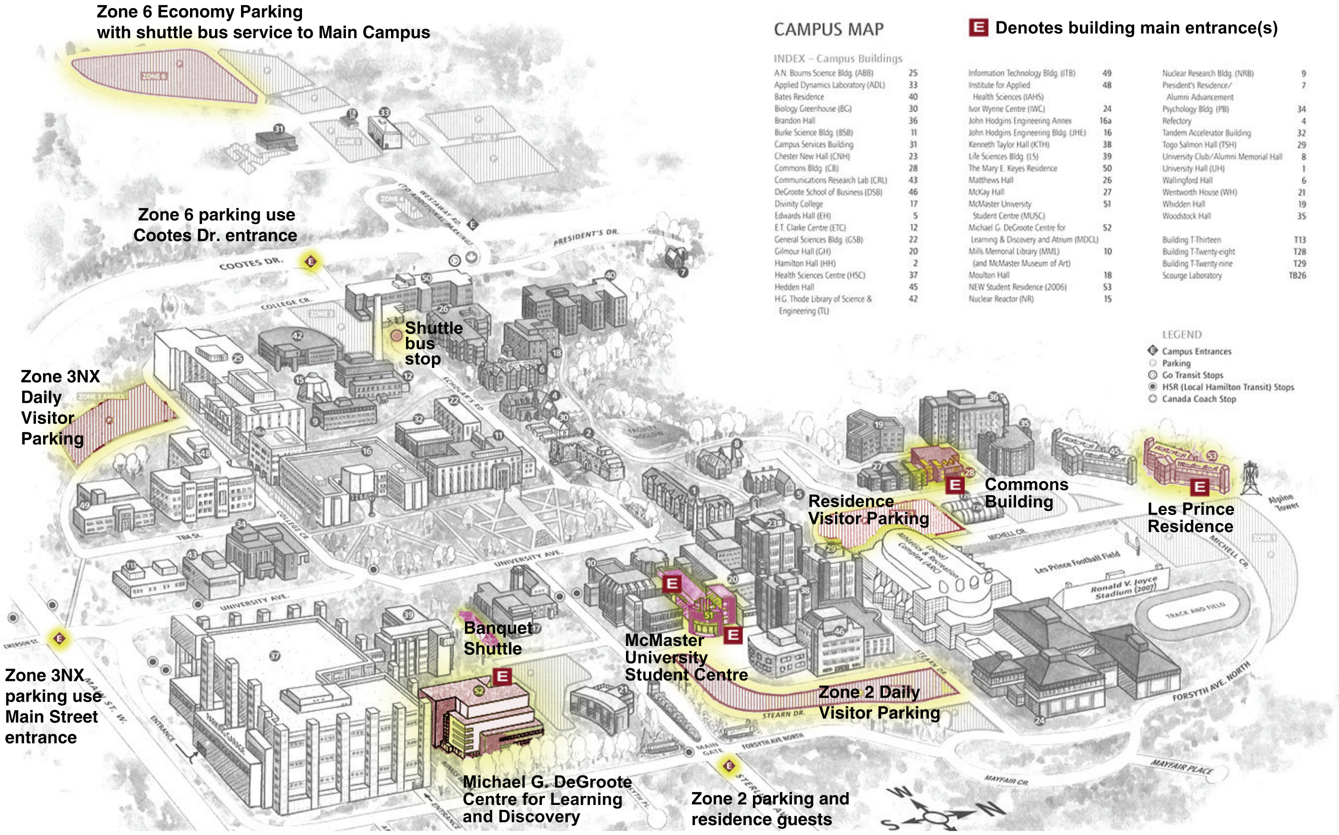
We study Semidefinite Programming, SDP, relaxations for Sensor Network Localization, SNL, with anchors and with noisy distance information. The main point of the paper is to view SNL as a (nearest) Euclidean Distance Matrix, EDM , completion problem and to show the advantages for using this latter, well studied model. We first show that the current popular SDP relaxation is equivalent to known relaxations in the literature for EDM completions. The existence of anchors in the problem is not special. The set of anchors simply corresponds to a given fixed clique for the graph of the EDM problem. We next propose a method of projection when a large clique or a dense subgraph is identified in the underlying graph. This projection reduces the size, and improves the stability, of the relaxation.

P16. Hyperplane Arrangements with Large Average Diameter

Feng Xie, Computing & Software, McMaster University

The largest possible average diameter of a bounded cell of a simple hyperplane arrangement is conjectured to be not greater than the dimension. We prove that this conjecture of Deza, Terlaky and Zinchenko is asymptotically tight in fixed dimension by constructing a family of hyperplane arrangements containing mostly cubical cells. The relationship with a result of Dedieu, Malajovich and Shub, the conjecture of Hirsch, and a result of Haimovich are presented. We give the exact value of the largest possible average diameter for simple arrangements having few hyperplanes and for arrangements having at most the dimension plus two hyperplanes. In dimensions two and three, we strengthen the lower and upper bounds for the average diameter of a bounded cell of a simple hyperplane arrangements.

The session where the author is presenting is listed in **bold**. Sessions P1-P17 denote posters.



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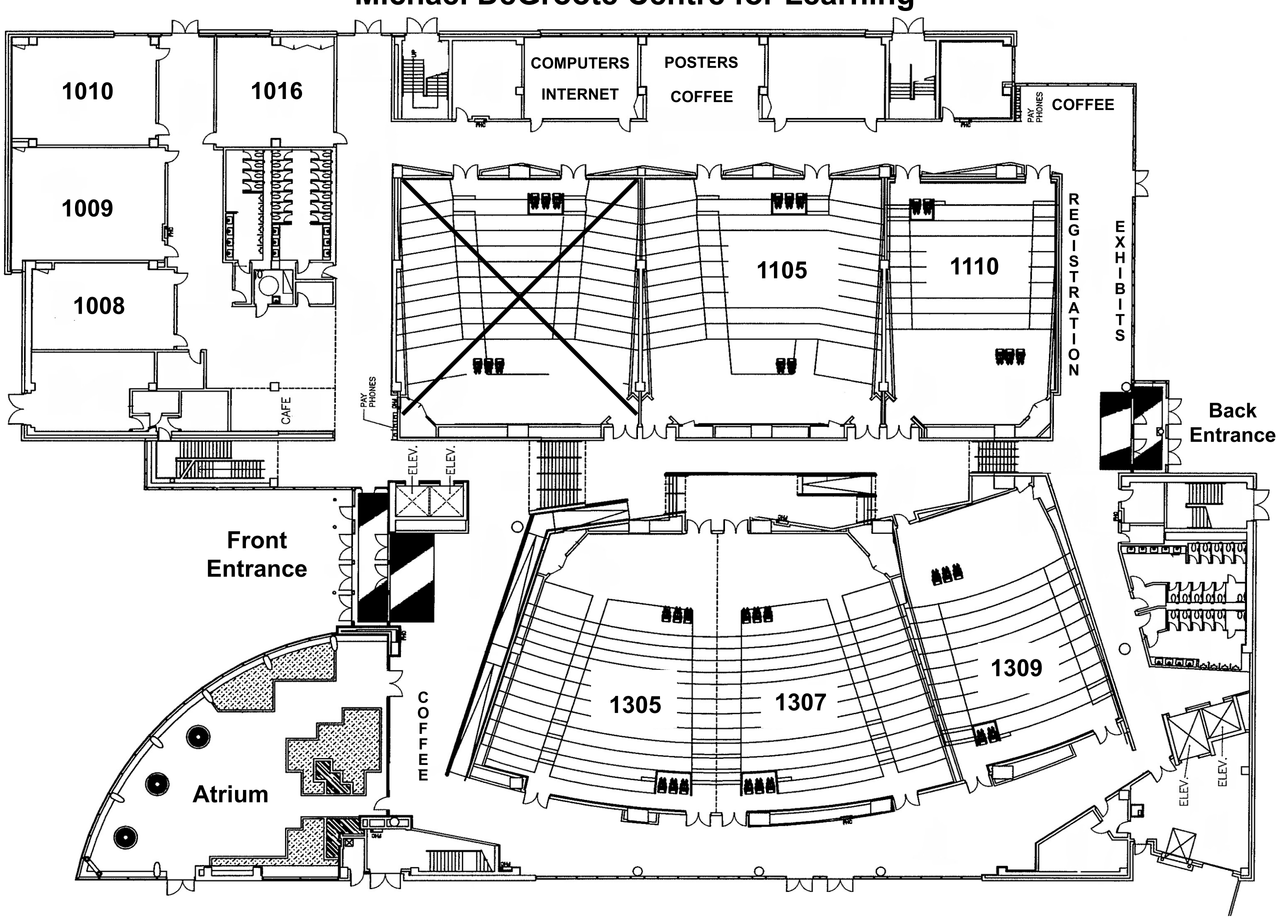

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